Physical Activity and Health in Dutch and Chinese Children

Lu, Congchao

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Congchao Lu

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by

Congchao Lu

born on 7 October 1982
in Tianjin, China

Supervisors

Dr. E. Corpeleijn
Prof. R.P. Stolk

Assessment Committee

Prof. J. Beulens
Prof. S. Kremers
Prof. A. Dijkstra

For my beloved son Dudu

写给嘟嘟

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Chapter 1

General introduction

Physical activity, sedentary behaviours and health in preschool children

From a global perspective, a lack of physical activity (PA) has been identified as the fourth leading risk factor for mortality.[1] Worldwide in 2010, 23% of adults were insufficiently active. Also 80% of adolescents aged 11–17 years, did not reach the World Health Organization recommendation of PA.[2] These recommendations say that children should accumulate at least 60 minutes of moderate-to-vigorous PA (MVPA) daily.[1] Strong evidence shows that physical inactivity increases the risk of many adverse health conditions, including major non-communicable diseases such as coronary heart disease, type 2 diabetes, and breast and colon cancers, and shortens life expectancy.[3] In 2013, the health care costs for being physically inactive were estimated around 53.8 billion dollars worldwide.[4]

Physical inactivity is not only an issue in adults and adolescents. Early childhood is a critical and rapid period of physical, cognitive, social, and emotional development. Three reviews extensively summarized how PA and health indicators were related in children younger than 6 years old.[5-7] These evidences showed that higher levels of PA were favourably associated with bone and skeletal health, motor skill development, psychosocial health, cognitive development, and cardio-metabolic health.

The positive association between sufficient PA and healthy weight are well known in adults [8] and also in school-aged children and adolescents [9], but less so in young children. For example, the associations between objective measurement of PA and Body Mass Index (BMI) remain inconclusive in preschoolers, i.e. a recently published meta-analysis indicated that most studies for examining this association were cross-sectional designs and longitudinal studies are needed.[10, 11] The prevalence of childhood obesity is increasing in all countries, with a rapid rise in low- and middle-income countries.[12] Children with overweight or obesity are at greater risk of obesity, diabetes type 2, heart disease, poor mental health, and some cancers later in life.[13] It is necessary to improve our understanding of the role of PA for obesity development during the preschool years, which is seen as a critical window for predicting childhood weight gain.[14] This issue is particularly important for policy makers, who need evidence-based recommendations to make informed decisions on and set out interventions that reduce the global burden of obesity.

The early childhood is a time during which habits of the child are formed and family lifestyle routines are open to changes and adaptations.[15] Previous reviews indicated that PA behaviours developed in early childhood track from childhood to adolescence and further into adulthood.[16-18] Thus, promotion of regular PA among young children is a public-health priority, and the early childhood should be targeted as a critical time to promote healthy lifestyle behaviours.[16]

To quantify the level of PA, we need to realize that PA is a complex construct. The definition of physical activity states that it is any bodily movement produced by skeletal muscles that requires energy expenditure.[19] In real life however, it can be classified qualitatively into categories based on function (recreation, transport, occupation, household) [20] or quantitatively based on intensity of the effort (sedentary, light, moderate, and vigorous intensity) [21] and of course by its duration (number of minutes in a certain activity) and it frequency (how many times per day, or per week for example). Scientific evidence underlying the previously mentioned PA recommendations relied mainly on a large number of participants with self-reported PA. The current recommendations recommend regular PA mostly focused on MVPA [1] since few data are available for health benefits from light PA [22, 23], and recommendations for children under five also took into account total PA (TPA).[15]

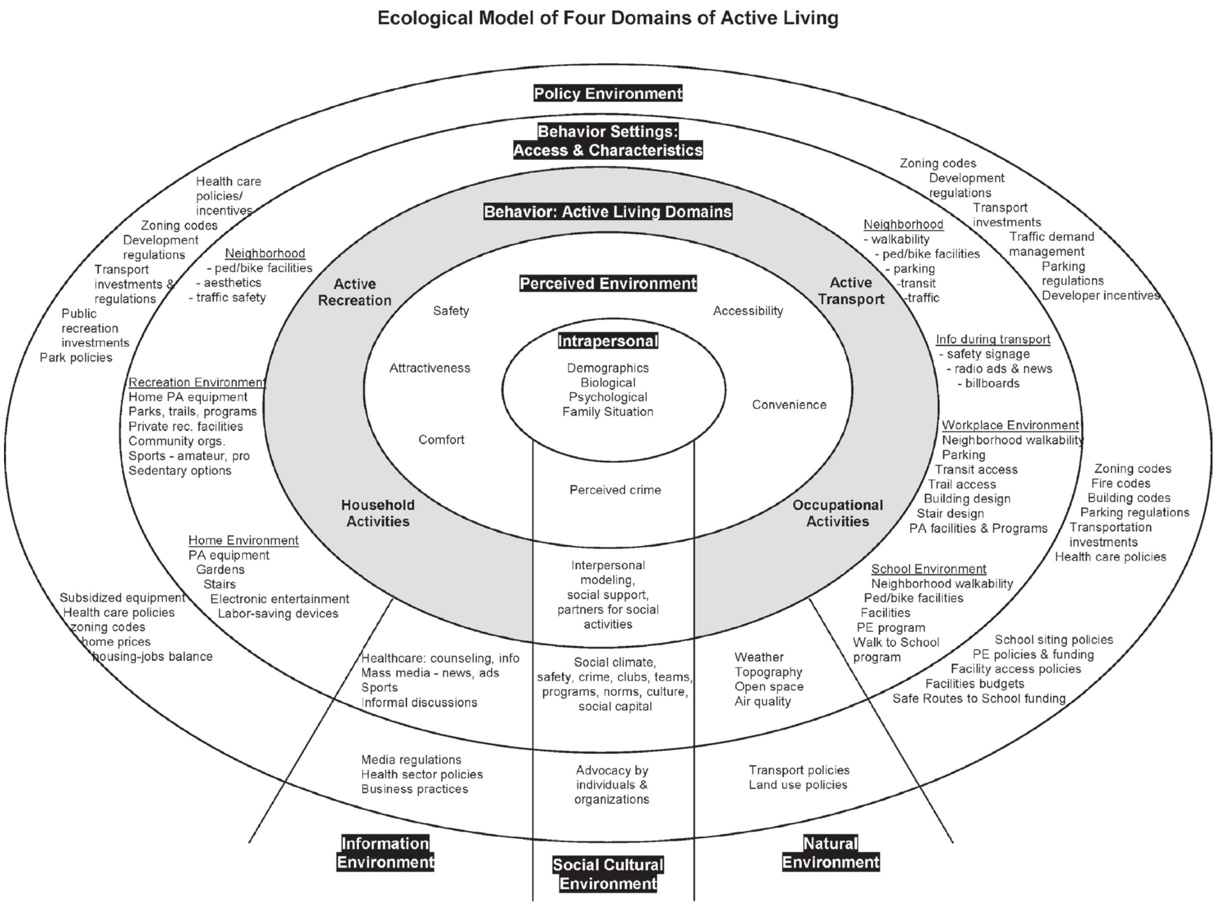
The health effects of light PA (LPA) are not well known today.[23] LPA is mostly defined as activities with energy expenditure at the level of 1.6 – 2.9 METs. One MET is the energy cost of resting quietly, often defined in terms of oxygen uptake as 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$.[24] It consists of activities such as slow walking, sitting and writing, cooking food, and washing dishes.[25] LPA can be important, since most of the minutes of TPA, which is mostly defined as all the time spent non-sedentary or not sleeping, consists of LPA. It thus remains a question whether the health effects observed for TPA [6] could be explained by higher levels of MVPA, or LPA, or both.

Compared to LPA, more studies have been performed to study sedentariness. Sedentary behaviours (SB) include activities that involve energy expenditure at the level of 1.0 – 1.5 METs, e.g., television viewing and sitting in a stroller.[25] Although scientists have reported that being sedentary is associated with significant health risks, less studies have objectively measured sedentary time (ST), e.g., via accelerometry. In most cases, study participants who are reported to be sedentary or inactive are actually those who did not meet the study's criteria for moderate or higher levels of activity.[25] Unlike PA, excessive SB may have unique health consequences during early childhood. Preschool years are marked by a critical period of cognitive development and for forming life-long SB habits.[16] A review summarized that screen time in the early years (0 to 4 years), in particular TV, was either not associated with or had detrimental associations with cognitive development.[26] An update review on studies in children synthesized findings from 235 studies in 71 countries. They indicated that different types of SB may have different impacts on health. Especially a higher duration of TV viewing and/or screen time was associated with unfavourable body composition in school-aged children and youth.[9] Thus, identifying the correlates of SB may help with specific interventions to promote active lifestyles.

Environmental determinants and physical activity

In times of increasing urbanization and environmental degradation, contemporary urban living is associated with a sedentary lifestyle for the entire city population.[27] In 1992, professor Daniel Stokols introduced a social ecological analysis of health promotive environments, emphasizing the transactions between individual or collective behaviour and the health resources and constraints that exist in specific environmental settings.[28] For identifying potential environmental and policy influences on PA, an ecological model was made by Sallis *et al* (Figure 1).[20]

The ecological model posits that there are multiple levels of influence on PA patterns, including factors at intrapersonal level (e.g. demographics, family situation), social cultural level (e.g. social support, role modelling), physical environment (e.g. neighbourhood, home, school), nature environment (e.g. weather, air quality), and policy level (e.g. health care policy, school policy). According to the ecological theory, higher levels of PA are expected when individuals live in supportive environments with supportive policies, when social support for engagement in PA is strong and when individuals are motivated and educated to be physically active.



Sallis JF, et al. 2006.
Annu. Rev. Public Health 27:297–322

Figure 1. An ecological approach to creating active living communities.

From the ecological perspective, factors on social and physical environment are especially important when aiming for PA promotion in young children. That's because environmental characters could be changed into favourable situations based on government policy, and a supportive environment is effective on promote PA.[29] Currently, researchers focus on neighbourhood physical environment in relation to children's PA, including residential density, land use mix diversity, street connectivity, walkability, accessibility, aesthetics, walking and cycling facilities, recreation facilities, urbanization and safety.[30] To date, most studies were conducted in a single country which represented a unique socio-cultural and physical environment. Some environmental characteristics may show inconsistency in their influence on PA between different nations, since these attributes are likely to modify the associations between various neighbourhood environments and PA.[31] For example, concerns about traffic safety may impact walking and bicycling, and then affect the level of TPA.[32] Because young children's outdoor time is largely regulated by parents, thus, parent perceptions of neighbourhood safety are likely to have the most direct influence on the nature and extent of children's outdoor play or commuting mode.[33] Within Europe, the Netherlands may be a particularly interesting country to explore the associations between traffic safety and PA, with its high prevalence rates of walking and cycling.[34] It offers the opportunity to explore the association of safety with both walking and the much less studied PA component cycling. Meanwhile, China is also a nation to test such a correlation, since the economic development may be related to unhealthy active lifestyles, e.g., inactive travelling mode such as travelling by cars, and many new drivers and common traffic accidents which may cause more concern of safety in urban cities.[35]

Besides, understanding the socio-cultural differences of PA in children can help tailor intervention programs in different settings.[36] For example, a positive attitude of parents on PA might encourage children to be active in their daily habits. In the Netherlands, children are mainly taken care of by their parents and/or may be looked after in day-care already at an early age (after three months of age). In China, the culture of childcare is different compared to the Dutch society. Children usually stay at home until three years of age, and grandparents engage heavily in taking care of their grandchildren. It is a traditional, common and acceptable idea that grandparents are involved in childcare when both parents have full time jobs, especially in early childhood. Due to the one-child policy enacted in the late 1970s, most families in China have one child only.[37] Therefore, grandparents may be overprotective of the only grandchild they have. They may discourage vigorous activities and encourage sedentary indoor activities when the outdoor environment and vigorous activities are perceived as unsafe.[38] The role of caregivers should be examined in preschool children's PA research, especially for Chinese grandparents, since there is evidence that grandparents' actions may have an impact on their grandchildren's PA.[39]

Physical activity patterns in preschool children

The effectiveness of future policy initiatives to promote PA and lower SB in young children will depend on a proper understanding of the PA patterns related to low PA in this age group.[40] Preschoolers' PA is characterized by frequent, short bursts of activity, and a high inter-individual variability in PA levels.[41, 42] Though an increasing number of studies have reported TPA levels in preschool year with a variety of different methods, it remains difficult to answer the question of how inactive the children really are, and when preschool children would become inactive.[43] Accordingly, to describe the distribution of intensity and duration of activities over the day, the PA patterns, it is relevant to discover at which moment of the day the most progress can be achieved with PA interventions. Some children are extremely active, but others only achieve low levels of PA in the same environment.[43] We hypothesize that some children are more active than others by nature, and therefore identifying children who are less active could help us to design interventions to make these children more active too.

The assessment of PA in preschool children by questionnaires is particularly difficult, because of their less structured activity patterns. To solve this, objective measurement of TPA via activity trackers is becoming more common in young children. It can provide a valid measure of total activity as well as elucidate the pattern and intensity of activity throughout the day.[44] To date, little is known about PA patterns using time-stamped data in preschool children [45], especially objectively monitored PA and sedentary time using activity trackers.[46] In addition to looking at total levels of PA at different intensities, identifying patterns of PA in relation to specific environmental settings is essential to understand what intervention could work as, and to understand the potential environmental influences on individual behaviour. For preschool children, household, preschool, neighbourhood and community environment are mainly settings for their daily PA behaviours.[43] Although activity trackers have the benefit of being objective, and quantitative, activity trackers cannot provide information on settings of physical activities, or describe the nature of the activity. Therefore, a combination of activity trackers and parents' report in questionnaires will be useful for interpretation of the findings.

Aim of the thesis

Overall, understanding the determinants on PA during early life is important for designing of more effective interventions to stimulate PA later in life, or to counteract the growing trend towards inactivity. The main aim of this thesis is to determine which environmental correlates are related to PA patterns in preschool children. To gain more insight in the determinants of PA in young children, we described the daily patterns of ST, LPA, and MVPA in both Chinese and Dutch preschoolers. To explore the potential health relevance, we examined the correlation between PA patterns and overweight / obesity in children in their early years.

The studies used in this thesis

The environmental health perspective of children is one of the great global health concerns. Environmental risks or disease burden vary from region to region. For a better understanding of the environmental correlates of PA of children in different nations, the GECKO (Groningen Expert Centre for Kids with Obesity) Drenthe birth cohort and PATH-CC (Physical Activity and Health in Tianjin Chinese Children) study were used in this thesis.

The GECKO Drenthe birth cohort

Birth cohort studies are ideal for investigating various environmental risks on later health, with the repeated measures of growth and development in early life, childhood, adolescence, and possibly adulthood (www.birthcohorts.net). The GECKO Drenthe study is a population-based birth cohort which focuses on early risk factors of overweight and obesity.[47] All mothers from children to be born from April 2006 to April 2007 and living in Drenthe, a northern province of The Netherlands, were invited to participate during the third trimester of their pregnancy. At baseline, parents of 3875 children intended to participate in the study, of whom 2874 ever actively participated. Monitoring of the children and their family started in the last trimester of pregnancy and is still ongoing. Data were used in this thesis from when the children were 4 to 7 years old. We used PA data measured by ActiGraph accelerometry, and environmental correlates from a questionnaire (household characteristics, parental and children's PA behaviours, and neighbourhood environment, e.g., traffic safety, road network and presence of

PA facilities).

The PATH-CC study

The PATH-CC study in Tianjin, China is focusing on identifying the relationship between PA, overweight and environmental determinants in childhood. Healthy children aged 3 to 6 years growing up in Tianjin were recruited in preschools by advertising posters in 2015. There were 1031 preschool children and their parents who joined in the study.[48] In parallel with the GECKO Drenthe cohort, PA data of Chinese children was measured by ActiGraph accelerometry, and leisure-time SB and PA activities were reported by their parents in questionnaires. Based on the GECKO questionnaires, we developed an adapted questionnaire for environmental correlates in China, including household characteristics, parental and children's PA behaviours, and aspects of neighbourhood environment like traffic safety and presence of PA facilities. A study protocol was shown in this thesis as an Appendix.

Outline of the thesis

The outline of this thesis is shown in figure 2.

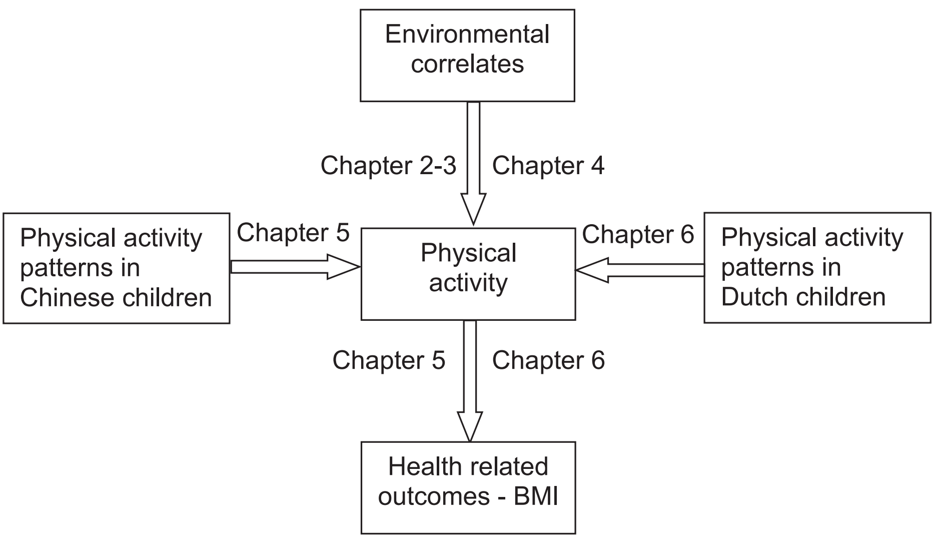


Figure 2. Overview of the thesis.

In **Chapter 2**, a systematic review was performed to review existing literature on factors of PA among Chinese children and adolescents.

In **Chapter 3**, the relationship between environmental correlates, preschool children's PA and ST was assessed in the urban area of Tianjin, China.

In **Chapter 4**, the relationship between environmental correlates and the Dutch children's PA and ST was assessed.

In **Chapter 5**, objectively measured ST and PA patterns of urban Chinese preschoolers during the day was described, and these patterns between children with and without overweight were compared.

In **Chapter 6**, objectively measured day-segmented PA patterns of the Dutch children were examined, and also these patterns between children with and without overweight were compared.

In **Chapter 7**, the correlates of PA in preschool children are extensively discussed, with special attention for culture differences between China and the Netherlands. Methodological issues and implications for future PA promotion were discussed.

Finally, **Chapter 8** provides a summary of the main findings of each chapter, separately, and also an overview of correlates of PA and ST in preschoolers found in this thesis.

REFERENCES

1. World Health Organization. Global recommendations on physical activity for health. Geneva, Switzerland: World Health Organization; 2010.

2. Hallal PC, Andersen LB, Bull FC, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. Lancet. 2012;380(9838):247-57. doi: 10.1016/S0140-6736(12)60646-1.

3. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet. 2012;380(9838):219-29. doi: 10.1016/S0140-6736(12)61031-9.

4. Ding D, Lawson KD, Kolbe-Alexander TL, et al. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. Lancet. 2016;388(10051):1311-24. doi: 10.1016/S0140-6736(16)30383-X.

5. Timmons BW, Leblanc AG, Carson V, et al. Systematic review of physical activity and health in the early years (aged 0-4 years). Appl Physiol Nutr Metab. 2012;37(4):773-92. doi: 10.1139/h2012-070.

6. Carson V, Lee EY, Hewitt L, et al. Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). BMC Public Health. 2017;17(Suppl 5)(854)doi: 10.1186/s12889-017-4860-0.

7. Pate RR, Hillman CH, Janz KF, et al. Physical activity and health in children younger than 6 years: a systematic review. Med Sci Sports Exerc. 2019;51(6):1282-91. doi: 10.1249/MSS.0000000000001940.

8. Jakicic JM, Powell KE, Campbell WW, et al. Physical activity and the prevention of weight gain in adults: a systematic review. Med Sci Sports Exerc. 2019;51(6):1262-9. doi: 10.1249/MSS.0000000000001938.

9. Carson V, Hunter S, Kuzik N, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. Appl Physiol Nutr Metab. 2016;41(6 Suppl 3):S240-65. doi: 10.1139/apnm-2015-0630.

10. Sijtsma A, Sauer PJ, Stolk RP, et al. Is directly measured physical activity related to adiposity in preschool children? Int J Pediatr Obes. 2011;6(5-6):389-400. doi: 10.3109/17477166.2011.606323.

11. Wiersma R, Haverkamp BF, van Beek JH, et al. Unravelling the association between accelerometer - derived physical activity and adiposity among preschool children: a systematic review and meta-analyses. Obes Rev. 2019;doi: 10.1111/obr.12936.

12. GBD 2015 Obesity Collaborators, Afshin A, Forouzanfar MH, et al. Health effects of overweight and obesity in 195 countries over 25 years. N Engl J Med. 2017;377(1):13-27. doi: 10.1056/NEJMoa1614362.

13. World Health Organization. Consideration of the evidence on childhood obesity for the Commission on Ending Childhood Obesity: report of the ad hoc working group on science and evidence for ending childhood obesity, Geneva, Switzerland. Available at:

https://apps.who.int/iris/handle/10665/206549. [accessed 12.08.2019].

14. Volger S, Rigassio Radler D, Rothpletz-Puglia P. Early childhood obesity prevention efforts through a life course health development perspective: a scoping review. PLoS One. 2018;13(12):e0209787. doi: 10.1371/journal.pone.0209787.

15. World Health Organization. Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age. Available at: https://apps.who.int/iris/handle/10665/311664. [accessed 12.08.2019].

16. Jones RA, Hinkley T, Okely AD, et al. Tracking physical activity and sedentary behavior in childhood: a systematic review. Am J Prev Med. 2013;44(6):651-8. doi: 10.1016/j.amepre.2013.03.001.

17. Telama R, Yang X, Leskinen E, et al. Tracking of physical activity from early childhood through youth into adulthood. Med Sci Sports Exerc. 2014;46(5):955-62. doi: 10.1249/MSS.0000000000000181.

18. Carson V, Lee EY, Hesketh KD, et al. Physical activity and sedentary behavior across three time-points and associations with social skills in early childhood. BMC Public Health. 2019;19(1):27. doi: 10.1186/s12889-018-6381-x.

19. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep. 1985;100(2):126-31.

20. Sallis JF, Cervero RB, Ascher W, et al. An ecological approach to creating active living communities. Annu Rev Public Health. 2006;27:297-322. doi: 10.1146/annurev.publhealth.27.021405.102100.

21. Butte NF, Ekelund U, Westerterp KR. Assessing physical activity using wearable monitors: measures of physical activity. Med Sci Sports Exerc. 2012;44(1 Suppl 1):S5-12. doi: 10.1249/MSS.0b013e3182399c0e.

22. Lee IM, Shiroma EJ. Using accelerometers to measure physical activity in large-scale epidemiological studies: issues and challenges. Br J Sports Med. 2014;48(3):197-201. doi: 10.1136/bjsports-2013-093154.

23. Fuzeki E, Engeroff T, Banzer W. Health benefits of light-Intensity physical activity: a systematic review of accelerometer data of the National Health and Nutrition Examination Survey (NHANES). Sports Med. 2017;47(9):1769-93. doi: 10.1007/s40279-017-0724-0.

24. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc. 2007;39(8):1423-34. doi: 10.1249/mss.0b013e3180616b27.

25. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". Exerc Sport Sci Rev. 2008;36(4):173-8. doi: 10.1097/JES.0b013e3181877d1a.

26. Carson V, Kuzik N, Hunter S, et al. Systematic review of sedentary behavior and cognitive development in early childhood. Prev Med. 2015;78:115-22. doi: 10.1016/j.ypmed.2015.07.016.

27. Kabisch N, van den Bosch M, Lafortezza R. The health benefits of nature-based solutions to urbanization challenges for children and the elderly - a systematic review. Environ Res. 2017;159:362-73. doi: 10.1016/j.envres.2017.08.004.

28. Stokols D. Translating social ecological theory into guidelines for community health promotion. Am J Health Promot. 1996;10(4):282-98. doi: 10.4278/0890-1171-10.4.282.

29. Aarts MJ, van de Goor IA, van Oers HA, et al. Towards translation of environmental determinants of physical activity in children into multi-sector policy measures: study design of a Dutch project. BMC Public Health. 2009;9:396. doi: 10.1186/1471-2458-9-396.

30. Ding D, Sallis JF, Kerr J, et al. Neighborhood environment and physical activity among youth a review. Am J Prev Med. 2011;41(4):442-55. doi: 10.1016/j.amepre.2011.06.036.

31. Ding D, Adams MA, Sallis JF, et al. Perceived neighborhood environment and physical activity in 11 countries: do associations differ by country? Int J Behav Nutr Phys Act. 2013;10:57. doi: 10.1186/1479-5868-10-57.

32. Aarts MJ, Mathijssen JJ, van Oers JA, et al. Associations between environmental characteristics and active commuting to school among children: a cross-sectional study. Int J Behav Med. 2013;20(4):538-55. doi: 10.1007/s12529-012-9271-0.

33. Datar A, Nicosia N, Shier V. Parent perceptions of neighborhood safety and children's physical activity, sedentary behavior, and obesity: evidence from a national longitudinal study. Am J Epidemiol. 2013;177(10):1065-73. doi: 10.1093/aje/kws353.

34. Kramer D, Maas J, Wingen M, et al. Neighbourhood safety and leisure-time physical activity among Dutch adults: a multilevel perspective. Int J Behav Nutr Phys Act. 2013;10:11. doi: 10.1186/1479-5868-10-11.

35. Jiang B, Liang S, Peng ZR, et al. Transport and public health in China: the road to a healthy future. Lancet. 2017;390(10104):1781-91. doi: 10.1016/S0140-6736(17)31958-X.

36. Franzini L, Elliott MN, Cuccaro P, et al. Influences of physical and social neighborhood environments on children's physical activity and obesity. Am J Public Health. 2009;99(2):271-8. doi: 10.2105/AJPH.2007.128702.

37. Kane P, Choi CY. China's one child family policy. BMJ. 1999;319(7215):992-4. doi: 10.1136/bmj.319.7215.992.

38. Johansson E, Mei H, Xiu L, et al. Physical activity in young children and their parents-An Early STOPP Sweden-China comparison study. Sci Rep. 2016;6:29595. doi: 10.1038/srep29595.

39. Chambers SA, Rowa-Dewar N, Radley A, et al. A systematic review of grandparents' influence on grandchildren's cancer risk factors. PLoS One. 2017;12(11):e0185420. doi: 10.1371/journal.pone.0185420.

40. Pate RR, O'Neill JR, Brown WH, et al. Top 10 research questions related to physical activity in preschool children. Res Q Exerc Sport. 2013;84(4):448-55. doi: 10.1080/02701367.2013.844038.

41. Bailey RC, Olson J, Pepper SL, et al. The level and tempo of children's physical activities: an observational study. Med Sci Sports Exerc. 1995;27(7):1033-41. doi: 10.1249/00005768-199507000-00012.

42. Baquet G, Stratton G, Van Praagh E, et al. Improving physical activity assessment in prepubertal children with high-frequency accelerometry monitoring: a methodological issue. Prev Med. 2007;44(2):143-7. doi: 10.1016/j.ypmed.2006.10.004.

43. Timmons BW, Naylor PJ, Pfeiffer KA. Physical activity for preschool children--how much and how? Can J Public Health. 2007;98 Suppl 2:S122-34.

44. Cliff DP, Reilly JJ, Okely AD. Methodological considerations in using accelerometers to assess habitual physical activity in children aged 0-5 years. J Sci Med Sport. 2009;12(5):557-67. doi: 10.1016/j.jsams.2008.10.008.

45. Hesketh KR, McMinn AM, Ekelund U, et al. Objectively measured physical activity in four-year-old British children: a cross-sectional analysis of activity patterns segmented across the day. Int J Behav Nutr Phys Act. 2014;11:1. doi: 10.1186/1479-5868-11-1.

46. Bornstein DB, Beets MW, Byun W, et al. Accelerometer-derived physical activity levels of preschoolers: a meta-analysis. J Sci Med Sport. 2011;14(6):504-11. doi: 10.1016/j.jsams.2011.05.007.

47. L'Abee C, Sauer PJ, Damen M, et al. Cohort Profile: the GECKO Drenthe study, overweight programming during early childhood. Int J Epidemiol. 2008;37(3):486-9. doi: 10.1093/ije/dym218.

48. Lu C, Wiersma R, Shen T, et al. Physical activity patterns by objective measurements in preschoolers from China. Child and Adolescent Obesity. 2019;2(1):1-17. doi: 10.1080/2574254X.2019.1585178.

Chapter 2

Factors of physical activity among Chinese children and adolescents: a systematic review

Congchao Lu, Ronald P. Stolk, Pieter J. J. Sauer, Anna Sijtsma, Rikstje Wiersma, Guowei Huang, Eva Corpeleijn

Int J Behav Nutr Phys Act. 2017; 14: 36. Doi: 10.1186/s12966-017-0486-y.

ABSTRACT

Background

Lack of physical activity is a growing problem in China, due to the fast economic development and changing living environment over the past two decades. The aim of this review is to summarize the factors related to physical activity in Chinese children and adolescents during this distinct period of development.

Methods

A systematic search was finished on Jan 10th, 2017, and identified 2200 hits through PubMed and Web of Science. English-language published studies were included if they reported statistical associations between factors and physical activity. Adapted criteria from the Strengthening The Reporting of OBservational studies in Epidemiology (STROBE) statement and evaluation of the quality of prognosis studies in systematic reviews (QUIPS) were used to assess the risk of bias of the included studies. Related factors that were reported in at least three studies were summarized separately for children and adolescents using a semi-quantitative method.

Results

Forty two papers (published 2002–2016) were included. Most designs were cross-sectional (79%), and most studies used questionnaires to assess physical activity. Sample size was above 1000 in 18 papers (43%). Thirty seven studies (88%) showed acceptable quality by methodological quality assessment. Most studies reported a low level of physical activity. Boys were consistently more active than girls, the parental physical activity was positively associated with children and adolescents' physical activity, children in suburban/rural regions showed less activity than in urban regions, and, specifically in adolescents, self-efficacy was positively associated with physical activity. Family socioeconomic status and parental education were not associated with physical activity in children and adolescents.

Conclusions

The studies included in this review were large but mostly of low quality in terms of study design (cross-sectional) and methods (questionnaires). Parental physical activity and self-efficacy are promising targets for future physical activity promotion programmes. The low level of physical activity raises concern, especially in suburban/rural regions. Future research is required to enhance our understanding of other influences, such as the physical environment, especially in early childhood.

Keywords: Physical activity; factors; children; adolescents; Chinese; review

BACKGROUND

Globally, many children and adolescents are relatively inactive, mostly too inactive to meet the physical activity recommendations [1,2]. The trend of physical inactivity is increasing rapidly in most societies around the world. This fact is not only in high-income countries but also increasingly in low- and middle-income countries [3,4], as a consequence of the fast economic development and changing living environment over the past two decades [5-7]. For example, a rapid increase of vehicle ownership in the population is likely to reduce the need for “active transport” [8], and Chinese city children especially depend on their parents for daily transportation. As elsewhere in the world, physical inactivity is acknowledged as a key factor of human health in Chinese society [9,10].

The health benefits of physical activity for children and adolescents are well established [11,12]. Participation in physical activity during childhood plays an integral role in adult health outcomes, such as increased bone mineral density, and, indirectly, by preventing overweight [13]. Therefore, the World Health Organization recommends that children and adolescents aged 5–17 years should accrue at least 60 minutes of moderate to vigorous intensity physical activity daily [14]. Data of the Chinese “2010 National Physical Fitness and Health Surveillance” showed that 77.3% (128,890 out of 166,757 participants) of students in schools failed to meet the recommendation [15]. This level of physical activity may be too low to maintain good health. Since physical activity patterns track from childhood to adolescence and adulthood [16,17], understanding those factors that influence physical activity during early life can aid in the design of more effective interventions to stimulate physical activity later in life, or to counteract the growing trend towards inactivity. Several comprehensive reviews of correlates of children’s and adolescents’ physical activity have been published [18-20], however, none have focused on developing countries. This review will systematically review the factors related to physical activity in Chinese children and adolescents.

METHODS

This review was conducted and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [21].

Search procedure

A systematic search for studies investigating factors influencing physical activity in children and adolescents in China was conducted using two English-language electronic databases (Web of science and PubMed). Search terms were made up of a combination of keywords: "China" OR "Chinese" AND "child*" OR "adolescen*" OR "student*" OR "youth*" AND "physical activity" OR "activity level" OR "exercise" OR "physically active" OR "motor behavio*". The study search was carried out before Jan 10th, 2017. Subsequent studies were identified by screening the reference lists of papers that fulfilled the inclusion criteria.

Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) the study was published in English; (2) the study population consisted of Chinese children or adolescents living in China (age 3–18 years, or with a mean age in this range); and (3) the study reported a measurement of physical activity as the dependent outcome and examined the statistical associations with certain factors. The exclusion criteria were as follows: (1) the study population was characterized by disabilities or an illness that could lower their ability in terms of bodily movement; (2) intervention studies and studies that measured physical activity as the independent variable were not included, unless they reported associations between related factors and physical activity as the dependent outcome; (3) studies on physical inactivity and physical activity measured in a specific setting for a limited period of the day (such as during a physical education class) were excluded; (4) studies which were only published as abstract, a comment, or review were excluded, due to a lack of data for extraction, but the reference lists were checked for relevant studies.

Search results

In total 2200 hits were identified after excluding duplicates. Ninety-two papers remained, after reading titles and abstracts for inclusion and exclusion criteria. After a review of all the papers, 42studies were included in this review. The literature review strategy is shown in Figure 1.

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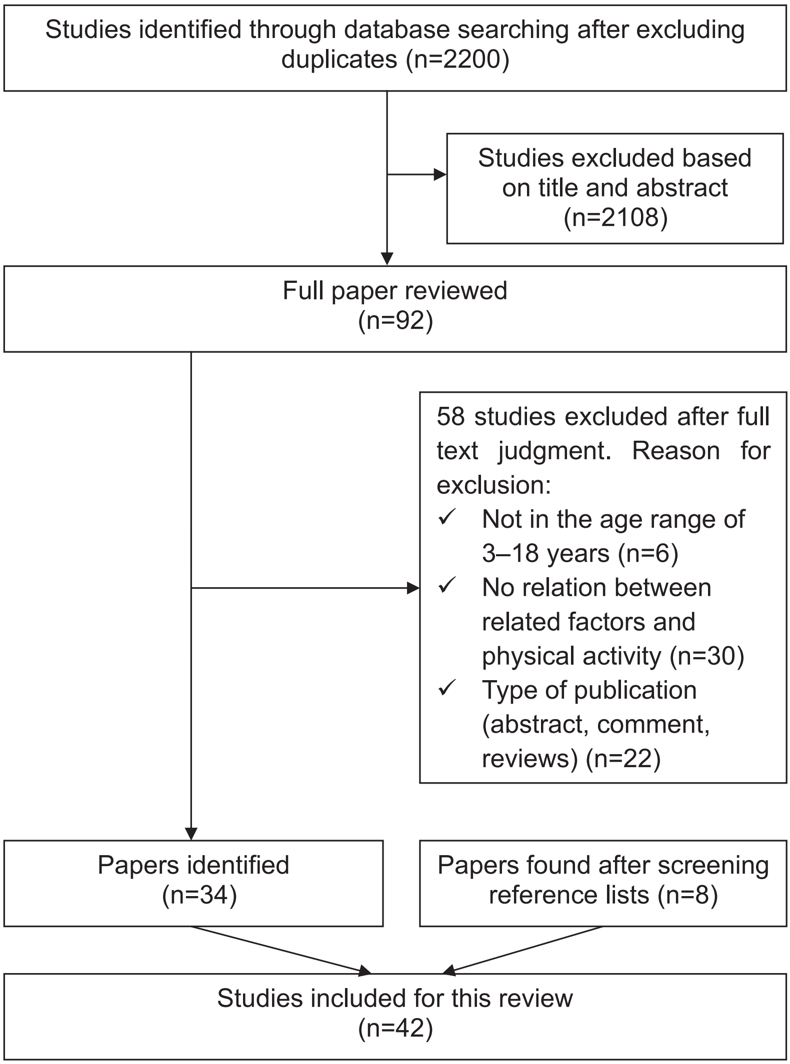

Figure 1. Flow chart of the literature search strategy.

Characteristics of the physical activity measurement

The outcomes were reported as total physical activity or leisure-time physical activity. If one study reported different intensities of physical activity, only moderate and vigorous physical activity were chosen for the summary. If both univariate and multivariate analyses were published, the adjusted multivariate results of potential correlates were selected for this review. Reported results separated by boys or girls, or different correlates for fathers or mothers, were also noted.

Method for summarizing results

For this review, we summarized potential associations that were examined in at least three studies. For every result in each paper, it is indicated whether the identified association is positive or negative. The direction of the association is expressed by a positive "+" or negative "–" association. For the summary of each variable, the hypothesized directions of associations were based on the rules drawn up by Sallis and colleagues [18]: the result was defined as no association (coded with a "0"), if 0–33% of findings supported the association, and as an inconclusive finding (coded with a "?"), if 34%–59%. If more than 59% of findings supported the association, the result was defined as a positive association (coded with a "+") or a negative association (coded with a "–"). We presented the correlates for children and adolescents separately, because, due to differences in age, results might show differences as demonstrated in previous studies [18,22].

Methodological quality assessment

Criteria for assessing the quality of studies were adapted from the Strengthening The Reporting of Observational studies in Epidemiology (STROBE) statement [23] and evaluation of the quality of prognosis studies in systematic reviews (QUIPS) [24]. Five items were considered the most important in the context of this review and were included in the checklist, including study design (met the criterion if a longitudinal design was used), study participation (met the criterion if study sample represent the population of interest in terms of key characteristics), outcome measurements (met the criterion if report a clear description of physical activity, and the instruments have an acceptable quality), related factors measurements (use validated methods and describe details of assessment), and data analysis (met the criterion if statistical tests used to assess the main outcomes appropriate, including confounding). A score was assigned to each study based on whether quality assessment items met the criterion (score = 1) or not (score = 0). Most studies used questionnaires to describe the activity level. It is known, however, that the validity of these questionnaires is limited. Therefore, in most studies we rated the validity as limited. The scores were summed and described as low quality (0–2) or acceptable quality (3–5).

Two reviewers independently screened titles and abstracts of all hits identified by the search, and the full text of all potentially eligible papers was screened for final selection by the same reviewers (CL & RW). Data extraction and the methodological quality were assessed independently by two reviewers (CL & RW); disagreement was discussed in a consensus meeting or by consulting a third reviewer (EC). The criteria for quality assessment are given in Additional file 1.

RESULTS

Study characteristics

A summary of the characteristics of the 42 papers is given in Table 1. The publication period ranged from 2002 to 2010 [25-41], with 25 papers (60%) published after 2010 [42-66]. Only 9 studies were longitudinal designs. The sample sizes ranged from 50 to 29,139 participants, and 18 papers (43%) had a sample size above one thousand. Seventeen papers included young children (aged 3–12 years or mean age in the period), 20 included only adolescents (13–18 years or mean age in the period), and 5 studies included both age groups. Objective assessment of physical activity was used in nine studies, such as an accelerometer [25,48,56,58-61], a pedometer [53], and heart rate monitoring [35]. The other studies used questionnaires to measure physical activity. From all the studies, 69% reported on the quality of the tools (reliability or validity) or referred to the original publication. The characteristics of the individual papers are summarized in Additional file 2.

Results of the methodological quality assessment

Overall, only two studies met all five quality criteria. Eighteen studies (43%) failed to meet the criteria for participation, since the response rate was less than 80% or not clearly described. Ten studies (24%) lacked information on handling confounders, and thus failed to meet the criteria for data analysis. In sum, 37 studies (88%) showed acceptable quality, and 5 studies (12%) low quality. Low quality studies are marked in Table 2. Results of the methodological quality assessment are summarized in Additional file 3.

Level of physical activity

The levels of physical activity described in the studies are summarized in Additional file 2. The outcomes of physical activity were varied due to different measurements. Fifteen studies provided data for children or adolescents meeting physical activity recommendations. Most studies ($N = 13$) used the same international guidelines, that is, participating in physical activity for at least 60 minutes of MVPA per day [14,67,68], and found a low level of physical activity, especially in large sample studies [40,49]. Two studies of children and seven of adolescents reported less than 50% of participants failed to meet the recommendations. The prevalence rates of compliance to recommendations of physical activity in children range from 3.6% to 89.4%, and in adolescents range from 4.7% to 63.4%. Results of the 15 studies are presented in Figure 2.

Table 1. Summary of characteristics of the included papers (*N* = 42).

Characteristics of the papers	N (%)	Paper No.
Year of publication		
2002–2005	5 (12)	[25-29]
2006–2010	12 (29)	[30-41]
2011–2016	25 (60)	[42-66]
Study design		
Longitudinal	9 (21)	[29,38,42,46,51,56-59]
Cross-sectional	33 (79)	[25-28,30-37,39-41,43-45,47-50,52-55,60-66]
Sample size		
50≤ n <100	4 (10)	[25,35,53,59]
100≤ n <500	11 (26)	[26,28,33,39,42,44,47,50,56,60,62]
500≤ n <1000	9 (21)	[29,30,36,38,46,54,58,61,66]
1000≤ n <10000	16 (38)	[27,31,32,34,37,41,43,45,48,51,52,55,57,63-65]
n >10000	2 (5)	[40,49]
Age group		
Children (3–12 yrs.)	17 (40)	[25,28,33,36,37,39,42,44,47,50,53,56,58-60,64,66]
Adolescent (13–18 yrs.)	20 (48)	[26,29-32,35,38,40,41,45,46,49,51,52,54,55,61-63,65]
Both (3–18 yrs.)	5 (12)	[27,34,43,48,57]
Method of PA measurement*		
Objective measurement of PA	9 (21)	
Reported reliability or validity	1 (2)	[25]
Mention of original reference	3 (7)	[53,60,61]
None reported	5 (12)	[35,48,56,58,59]
PA measured by questionnaires	35 (83)	
Reported reliability and validity	5 (12)	[28,33,35,40,56]
Reported reliability or validity	8 (19)	[26,29,36,39,44,45,60,63]
Mention of original reference	14 (33)	[27,31,32,34,37,41,42,46,47,50,52,54,62,65]
None reported	8 (19)	[30,38,43,49,55,57,64,66]

**Totals may add up to more than 100%, since two studies included both objective and questionnaire measurement of PA [35,60].*

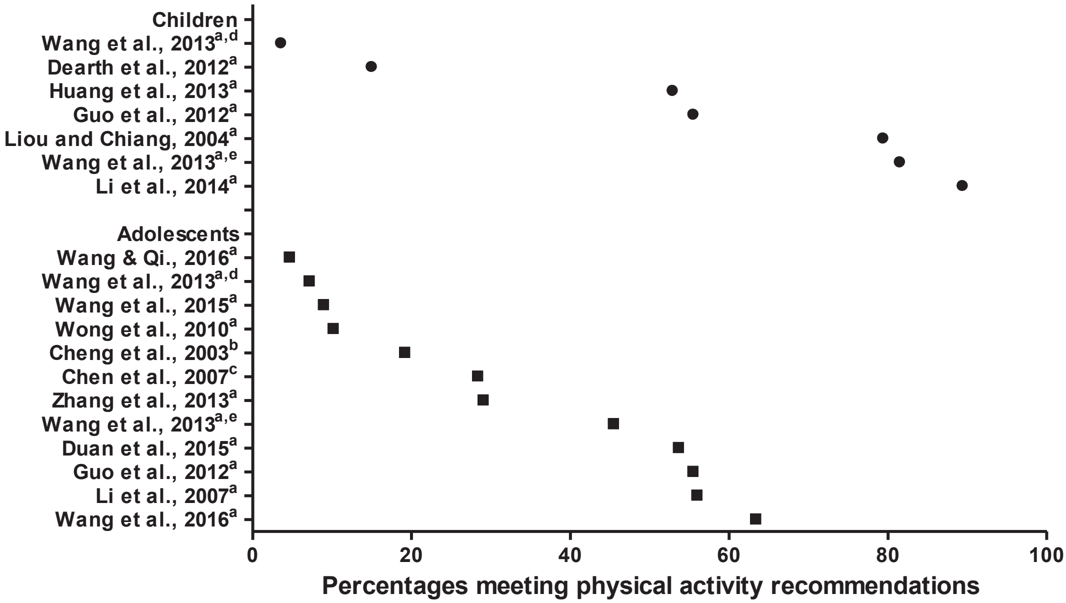

Figure 2. Prevalence (%) of compliance with recommendations of physical activity in 15 studies.

a Recommendation to participate in physical activity for at least 60 minutes of MVPA per day;

b Recommendation of three or more sessions per week of activities that last 20 min. or more, and that require moderate to vigorous levels of exertion (Sallis, 1994 [92]);

c Recommendation to participate in physical activity 3 or more times a week for at least 30 minutes, which entails deep breathing and increased heartbeat (Taiwanese recommendations for physical activity).

d Chinese-specific cut-off points for accelerometry used in study (Wang et al., 2013 [48]).

e Freedson's cut-off points for accelerometry used in study (Wang et al., 2013 [48]).

Factors influencing physical activity

Potential correlates for physical activity and factors influencing the activity level are summarized in Table 2. As described before, a correlation was defined as positive if 59–100% of studies found a positive ("+") association and as negative if 59–100% of studies found a negative ("−") association. Eleven variables were investigated in at least three studies: gender, urbanization, maternal physical activity, paternal physical activity, weight status, socioeconomic status, parental education, self-efficacy, age, previous physical activity and intention. Gender (*N* = 20 papers), both in children and adolescents, was consistently found to have a positive association with physical activity: thus, boys were more active than girls. For maternal physical activity (*N* = 5 papers), it was shown that both children and adolescents were more active if their mother were more active. Paternal physical activity was also found (*N* = 3 papers) to have a positive association with physical activity in adolescents. Urbanization (*N* = 8 papers) yielded different results for young children and adolescents. For young children, those living in urban regions showed more physical activity than suburban/rural children. The correlates for urbanization in adolescents were inconclusive. The weight status (*N* = 9 papers) showed no association with children's physical activity, and showed inconsistent results with adolescents' physical activity. In both young children and adolescents, family socioeconomic status (*N* = 9 papers) and parental education (*N* = 7 papers) were found to have no association with their physical activity level. Age as a factor of physical activity showed inconsistent results, this may be attributed to the limited range in age of most studies, thus it was difficult to arrive at any conclusion. In adolescents, self-efficacy was also investigated (*N* = 4 papers) and showed a consistently positive association with physical activity. In addition, we found some factors that are not presented in the Table 2 due to insufficient papers for summarized results. For more information see Additional file 2.

Table 2. Potential correlates of physical activity in young children and adolescents.

Variables	Age group	Related to PA		Unrelated to PA	Summary	
		Paper No.	Corr[a]	Paper No.	n/N (%)	Corr[a]
Gender (male)	Children	[36], [43][b]MVPA, [44]Lt(VPA), [48]MVPA, [52]MVPA, [53], [60]MVPA	+	[25], [27]MVPA, [28], [37][b]MVPA	+7/11 (64)	+
	Adolescents	[27]MVPA, **[29]**, [31], [32]Lt(VPA), [41]Lt, [43][b]MVPA, [45], **[46]**Lt, [48]MVPA, [61]MVPA, [63]MVPA	+	[30][b], [32]Lt(MPA)	+11/13 (85)	+
Mother's PA	Children	**[42]**Lt(MVPA), [50]MVPA, **[57]**Lt	+	[34]MVPA	+3/4 (75)	+
	Adolescents	**[57]**Lt, [65]MVPA	+	[34]MVPA	+2/3 (67)	+
Father's PA	Children	[34]MVPA, **[57]**Lt	+	None		
	Adolescents	[34]MVPA, **[57]**Lt, [65]MVPA	+	None	+3/3 (100)	+
Self-efficacy	Children	[60]MVPA	+	None		
	Adolescents	**[29]**, **[38]**Lt, [54], [62]MVPA	+	None	+4/4 (100)	+
Urbanization (urban)	Children	[33]MVPA(F), [34]MVPA, [52]MVPA	+	[36], **[42]**Lt(MVPA)	+3/5 (60)	+
	Adolescents	[31], [34]MVPA	+	[30][b]M, [32]Lt(MPA&VPA)	+2/5 (40)	?
		[30][b]F	−			
Weight status	Children	[64][b]	−	[47]MVPA, [48]MVPA, [53], [60]MVPA, [66]Lt	−1/6 (17)	0
	Adolescents	[49], [63]MVPA	−	[31], [48]MVPA	−2/4 (50)	?
SES	Children	[43][b,c]MVPA	+	[36], **[42]**Lt(MVPA)	+1/3 (33)	0
	Adolescents	[43][b,c]MVPA, [54]	+	[30][b]F, [32]Lt(MPA&VPA), [63][c]MVPA, [65]MVPA	+2/8 (25)	0
		[30][b]M, [61][c]MVPA	−			
Parental education	Children	None		[36], **[42]**[d]Lt(MVPA), [43][b]MVPA, [47]MVPA	0/4 (0)	0

Variables	Age group	Related to PA		Unrelated to PA	Summary	
		Paper No.	Corr[a]	Paper No.	n/N (%)	Corr[a]
	Adolescents	[30][b,d]M	+	[30][b,d]F, [31], [43][b]MVPA,	+1/5 (20)	0
		[29]	−			
Age	Children	[37]MVPA, **[42]**Lt(MVPA)	+	[28], [53],[60]MVPA	+2/5 (40)	?
	Adolescents	[27]MVPA, [31], [45]	−	[30][b], [32]Lt(MPA&VPA), [54], [61]MVPA, [63]MVPA	−3/8 (38)	?
Previous PA	Children	None				
	Adolescents	**[38]**Lt, **[46]**Lt, **[51]**Lt(MVPA)	+ −	[62]MVPA	+2/4 (50)	?
Intention	Children	None				
	Adolescents	[65]MVPA	+	**[38]**Lt, **[46]**Lt, [62]MVPA	+1/4 (25)	0

Note. Bold longitudinal study, F female, Lt leisure time physical activity, M male, MPA moderate physical activity, MVPA moderate-to-vigorous physical activity, PA physical activity, SES socioeconomic status (household income), Underline objective measurement of physical activity, VPA vigorous physical activity.

[a] *Correlates were examined in at least three studies. The result is defined as no correlation ("0") if 0–33% of findings supported the correlation, as inconclusive ("?"), if it was 34%–59%, and positive ("+"), or negative ("−"), if it was 59%−100% (Sallies 2000 [18]).*

[b] *Low quality study.*

[c] *Middle level SES (family income ranging from RMB 2000 to RMB 5000 per month).*

[d] *Maternal education.*

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DISCUSSION

For this review, we identified 42 papers published in English summarizing potential factors influencing physical activity in Chinese children and adolescents, and further identified eleven factors that were investigated in at least three studies. The results showed boys were consistently more active than girls. The parental physical activity was positively associated with children and adolescents' physical activity. Children in suburban/rural regions showed less activity than in urban regions, and, specifically in adolescents, self-efficacy was positively associated with physical activity.

For the difference in physical activity between rural and urban regions, our finding is different from studies in western countries. A review showed no difference in children's physical activity between rural and urban areas in the United States [69]; another study in Brazil showed children from rural areas were more active than those from urban areas. The direction and significance of rural-urban difference in physical activity might vary by the type of population, how long ago the study was done, and also by the method of physical activity measurement [70]. One study found children who lived in rural areas of China also showed an obviously increasing trend towards overweight or obesity prevalence in recent years [71], as physical activity is an acknowledged component of energy-balance-related behaviors. One explanation is that this might be due to the rapid industrialization and environmental contamination in the Chinese countryside, limited number of children's playgrounds, and lack of physical activity facilities compared to urban schools. Another reason explaining this is that children, in rural areas especially, watch TV frequently, and longer TV-watching time may limit the chances for physical activity [72]. One study found that the daily viewing time of children in China's rural areas significantly increased from 0.7 hour to 1.7 hours between 1997 and 2006 [73].

Families who live in urban areas usually have higher levels of education and socioeconomic status compared to suburban/rural areas, but there is only a small difference in family media equipment (television, mobile phones) between urban and rural areas, except for some western regions of China [74]. That might explain the reason that we found no association between parental education or family socioeconomic status and physical activity in this review. It should be noted however that the studies on urbanization, household income, and parental education were often of low quality. Future research is needed to find out whether this difference between rural/sub-rural and urban areas is related to environmental factors outside the household, such as the neighborhood characteristics or school environment.

The levels of physical activity included in this review were reported in various ways, but the low level of physical activity was clearly shown in most studies in Figure 2, especially in Chinese adolescents. The result of age was inconclusive in Table 2, since most studies included a limited range of ages, and so it was difficult to arrive at any conclusion. A decrease in physical activity related to age during adolescence has been reported before in North American children [75,76]. A recent systematic review of European children and adolescents also supported the same point [77]. Chinese adolescents (13–18 years) are in middle/high school, and under pressure from high school or college entrance examinations. Compared to children, adolescents spend more time in school and doing homework. Information on policy-influencing physical activity is scarce for Chinese children and adolescents, and further confirmation is needed, since a decrease in physical activity with increasing age and thus a change in energy balance may contribute substantially to the obesity epidemic. An effective public health policy to promote physical activity during school age may be of benefit to Chinese society [71,78].

The finding that male sex was a consistently positive correlate in Chinese children and adolescents is in agreement with previous reviews [78,79]. Apparently, boys report more physical activity than girls vis-à-vis different cultures and populations. The correlation between parental physical activity and children or adolescents physical activity was consistently positive in the Chinese studies. This was confirmed in some studies from different countries [80,81], although not always consistently in the reviews [82,83]. Chinese mothers have a long and deep influence on children's lifestyles in traditional Chinese culture, much like mothers in other societies. This finding also suggests that to increase physical activity in children, parents need to be active themselves. Family-based interventions to increase physical activity level may be most effective if parents and children are encouraged to engage in physical activities together.

Self-efficacy for adolescent physical activity was defined as a young person's belief in his/her ability to participate in physical activity and to perform physical activity despite existing barriers [84]. It has been identified as a determinant or mediator of physical activity in adolescents in previous reviews, mostly in developed countries [85,86]. We identified that self-efficacy was consistently positively associated with adolescent physical activity from four papers of relatively high quality, of which two studies had a longitudinal design with self-efficacy measured by different scales, validated or adapted from previously validated measurements [87,88]. This suggests that programs to promote physical activity in adolescents, which strengthen physical activity self-efficacy, have a high potential for being effective.

The adapted ecological model by the Lancet Physical Activity Series Working Group provides a comprehensive overview of the possible correlates of daily physical activity [89]. Based on the findings of Bauman and colleagues, combined with the findings from this review, we can conclude that, in particular, the psychological, cognitive, social, and environmental factors were difficult to summarize due to limited research. An understanding of the physical environmental correlates of transport and leisure-time activity in a developing country such as China is urgently needed to support the development of interventions to reverse the rapid trend towards inactivity. The inactivity trend may be driven by urbanization, passive entertainment, and motorized transport. For young people, this is especially important, because children and adolescents have less autonomy in their behaviors and are more likely than adults to be influenced by the environment, directly (through parents or peers) or indirectly [90,91]. For example, active rather than passive videogames may stimulate physical activity in children [59], and increasing awareness of neighborhood sport facilities or building more such facilities may help active adolescents maintain or increase their leisure time PA [40,51].

According to the results of our methodological quality assessment, lack of a longitudinal study design and using indirect measurements for outcome or determinants assessment have limited the quality of the research included in this review. To provide a full description of factors examined, we kept low quality papers in table 2. Sensitivity analysis showed that the present results would not be changed wether low quality studies were excluded or not. High quality longitudinal studies using accelerometry or other objective devices to measure daily physical activity are needed to better understand the low level of activity, and how this relates to urbanization, fast economic development, and the rapidly changing living environment.

One limitation in this review is the limited number of studies of good quality. Another limitation is that only English-language published studies were included in our review. Papers published in Chinese might have given more information on this topic. A search till Dec, 10th, 2014 in Weipu, Wanfang and the CNKI Chinese Database resulted in 22 papers. However, the quality of these papers was low. Mostly papers published in Chinese were cross-sectional studies and used an invalid or poorly validated physical activity measurement tool. Moreover, for non-Chinese speakers, data of papers published in Chinese are not accessible for verification or reference. Furthermore, the majority of these studies were also published in internationally peer-reviewed journals in English. The inclusion criteria to publish in internationally peer reviewed journals in English guarantees a minimum in report quality as well as general accessibility to the results.

CONCLUSION

The present review shows that Chinese children and adolescents have a low level of physical activity. Gender, urbanization, parental physical activity, and self-efficacy are important factors influencing physical activity. These factors could be taken into consideration in order to design effective interventions to counteract or halt the trend towards inactivity in young people. The results also suggest that the factors influencing the physical activity of Chinese children and adolescents are not yet fully understood, due to limited research quality and inconclusive findings. Future research is required to enhance our understanding of other influences, such as the physical environment, especially in early childhood.

REFERENCES

[1] Guthold R, Cowan MJ, Autenrieth CS, Kann L, Riley LM. Physical activity and sedentary behavior among schoolchildren: a 34-country comparison. J Pediatr. 2010;157(1):43,49.e1; doi:10.1016/j.jpeds.2010.01.019.

[2] de Moraes AC, Guerra PH, Menezes PR. The worldwide prevalence of insufficient physical activity in adolescents; a systematic review. Nutr Hosp. 2013;28(3):575-84; doi:10.3305/nh.2013.28.3.6398.

[3] Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. Lancet. 2012;380(9838):247-57; doi:10.1016/S0140-6736(12)60646-1.

[4] Muller AM, Khoo S, Lambert R. Review of physical activity prevalence of Asian school-age children and adolescents. Asia Pac J Public Health. 2013;25(3):227-38; doi:10.1177/1010539513481494.

[5] Qin L, Corpeleijn E, Jiang C, Thomas GN, Schooling CM, Zhang W, et al. Physical activity, adiposity, and diabetes risk in middle-aged and older Chinese population: the Guangzhou Biobank Cohort Study. Diabetes Care. 2010;33(11):2342-8; doi:10.2337/dc10-0369.

[6] Zhu YG, Ioannidis JP, Li H, Jones KC, Martin FL. Understanding and harnessing the health effects of rapid urbanization in China. Environ Sci Technol. 2011;45(12):5099-104; doi:10.1021/es2004254.

[7] Xu P, Chen Y, Ye X. Haze, air pollution, and health in China. Lancet. 2013;382(9910):2067; doi:10.1016/S0140-6736(13)62693-8.

[8] Qin L, Stolk RP, Corpeleijn E. Motorized transportation, social status, and adiposity: the China Health and Nutrition Survey. Am J Prev Med. 2012;43(1):1-10; doi:10.1016/j.amepre.2012.03.022.

[9] Ng SW, Howard AG, Wang HJ, Su C, Zhang B. The physical activity transition among adults in China: 1991-2011. Obes Rev. 2014;15 Suppl 1:27-36; doi:10.1111/obr.12127.

[10] Tian Y, Jiang C, Wang M, Cai R, Zhang Y, He Z, et al. BMI, leisure-time physical activity, and physical fitness in adults in China: results from a series of national surveys, 2000-14. Lancet Diabetes Endocrinol. 2016;4(6):487-97; doi:10.1016/S2213-8587(16)00081-4.

[11] Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act. 2010;7:40; doi:10.1186/1479-5868-7-40.

[12] Timmons BW, Leblanc AG, Carson V, Connor Gorber S, Dillman C, Janssen I, et al. Systematic review of physical activity and health in the early years (aged 0-4 years). Appl Physiol Nutr Metab. 2012;37(4):773-92; doi:10.1139/h2012-070.

[13] Loprinzi PD, Cardinal BJ, Loprinzi KL, Lee H. Benefits and environmental determinants

of physical activity in children and adolescents. Obes Facts. 2012;5(4):597-610; doi:10.1159/000342684.

[14] World Health Organization. Global recommendations on physical activity for health. : Geneva: World Health Organization; 2010.

[15] Zhang X, Song Y, Yang TB, Zhang B, Dong B, Ma J. Analysis of current situation of physical activity and influencing factors in Chinese primary and middle school students in 2010. Zhonghua Yu Fang Yi Xue Za Zhi. 2012;46(9):781-8.

[16] Jones RA, Hinkley T, Okely AD, Salmon J. Tracking physical activity and sedentary behavior in childhood: a systematic review. Am J Prev Med. 2013;44(6):651-8; doi:10.1016/j.amepre.2013.03.001.

[17] Telama R. Tracking of physical activity from childhood to adulthood: a review. Obes Facts. 2009;2(3):187-95; doi:10.1159/000222244.

[18] Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc. 2000;32(5):963-75.

[19] Hinkley T, Crawford D, Salmon J, Okely AD, Hesketh K. Preschool children and physical activity: a review of correlates. Am J Prev Med. 2008;34(5):435-41; doi:10.1016/j.amepre.2008.02.001.

[20] Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth a review. Am J Prev Med. 2011;41(4):442-55; doi:10.1016/j.amepre.2011.06.036.

[21] Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Grp. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Int J Surg. 2010;8(5):336-41; doi:10.1016/j.ijsu.2010.02.007.

[22] Ferreira I, van der Horst K, Wendel-Vos W, Kremers S, van Lenthe FJ, Brug J. Environmental correlates of physical activity in youth - a review and update. Obes Rev. 2007;8(2):129-54; doi:10.1111/j.1467-789X.2006.00264.x.

[23] Vandenbroucke JP, Von Elm E, Altman DG, Gotzsche PC, Mulrow CD, Pocock SJ, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. Epidemiology. 2007;18(6):805-35; doi:10.1097/EDE.0b013e3181577511.

[24] Hayden JA, Cote P, Bombardier C. Evaluation of the quality of prognosis studies in systematic reviews. Ann Intern Med. 2006;144(6):427-37; doi:10.7326/0003-4819-144-6-200603210-00010.

[25] Rowlands AV, Eston RG, Louie L, Ingledew DK, Tong KK, Fu FH. Physical activity levels of Hong Kong Chinese children: Relationship with body fat. Pediatric Exercise Science. 2002;14(3):286-96.

[26] Cheng KY, Cheng PG, Mak KT, Wong SH, Wong YK, Yeung EW. Relationships of perceived benefits and barriers to physical activity, physical activity participation and physical fitness in Hong Kong female adolescents. J Sports Med Phys Fitness. 2003;43(4):523-9.

[27] Tudor-Locke C, Ainsworth BE, Adair LS, Du S, Popkin BM. Physical activity and inactivity in Chinese school-aged youth: the China Health and Nutrition Survey. Int J Obes Relat Metab Disord. 2003;27(9):1093-9; doi:10.1038/sj.ijo.0802377.

[28] Liou YM, Chiang LC. Levels of physical activity among school-age children in Taiwan: a comparison with international recommendations. J Nurs Res. 2004;12(4):307-16.

[29] Wu TY, Pender N. A panel study of physical activity in Taiwanese youth: testing the revised health-promotion model. Fam Community Health. 2005;28(2):113-24.

[30] Shi Z, Lien N, Kumar BN, Holmboe-Ottesen G. Physical activity and associated socio-demographic factors among school adolescents in Jiangsu Province, China. Prev Med. 2006;43(3):218-21; doi:10.1016/j.ypmed.2006.04.017.

[31] Chen LJ, Haase AM, Fox KR. Physical activity among adolescents in Taiwan. Asia Pac J Clin Nutr. 2007;16(2):354-61.

[32] Li M, Dibley MJ, Sibbritt DW, Zhou X, Yan H. Physical activity and sedentary behavior in adolescents in Xi'an City, China. J Adolesc Health. 2007;41(1):99-101; doi:10.1016/j.jadohealth.2007.02.005.

[33] Chen JL, Unnithan V, Kennedy C, Yeh CH. Correlates of physical fitness and activity in Taiwanese children. Int Nurs Rev. 2008;55(1):81-8; doi:10.1111/j.1466-7657.2007.00588.x.

[34] Li L, Lin C, Cao H, Lieber E. Intergenerational and urban-rural health habits in Chinese families. Am J Health Behav. 2009;33(2):172-80; doi:10.5555/ajhb.2009.33.2.172.

[35] Wang J, Huo JS, Sun J, Ning ZX. Physical performance of migrant schoolchildren with marginal and severe iron deficiency in the suburbs of Beijing. Biomed Environ Sci. 2009;22(4):333-9; doi:10.1016/S0895-3988(09)60064-7.

[36] Huang SJ, Hung WC, Sharpe PA, Wai JP. Neighborhood environment and physical activity among urban and rural schoolchildren in Taiwan. Health Place. 2010;16(3):470-6; doi:10.1016/j.healthplace.2009.12.004.

[37] Lam JWK, Sit CHP, Cerin E. Physical activity and sedentary behaviors in Hong Kong primary school children: Prevalance and gender differences. Prev Med. 2010;51(1):96-7; doi:10.1016/j.ypmed.2010.04.017.

[38] Luszczynska A, Cao DS, Mallach N, Pietron K, Mazurkiewicz M, Schwarzer R. Intentions, planning, and self-efficacy predict physical activity in Chinese and Polish adolescents: Two moderated mediation analyses. Int J Clin Health Psychol. 2010;10(2):265-78.

[39] Pang B, Ha ASC. Subjective task value in physical activity participation: The perspective of Hong Kong schoolchildren. European Physical Education Review. 2010;16(3):223-35;

doi:10.1177/1356336X10382971.

[40] Wong BY, Cerin E, Ho SY, Mak KK, Lo WS, Lam TH. Adolescents' physical activity: competition between perceived neighborhood sport facilities and home media resources. Int J Pediatr Obes. 2010;5(2):169-76; doi:10.3109/17477160903159432.

[41] Xu F, Li J, Liang Y, Wang Z, Hong X, Ware RS, et al. Associations of Residential Density with Adolescents' Physical Activity in a Rapidly Urbanizing Area of Mainland China. Journal of Urban Health-Bulletin of the New York Academy of Medicine. 2010;87(1):44-53; doi:10.1007/s11524-009-9409-9.

[42] Dearth-Wesley T, Gordon-Larsen P, Adair LS, Zhang B, Popkin BM. Longitudinal, cross-cohort comparison of physical activity patterns in Chinese mothers and children. Int J Behav Nutr Phys Act. 2012;9:39; doi:10.1186/1479-5868-9-39.

[43] Guo X, Zhang X, Li Y, Zhou X, Yang H, Ma H, et al. Differences in healthy lifestyles between prehypertensive and normotensive children and adolescents in Northern China. Pediatr Cardiol. 2012;33(2):222-8; doi:10.1007/s00246-011-0112-8.

[44] Cheung PPY. Association of after-school physical activity levels and organized physical activity participation in Hong Kong children. European Physical Education Review. 2012;18(2):182-90; doi:10.1177/1356336X12440021.

[45] Wen X, Hui SS. Parenting Style as a Moderator of the Association Between Parenting Behaviors and the Weight Status of Adolescents. Journal of Early Adolescence. 2012;32(2):252-68; doi:10.1177/0272431610393249.

[46] Cao DS, Schuz N, Xie GR, Lippke S. Planning skills moderate the intention-planning cognitions-behaviour relation: a longitudinal study on physical activity in Chinese adolescents. Res Sports Med. 2013;21(1):12-23; doi:10.1080/15438627.2012.738441.

[47] Huang WY, Wong SH, Salmon J. Correlates of physical activity and screen-based behaviors in Chinese children. J Sci Med Sport. 2013;16(6):509-14; doi:10.1016/j.jsams.2012.12.011.

[48] Wang C, Chen P, Zhuang J. A national survey of physical activity and sedentary behavior of Chinese city children and youth using accelerometers. Res Q Exerc Sport. 2013;84 Suppl 2:S12-28; doi:10.1080/02701367.2013.850993.

[49] Zhang YX, Zhao JS, Zhou JY, Chu ZH, Wu GJ. Comparison on physical activity among adolescents with different weight status in Shandong, China. J Trop Pediatr. 2013;59(3):226-30; doi:10.1093/tropej/fms074.

[50] Li B, Adab P, Cheng KK. Family and neighborhood correlates of overweight and obesogenic behaviors among Chinese children. Int J Behav Med. 2014;21(4):700-9; doi:10.1007/s12529-013-9333-y.

[51] Wong BY, Ho SY, Lo WS, Cerin E, Mak KK, Lam TH. Longitudinal relations of perceived availability of neighborhood sport facilities with physical activity in adolescents: an analysis of

potential moderators. J Phys Act Health. 2014;11(3):581-7; doi:10.1123/jpah.2012-0077.

[52] Duan J, Hu H, Wang G, Arao T. Study on Current Levels of Physical Activity and Sedentary Behavior among Middle School Students in Beijing, China. PLoS One. 2015;10(7); doi:10.1371/journal.pone.0133544.

[53] Gao Y, Wang J, Lau PWC, Ransdell L. Pedometer-determined physical activity patterns in a segmented school day among Hong Kong primary school children. Journal of Exercise Science & Fitness. 2015;13(1):42-8; doi:10.1016/j.jesf.2015.03.002.

[54] Ho FK, Louie LH, Chow CB, Wong WH, Ip P. Physical activity improves mental health through resilience in Hong Kong Chinese adolescents. BMC Pediatr. 2015;15:48; doi:10.1186/s12887-015-0365-0.

[55] Wang X, Liu QM, Ren YJ, Lv J, Li LM. Family influences on physical activity and sedentary behaviours in Chinese junior high school students: a cross-sectional study. BMC Public Health. 2015;15:287; doi:10.1186/s12889-015-1593-9.

[56] Wong SH, Huang WY, He G. Longitudinal changes in objectively measured physical activity differ for weekdays and weekends among Chinese children in Hong Kong. BMC Public Health. 2015;15:1310; doi:10.1186/s12889-015-2618-0.

[57] Dong F, Howard AG, Herring AH, Thompson AL, Adair LS, Popkin BM, et al. Parent-child associations for changes in diet, screen time, and physical activity across two decades in modernizing China: China Health and Nutrition Survey 1991-2009. Int J Behav Nutr Phys Act. 2016;13(1):118; doi:10.1186/s12966-016-0445-z.

[58] Huang WY, Wong SH, He G, Salmon J. Isotemporal Substitution Analysis for Sedentary Behavior and Body Mass Index. Med Sci Sports Exerc. 2016;48(11):2135-41; doi:10.1249/MSS.0000000000001002.

[59] Lau PW, Wang JJ, Maddison R. A Randomized-Controlled Trial of School-Based Active Videogame Intervention on Chinese Children's Aerobic Fitness, Physical Activity Level, and Psychological Correlates. Games Health J. 2016;5(6):405-12; doi:10.1089/g4h.2016.0057.

[60] Wang JJ, Baranowski T, Lau PW, Chen TA, Zhang SG. Psychological Correlates of Self-Reported and Objectively Measured Physical Activity among Chinese Children-Psychological Correlates of PA. Int J Environ Res Public Health. 2016;13(10):E1006; doi:10.3390/ijerph13101006.

[61] Wang L, Qi J. Association between Family Structure and Physical Activity of Chinese Adolescents. Biomed Res Int. 2016;2016:4278682; doi:10.1155/2016/4278682.

[62] Wang L, Zhang Y. An extended version of the theory of planned behaviour: the role of self-efficacy and past behaviour in predicting the physical activity of Chinese adolescents. J Sports Sci. 2016;34(7):587-97; doi:10.1080/02640414.2015.1064149.

[63] Wang X, Hui Z, Terry PD, Ma M, Cheng L, Deng F, et al. Correlates of Insufficient Physical Activity among Junior High School Students: A Cross-Sectional Study in Xi'an, China. Int J

Environ Res Public Health. 2016;13(4):397; doi:10.3390/ijerph13040397.

[64] Xu X, Sharma M, Liu L, Hu P, Zhao Y. Mediation of the Physical Activity and Healthy Nutrition Behaviors of Preschool Children by Maternal Cognition in China. International Journal of Environmental Research and Public Health. 2016;13(9):909; doi:10.3390/ijerph13090909.

[65] Yeung DC, Yuan X, Hui SS, Feresu SA. Determinants of moderate to vigorous physical activity and obesity in children: a structural equation modeling analysis. World J Pediatr. 2016;12(2):170-6; doi:10.1007/s12519-015-0057-8.

[66] Zheng W, Chen Y, Zhao A, Xue Y, Zheng Y, Mu Z, et al. Associations of sedentary behavior and physical activity with physical measurements and dyslipidemia in school-age children: a cross-sectional study. BMC Public Health. 2016;16(1):1186; doi:10.1186/s12889-016-3826-y.

[67] O'Donovan G, Blazevich AJ, Boreham C, Cooper AR, Crank H, Ekelund U, et al. The ABC of Physical Activity for Health: a consensus statement from the British Association of Sport and Exercise Sciences. J Sports Sci. 2010;28(6):573-91; doi:10.1080/02640411003671212.

[68] Cavill N, Biddle S, Sallis J. Health enhancing physical activity for young people: Statement of the United Kingdom Expert Consensus Conference. Pediatr Exerc Sci. 2001;13(1):12-25; doi:10.1123/pes.13.1.12.

[69] Sandercock G, Angus C, Barton J. Physical activity levels of children living in different built environments. Prev Med. 2010;50(4):193-8; doi:10.1016/j.ypmed.2010.01.005.

[70] Fan JX, Wen M, Kowaleski-Jones L. Rural-urban differences in objective and subjective measures of physical activity: findings from the National Health and Nutrition Examination Survey (NHANES) 2003-2006. Prev Chronic Dis. 2014;11:E141; doi:10.5888/pcd11.140189.

[71] Sun H, Ma Y, Han D, Pan CW, Xu Y. Prevalence and trends in obesity among China's children and adolescents, 1985-2010. PLoS One. 2014;9(8):e105469; doi:10.1371/journal.pone.0105469.

[72] Guillaume M, Lapidus L, Bjorntorp P, Lambert A. Physical activity, obesity, and cardiovascular risk factors in children. The Belgian Luxembourg Child Study II. Obes Res. 1997;5(6):549-56; doi:10.1002/j.1550-8528.1997.tb00576.x.

[73] Cui Z, Hardy LL, Dibley MJ, Bauman A. Temporal trends and recent correlates in sedentary behaviours in Chinese children. Int J Behav Nutr Phys Act. 2011;8:93; doi:10.1186/1479-5868-8-93.

[74] National Bureau of Statistics of the People's Republic of China. China Statistical Yearbook. 2014; Available at: http://www.stats.gov.cn/tjsj/ndsj/. Accessed Feb/15, 2016.

[75] Caspersen CJ, Pereira MA, Curran KM. Changes in physical activity patterns in the United States, by sex and cross-sectional age. Med Sci Sports Exerc. 2000;32(9):1601-9.

[76] Allison KR, Adlaf EM, Dwyer JJ, Lysy DC, Irving HM. The decline in physical activity among adolescent students: a cross-national comparison. Can J Public Health. 2007;98(2):97-100.

[77] Van Hecke L, Loyen A, Verloigne M, Van der Ploeg HP, Lakerveld J, Brug J, et al. Variation in population levels of physical activity in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC. Int J Behav Nutr Phys Act. 2016;13:70; doi:10.1186/s12966-016-0396-4.

[78] Bauman A, Allman-Farinelli M, Huxley R, James WP. Leisure-time physical activity alone may not be a sufficient public health approach to prevent obesity--a focus on China. Obes Rev. 2008;9 Suppl 1:119-26; doi:10.1111/j.1467-789X.2007.00452.x.

[79] Van Der Horst K, Paw MJ, Twisk JW, Van Mechelen W. A brief review on correlates of physical activity and sedentariness in youth. Med Sci Sports Exerc. 2007;39(8):1241-50; doi:10.1249/mss.0b013e318059bf35.

[80] Holm K, Wyatt H, Murphy J, Hill J, Odgen L. Parental influence on child change in physical activity during a family-based intervention for child weight gain prevention. J Phys Act Health. 2012;9(5):661-9.

[81] Sijtsma A, Sauer PJ, Corpeleijn E. Parental correlations of physical activity and body mass index in young children--he GECKO Drenthe cohort. Int J Behav Nutr Phys Act. 2015;12:132; doi:10.1186/s12966-015-0295-0.

[82] Edwardson CL, Gorely T. Parental influences on different types and intensities of physical activity in youth: A systematic review. Psychol Sport Exerc. 2010;11(6):522-35; doi:10.1016/j.psychsport.2010.05.001.

[83] Trost SG, Loprinzi PD. Parental influences on physical activity behavior in children and adolescents: a brief review. American Journal of Lifestyle Medicine. 2011;5(2):171-81; doi:10.1177/1559827610387236.

[84] Voskuil VR, Robbins LB. Youth physical activity self-efficacy: a concept analysis. J Adv Nurs. 2015;71(9):2002-19; doi:10.1111/jan.12658.

[85] Craggs C, Corder K, van Sluijs EM, Griffin SJ. Determinants of change in physical activity in children and adolescents: a systematic review. Am J Prev Med. 2011;40(6):645-58; doi:10.1016/j.amepre.2011.02.025.

[86] Lubans DR, Foster C, Biddle SJ. A review of mediators of behavior in interventions to promote physical activity among children and adolescents. Prev Med. 2008;47(5):463-70; doi:10.1016/j.ypmed.2008.07.011.

[87] Sallis JF, Pinski RB, Grossman RM, Patterson TL, Nader PR. The development of self-efficacy scales for healthrelated diet and exercise behaviors. Health Educ Res. 1988;3(3):283-92; doi:10.1093/her/3.3.283.

[88] Schwarzer R, Luszczynska A, Ziegelmann JP, Scholz U, Lippke S. Social-cognitive

predictors of physical exercise adherence: three longitudinal studies in rehabilitation. Health Psychol. 2008;27(1 Suppl):S54-63; doi:10.1037/0278-6133.27.1.

[89] Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW, et al. Correlates of physical activity: why are some people physically active and others not? Lancet. 2012;380(9838):258-71; doi:10.1016/S0140-6736(12)60735-1.

[90] Davison KK, Lawson CT. Do attributes in the physical environment influence children's physical activity? A review of the literature. Int J Behav Nutr Phys Act. 2006;3:19; doi:10.1186/1479-5868-3-19.

[91] Panter JR, Jones AP, van Sluijs EM. Environmental determinants of active travel in youth: a review and framework for future research. Int J Behav Nutr Phys Act. 2008;5:34; doi:10.1186/1479-5868-5-34.

[92] Sallis JF, Patrick K. Physical activity guidelines for adolescents: consensus statement. Pediatr Exerc Sci. 1994;6:302-14.

[93] Eston RG, Rowlands AV, Ingledew DK. Validity of heart rate, pedometry, and accelerometry for predicting the energy cost of children's activities. J ApplPhysiol (1985). 1998;84(1):362-71.

[94] China Health and Nutrition Survey. Questionnaires: 1997 survey. Available at: http://www.cpc.unc.edu/projects/china/data/questionnaires. Accessed Feb/15, 2016.

[95] Bouchard C, Tremblay A, Leblanc C, Lortie G, Savard R, Theriault G. A method to assess energy expenditure in children and adults. Am J ClinNutr. 1983;37(3):461-7.

[96] Garcia AW, George TR, Coviak C, Antonakos C, Pender NJ. Development of the child/adolescent activity log: a comprehensive and feasible measure of leisure-time physical activity. Int J Behav Med. 1997;4(4):323-38; doi:10.1207/s15327558ijbm0404_5.

[97] Lan TY, Chang HY, Tai TY. Relationship between components of leisure physical activity and mortality in Taiwanese older adults. Prev Med. 2006;43(1):36-41; doi:10.1016/j.ypmed.2006.03.016.

[98] Booth ML, Okely AD, Chey TN, Bauman A. The reliability and validity of the Adolescent Physical Activity Recall Questionnaire. Med Sci Sports Exerc. 2002;34(12):1986-95; doi:10.1249/01.MSS.0000038981.35052.D3.

[99] Sallis JF, Strikmiller PK, Harsha DW, Feldman HA, Ehlinger S, Stone EJ, et al. Validation of interviewer- and self-administered physical activity checklists for fifth grade students. Med Sci Sports Exerc. 1996;28(7):840-51.

[100] China Health and Nutrition Survey. Questionnaire: 2000 survey. Available at: http://www.cpc.unc.edu/projects/china/data/questionnaires. Accessed Feb/15, 2016.

[101] China Health and Nutrition Survey. 2006 Child questionnaire. Available at: http://www.cpc.unc.edu/projects/china/data/questionnaires. Accessed Feb/15, 2016.

[102] Crocker PR, Bailey DA, Faulkner RA, Kowalski KC, McGrath R. Measuring general levels of physical activity: preliminary evidence for the Physical Activity Questionnaire for Older Children. Med Sci Sports Exerc. 1997;29(10):1344-9.

[103] Qu NN, Li KJ. Study on the reliability and validity of international physical activity questionnaire (Chinese Vision, IPAQ). Zhonghua Liu Xing Bing XueZaZhi. 2004;25(3):265-8.

[104] Lee KS, Trost SG. Validity and reliability of the 3-day physical activity recall in Singaporean adolescents. Res Q Exerc Sport. 2005;76(1):101-6; doi:10.1080/02701367.2005.10599265.

[105] Criterion-related validity of a 0–10 scale physical activity rating in Chinese youth. Proceedings of the 2001 Asia-Pacific Rim Conference on Exercise and Sports Science: the new perspective of exercise & sports science for the better life in the 21st century.; July; Seoul, Korea: Seoul National University.; 2001.

[106] Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381-95; doi:10.1249/01.MSS.0000078924.61453.FB.

[107] Huang YJ, Wong SH, Salmon J. Reliability and validity of the modified Chinese version of the Children's Leisure Activities Study Survey (CLASS) questionnaire in assessing physical activity among Hong Kong children. PediatrExercSci. 2009;21(3):339-53.

[108] Godin G, Shephard R. Godin leisure-time exercise questionnaire. Med Sci Sports Exerc. 1997;29(6):36-8.

[109] Wang JJ, Baranowski T, Lau WP, Chen TA, Pitkethly AJ. Validation of the Physical Activity Questionnaire for Older Children (PAQ-C) among Chinese Children. Biomed Environ Sci. 2016;29(3):177-86; doi:10.3967/bes2016.022.

[110] Janz KF. Validation of the CSA accelerometer for assessing children's physical activity. Med Sci Sports Exerc. 1994;26(3):369-75.

[111] Godin G, Shephard RJ. A simple method to assess exercise behavior in the community. Can J Appl Sport Sci. 1985;10(3):141-6.

[112] Fogelholm M, Malmberg J, Suni J, Santtila M, Kyrolainen H, Mantysaari M, et al. International Physical Activity Questionnaire: Validity against fitness. Med Sci Sports Exerc. 2006;38(4):753-60; doi:10.1249/01.mss.0000194075.16960.20.

[113] Macfarlane DJ, Lee CC, Ho EY, Chan KL, Chan DT. Reliability and validity of the Chinese version of IPAQ (short, last 7 days). J Sci Med Sport. 2007;10(1):45-51; doi:S1440-2440(06)00086-7.

Appendix 2.1

Additional file 1. Criteria of quality assessment.

	Items to be considered for assessment of potential opportunity for bias
Study design	Was the study design a longitudinal study?
Study participation	Does the study sample represent the population of interest in terms of key characteristics? The study should describe details of the participant eligibility criteria, sources, and methods of selection of participants. There should be adequate participation in a study by eligible individuals. Response rate should be adequate (at least 80%).
Outcome measurement	Did the study report a clear description of the outcome of physical activity, and did the instruments have acceptable quality? Direct measurement by accelerometer (pedometer or heart rate monitor) and by questionnaire, which reported reliability or validity, or referred to any documentation on reliability or validity of the tools, were classified as of acceptable quality.
Related factors measurement	Did related factors measurement use validated methods and describe details of assessment? A clear description of related factors measurement was provided. The factors measurement should be used as a valid tool; socio demographic factors should be present as appropriate cut-off points.
Data analysis	Were the statistical tests used to assess the main outcomes appropriate? There was sufficient presentation of data to assess the adequacy of the analysis. Important potential confounders should be included in the analysis, by stratification or modeling.

Appendix 2.2

Additional file 2. Characteristics of the papers identified in this review.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[25] (Rowlands et al., 2002)	n=50 (52) Age: 8–11, (9.1±0.9) Design: cross-sectional Location: Hong Kong	CSA uniaxial accelerometer (Model 7164) [93]	Average daily count 7 days (counts/day) (299, 384–140, 427), weekdays (299, 407±147,075), weekend days, (311, 732–173, 137).	Physical activity negatively correlated with body fat (sum of skinfolds) in boys but not girls. There was no main effect for gender on physical activity.
[26] (Cheng et al., 2003)	n=260 (100) Age: 11–18 (14.7±1.5) Design: cross-sectional Location: Hong Kong	Questionnaire	Leisure time physical activity: (2.62±4.58) MET hour/week. Met PA recommendation: 19.2%.	Physical activity participation correlated with perceived benefits (body image and health) in female adolescents.
[27] (Tudor-Locke et al., 2003)	n=2675 (46.8) Age: 6–18 (11.5±3.3) Design: cross-sectional Location: Eight provinces in mainland China: Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu and Shandong.	Questionnaire of the China Health and Nutrition Survey [94]	72% of children and adolescents engage in in-school MVPA for a median of 90–110 min./week. Relatively few children and adolescents (8%) participate in any MVPA outside of school.	Female (≥12 yrs.) engaged in shorter durations of MVPA during school hours compared to males.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[28] (Liou and Chiang, 2004)	n=463 (46.2) Age: 9–12 (10.8) Design: cross-sectional Location: Taiwan	Modified version of the "Three-day Physical Activity Logs (3-d PAL)" [95]	MVPA (min./day) boys: (152.4±113.5), girls: (160.7±113.6). Met PA recommendation: 79.4%.	There were no significant main effects for age or gender, and no interaction was found between energy expenditure and MVPA.
[29] (Wu and Pender, 2005)	n=583 (48.7) Age: 13–16 (14.7±0.6) Design: longitudinal (one year follow-up) Location: Taiwan	Modified version of the Child/Adolescent Activity Log-CAAL [96]	No report	Gender, social support, modeling, self-efficacy, and perceived benefits and barriers to performing physical activity influence physical activity in adolescents directly and indirectly. Adolescents with higher parent education levels engaged in less physical activity.

2

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[30] (Shi et al., 2006)	n=824 (47.7) Age: 12–14 Design: cross-sectional Location: Zhenjiang and Xuzhou (Jiangsu province)	Questionnaire	45.2 % of adolescents had vigorous physical activity≥3 times/week, 38.5% engaged in low level PA, while 26.1% engaged in high level PA (Physical activity level was based on three variables: active commuting to school, housework, and vigorous physical activity).	Girls in rural areas had a high physical activity score. High household socioeconomic status and low education of father were associated with low physical activity among boys. Age and region (south/north) were not significant.
[31] (Chen et al., 2007)	n=2235 (48.2) Age: 12–18 Design: cross-sectional Location: Taiwan	Personal Health Behaviors and Adolescent Questionnaire [97]	The prevalence of engaging in any level of physical activity was 78.2% among adolescents. Met PA recommendation: 28.4%.	Boys and urban adolescents were more active than girls and rural adolescents. The prevalence of physical activity declined with age. Other factors associated with physical activity included educational status, smoking, and weight control. Parental education and weight status were not associated with physical activity.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[32] (Li et al., 2007)	n=1760 (50) Age: 11–17 Design: cross-sectional Location: Xian (Shanxi province)	Modified version of "Adolescents Physical Activity Recall Questionnaire" [98]	Light physical activity: boys, 1.4 hours/week, girls, 1.1 hours/week; Moderate physical activity: boys, 8.6 hours/week, girls, 7.4 hours/week; Vigorous physical activity: boys, 4.7 hours/week, girls, 2.3 hours/week. Met PA recommendation: 56%.	Males spent more hours in light and vigorous activities than females. Those living in rural areas spent significantly more hours doing light physical activities. There were no differences in the activity percentage (by guidelines) for age and wealth index.
[33] (Chen et al., 2008)	n=331 (52) Age: 7–8 Design: cross-sectional Location: Taiwan	Children's self-administered physical activity checklist (SAPAC) [99]	No report	More moderate and vigorous activity METs (MVPAMETs) were related to less authoritarian parenting in boys and higher skinfold thickness in girls. Attending an urban school was found to contribute to the variance in more MVPAMETs in girls.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** **(**M±SD)	**Main findings**
[34] (Li et al., 2009)	n=2500 Age: 6–18 Design: cross-sectional Location: Nine provinces in mainland China (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong).	Questionnaire of the China Health and Nutrition Survey [100]	52.8% of children spent more than 2 hours in physical activities per week.	Urban children reported more time exercising than rural children. Children's exercise time was associated with fathers' exercise time, but not associated with mothers' exercise time.
[35] (Wang et al., 2009)	n=91(49.5) Age: 11–14 Design: cross-sectional Location: Beijing	HR monitor (RS 400, Polar Electro, Kempele, Finland) & questionnaire	Net HR at leisure time (beats/min): boys (22.57±4.20), girls (22.86±4.58).	Severe iron deficiency impairs habitual physical activity.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[36] (Huang et al., 2010)	n=523 (51.5) Age: 11–12 Design: cross-sectional Location: Taiwan	Modified version of the Child/Adolescent Activity Log-CAAL [4] & adapted short form International Physical Activity Questionnaire (IPAQ)	Energy consumption (MET. hrs. per week): urban children (89±56.54), rural children (78.25±52.99).	Multiple regression results showed gender and accessibility to facilities had a significant impact on the children's physical activity. Geographical location in either rural or urban areas, educational level of the head of household, monthly family income, and walkability had no correlation with physical activity.
[37] (Lam et al., 2010)	n=1147 (46.7) Age: 9–13 (10.45) Design: cross-sectional Location: Hong Kong	Adapted Questionnaire of CHNS [101]	MVPA (min/week) boys: 389±371; girls: 375±353.	Older children spent more time in MVPA, and there was no difference in MVPA between boys and girls.
[38] (Luszczynska et al., 2010)	n=534 (54) Age: 12–18 (13.8±1.4) Design: longitudinal (four weeks follow-up) Location: Central region of China	Questionnaire	Index of leisure time physical activity, Time 1: 8.82±4.59 Time 2: 10.41±6.46	Physical activity was predicted by baseline activity, planning, self-efficacy, and the self-efficacy*planning interaction.

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Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** **(**M±SD)	**Main findings**
[39] (Pang and Ha, 2010)	n=335 (48.7) Age: 10–11 (10.71) Design: cross-sectional Location: Hong Kong	Modified Chinese version of Physical Activity Questionnaire for Children (PAQ-C) [102]	Physical activity participation (MVPA): 2.24±0.54.	Children's perceived subjective task value (attainment, intrinsic, and utility value) correlated with their physical activity participation.
[40] (Wong et al., 2010)	n=29,139 (56.5) Age: (14.5±0.13) Design: cross-sectional Location: Hong Kong	Questionnaire	Met PA recommendation: 10.2%.	Perceived availability of sports facilities was positively associated, and that of computer/Internet negatively associated with being sufficiently active.
[41] (Xu et al., 2010)	n=2375 (53.8) Age: 13–15 (13.9±1.0) Design: cross-sectional Location: Nanjing (Jiangsu province)	Adapted Chinese version of IPAQ [103]	Recreational physical activity time: 11.6±5.3 (hrs./wk.)	Boys were more likely to spend more time on physical activity. Residential density was negatively associated with recreational physical activity time.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[42] (Dearth-Wesley et al., 2012)	n=353 (46.7) Age: (6–9 at baseline, <12 throughout the study) Design: longitudinal (two to four years follow-up) Location: Nine provinces in mainland China (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong).	Questionnaire of the China Health and Nutrition Survey [27]	Leisure-time MVPA (MET. hrs. per week): 2000 Cohort: 7.5 at baseline, and 21.1 at follow-up. 2004 Cohort: 10.6 at baseline, and 14.7 at follow-up. Met PA recommendation: 15% on average.	Children experienced increases in leisure-time sports activities with increasing age. Mother-child associations were positive for leisure-time sports activities. Household location (urban/rural), household income, and maternal education were not associated with children's activities.
[43] (Guo et al., 2012)	n=4445(48.3) Age: 5–18 Design: cross-sectional Location: Liaoning province	Questionnaire	Met PA recommendation: 55.5%.	Boys were more active than girls. A family income ranging from RMB 2000 to RMB 5000 per month was associated with a higher possibility of having appropriate physical activity than an income less than RMB 2000. Parental education level had no influence on physical activity.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[44] (Cheung, 2012)	n=456 (49.6) Age: 10–12 (11.4±0.97) Design: cross-sectional Location: Hong Kong	Three-Day Physical Activity Recall (3DPAR) [104]	Children spent the most time in light intensity PA (6.07 time blocks) and the least time in higher intensity PA (moderate =1.19; hard=0.53; very hard=0.11)	Boys spent more time blocks on high intensity PA than girls. Children who participated in organized PA programs spent fewer time blocks on light intensity PA and more time blocks in vigorous PA.
[45] (Wen and Hui, 2012)	n=1869 (48.6) Age: 10–15 (12.5±0.9) Design: cross-sectional Location: Shantou (Guangdong province) & Ganzhou (Jiangxi province)	Physical activity rating questionnaire for children and youth (PARCY) [105]	PA level score: (5.1±2.8)	Parents' responsiveness, demandingness, and diet- and physical-activity monitoring were found to be related to adolescents' physical activity.
[46] (Cao et al., 2013)	n=534 (52) Age: 13.95±1.67 Design: longitudinal (four weeks follow-up) Location: Central region of China	Adapted 7-day physical activity recall questionnaire (IPAQ) [106]	Leisure time physical activity (minutes/week): Time 1: 85.48 ±84.53, Time 2: 86.77 ± 74.35.	Adolescents who had more skills were more likely to successfully translate their intentions into plans. (Prospective anticipation of when, where, and how to perform physical activities.)

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[47] (Huang et al., 2013)	n=280 (52.1) Age: 11.1±0.9 Design: cross-sectional Location: Hong Kong	Children's Leisure Activities Study Survey questionnaire-Chinese version (CLASS-C) [107]	MVPA: (min./day): boys, 72.0±50.6, girls, 75.9±52.7. Met PA recommendation: 52.9%.	Participation in school sports teams and self-efficacy were positively associated with PA in boys. Girls who reported participation in school sports teams, who perceived more peer support, had a more supportive home PA environment, and those who spent more time doing homework were more physically active.
[48] (Wang et al., 2013)	n=2163 (49.8) Age: 9–17 (13.41±2.25) Design: cross-sectional Location: Eleven cities in China (Chengdu, Fuyang, Ganzhou, Guangzhou, Shanghai, Shenyang, Tianjin, Tongzhou, Wenzhou, Xian and Yingtan)	Accelerometers (Actigraph GT3X or GT3X+)	Chinese-specific cutoff points: MVPA (min./day): 28.26±17.66. Met PA recommendation: 9-12 years old (3.6%), 13-17 years old (7.2%), total (5.6%). Freedson's cut-off points: MVPA (min/day): 76.94±37.02. Met PA recommendation: 9–12 years old (81.5%), 13-17 years old (45.5%), total (61.1%).	Chinese children and youth were more active during weekdays than during weekend days, and boys were more active than girls. No difference in physical activity was found across different BMI categories.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[49] (Zhang et al., 2013)	n=19,523 (49.9) Age: 13–18 Design: cross-sectional Location: Shandong province	Questionnaire	Met PA recommendation: 29.1%.	Weight status: overweight/obese adolescents had poor PA status compared with underweight/normal weight adolescents.
[50] (Li et al., 2014)	n=497 (48.3) Age: 8–10 Design: cross-sectional Location: Guangzhou (Guangdong province) and Hechi (Jiangxi province)	Godin Leisure-time Exercise Questionnaire [108]	Met PA recommendation: 84.9%.	Children whose mothers reported engaging in exercise sometimes or frequently were over four times as likely to meet the daily recommended level of MVPA, compared to children whose mothers never or rarely exercised. Children who lived with one grandparent were also more likely to achieve at least 60 min. of MVPA per day, compared with children who lived away from all grandparents.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[51] (Wong et al., 2014)	n= 9993 (63.2) Age: 14±1.7 Design: longitudinal (16 months follow-up) Location: Hong Kong	Questionnaire	Weekly frequency of leisure time MVPA for at least 30 minutes. Subjects number (%). None: baseline, n=2179 (21.8); follow-up, n=2418 (24.2). Less than once a week: baseline, n=2728 (27.3); follow-up, n=2558 (25.6). 1-3 times a week: baseline, n=3298 (33.0); follow-up, n=3708 (37.1). 4–6 times a week: baseline, n=819 (8.2); follow-up, n=560 (5.6). Daily or more: baseline, n=969 (9.7); follow-up, n=749 (7.5).	Increasing awareness of neighborhood sport facilities or building more such facilities may help active adolescents maintain or increase their leisure time PA.

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Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[52] (Duan et al., 2015)	n=1715 (48.5) Age: 12–15 (13.3±1.0) Design: cross-sectional Location: Beijing	Adapted Questionnaire of CHNS [27]	Met PA recommendation: 53.7%.	Boys spent more time engaged in physical activity than girls did. Each 10-unit increase in attitudes toward physical education was associated with increased odds of 1.15 for spending more than 1 hr./day on MVPA. Students in suburban schools reported engaging in physical activity less, when compared with those in urban schools.
[53] (Gao et al., 2015)	n=68 (58.8) Age: 10–11 Design: cross-sectional Location: Hong Kong	Pedometers (SW 700,YAMAX Corporation, Tokyo, Japan)	Total daily steps: 9341±2478.	Boys were more active than girls. Students accumulated 914 steps more on days that included PE classes than on days without PE classes. No significant differences in body weight status (normal weight vs. overweight and obesity) and travel mode (active vs. passive modes).

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[54] (Ho et al., 2015)	n=775 (55.8) Age: 12–14 (12.28±0.77) Design: cross-sectional Location: Hong Kong	Physical Activity Rating Questionnaire for Children and Youth (PARCY) [105]	Physical activity level score: 5.41, corresponding to light daily PA for at least 20 minutes.	Physical activity level correlated with the adolescent's mental well-being, self-efficacy, resilience, and socioeconomic status, but not with age, school connectedness, or family connectedness.
[55] (Wang et al., 2015)	n=7286(47.7) Age: 13–15 Design: cross-sectional Location: Hangzhou (Jiangsu province)	Questionnaire	Met PA recommendation: 9%.	Families' involvement in their adolescents' physical activity on most days of the week was associated with a higher level of adolescents' MVPA.
[56] (Wong et al., 2015)	n= 412 (46.0) Age: Baseline, 7.8±1.0; 1 year follow up, 8.6±1.0; 2 year follow up, 9.5±1.0. Design: longitudinal Location: Hong Kong	Acti-Graph GT3X accelerometer (ActiGraph, Pensacola, Florida, USA)	MVPA (min/d): baseline, 61.5±23.3; 1 year follow up, 50.0±20.4; 2 year follow up, 45.6±20.7.	Chinese children were more physically active on weekends than weekdays. An age-related decline in MVPA was more marked on weekends than weekdays.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[57] (Dong et al., 2016)	n=5201 Age: 7–17 Survey 1991, 12.6±3.2 (48.6), Survey 2000, 13.0±2.9 (47.3), Survey 2009, 14.2±2.3 (46.8). Design: longitudinal Location: Nine provinces in mainland China (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong).	Questionnaire	No report	Children were more likely to participate in leisure-time sports if their parents participated in leisure-time sports.
[58] (Huang et al., 2016)	n= 672 (46.6) Age: 7.6±1.0 Design: longitudinal (2 year follow up) Location: Hong Kong	ActiGraph GT3X+ accelerometer	No report	Low correlations were observed between different behavioral variables and MVPA. LPA and sleep was positive associated with MVPA, screen time and academic-related activities were negative associated with MVPA.

Paper No. (Authors & year)	**Sample** n (female %) Age: (M±SD years) Design & Geographical location	**Methods for assessing PA** (reference list below)	**Level of PA** (M±SD)	**Main findings**
[59] (Lau et al., 2016)	n= 80 (31.3) Age: 8–11 (9.23±0.52) Design: longitudinal (12 weeks follow-up) Location: Hong Kong	ActiGraph GT3X+ accelerometer.	MVPA (min/d): Intervention group, baseline, 19.20±7.50, Post-test, 29.33±14.67; Control group, baseline, 20.36±8.50, Post-test, 23.71±12.40.	A 12-week (60 minutes twice per week) school-based Active video games (AVGs) intervention can improve Chinese children's PA level. These findings indicated that AVGs could be used as an alternative means to engage Chinese children in PA in school setting.
[60] (Wang JJ et al., 2016)	n= 449 (43.9) Age: 8–13 (10.2±1.1) Design: cross-sectional Location: Hong Kong	ActiGraph GT3X accelerometers, Physical Activity Questionnaire for Older Children (PAQ-C) [109]	PAQ-C Score: 2.71±0.70; Objective MVPA (min/day): 43.09±12.74.	Higher levels of self-efficacy and autonomous motivation were positively related to PA level.
[61] (Wang L & Qi J, 2016)	n= 612 (48.1) Age:10–16 (12±1.2) Design: cross-sectional Location: Shanghai	Actigraph GT3X accelerometers [110]	The participating children spent an average of (22±14.5) minutes/day in MVPA based on the Chinese specific cutoff points. Met PA recommendation: 4.7%.	Adolescents living in single-parent households and step families were more physically active than those living in two-parent homes and with biological parents, respectively. However, adolescents residing with grandparents were less active than those living with neither grandparent.

Paper No. (Authors & year)	Sample n (female %) Age: (M±SD years) Design & Geographical location	Methods for assessing PA (reference list below)	Level of PA (M±SD)	Main findings
[62] (Wang L & Zhang Y, 2016)	n= 488 (42.8) Age:12–16 (13.91±0.96) Design: cross-sectional Location: Shanghai	Godin Leisure Time Exercise Questionnaire [111]	No report	Self-efficacy was the only significant predictor of physical activity behavior (MVPA) in the multiple regression model, when all variables were entered into the equation including intention, past physical activity behaviour and perceived behaviour control.
[63] (Wang X et al., 2016)	n= 1032(47.8) Age: 12–15, boys (13.8±0.8), gilrs (13.9±0.9). Design: cross-sectional Location: Xi an	Physical Activity Questionnaire for Middle School Students (PAQMSS) [112]	MVPA (min/week): Median (25th–75th), Boys, 610 (290–1215); Girls, 390 (205–775). Met PA recommendation: 63.4%.	Obesity and high socioeconomic status (SES) were positively associated with IPA, whereas male sex, underweight status, and high family support level for physical activity showed inverse associations. Age was not associated with IPA.
[64] (Xu et al., 2016)	n= 1208 Age: 3–7 (5±0.8) Design: cross-sectional Location: Chongqing, Chengdu, Taiyuan, and Shijiazhuang	Questionnaire	Minutes spend on PA throughout the day: Overweight and Obese (113.27±72.91); Normal Weight (101.25±53.25); Underweight (95.04±50.70).	Positive correlations were found between maternal social cognition and preschool children's physical activity (PA) behavior.

Paper No. (Authors & year)	Sample n (female %) Age: (M±SD years) Design & Geographical location	Methods for assessing PA (reference list below)	Level of PA (M±SD)	Main findings
[65] (Yeung et al., 2016)	n= 2517 (49.0) Age: 13–19 (15.65±1.71) Design: cross-sectional Location: Hong Kong	International Physical Activity Questionnaire-Short Form (IPAQ-SF) [113]	MVPA (min/wk): 121.32±210.80	Children's intention to participate in PA was a strong predictor of their engagement in MVPA. Parents' exercise habit had both direct and indirect (via attitude) effects on their children's intention to participate in PA. Children's attitude toward PA, parents' exercise habit, and SES had significant effects on the children's intention to participate in PA.
[66] (Zheng et al., 2016)	n= 770 (48.3) Age: boys, 9.3±1.8; girls, 9.4±1.7. Design: cross-sectional Location: seven urban areas (Beijing, Guangzhou, Chengdu, Shenyang, Suzhou, Lanzhou, and Zhengzhou) and two rural areas (a lowland area and a mountainous area, both in Hebei province)	Questionnaire	Leisure-time PA: ≥60mins/week, boys, n=254 (63.8%); girls, n=266 (71.5%); School-time PA: ≥100mins/week, boys, n=276 (69.3%); girls, n=235 (63.2%).	Physical activity was significantly associated with dyslipidemia in both genders. Increasing leisure-time physical activity for boys and school-time physical activity for girls may be critical.

Appendix 2.3

Additional file 3. Methodological quality assessment per quality item and per study.

No.	Authors. year	Study design	Study participation	Outcome measurement	Related factors measurement	Data analysis	Total
[25]	Rowlands et al. 2002	0	0	1	1	1	3
[26]	Cheng et al. 2003	0	1	1	1	0	3
[27]	Tudor-Locke et al. 2003	0	0	1	1	1	3
[28]	Liou and Chiang. 2004	0	1	1	1	1	4
[29]	Wu and Pender. 2005	1	0	1	1	1	4
[30]	Shi et al. 2006	0	1	0	1	0	2
[31]	Chen et al. 2007	0	1	1	1	1	4
[32]	Li et al. 2007	0	1	1	1	0	3
[33]	Chen et al. 2008	0	0	1	1	1	3
[34]	Li et al. 2009	0	1	1	1	0	3
[35]	Wang et al. 2009	0	0	1	1	0	2
[36]	Huang et al. 2010	0	0	1	1	1	3
[37]	Lam et al. 2010	0	0	1	1	0	2
[38]	Luszczynska et al. 2010	1	0	0	1	1	3
[39]	Pang and Ha. 2010	0	1	1	1	1	4
[40]	Wong et al. 2010	0	1	1	1	1	4
[41]	Xu et al. 2010	0	1	1	1	1	4
[42]	Dearth-Wesley et al. 2012	1	0	1	1	1	4
[43]	Guo et al. 2012	0	1	0	0	1	2
[44]	Cheung. 2012	0	1	1	1	0	3
[45]	Wen and Hui. 2012	0	1	1	1	1	4
[46]	Cao et al. 2013	1	0	1	1	1	4
[47]	Huang et al. 2013	0	0	1	1	1	3
[48]	Wang et al. 2013	0	0	1	1	1	3
[49]	Zhang et al. 2013	0	1	0	1	1	3
[50]	Li et al. 2014	0	1	1	1	1	4

No.	Authors. year	Study design	Study participation	Outcome measurement	Related factors measurement	Data analysis	Total
[51]	Wong et al. 2014	1	0	1	1	1	4
[52]	Duan et al. 2015	0	1	1	1	0	3
[53]	Gao et al. 2015	0	1	1	1	0	3
[54]	Ho et al. 2015	0	1	1	1	1	4
[55]	Wang et al. 2015	0	1	0	1	1	3
[56]	Wong et al. 2015	1	0	1	1	1	4
[57]	Dong et al. 2016	1	1	1	1	1	5
[58]	Huang et al. 2016	1	0	1	1	1	4
[59]	Lau et al. 2016	1	1	1	1	1	5
[60]	Wang JJ et al. 2016	0	0	1	1	1	3
[61]	Wang andQi. 2016	0	0	1	1	1	3
[62]	Wang and Zhang. 2016	0	0	1	1	1	3
[63]	Wang Xet al. 2016	0	1	1	1	1	4
[64]	Xuet al. 2016	0	1	0	1	0	2
[65]	Yeung et al. 2016	0	1	1	1	1	4
[66]	Zheng et al. 2016	0	1	0	1	1	3

**A score was assigned to each study based on whether quality assessment items were met the criterion (score = 1) or not (score = 0). The scores were summed and described as low quality (0–2) or acceptable quality (3–5).*

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Chapter 3

Environmental correlates of sedentary behaviors and physical activity in Chinese preschool children: a cross-sectional study

Congchao Lu, Tong Shen, Guowei Huang, Eva Corpeleijn

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ABSTRACT

Objective

This cross-sectional study examined environmental correlates of sedentary behavior (SB) and physical activity (PA) in preschool children in the urban area of Tianjin, China.

Methods

Data were collected from the Physical Activity and Health in Tianjin Chinese Children study, involving healthy children 3–6 years old and their families. In all children (*N* = 980), leisure-time SB (LTSB) and leisure-time PA (LTPA) were reported in min/day by parents. In a subgroup (*n* = 134), overall sedentary time, light PA, and moderate-to-vigorous PA (MVPA) were objectively measured using ActiGraph accelerometry (≥3 days, ≥10 h/day). Environmental correlates were collected using a questionnaire that included home and neighborhood characteristics (e.g. traffic safety, presence of physical activity facilities) and children's behaviors. Potential correlates were identified using linear regression analysis.

Results

Multiple linear regression analysis showed that "having grandparents as primary caregivers" (*β*s and 95% Confidence Interval (CI) for overall sedentary time: 29.7 (2.1 to 57.2); LTSB (ln): 0.19 (0.11 to 0.28)) and "having a television (for LTSB (ln): 0.13 (0.00 to 0.25)) or computer (for LTSB (ln): 0.13 (0.03 to 0.23)) in the child's bedroom" were both associated with higher SB. Furthermore, "having grandparents as primary caregivers" was associated with less MVPA (*β* (95%CI): −7.6 (−14.1 to −1.2)), and "active commuting to school by walking" correlated with more MVPA (*β* (95%CI): 9.8 (2.2 to 17.4)). The path model showed that "more neighborhood PA facilities close to home" was indirectly related to higher LTPA (ln), which was partly mediated by "outdoor play" (path coefficients (95%CI): 0.005 (0.002 to 0.008)) and "going to these facilities more often" (path coefficients (95%CI): 0.013 (0.008 to 0.018)). Traffic safety was not a correlate.

Conclusion

Family structure and media exposure in the home maybe important factors in shaping preschoolers' PA patterns. Built environmental correlates could indirectly influence preschoolers' LTPA through parental help with engaging in active behaviors.

Keywords: Active commuting; built environment; family structure; media exposure; traffic safety

INTRODUCTION

As the 4th leading cause of death worldwide, physical inactivity is responsible for a substantial economic burden and is becoming a growing problem across the world.[1,2] After 4 decades of open reforms since 1979, China has undergone a tremendous transformation in terms of economic development and environmental changes. In this increasingly urbanized country, the daily lives of Chinese citizens have been accompanied by higher community urbanicity, which includes higher vehicle, TV, and computer ownership. All of these have contributed to the rapid decline in physical activity (PA) in China.[3] The World Health Organization (WHO) has recommended that children and young people 5–17 years old should accumulate at least 60 min of moderate-to-vigorous physical activity (MVPA) daily.[4] However, the proportion of Chinese children and adolescents who engage in recommended levels of PA has been declining for decades.[5,6] Data from the 2017 national survey of 131,859 school students in China showed that only 34.1% of children and adolescents met the PA guidelines of 1 h of MVPA daily.[7] Moreover, sedentary behaviors (SB) of school students increased moderately between 2004 and 2011.[8]

It is widely accepted that sufficient PA and less sedentary time (ST) have a positive effect on improving both fitness and energy balance in adults,[9] as well as in school-aged children and adolescents.[10,11] Over the past 4 decades, the rapid increase in overweight and obesity among school-aged children and adolescents, particularly in urban cities in the mainland of China, is becoming a public health challenge.[12] For example, a national survey in China in 1985 showed that about 2% of school students were overweight or obese,[13] whereas data from the 2017 national survey showed that 15.1% of 131,859 school students were overweight, and 10.7% were obese.[7] This upward trend is also seen in Chinese preschoolers (3–6 years old).[14]

The preschool years are a critical period of growth and development. It is believed that sufficient PA during the early years of life improves bone and cardiovascular health, assists with the development of mental health, and has a positive influence on cognitive function.[15] PA promotion in preschool years is considered a key component in early interventions for childhood overweight and obesity.[16] In April 2019, the WHO published recommendations for children under 5 years of age. It was recommended that preschool children (3–4 years old) take part in at least 180 min of activity (with at least 60 min of MVPA) each day, with ST of no more than 1 h per day and less being better.[17] The 60 min of MVPA (energetic play) for preschoolers was also recommended by Canada (3–4 years old),[18] Australia (3–5 years old),[19] and China (3–

6 years old)[20] but was not mentioned in the 2018 Physical Activity Guidelines for American preschoolers (3–5 years old).[21] However, a recent report showed that only 28% of Chinese preschool children would meet this guideline based on accelerometer-derived PA.[22] Thus, to develop evidence-based public health strategies to reduce SB and promote PA from early childhood, there is a need to understand the determinants of the behaviors themselves.

Children's behaviors are influenced at different levels by a range of individual and social factors, as well as factors relating to the home, community, school environment, and policy.[23] The 2018 Physical Activity Guidelines for Americans indicated that caregivers have a critical role in supporting and encouraging young children to be physically active and in modeling participation in regular PA.[21] In Chinese society, the 1-child generation has dramatically changed family structure and lifestyle for almost 35 years (from 1980[24] to 2015[25]) on the mainland of China, resulting in the child's becoming the focus of the entire family.[26] The literature shows that Chinese adolescents residing with grandparents are less active than those not living with grandparents.[27] However, less is known about the role played by grandparents in developing and shaping children's PA patterns during preschool years,[28] especially in families in which 2 parents work full time, so the grandparents have taken responsibility for the children's before-school or out-of-school activity (e.g., transportation to school). Home PA facilities or barriers may directly impact children's behaviors because these facilities or barriers provide caregivers with an opportunity to either encourage children to be active or to inhibit their participation in activities.[23,29] For example, 1 study found consistent evidence across 12 countries that children (9–11 years old) with at least 1 electronic media device in their bedrooms did less MVPA (4 min/day) than children with no devices.[30] In another study, children spent more time using electronic media indoors at the expense of engaging in outdoor play.[31] Furthermore, in present-day China, the neighborhood's built environment may influence children's PA behaviors,[32,33] especially for those with reduced access to public spaces (such as sports areas, parks, and open recreational fields) suitable for leisure-time activities.[34] A study in the Netherlands indicated that convenient neighborhood PA facilities had an indirect positive effect (through parental support) on PA behaviors of Dutch preschoolers, even in relatively rural areas.[35] It is important to note that leisure-time PA is considered a dominant form of overall PA among children in developed countries.[36] Identifying these correlations between built environments and overall and leisure-time PA may help with specific interventions that can promote active lifestyles from an early age. A supportive social environment is also an essential component for enhancing PA in communities, and effective social support is essential for creating active communities.[23] For example, young children in the United States were found to be more likely to participate in PA in safe neighborhoods.[37] In contrast, a cross-sectional analysis of a population-based cohort study found that a safe neighborhood was positively associated with higher SB in Swiss preschoolers.[38] Thus, the influence of the environmental characteristics may vary by country and should be further studied.

The aim of this study was to examine which home and neighborhood environmental characteristics correlated with preschoolers' sedentary time (ST_{acc}) and PA—composed of light physical activity (LPA_{acc}) and moderate-to-vigorous physical activity ($MVPA_{acc}$)—as measured by ActiGraph accelerometry, as well as their correlation with leisure-time sedentary behaviors ($LTSB_q$) and leisure-time physical activity ($LTPA_q$) based on a questionnaire reported by parents. It was hypothesized that children living in a supportive environment (e.g., less media exposure in the home or more PA facilities in the neighborhood) would be less sedentary and more active than those living in a nonsupportive environment. Understanding the associations between environmental factors and children's behaviors in particular settings could be critical for designing specific PA promotion projects. Such evidence would support key strategies for reducing SB and increasing PA among young children in modern urban cities in China.

METHODS

The PATH-CC study

Data were derived from the Physical Activity and Health in Tianjin Chinese Children study (PATH-CC), which focuses on identifying the relationship between environmental determinants, PA, and overweight among children in Tianjin, China. Details of the study have been reported elsewhere.[22] Tianjin is the 4th largest city in northern China, with more than 15 million residents in 2015. Preschools in China generally cater to children 3–6 years old and are under the guidance of the national ministry of education. For example, in Tianjin, most children 3–6 years old attend local preschools in the city.[39] Four preschools located in 4 different districts were selected at random for the study. Healthy children were recruited by means of advertising posters in preschools. Children with any disease or disability that could seriously influence daily PA (such as movement difficulties, asthma, or cardiovascular diseases) were excluded from the study. In total, 1031 healthy children and their parents participated in the study between March 2015 and November 2015. The participation rate was 93.7% (i.e., 1031 out of 1100 children in the recruited preschools) (flowchart, Fig.1). Written informed consent was obtained from the parents, and the study was approved by the Medical Ethics Committee of the Tianjin Medical University and performed in accordance with the Declaration of Helsinki.

Data collection

The questionnaire data and child anthropometry measurements used in this study were collected in May 2015. Child and family information and environmental characteristics of the home and neighborhood were addressed in the questionnaires, which were sent to parents for data collection purposes, along with the child leisure-time activities questionnaires. The children's height and weight were measured by trained school nurses in preschools. Children's overweight and obesity were classified according to the age-specific and gender-specific cut-offs of Cole and Lobstein.[40] From June 2015 to November 2015 (except for summer holidays from July 17 to August 31), daily ST, LPA, and MVPA were assessed in a group of child volunteers participating in the study by using ActiGraph GT3X (Actigraph, Pensacola, FL, USA) accelerometry, and the season (summer or autumn) was recorded for later adjustment.

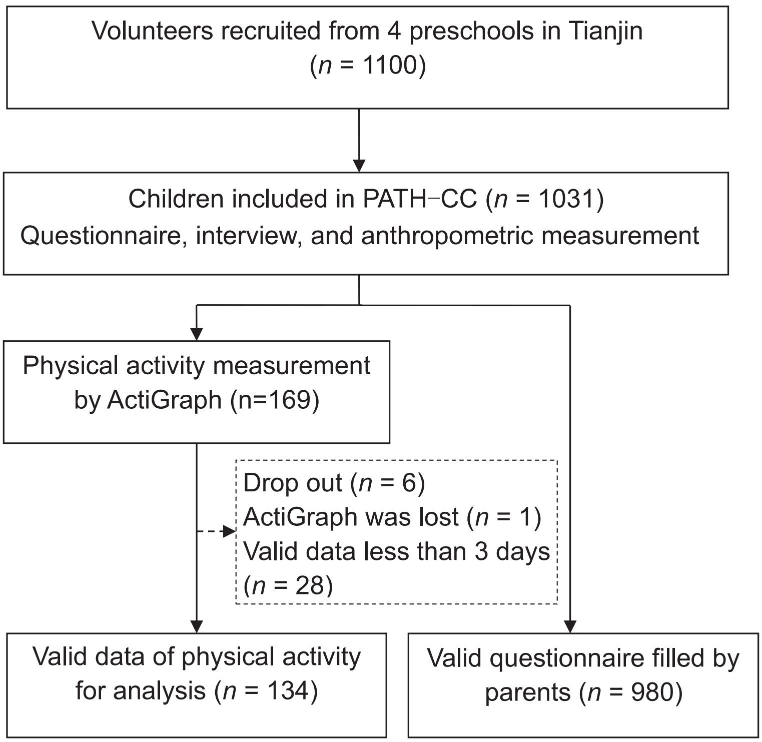

Fig. 1. Flowchart of participants in the PATH-CC study.

PATH-CC = Physical Activity and Health in Tianjin Chinese Children.

Measures of ST, LPA and MVPA using accelerometry

The ActiGraph has been shown to be a reliable and valid device to measure PA volume and intensity in preschool children. Details of the ActiGraph measurements used in this study have been reported elsewhere.[22] Parents were instructed to have their children wear the ActiGraph with an elastic belt on the iliac crest of the right hip for 7 consecutive days during all waking hours, except when bathing or swimming.[41] Data were collected using a frequency of 30 Hz. Collected data were analyzed in 15-s epochs. The time spent wearing and not wearing the accelerometer was classified as recommended by Choi et al.,[42] and the cut-off points for calculating time spent in ST, LPA, and MVPA were used as recommended by Butte et al.[43] To obtain valid measurements in this study, participants had to wear the accelerometer for at least 10 h/day for at least 3 days, regardless of whether these were weekdays or weekend days.[44] Time spent doing ST, LPA, and MVPA was calculated as means over at least 3 wearing days.

Measures of LTSB behaviours and LTPA

Children's $LTSB_q$ and $LTPA_q$ were reported by parents or guardians through questionnaires. In this study, leisure time was defined as time spent outside of school hours on weekdays (including interest classes after school and time spent outdoors and at home, but not travel time) and entire weekend days. The $LTSB_q$ questionnaire used in this study was adapted from the Neighborhood Impact on Kids Survey—Sedentary Behaviors.[45] The $LTPA_q$ questionnaire was adapted from a 7-day activity questionnaire for Chinese primary school pupils, and it showed a reliable estimate of the PA during the past week by Chinese children.[46] In a pilot study conducted before the survey, 50 parents (37 mothers and 13 fathers) of preschoolers answered questions about their children's common SB and activities during leisure time. The final version of the $LTSB_q$ questionnaire included 5 sedentary behaviors that were found to be most prevalent in preschoolers; 12 activities were included in the $LTPA_q$ questionnaire. Parents reported the frequency and duration of these behaviors. For example, the questionnaire asked how many min per day, on average, their children spent on each item during leisure time on schooldays in the past week (response categories ranged from 0–5 days) and on days over the past weekend (response categories ranged from 0–2 days). The average number of minutes was computed to obtain an overall average $LTSB_q$ or $LTPA_q$ per day. Details of these behaviors and activities carried out by the children participating in this study are presented in Supplementary Table1. In the validation study of the leisure-time questionnaire involving 41 children aged 5.3 ± 1.0 years, children were assessed for 7 continuous days by using both ActiGraph measurements and the questionnaire. A positive correlation was found between $LTSB_q$ and ST_{acc} ($\rho = 0.365$, $p = 0.019$), as well as for ST_{acc} on weekends or holidays ($\rho = 0.425$, $p = 0.006$) and on schooldays ($\rho = 0.348$, $p = 0.026$). However, no correlation was found for $LTPA_q$ and ActiGraph-derived PA.

Environmental correlates

Home and neighborhood characteristics were assessed using a revised and translated questionnaire reported on elsewhere.[35,47] The English questionnaire was translated into Mandarin Chinese by a professional translator and back-translated into English by 2 other translators. The discrepancies were reviewed by an independent translator. All these translators were fluent in both English and Mandarin Chinese. Following the back-translation, the Chinese environmental questionnaire was evaluated in the pilot study together with the leisure-time questionnaires mentioned above. The final version of the environmental questionnaire was adapted according to Chinese cultural background by an expert committee, and it was approved by the original authors.[35] Parents reported their home characteristics (household income; primary caregivers for their child; the presence or absence of an elevator, garden, or car; the number of televisions and computers in the household; and the presence or absence of a television or computer in the child's bedroom) and children's PA behaviors (outdoor play and the means of commuting to school). The children's outdoor play was reported in terms of frequency and duration and given in min per week. Parents reported the walking distance from home to 6 PA facilities (e.g., green area or park) in their neighborhoods and the frequency of taking their children to these facilities each week. A distance index was compiled by combining the 6 places; a higher score meant all places were close to home. The questionnaire also included a scale of social support within families and communities, a scale of traffic safety, and a scale of environmental quality in the neighborhood, assessed by 4 items. An acceptable internal consistency was found for each scale (Cronbach α from 0.614–0.712).[48] In this study, the sum score of each item was computed, with higher scores representing better quality. A description of these scales is presented in Supplementary Table 2.

Statistical analysis

Data were presented as rates in number (n) and percentages, as means with standard deviations (SDs) or, if data were skewed, as the median within the 25th–75th percentile. Dependent skewed variables (e.g., $LTSB_q$ and $LTPA_q$) were transformed as natural logarithms (ln) for linear regression. ST_{acc}, LPA_{acc} and $MVPA_{acc}$ were normally distributed and presented as means by min/day. Differences among groups were tested using a *t* test: the Mann-Whitney U test or the χ^2 test. To determine the relationships between potential correlates and PA outcomes, linear regression analysis, adjusted for age, gender, and body mass index (BMI), was used. For ActiGraph outcomes, models were also adjusted for season (summer/autumn), because season has been found to be associated with accelerometer-determined PA measurements.[49] Multiple regression models were then used for potential factors (variables with $p < 0.05$ in the univariate analyses) for each outcome. Because "outdoor play" ($\rho = 0.143$, $p < 0.05$) and "frequency of taking children to PA facilities" ($\rho = 0.558$, $p < 0.05$) were both correlated with "distance index", ordinary least square regression-based path analysis was used to estimate the direct and indirect effects of "distance index" on $LTPA_q$ in mediation models with the PROCESS macro for SPSS (Hayes, 2018, http://www.afhayes.com/). In the path model, the "distance index" was entered as an independent variable, "outdoor play" and "frequency of taking children to PA facilities" were entered as mediators, and the other variables were entered as covariates. For the indirect effects, 10,000 bootstrap samples were used for bias-corrected bootstrap confidence intervals. The given path coefficients were shown as unstandardized β. Missing data were not imputed because only a small proportion (less than 3%) was missing. IBM SPSS Statistics 22 for Windows (USA) was used for this study, with test level $\alpha = 0.05$.

RESULTS

The characteristics of the study population are presented in Table 1. A total of 980 children, aged 4.8 ± 1.1 years, had complete data on parent-reported environmental characteristics, $LTSB_q$, and $LTPA_q$. Of these children, 836 (85%) and their families had lived in their current neighborhood for 1 or more years, and 92 (9%) had lived there for 6 months to 1 year. There were 469 (48%) families who reported living in an apartment that was smaller than 90 m^2. Thirty-seven mothers and 7 fathers reported having no job during the study. Most children (85%) had a mother with a university degree. The questionnaire data were reported mainly by mothers (n = 693; 71%), with fathers (n = 210; 21%) and grandparents (n = 77; 8%) reporting less often.

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With regard to the levels of SB and PA, the questionnaire data on leisure-time activities showed that, on average, children spent more than 2 h per day in SB, $LTSB_q$ (132.9 (85.7 to 188.6)), and more than 1.5 h per day in more active behaviors, $LTPA_q$ (104.3 (60.0 to168.2)), in min/day. No difference in the level of $LTSB_q$ or $LTPA_q$ was found between data reported by the mother and data reported by the father (all $p > 0.05$). The subgroup of 134 children aged 5.4 ± 0.9 years who had valid ActiGraph data (Fig. 1) spent almost 8 h/day being sedentary, ST_{acc} (468.6 ± 80.5 min/day); more than 4 hours doing LPA, LPA_{acc} (249.6 ± 17.1 min/day); and an average of 50 min doing MVPA, $MVPA_{acc}$ (50.5 ± 17.1 min/day).

The children in the ActiGraph group (n = 134) were older than the children in the total questionnaire group (n = 980, $p < 0.05$), because the ActiGraph measurements, which took 6 months, were initiated after the data collection by questionnaire. Most characteristics were comparable between the 2 groups, except for the presence or absence of an elevator in the household ($p < 0.05$). Univariate associations between potential correlates and children's ST and PA outcomes are presented in Supplementary Table 3. No correlation was found between these outcomes and household income; the presence or absence of a lift, garden, or car; the number of computers in the household; or parental perception of traffic safety in the neighborhood.

Table 1. Characteristics of the study population in the PATH-CC study.

Variable	Code/Range	Leisure-time group (n=980)	ActiGraph group (n=134)
Gender	0=male	550 (56.1%)	76 (56.7%)
	1=female	430 (43.9%)	58 (43.3%)
Age [a]	3–6 (years)	4.8 ± 1.1	5.4 ± 0.9
Body mass index	12.7–22.5	15.2 (14.4; 16.3)	15.2 (14.5; 16.3)
Body weight status	0=Normal weight / underweight	856 (87.8%)	118 (88.1%)
	1=Obesity & overweight	119 (12.2%)	16 (11.9%)
Ethnicity	0=other nationality	59 (6.0%)	7 (5.2%)
	1=Han nationality	921 (94.0%)	127 (94.8%)
Season in which accelerometer was worn	0=summer (June and July)	—	58 (43.3%)
	1=autumn (September, October and November)	—	76 (56.7%)
Person who filled in questionnaires	0=mother	693 (70.7%)	94 (70.1%)
	1=father	210 (21.4%)	30 (22.4%)
	2=grandparents	77 (7.9%)	10 (7.5%)
Duration of residency	0=less than 1 year	121 (12.6%)	16 (12.5%)
	1=one to three years	278 (29.0%)	42 (32.8%)
	2=more than 3 years	558 (58.3%)	70 (54.7%)
Home characteristics			
Household income	0=low (less than RMB 30,000/person/year)	274 (28.0%)	36 (26.9%)
	1=middle (RMB 30,000−50,000 /person/year)	307 (31.3%)	47 (35.1%)
	2=high (more than RMB 50,000 /person/year)	399 (40.7%)	51 (38.1%)
Having grandparents as primary caregivers	0=no	627(64.0%)	83 (61.9%)
	1=yes	353(36.0%)	51 (38.1%)
Presence/absence of an elevator [b]	0=no	715 (73.0%)	113 (84.3%)
	1=yes	265 (27.0%)	21 (15.7%)

Variable	Code/Range	Leisure-time group (n=980)	ActiGraph group (n=134)
Presence/absence of a garden	0=no	930 (94.9%)	126 (94.0%)
	1=yes	50 (5.1%)	8 (6.0%)
Presence/absence of a car	0=no	152 (15.6%)	26 (19.8%)
	1=yes	825 (84.4%)	105 (80.2%)
Number of televisions in the household	0=no/1 TV	687 (70.2%)	87 (65.9%)
	1=2 or more TVs	291 (29.8%)	45 (34.1%)
Number of computers in the household	0=no/1 computer	437 (45.4%)	51 (40.5%)
	1=2 or more computers	525 (54.6%)	75 (59.5%)
Having a television in the bedroom	0=no	851 (88.0%)	110 (83.3%)
	1=yes	116 (12.0%)	22 (16.7%)
Having a computer in the child's bedroom	0=no	773 (81.1%)	98 (76.0%)
	1=yes	180 (18.9%)	31 (24.0%)
Children's behaviours			
Child's outdoor play	0–17.5 (h/week)	3.0 (2.0; 5.3)	3.1 (2.3; 5.3)
Active commutingto school	0=inactive	798 (81.9%)	106 (80.9%)
	1=walking	176 (18.1%)	25 (19.1%)
Frequency of going to physical activity facilities	0=no/1 time per week	316 (32.2%)	42 (31.3%)
	1=2 or 3 times per week	301 (30.7%)	50 (37.3%)
	2=more than 3 times per week	363 (37.0%)	42 (31.3%)
Parental perception of neighborhood environment			
Number of physical activity facilities			
Within 5 min' walk	0=no facility	431 (44.0%)	57 (42.5%)
	1=1 facility	339 (34.6%)	51 (38.1%)
	2=2 or more facilities	210 (21.4%)	26 (19.4%)
Within 10 min' walk	0=no facility	235 (24.0%)	31 (23.1%)
	1=1 facility	355 (36.2%)	44 (32.8%)
	2=2 or more facilities	390 (39.8%)	59 (44.0%)
Within 20 min' walk	0=no/1 facility	406 (41.4%)	46 (34.3%)
	1=2 or more facilities	574 (58.6%)	88 (65.7%)
Within 30 min' walk	0=no/1 facility	340 (34.7%)	41 (30.6%)

Variable	Code/Range	Leisure-time group (n=980)	ActiGraph group (n=134)
	1=2 or more facilities	640 (65.3%)	93 (69.4%)
Distance index [c]	0–29 (high–close to home)	8 (5; 13)	9 (5; 13)
Social support	4–20 (high–better quality)	15 (13; 16)	14 (13; 16)
Traffic safety	4–20 (high–better quality)	11 (9; 12)	11 (9; 12)
Environmental quality	4–20 (high–better quality)	11 (9; 13)	11 (10; 12)

Data were presented as rates in number and percentages as means ± SDs, or, if data were skewed, as the median, along with the 25th to 75th percentile.

[a] *$P < 0.05$, t-test was used.*

[b] *$P < 0.05$, χ^2 test was used.*

[c] *The distance index was synthesized by the six PA facilities in the neighborhood; a higher score meant these places were close to home.*

Missing data in Leisure-time group: "Body weight status", n = 5; "Duration of residency", n = 23; "Presence/absence of a car", n = 3; "Number of televisions in the household", n = 2; "Number of computers in the household", n = 18; "Having a television in the bedroom", n = 13; "Having a computer in the child's bedroom", n = 27; "Active commuting to school", n = 6.

Missing data in ActiGraph group: "Duration of residency", n = 6; "Presence/absence of a car", n = 3; "Number of televisions in the household", n = 2; "Number of computers in the household", n = 8; "Having a television in the bedroom", n = 2; "Having a computer in the child's bedroom", n = 5; "Active commuting to school", n = 3.

The multiple regression analysis in Table 2 shows the associations between significant factors found in Supplementary Table 3 and these outcomes, with adjustment for the children's genders, ages and BMIs; the season; and the household income. "Number of televisions" was not included because of co-linearity with "having a television in the child's bedroom" ($\rho = 0.424$, $p = 0.000$). "Distance index" was selected because it represents a synthesized variable for the accessibility of PA facilities. Table 2 shows that girls spent fewer minutes in $MVPA_{acc}$ than boys, and older children and children with higher BMIs showed more $LTSB_q$. "Having grandparents as primary care givers" was associated with higher ST_{acc} (29.7 (2.1 to 57.2), $p = 0.035$) and $LTSB_q$ (ln: 0.19 (0.11 to 0.28), $p = 0.000$), and lower $MVPA_{acc}$ (−7.6 (−14.1 to −1.2), $p = 0.020$). Having a television (ln: 0.13 (0.00 to 0.25), $p = 0.047$) or a computer (ln: 0.13 (0.03 to 0.23), $p = 0.015$) in the child's bedroom were both associated with higher $LTSB_q$. More "outdoor play" correlated with lower ST_{acc} (−6.8 (−12.0 to −1.7), $p = 0.010$) and higher $LTPA_q$ (0.08 (0.07 to 0.10), $p = 0.000$). "Active commuting to school by walking" correlated with lower ST_{acc} (−45.5 (−78.1 to −12.9), $p = 0.007$) and higher $MVPA_{acc}$ (9.8 (2.2 to 17.4), $p = 0.012$). "Children went to PA facilities more often" was associated with higher $LTPA_q$ (ln: 0.18 (0.11 to 0.25), $p = 0.000$). However, no correlation was found between "distance index" and these outcomes. No significant factor was found for LPA_{acc} (all $p > 0.05$). No correlation was found between "social support" or "environmental quality" and these outcomes when both variables were added to these models; the directions of correlation for other variables were not changed.

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Table 2-1. Results of multiple regression analysis of correlates among preschoolers in the PATH-CC study.

Variable	ST_{acc}		LPA_{acc}		$MVPA_{acc}$	
	β (95% CI)	*p*	β (95% CI)	*p*	β (95% CI)	*p*
Constant	**394.3 (204.4, 584.2)**	**0.000**	**370.2 (252.9, 487.5)**	**0.000**	**86.8 (42.6, 131.0)**	**0.000**
Female	12.9 (−13.5, 39.3)	0.335	−12.8 (−29.1, 3.5)	0.123	**−8.2 (−14.4, −2.1)**	**0.009**
Age	9.9 (−9.6, 29.4)	0.318	−8.9 (−21.0, 3.1)	0.146	−1.0 (−5.6, 3.5)	0.652
Body mass index	3.7 (−4.4, 11.7)	0.370	−3.5 (−8.5, 1.5)	0.168	−1.1 (−2.9, 0.8)	0.267
Season	−29.6 (−67.1, 7.8)	0.120	−8.0 (−31.1, 15.2)	0.497	−3.4 (−12.2, 5.3)	0.436
Household income	−1.0 (−17.6, 15.7)	0.908	−5.1 (−15.3, 5.2)	0.331	−1.3 (−5.2, 2.6)	0.513
Having grandparents as primary caregivers	**29.7 (2.1, 57.2)**	**0.035**	−9.5 (−26.5, 7.5)	0.271	**−7.6 (−14.1, −1.2)**	**0.020**
Having a TV in the child's bedroom	31.2 (−5.1, 67.5)	0.092	−1.6 (−24.1, 20.8)	0.885	2.3 (−6.2, 10.7)	0.594
Having a computer in the child's bedroom	−28.5 (−59.6, 2.5)	0.071	2.2 (−16.9, 21.4)	0.817	−1.0 (−8.3, 6.2)	0.775
Child's outdoor play	**−6.8 (−12.0, −1.7)**	**0.010**	2.0 (−1.2, 5.2)	0.213	0.5 (−0.7, 1.7)	0.432
Active commuting to school by walking	**−45.5 (−78.1, −12.9)**	**0.007**	0.0 (−20.1, 20.2)	0.997	**9.8 (2.2, 17.4)**	**0.012**
Frequency of going to PA facilities	−7.7 (−27.5, 12.2)	0.444	5.1 (−7.2, 17.3)	0.415	2.2 (−2.4, 6.8)	0.348
Distance index [a]	−0.4 (−2.8, 2.1)	0.759	0.0 (−1.5, 1.6)	0.955	−0.2 (−0.8, 0.3)	0.396

Table 2-2. Results of multiple regression analysis of correlates among preschoolers in the PATH-CC study.

Variable	$LTSB_q$ (ln)		$LTPA_q$ (ln)	
	β (95% CI)	*p*	β (95% CI)	*p*
Constant	**4.00 (3.58, 4.42)**	**0.000**	**3.85 (3.37, 4.34)**	**0.000**
Female	−0.01 (−0.09, 0.07)	0.773	−0.03 (−0.13, 0.06)	0.472
Age	**0.10 (0.06, 0.13)**	**0.000**	0.02 (−0.02, 0.06)	0.356
Body mass index	**0.02 (0.00, 0.04)**	**0.038**	0.01 (−0.01, 0.04)	0.410
Season	—	—	—	—
Household income	−0.02 (−0.07, 0.03)	0.388	−0.03 (−0.08, 0.03)	0.356
Having grandparents as primary caregivers	**0.19 (0.11, 0.28)**	**0.000**	0.01 (−0.09, 0.10)	0.900
Having a TV in the child's bedroom	**0.13 (0.00, 0.25)**	**0.047**	0.06 (−0.08, 0.21)	0.381
Having a computer in the child's bedroom	**0.13 (0.03, 0.23)**	**0.015**	0.03 (−0.09, 0.15)	0.632
Child's outdoor play	−0.01 (−0.02, 0.00)	0.153	**0.08 (0.07, 0.10)**	**0.000**
Active commuting to school by walking	−0.03 (−0.13, 0.07)	0.590	0.05 (−0.07, 0.16)	0.443
Frequency of going to PA facilities	−0.04 (−0.09, 0.02)	0.236	**0.18 (0.11, 0.25)**	**0.000**
Distance index*	0.00 (−0.01, 0.01)	0.437	0.00 (−0.01, 0.01)	0.766

Note: Bold: $p < 0.05$.

[a] The distance index was synthesized by the 6 PA facilities in the neighborhood; a higher score meant these places were close to home.

Abbreviations: CI = confidence interval; ln = natural logarithm; LPA_{acc}= light physical activity measured by accelerometry; $LTPA_q$ (ln) = leisure-time physical activity measured by questionnaire was natural logarithm (ln)-transformed; $LTSB_q$(ln) = leisure-time sedentary behaviors measured by questionnaire was natural logarithm (ln)-transformed; $MVPA_{acc}$ = moderate-to-vigorous physical activity measured by accelerometry; PA = physical activity; PATH-CC = Physical Activity and Health in Tianjin Chinese Children; ST_{acc} = sedentary time measured by accelerometry.

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In Fig. 2, the path coefficient model shows that if parents perceived more PA facilities close to home, they showed more support for taking children to “outdoor play” (path coefficients (95%CI) for $LTPA_q$ (ln): 0.005 (0.002 to 0.008)) and “going to these facilities more often” (path coefficients (95%CI) for $LTPA_q$ (ln): 0.013 (0.008 to 0.018)), which were associated with more $LTPA_q$ than for children who had PA facilities far from home. This indirect effect on children’s active behaviors was also significant for “number of PA facilities” and children’s $LTPA_q$; for example, the number of PA facilities within 10, 20, and 30 min of walking distance. Thus, it was shown that having access to more PA facilities was, indeed, reflected in a greater use of these facilities.

A sensitivity analysis was used for accelerometry data by including in the defined valid measurements that participants also needed to have for at least 1 weekend day. This shows that the findings were materially unchanged, despite lower power (107 children were included). The findings changed for 2 factors: for “season,” which became significant; and for “having grandparents as primary caregivers”; the association attenuated with ST_{acc} (30.6 (−0.2 to 61.4), $p = 0.052$), and the p value was at the boundary of 0.05. Outcomes of this sensitivity analysis are presented in Supplementary Table 4.

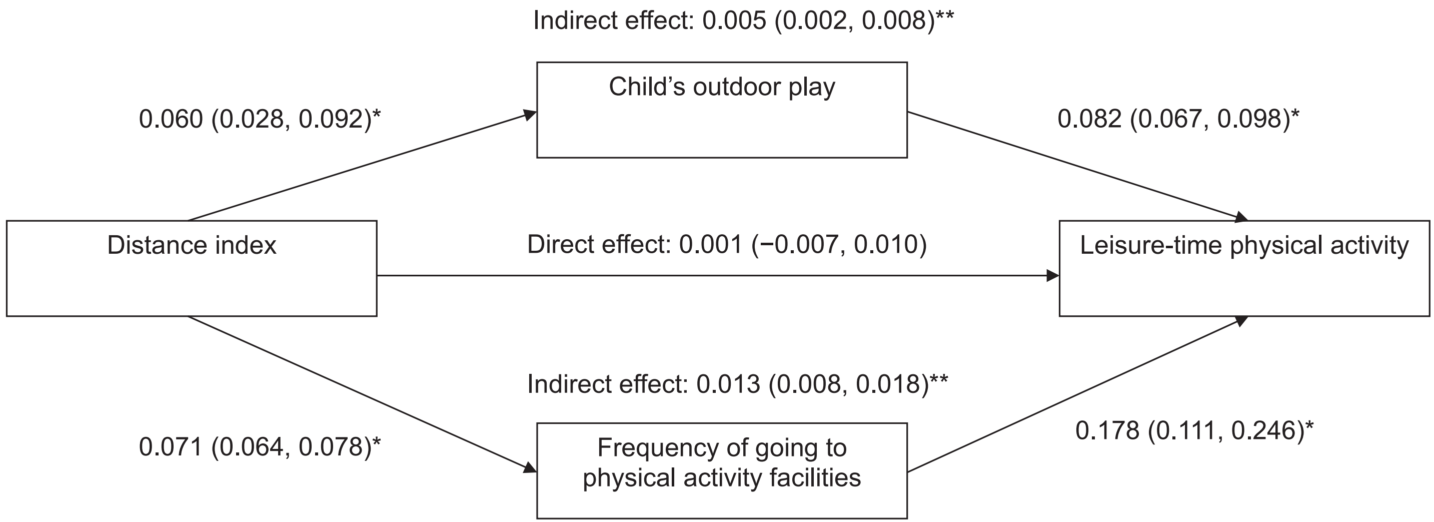

Fig.2. Direct and indirect pathways of neighborhood PA facilities on leisure-time PA among preschoolers in the PATH-CC study.

*Ordinary least square regression-based path analysis was used for direct and indirect effects; unstandardised β was given in the model, adjusted for the child's age and gender, body mass index, household income, primary caregivers, having a TV or computer in the child's bedroom, and active commuting to school. Children's leisure-time PA was natural logarithm (ln)-transformed of means by min/day. The distance index was synthesized by the 6 PA facilities in the neighborhood; a higher score meant these places were close to home. * $p < 0.05$; ** 95% CI does not include 0. PA = physical activity; PATH-CC = Physical Activity and Health in Tianjin Chinese Children.*

DISCUSSION

This study examined the associations of the environmental correlates of SB and PA over the whole day by using ActiGraphs and during leisure time by using questionnaires among preschool children living in a rapidly urbanizing city in the mainland of China. The results showed that the Chinese social culture of children having grandparents as their main caregivers correlated with preschoolers spending more time in SB and less time in MVPA. Children's outdoor play and active commuting also correlated with more PA (e.g., $LTPA_q$ or $MVPA_{acc}$) and less ST_{acc}. Furthermore, parental perception of more PA facilities in the neighborhood may indirectly enhance children's $LTPA_q$ by supporting children in engaging in active behaviors.

Grandparents may play an important role in influencing Chinese preschoolers' PA patterns, such as a correlation with higher SB and lower MVPA. Grandparent care is a traditional sociocultural custom in Chinese societies.[50] Previous researchers have reported that Chinese grandparents had an influence on children's weight status because of their limited understanding of risk factors for obesity and because they overindulge their grandchildren.[51] This may be because many of the older generation experienced a lengthy famine during childhood[52] and because the single grandchild is the focus of attention in the Chinese families of today.[53] When it comes to PA, they may be overprotective and encourage their grandchildren to engage in less vigorous or even sedentary indoor activities because they are less active themselves and transfer this inclination to a restriction of their grandchildren's vigorous activities.[54] However, a study of preschoolers in Japan found that grandparents had no impact on their grandchildren's PA.[55] One Spanish research study indicated that when parents' work leads to a difficult and tough situation, the role of grandparents was very important in the life of the family.[56] Therefore, family-based education about healthy lifestyle behaviors in young children should involve not only the parents but also the grandparents who care for the children.

Our results showed that access to media equipment, particularly a television or computer in the child's bedroom, was associated with higher levels of $LTSB_q$ in preschoolers. Similar findings have been reported for British children.[57] A systematic review found that reducing the parents' own screen time could lead to a decrease in the children's screen time.[58] A study in Finland examined parental educational levels and preschoolers' screen time and found that parental role models, attitudes, and norms were important mediators of preschoolers' screen time.[59] Thus, to reduce SB in the household, support and behavioral interventions by parents are needed.

Family-based strategies to limit media access may be an important way to reduce children's SB during leisure time. For example, "removing electronic media from children's bedrooms" was seen as useful in targeted obesity prevention initiatives.[60] This strategy could also be used to minimize ST in the early years.[61] Furthermore, recommendations about the use of mobile media for young children are needed.[62] Our study showed that 62% of children interact with a mobile phone, tablet, or electronic games for 30 min per day 5 days per week (Supplementary Table 1).

Our study also confirmed a correlation between families' having and using PA facilities in their neighborhood and young children's $LTPA_q$. This finding was consistent with that of a previous study, which demonstrated that access to PA destinations correlates with leisure-time PA in Chinese adults.[63] Another study, in Hong Kong, reported that building more neighborhood sports facilities may help active adolescents to maintain or increase their leisure-time PA.[64] For preschool children, as expected, the influence of the built environment was indirect and required the parents' or caregivers' support because young children are less autonomous than adults.[35] More and more evidence shows that parents' PA has a positive influence on children's PA.[65,66] For example, a study in Canada found that maternal support was significantly related to preschoolers' objectively measured ST, LPA, and MVPA.[67] Thus, improving the availability of PA facilities is a sensible action to take, not least because children and their caregivers can then do activities together, which benefits both groups.

In addition, some environmental correlates may influence other PA domains, and this needs to be studied further. Although no evidence was found in our study that parental perception of "traffic safety" was a correlate of children's PA behaviors, parental perception of greater "traffic safety" was associated with children's active commuting to school ($\rho = 0.102$, $p < 0.05$), and more "social support" was associated with children spending more time in "outdoor play" ($\rho = 0.223$, $p < 0.05$). In addition, more "social support" ($\rho = 0.272$, $p < 0.05$) and "higher quality of neighborhood environments" were both associated with children going to PA facilities more frequently ($\rho = 0.165$, $p < 0.05$). Therefore, comprehensive correlation of supportive school environments, active transportation, safe neighborhoods, and supportive home environments should be studied further; multiple approaches to public health policy should be made to promote sufficient PA.[6,23,68]

To the best of our knowledge, this is the first study that examined correlates of home and neighborhood characteristics in the PA patterns of Chinese preschool children. An important strength of this study was that it investigated both correlates of objectively measured PA throughout the day and subjectively measured PA and SB during leisure time. This provided a better understanding of how different environmental factors influence children's behaviors in particular settings. Limitations of the present study include its cross-sectional design, which means that causality cannot be addressed. Also, environmental characteristics, $LTPA_q$, and $LTSB_q$ were reported by parents, so findings must be interpreted with caution. Furthermore, it is not known how these results would translate to other populations in a different part of the world because the children in this study were recruited in a single Chinese city, and the correlates for being sedentary or active are likely to depend on the area-specific context.

CONCLUSIONS

This study provides evidence showing that children's caregivers, children's active behaviors, media exposure at home, and better neighborhood facilities are important factors in shaping Chinese preschoolers' PA patterns. The promotion of PA for young children should take into consideration the children's caregivers and their influence on children's active behaviors. Having convenient neighborhood PA facilities may not be enough to enhance children's PA throughout the day. Thus, a comprehensive approach, including supportive home environments, active transportation, and safe and supportive school and neighborhood environments, is needed to prevent deterioration in young children's PA patterns.

REFERENCES

1. Ding D, Lawson KD, Kolbe-Alexander TL, Finkelstein EA, Katzmarzyk PT, van Mechelen W, et al. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *Lancet* 2016;388:1311–24.

2. Kohl HW3rd, Craig CL, Lambert EV, Inoue S, Alkandari JR, Leetongin G, et al. The pandemic of physical inactivity: global action for public health. *Lancet* 2012;380:294–305.

3. Zang J, Ng SW. Age, period and cohort effects on adult physical activity levels from 1991 to 2011 in China. *Int J Behav Nutr Phys Act*. 2016;13:40. Doi: 10.1186/s12966-016-0364-z.

4. World Health Organization. Global recommendations on physical activity for health. Geneva: World Health Organization; 2010.

5. Li F, Mao L, Chen P. Physical activity and prevention of chronic disease in Chinese youth: a public health approach. *J Sport Health Sci* 2019;8:512–5.

6. Lu C, Stolk RP, Sauer PJ, Sijtsma A, Wiersma R, Huang G, et al. Factors of physical activity among Chinese children and adolescents: a systematic review. *Int J Behav Nutr Phys* Act. 2017;14:36. Doi: 10.1186/s12966-017-0486-y.

7. Zhu Z, Tang Y, Zhuang J, Liu Y, Wu X, Cai Y, et al. Physical activity, screen viewing time, and overweight/obesity among Chinese children and adolescents: an update from the 2017 physical activity and fitness in China-the youth study. *BMC Public Health* 2019;19:197. Doi: 10.1186/s12889-019-6515-9.

8. Wei X, Zang Y, Jia X, He X, Zou S, Wang H, et al. Age, period and cohort effects and the predictors of physical activity and sedentary behaviour among Chinese children, from 2004 to 2011. *BMC Public Health* 2017;17:353. Doi: 10.1186/s12889-017-4215-x.

9. Jakicic JM, Powell KE, Campbell WW, Dipietro L, Pate RR, Pescatello LS, et al. Physical activity and the prevention of weight gain in adults: a systematic review. *Med Sci Sports Exerc* 2019;51:1262–9.

10. Poitras VJ, Gray CE, Borghese MM, Carson V, Chaput JP, Janssen I, et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab* 2016;41 (6 Suppl 3):S197–239.

11. Carson V, Hunter S, Kuzik N, Gray CE, Poitras VJ, Chaput JP, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. *Appl Physiol Nutr Metab* 2016;41(6 Suppl 3):S240–65.

12. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014;384:766–81.

13. Ji CY, Sun JL, Chen TJ. Dynamic analysis on the prevalence of obesity and overweight school-age children and adolescents in recent 15 years in China. *Zhonghua Liu Xing Bing Xue*

Za Zhi 2004;25:103-8.[in Chinese]

14. Xiao Y, Qiao Y, Pan L, Liu J, Zhang T, Li N, et al. Trends in the prevalence of overweight and obesity among Chinese preschool children from 2006 to 2014. *PLoS One* 2015;10:e0134466. Doi: 10.1371/journal.pone.0134466.

15. Carson V, Lee EY, Hewitt L, Jennings C, Hunter S, Kuzik N, et al. Systematic review of the relationships between physical activity and health indicators in the early years (0–4 years). *BMC Public Health* 2017;17(Suppl 5):854. Doi: 10.1186/s12889-017-4860-0.

16. de Onis M, Blossner M, Borghi E. Global prevalence and trends of overweight and obesity among preschool children. *Am J Clin Nutr* 2010;92:1257–64.

17. World Health Organization. Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age. Available at: https://apps.who.int/iris/handle/10665/311664. [accessed 12.08.2019].

18. Tremblay MS, Chaput JP, Adamo KB, Aubert S, Barnes JD, Choquette L, et al.Canadian 24-Hour Movement Guidelines for the Early Years (0-4 years): An Integration of Physical Activity, Sedentary Behaviour, and Sleep. *BMC Public Health* 2017;17(Suppl 5):874. Doi: 10.1186/s12889-017-4859-6.

19. Okely AD, Ghersi D, Hesketh KD, Santos R, Loughran SP, Cliff DP, et al.A collaborative approach to adopting/adapting guidelines - The Australian 24-Hour Movement Guidelines for the early years (Birth to 5 years): an integration of physical activity, sedentary behavior, and sleep. BMC Public Health. 2017;17(Suppl 5):869. Doi: 10.1186/s12889-017-4867-6.

20. National Working Committee on Children and Women under State Council. Available at: http://www.nwccw.gov.cn/2018-06/13/content_210391.htm. [accessed 12/08/2019].

21. Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA, et al. The Physical Activity Guidelines for Americans. *JAMA* 2018;320:2020–8.

22. Lu C, Wiersma R, Shen T, Huang G, Corpeleijn E. Physical activity patterns by objective measurements in preschoolers from China. *Child and Adolescent Obesity* 2019;2:1–17.

23. Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J. An ecological approach to creating active living communities. *Annu Rev Public Health* 2006;27:297–322.

24. Kane P, Choi CY. China's one child family policy. *BMJ* 1999;319:992–4.

25. Feng W, Gu B, Cai Y. The End of China's One-Child Policy. *Stud Fam Plann* 2016;47:83–6.

26. Feng X, Poston Jr DL, Wang X. China’s one-child policy and the changing family. *J Comp Fam Stud* 2014;45:17–29.

27. Wang L, Qi J. Association between family structure and physical activity of Chinese adolescents. *Biomed Res Int* 2016;2016:4278682. Doi: 10.1155/2016/4278682.

28. Chambers SA, Rowa-Dewar N, Radley A, Dobbie F. A systematic review of grandparents' influence on grandchildren's cancer risk factors. *PLoS One* 2017;12:e0185420. Doi: 10.1371/journal.pone.0185420.

29. Hinkley T, Salmon J, Okely AD, Hesketh K, Crawford D. Correlates of preschool children's physical activity. *Am J Prev Med* 2012;43:159–67.

30. Harrington DM, Gillison F, Broyles ST, Chaput JP, Fogelholm M, Hu G, et al.Household-level correlates of children's physical activity levels in and across 12 countries. *Obesity (Silver Spring)* 2016;24:2150–7.

31. Bassett DR, John D, Conger SA, Fitzhugh EC, Coe DP. Trends in physical activity and sedentary behaviors of United States youth. *J Phys Act Health* 2015;12:1102–11.

32. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth a review. *Am J Prev Med* 2011;41:442–55.

33. An R, Shen J, Yang Q, Yang Y. Impact of built environment on physical activity and obesity among children and adolescents in China: a narrative systematic review. *J Sport Health Sci* 2019;8:153–69.

34. Li F. Physical activity and health in the presence of China's economic growth: meeting the public health challenges of the aging population. *J Sport Health Sci* 2016;5:258–69.

35. Lu C, Huang G, Corpeleijn E. Environmental correlates of sedentary time and physical activity in preschool children living in a relatively rural setting in the Netherlands: a cross-sectional analysis of the GECKO Drenthe cohort. *BMJ Open* 2019;9:e027468. Doi: 10.1136/bmjopen-2018-027468.

36. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW, et al. Correlates of physical activity: why are some people physically active and others not? *The Lancet* 2012;380:258–71.

37. Datar A, Nicosia N, Shier V. Parent perceptions of neighborhood safety and children's physical activity, sedentary behavior, and obesity: evidence from a national longitudinal study. *Am J Epidemiol* 2013;177:1065–73.

38. Schmutz EA, Leeger-Aschmann CS, Radtke T, Muff S, Kakebeeke TH, Zysset AE, et al. Correlates of preschool children's objectively measured physical activity and sedentary behavior: a cross-sectional analysis of the SPLASHY study. *Int J Behav Nutr Phys Act* 2017;14:1. Doi: 10.1186/s12966-016-0456-9.

39. Li N, Zhang S, Li W, Wang L, Liu H, Li W, et al. Prevalence of hyperuricemia and its related risk factors among preschool children from China. *Sci Rep* 2017;7:9948. Doi: 10.1038/s41598-017-10120-8.

40. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatr Obes* 2012;7:284–94.

41. Cliff DP, Reilly JJ, Okely AD. Methodological considerations in using accelerometers to

assess habitual physical activity in children aged 0-5 years. *J Sci Med Sport* 2009;12:557–67.

42. Choi L, Liu Z, Matthews CE, Buchowski MS. Validation of accelerometer wear and nonwear time classification algorithm. *Med Sci Sports Exerc* 2011;43:357–64.

43. Butte NF, Wong WW, Lee JS, Adolph AL, Puyau MR, Zakeri IF. Prediction of energy expenditure and physical activity in preschoolers. *Med Sci Sports Exerc* 2014;46:1216–26.

44. Penpraze V, Reilly JJ, MacLean CM, Montgomery C, Kelly LA, Paton JY, et al. Monitoring of physical activity in young children: how much is enough? *Pediatric Exercise Science* 2006;18:483–91.

45. Seattle Children's NIK Project. NIK Neighborhood Impact on Kids (NIK) Surveys. Available at: http://www.seattlechildrens.org/research/child-health-behavior-and-development/saelens-lab/measures-and-protocols/. [accessed 12.08.2019].

46. Liu AL, Ma GS, Zhang Q, Ma WJ. Reliability and validity of a 7-day physical activity questionnaire for elementary students. *Zhonghua Liu Xing Bing Xue Za Zhi* 2003;24:901–4.[in Chinese]

47. Aarts MJ, Wendel-Vos W, van Oers HA, van de Goor IA, Schuit AJ. Environmental determinants of outdoor play in children: a large-scale cross-sectional study. *Am J Prev Med* 2010;39:212–9.

48. Bland JM, Altman DG. Cronbach's alpha. *BMJ* 1997;314:572. Doi: 10.1136/bmj.314.7080.572.

49. Rich C, Griffiths LJ, Dezateux C. Seasonal variation in accelerometer-determined sedentary behaviour and physical activity in children: a review. *Int J Behav Nutr Phys Act* 2012;9:49. Doi: 10.1186/1479-5868-9-49.

50. Xu L, Chi I, Wu S. Grandparent-grandchild relationships in Chinese immigrant families in Los Angeles: roles of acculturation and the middle generation. *Gerontol Geriatr Med* 2018;4: 4:2333721418778196. doi: 10.1177/2333721418778196..

51. Li B, Adab P, Cheng KK. The role of grandparents in childhood obesity in China - evidence from a mixed methods study. *Int J Behav Nutr Phys Act* 2015;12:91. Doi: 10.1186/s12966-015-0251-z.

52. Wang H, Zhai F. Programme and policy options for preventing obesity in China. *Obes Rev* 2013;14(Suppl 2):134–40.

53. Hesketh T, Lu L, Xing ZW. The effect of China's one-child family policy after 25 years. *N Engl J Med* 2005;353:1171–6.

54. Johansson E, Mei H, Xiu L, Svensson V, Xiong Y, Zhang J, et al. Physical activity in young children and their parents-An Early STOPP Sweden-China comparison study. *Sci Rep* 2016;6:29595. doi: 10.1038/srep29595.

55. Watanabe E, Lee JS, Kawakubo K. Associations of maternal employment and three-generation families with pre-school children's overweight and obesity in Japan. *Int J Obes (Lond)* 2011;35:945–52.

56. Lakó JH. The issues of the relationship of grandparents and grandchildren in the light of physical activity. *European J Ment Health* 2014;9:178–94.

57. Jago R, Sebire SJ, Lucas PJ, Turner KM, Bentley GF, Goodred JK, et al. Parental modelling, media equipment and screen-viewing among young children: cross-sectional study. *BMJ Open* 2013;3.e002593. Doi: 10.1136/bmjopen-2013-002593.

58. Xu H, Wen LM, Rissel C. Associations of parental influences with physical activity and screen time among young children: a systematic review. *J Obes* 2015;2015:546925. Doi: 10.1155/2015/546925.

59. Maatta S, Kaukonen R, Vepsalainen H, Lehto E, Ylonen A, Ray C, et al. The mediating role of the home environment in relation to parental educational level and preschool children's screen time: a cross-sectional study. *BMC Public Health* 2017;17:688. Doi: 10.1186/s12889-017-4694-9.

60. Tandon PS, Zhou C, Sallis JF, Cain KL, Frank LD,Saelens BE. Home environment relationships with children's physical activity, sedentary time, and screen time by socioeconomic status. *Int J Behav Nutr Phys Act* 2012;9:88. Doi: 10.1186/1479-5868-9-88.

61. Poitras VJ, Gray CE, Janssen X, Aubert S, Carson V, Faulkner G, et al. Systematic review of the relationships between sedentary behaviour and health indicators in the early years (0-4 years). *BMC Public Health* 2017;17:868. Doi: 10.1186/s12889-017-4849-8.

62. Kabali HK, Irigoyen MM, Nunez-Davis R, Budacki JG, Mohanty SH, Leister KP, et al.Exposure and use of mobile media devices by young children. *Pediatrics* 2015;136:1044–50.

63. Su M, Tan YY, Liu QM, Ren YJ, Kawachi I, Li LM, et al. Association between perceived urban built environment attributes and leisure-time physical activity among adults in Hangzhou, China. *Prev Med* 2014;66:60–4.

64. Wong BY, Ho SY, Lo WS, Cerin E, Mak KK, Lam TH. Longitudinal relations of perceived availability of neighborhood sport facilities with physical activity in adolescents: an analysis of potential moderators. *J Phys Act Health* 2014;11:581–7.

65. Brouwer SI, Kupers LK, Kors L, Sijtsma A, Sauer PJJ, Renders CM, et al.Parental physical activity is associated with objectively measured physical activity in young children in a sex-specific manner: the GECKO Drenthe cohort. *BMC Public Health* 2018;18:1033. Doi: 10.1186/s12889-018-5883-x.

66. Sijtsma A, Sauer PJ, Corpeleijn E. Parental correlations of physical activity and body mass index in young children--he GECKO Drenthe cohort. *Int J Behav Nutr Phys Act* 2015;12:132. Doi: 10.1186/s12966-015-0295-0.

67. Maltby AM, Vanderloo LM, Tucker P. Exploring mothers' influence on preschoolers'

physical activity and sedentary time: a cross sectional study. *Matern Child Health J* 2018;22:978–85.

68. Bauman A, Allman-Farinelli M, Huxley R, James WP. Leisure-time physical activity alone may not be a sufficient public health approach to prevent obesity--a focus on China. *Obes Rev* 2008;9 Suppl 1:119–26.

Appendix 3.1

Supplementary Table 1. Parental report of leisure-time sedentary behaviors and activities of children in the PATH-CC study.

n = 980	Children (%)	Frequency /week	Median (25th; 75th) (min/time)	Median (25th; 75th) (min/week)
Leisure-time sedentary behaviors				
Reading, writing or drawing	908 (93)	7 (4; 7)	40 (30; 60)	220 (140; 420)
Watching TV	906(92)	7 (5; 7)	60 (38; 90)	360 (180; 540)
Playing with toys (stationary but moving arms)	824 (84)	6 (3; 7)	39 (30; 60)	210 (120; 360)
Playing with mobile phone, tablet or electronic games	606 (62)	5 (2; 7)	30 (20; 60)	120 (60; 270)
Using a computer	249 (25)	3 (2; 6)	39 (30; 60)	120 (60; 240)
Leisure-time physical activities				
Running	821 (84)	6 (3; 7)	39 (30; 60)	210 (100; 360)
Football	789 (81)	5 (3; 7)	51 (30; 77)	210 (120; 395)
Climbing stairs	640 (65)	7 (7; 7)	10 (5; 13)	54 (35; 83)
Walking	638 (65)	4 (2; 7)	45 (30; 60)	160 (80; 270)
"Naughty castle"	516 (53)	1 (1; 2)	60 (60; 120)	90 (60; 120)
Playing on slide or swing	495 (51)	3 (2; 5)	27 (15; 30)	70 (40; 140)
Cycling	476 (49)	2 (1; 4)	30 (20; 45)	60 (30; 120)
Roller skating or scootering	387 (39)	2 (1; 4)	30 (20; 60)	60 (40; 120)
Dancing	183 (19)	2 (1; 5)	60 (30; 90)	90 (60; 130)
Taekwondo or other sports	146(15)	2 (1; 4)	30 (20; 60)	80 (50; 120)
Climbing hills	134 (14)	1 (1; 2)	38 (22; 60)	60 (30; 120)
Swimming	59 (6)	1 (1; 2)	60 (30; 90)	70 (40; 120)

Abbreviation: PATH-CC = Physical Activity and Health in Tianjin Chinese Children.

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Appendix 3.2

Supplementary Table 2. Overview of the scales of neighbourhood characteristics in the PATH-CC study.

Concept	Items	Cronbach's α	Response categories	Code/sum score calculation
Number of physical activity facilities	* How long would it take for your child to walk from your home to the places below? …green area or fountain …water (such as a lake, pond or river) …outdoor fitness centre (square or playground) …gym, sports centre or swimming pool …park …adventure playground	Not applicable	____min	Response categories were summed into number of facilities within 0–5 minutes, within 0–10 minutes, within 0–20 minutes, and within 0–30 minutes.
Distance index	A distance index was made combining the 6 places together.	0.621	0–5	Answers: 0–5 min were recorded as 5, 6–10 min were recorded as 4, 11–20 min were recorded as 3, 21–30 min were recorded as 2, more than 30 min were recorded as 1, and missing was recorded as 0. Sum score was computed, range 0–29, higher scores show that all places were close to home.
Frequency of going to PA facilities	* How often do you take your child to the place each week? E.g. 7 times/week …green area or fountain …water (such as a lake, pond, or river) …outdoor fitness centre (square or playground) …gym, sports centre or swimming pool …public park …adventure playground	Not applicable	____times /week	Depending on the answer, three categories were created by combining the frequency of going to 6 places together: no/one time per week; two or three times per week; more than three times per week.

Concept	Items	Cronbach's α	Response categories	Code/sum score calculation
Social support	* There are sufficient sports facilities in our neighbourhood. * People in our neighbourhood often do exercise (jogging, physical fitness activities, Chinese square dancing, etc.). * The caregiver often encourages my child to be physically active. * The caregiver often accompanies my child during activities.	0.712	5-point scale (strongly disagree to strongly agree)	Sum score was computed, range 4–20, higher scores represent better quality.
Traffic safety	* There are sufficient public transport facilities, such as pedestrian crossings, traffic lights, overpasses and street lights for pedestrians (children) in our neighbourhood. * There are many cars or non-motorized vehicles (such as tricycles, electro-mobile vehicles) in our neighbourhood streets. * Most drivers exceed the speed limits while driving in my neighbourhood. * In general, the traffic situation in our neighbourhood is too unpleasant or inconvenient for my child go out.	0.614	5-point scale (strongly disagree to strongly agree)	Sum score was computed, range 4–20, higher scores represent better quality.
Environmental quality	* The air quality is too poor for my child go out. * The water quality (river or pond) is too poor for my child to go out. * The street environment is too dirty for my child to go out. * There are too many exhaust fumes (from cars, buses) in our neighbourhood for my child to go out.	0.702	5-point scale (strongly disagree to strongly agree)	Sum score was computed, range 4–20, higher scores represent better quality.

Abbreviation: PATH-CC = Physical Activity and Health in Tianjin Chinese Children.

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Appendix 3.3

Supplementary Table 3. Correlates of sedentary time and physical activity among preschoolers in the PATH-CC study.

Variable	ST_{acc}	LPA_{acc}	$MVPA_{acc}$	$LTSB_q$ (ln)	$LTPA_q$ (ln)
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Home characteristics					
Household income	−8.5 (−25.5, 8.6)	−3.9 (−13.7, 6.0)	−1.3 (−5.2, 2.5)	−0.02 (−0.07, 0.03)	0.01 (−0.05, 0.07)
Having grandparents as primary caregivers	14.8 (−12.3, 41.9)	−7.6 (−23.3, 8.0)	−5.9 (−12.0, 0.1)	**0.19 (0.11, 0.27)**	0.03 (−0.08, 0.13)
Presence/absence of a lift	−25.5 (−61.3, 10.2)	10.3 (−10.5, 31.1)	3.9 (−4.2, 12.0)	−0.03 (−0.12, 0.05)	−0.09 (−0.20, 0.02)
Presence/absence of a garden	—	—	—	−0.12 (−0.30, 0.06)	0.04 (−0.18, 0.26)
Presence/absence of a car	21.9 (−11.1, 54.9)	−17.3 (−36.1, 1.5)	−3.4 (−10.7, 3.8)	−0.06 (−0.17, 0.05)	0.05 (−0.08, 0.19)
Number of televisions in the household	2.2 (−25.2, 29.6)	2.6 (−13.1, 18.2)	2.4 (−3.6, 8.4)	**0.14 (0.06, 0.23)**	0.07 (−0.03, 0.18)
Number of computers in the household	−17.6 (−45.1, 9.9)	−3.5 (−19.3, 12.4)	3.0 (−3.1, 9.2)	−0.02 (−0.10, 0.06)	0.02 (−0.08, 0.12)
Having a television in the child’s bedroom	**36.3 (1.5, 71.1)**	−1.2 (−21.4, 19.1)	1.0 (−6.7, 8.8)	**0.18 (0.06, 0.30)**	0.09 (−0.07, 0.24)
Having a computer in the child’s bedroom	−7.4 (−37.9, 23.1)	−1.7 (−19.1, 15.7)	−2.3 (−9.0, 4.5)	**0.16 (0.06, 0.26)**	0.05 (−0.07, 0.18)

Variable	ST_{acc}	LPA_{acc}	$MVPA_{acc}$	$LTSB_q$ (ln)	$LTPA_q$ (ln)
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Children's behaviors					
Child's outdoor play	**−6.4 (−11.1, −1.8)**	1.8 (−0.9, 4.6)	0.3 (−0.8, 1.3)	−0.01 (−0.02, 0.00)	**0.10 (0.08, 0.11)**
Active commuting to school by walking	**−41.6 (−74.3, −8.8)**	−3.1 (−22.3, 16.2)	7.1 (−0.2, 14.3)	−0.01 (−0.11, 0.09)	**0.15 (0.03, 0.28)**
Frequency of going to PA facilities	**−17.7 (−34.0, −1.5)**	6.0 (−3.6, 15.5)	1.7 (−2.0, 5.5)	−0.03 (−0.08, 0.02)	**0.28 (0.22, 0.33)**
Parental perception of neighborhood environmental characteristics					
Parents' reported number of PA facilities					
Within 5 min walk	−4.9 (−22.1, 12.3)	3.2 (−6.8, 13.1)	−0.5 (−4.4, 3.3)	−0.01 (−0.06, 0.04)	0.04 (−0.02, 0.10)
Within 10 min walk	−1.2 (−17.8, 15.3)	4.9 (−4.6, 14.5)	−1.2 (−4.9, 2.5)	0.01 (−0.05, 0.06)	**0.12 (0.06, 0.18)**
Within 20 min walk	−26.7 (−54.0, 0.7)	11.2 (−4.7, 27.1)	1.6 (−4.7, 7.8)	0.02 (−0.06, 0.10)	**0.25 (0.15, 0.35)**
Within 30 min walk	−21.0 (−49.2, 7.3)	11.1 (−5.3, 27.5)	−0.1 (−6.5,6.3)	0.01 (−0.07, 0.10)	**0.25 (0.15, 0.35)**
Distance index *	−1.4 (−3.5, 0.7)	0.1 (−1.1, 1.4)	−0.1 (−0.6, 0.4)	−0.00 (−0.01, 0.01)	**0.02 (0.01, 0.03)**
Social support	2.2 (−3.3, 7.7)	0.0 (−3.1, 3.2)	−0.4 (−1.6, 0.9)	−0.01(−0.03, 0.00)	**0.06 (0.04, 0.08)**
Traffic safety	0.4 (−5.2, 6.0)	−2.2 (−5.4, 1.0)	−0.1 (−1.4, 1.1)	−0.01(−0.02, 0.01)	0.01 (−0.01, 0.03)
Environmental quality	3.5 (−1.8, 8.8)	−2.3 (−5.4, 0.8)	**−1.3 (−2.5, −0.1)**	−0.00 (−0.02, 0.01)	**0.02 (0.01, 0.04)**

*Bold: p value < 0.05. * Distance index was synthesized by the 6 PA facilities in the neighbourhood; a higher score meant these places were close to home. Abbreviations: ln= natural logarithm ;LPA_{acc} = light physical activity measured by accelerometry; $LTPA_q$(ln)= leisure-time physical activity measured by questionnaire was natural logarithm (ln)-transformed; $LTSB_q$ (ln)= leisure-time sedentary behaviors measured by questionnaire was natural logarithm (ln)-transformed; $MVPA_{acc}$= moderate-to-vigorous physical activity measured by accelerometry; PA=physical activity; ST_{acc}=sedentary time measured by accelerometry. Correlates for ST_{acc}, LPA_{acc} and $MVPA_{acc}$ were adjusted for children's gender, age, body mass index, and season; correlates of $LTPA_q$ (ln) and $LTSB_q$ (ln) were adjusted for children's gender, age and body mass index.*

Appendix 3.4

Supplementary Table 4. Results of multiple regression analysis of correlates among 107 preschoolers in the PATH-CC study.

Variable	ST_{acc}		LPA_{acc}		$MVPA_{acc}$	
	β (95% CI)	*p*	β (95% CI)	*p*	β (95% CI)	*p*
Constant	**439.1 (222.9, 655.3)**	**0.000**	**380.4 (259.1, 501.6)**	**0.000**	**94.1 (45.5, 142.7)**	**0.000**
Female	27.8 (−2.2, 57.8)	0.069	−13.8 (−30.6, 3.1)	0.107	**−8.8 (−15.6, −2.1)**	**0.011**
Age	2.9 (−18.8, 24.5)	0.793	−7.3 (−19.4, 4.9)	0.237	−0.2 (−5.0, 4.7)	0.941
Body mass index	2.3 (−6.5, 11.2)	0.603	−4.3 (−9.3, 0.6)	0.085	−1.5 (−3.5, 0.5)	0.139
Season	**−43.8 (−85.6, −2.0)**	**0.040**	−5.7 (−29.2, 17.7)	0.629	−4.2 (−13.6, 5.2)	0.375
Household income	4.3 (−15.3, 23.9)	0.664	−5.9 (−16.8, 5.1)	0.290	−2.1 (−6.4, 2.3)	0.357
Having grandparents as primary caregivers	30.6 (−0.2, 61.4)	0.052	−13.7 (−31.0, 3.6)	0.118	**−7.7 (−14.6, −0.8)**	**0.030**
Having a TV in the child's bedroom	22.7 (−19.1, 64.5)	0.284	6.7 (−16.8, 30.1)	0.574	3.8 (−5.6, 13.3)	0.419
Having a computer in the child's bedroom	−22.5 (−57.0, 12.0)	0.198	4.4 (−14.9, 23.7)	0.652	−2.7 (−10.5, 5.0)	0.485
Child's outdoor play	**−7.7 (−14.0, −1.4)**	**0.017**	2.3 (−1.3, 5.8)	0.206	0.2 (−1.2, 1.7)	0.737
Active commuting to school by walking	**−45.0 (−81.1, −8.9)**	**0.015**	6.8 (−13.5, 27.0)	0.509	**10.5 (2.4, 18.6)**	**0.012**
Frequency of going to PA facilities	1.3 (−21.6, 24.2)	0.911	7.2 (−5.6, 20.1)	0.267	2.2 (−2.9, 7.4)	0.395
Distance index*	−2.2 (−5.1, 0.7)	0.139	−0.1 (−1.7, 1.5)	0.907	−0.2 (−0.8, 0.5)	0.590

Bold: $p < 0.05$.

* The distance index was synthesized by the 6 PA facilities in the neighbourhood; a higher score meant these places were close to home.

Abbreviations: ln= natural logarithm;LPA_{acc},= light physical activity measured by accelerometry; $MVPA_{acc}$,= moderate-to-vigorous physical activity measured by accelerometry; PA= physical activity; ST_{acc}= sedentary time measured by accelerometry.

Valid accelerometry measurements were defined as "participants had to wear the accelerometer for at least 10 hours/day for at least 3days, and at least 1weekend day," and 107 children were included in this analysis.

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Chapter 4

Environmental correlates of sedentary time and physical activity in preschool children living in a relatively rural setting in the Netherlands: a cross-sectional analysis of the GECKO Drenthe cohort

Congchao Lu, Guowei Huang, Eva Corpeleijn

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ABSTRACT

Objectives

This study examined the relationship between environmental correlates and children's sedentary time (ST), light physical activity (LPA), and moderate-to-vigorous physical activity (MVPA) in preschool children.

Design

Cross-sectional study

Setting

A birth cohort in Drenthe, a northern province and relatively rural area of the Netherlands.

Participants

Valid data both for the ActiGraph and the questionnaire were obtained from 505 child–parent pairs.

Primary and secondary outcome measures

ST, LPA and MVPA of children were objectively measured by ActiGraph accelerometry (minimum three wearing days, more than 10 hours/day). Environmental correlates were collected using a questionnaire reported by parents that included household characteristics, parental and children's PA behaviours and neighbourhood environment (eg, traffic safety, road network, and presence of PA facilities). Potential correlates were identified using linear regression analysis, adjusted by age, gender, siblings, and maternal age and education level. Ordinary least square regression-based path analysis was used to estimate direct and indirect effects on activity outcomes in mediation models.

Results

Linear regression analysis showed that 'parents taking children to play sports' was related to less ST, more LPA and MVPA; more outdoor play was also related to less ST and more LPA, but not MVPA. Parents who perceived more PA facilities in their neighbourhood showed more support for 'taking children to play sports', and this was associated with less ST or more MVPA compared with children living with less PA facilities in their neighbourhood. No evidence was found for a relation between traffic safety or road network with ST, LPA and MVPA.

Conclusions

This study indicated that parental support and child outdoor play may influence children's daily PA patterns. Convenient neighbourhood PA facilities, such as parks and playgrounds, had an indirect effect through parental support associated with lower children's ST and higher MVPA, even in relatively rural areas.

Keywords: Physical activity; sedentary behaviours; environmental correlates; parental support; preschool children; traffic safety

INTRODUCTION

The trend of physical inactivity is increasing rapidly in most societies around the world, equally in adults as well as in young people.[1] Preschool years are a critical period of cognitive development and for the development of lifelong health habits,[2, 3] for example, energy-balance-related behaviours, including physical activity (PA) and sedentary behaviours (SB). The promotion of children's PA in their early years has become an important public health aim because it is associated with multiple health indicators. A systematic review has summarized that increased or higher PA was favourably associated with children's bone and skeletal health, motor skill development, psychosocial health, cognitive development, and cardiometabolic health.[4] It also becomes more and more evident, that the preschool years are a critical period for the development of childhood obesity.[5] Unlike PA, SB are a distinct group of behaviours; high levels of SB can be accumulated even when children meet PA recommendations. Excessive SB may have adverse health consequences, for example, higher durations/frequencies of screen time and television viewing were associated with obesity risk in school-aged children and youth.[6]

From an ecological perspective, it is vital to focus not only on the individual determinants of PA but also on determinants in the social (eg, family) and physical (eg, neighbourhood) environments.[7] The relationship between family, neighbourhood environments, and children's PA levels is supported by multiple studies. For example, two reviews found consistent evidence that parental PA and support were positively associated with children's PA.[8, 9] Parental PA was associated with directly measured PA in young Dutch children.[10] Besides, preschool children are highly dependent on their parents to create opportunities for diminishing their sedentary time (ST).[11] In addition to parental influence, built environmental characteristics, such as road and sidewalk infrastructure and traffic safety, could affect children's PA, since these may influence children's mode of transportation or their opportunities for playing outside.[12] A report demonstrated that each additional hour spent outdoors was associated with seven additional minutes of moderate-to-vigorous PA (MVPA) and 13 min less in ST among 7–14-year-old Canadian children per day.[13] For preschool children, the correlation between outdoor play, objectively measured total PA and ST needs to be assessed, as outdoor time may be a good opportunity for children to be active.[14] When investigating how more time can be spent in high-intensity activity, it is necessary to take into account that lifestyle behaviours do not exist in isolation.[15, 16] A change in any behaviour must be done at the expense of one of the other behaviours, and each intensity of activity should be studied in relation to changes in other intensities, for example, ST, light PA (LPA) and MVPA.[17]

Parental perceptions of neighbourhood environmental characteristics may have a particular impact on children's PA level, since parents are most often the main decision-makers with regard to their child's activities.[18, 19] Understanding the impact of the built environment on PA among young people is especially important for the design of effective interventions. First of all, intervention needs to be encouraged starting at an early age, since health benefits of sufficient PA during preschool years are increasingly being recognized.[4, 20] Second, the literature shows that interventions focused on behaviour modification that target individuals have limited effects on PA improvements, suggesting that supportive policies, along with social and physical environments, are required to support effective interventions.[7, 21] Third, changes in built environments and policies are expected to have long-term impact on most of the people living in those places, for example, by enhancing PA or reducing obesity.[7] However, the number of studies investigating the correlates of family, built environment, and objectively measured ST, LPA, and MVPA in preschool children is limited.[22, 23]

Studies from developed countries have found a higher prevalence of obesity in rural areas.[24] Compared with urban populations, people living in rural areas could be limited in their facilities for PA.[25] At the same time, little is known about how these environmental factors are related to ST and total PA in rural populations, especially in young children.

The aim of this cross-sectional study was to examine whether neighbourhood characteristics are related to ST and total PA—divided into LPA and MVPA—objectively measured by accelerometry in preschool children from the Groningen Expert Centre for Kids with Obesity (GECKO) Drenthe birth cohort. The province of Drenthe is a relatively sparsely populated rural area with a population density of 183 per km^2 in year 2017, where, unlike in many other parts of the Netherlands, the land use is mainly for agriculture. It is hypothesized that children living in a supportive neighbourhood environment at 45 months (eg, more PA facilities) will be more active compared with those living in a non-supportive environment, even in relatively rural areas. Furthermore, it will be explored how parental behaviours mediate the correlations between environmental characteristics and the child's daily activity patterns.

METHODS

GECKO Drenthe birth cohort

Data were derived from the GECKO Drenthe birth cohort, which focuses on the development of overweight and obesity in children living in Drenthe, a northern province of the Netherlands. Details of the study have been reported elsewhere.[26] All mothers of children born between April 2006 and April 2007, and living in Drenthe, were invited to participate during the third trimester of their pregnancy. At baseline, parents of 3875 children intended to participate in the study, but only 2874 actually ended up participating.

Data collection

Questionnaire data used in this study were collected by a series of questionnaires during the cohort follow-up.[26] Child and family information including birth dates of family members, parental educational levels and ethnicity were collected at baseline. At follow-up, changes in number of siblings and family members were reported. Questionnaires for parents about environmental correlates were handed out during visits to the Well Baby Clinic when the child was 45 months of age. Children who had complete data on environmental correlates were selected as potential participants for this study. Flowchart of the participants used in this study is shown in figure 1. When children were in their second year of preschool, around 5–6 years, trained Youth Health Care nurses measured height and weight as part of a regular health screening. Overweight and obesity of children were classified according to the age-specific and gender-specific cut-offs of Cole and Lobstein.[27] Parental educational level, as an indicator of socioeconomic status in the Netherlands, was assessed as low/middle education or higher vocational education and university.[28]

Environmental correlates

Environmental correlates were assessed (2010–2011) using a Dutch questionnaire developed by Aarts *et al*, and the level of internal consistency of the scales was acceptable in this study.[29] Parents/guardians reported their household characteristics (type and ownership of house, number of cars, and presence of garden and dog), their behaviours (taking child cycling/to play sports/accompanying going out), and their children's PA behaviours (outdoor play, regular cycling, and going out by bicycle). The child's outdoor play was reported by parents in frequency and duration, and given in hours per week. Parents reported their perception of the traffic situation (Cronbach's α=0.708) and road network (Cronbach's α=0.631) in their neighbourhood in terms of two concepts. Each concept included five items, and each item had five options from 'totally disagree' to 'totally agree'. For a better understanding of the effect of environmental correlates, all items for each concept were combined into one dichotomized variable (favourable vs less favourable situation). For the presence of PA facilities (Cronbach's α=0.651), parents reported their presence for six items (eg, park and playground) within a defined distance in their neighbourhood (eg, within a 5 min' walk or 20–30 min). A distance index was made combining the six places together; a higher score meant all places were close to their home.

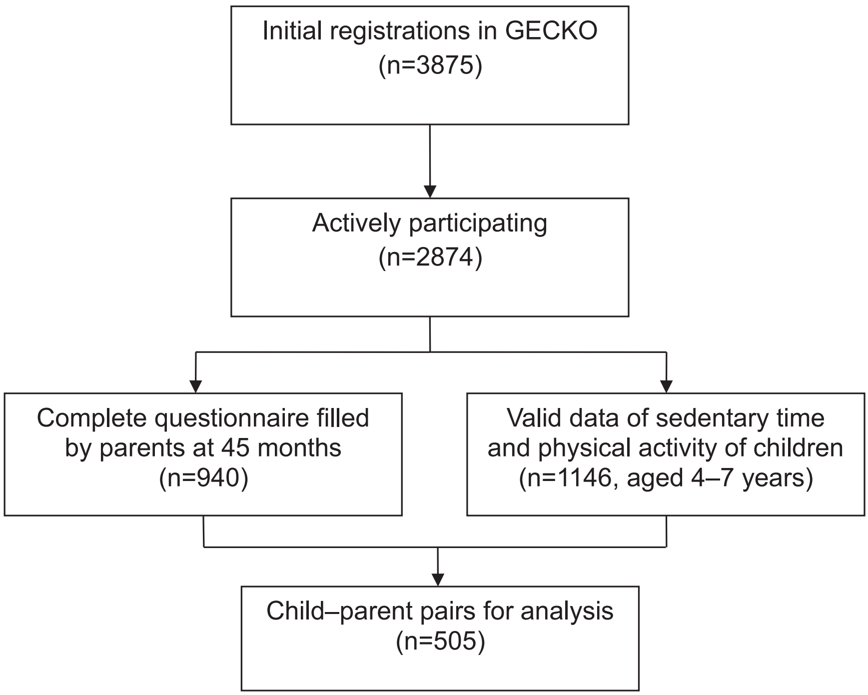

Figure 1. Flowchart of the participants in the GECKO study, the Netherlands.

ST and PA

ST, LPA and MVPA in children were assessed using ActiGraph GT3X (ActiGraph, Pensacola, FL, USA) accelerometry (2011–2013), with an average age of (5.6 ± 0.9) year. Details of the measurements have been reported elsewhere.[30] The ActiGraph has been shown to be a reliable and valid device to measure PA volume and intensity in preschool children.[31] Parents were instructed to have their child wear the ActiGraph on the iliac crest of the right hip with an elastic belt for four consecutive days—with at least one of the days being during the weekend—for all waking hours, except when bathing or swimming. Data were collected using a frequency of 30 Hz. Collected data were analyzed in 15 s epochs. The accelerometer wear and non-wear time was classified as recommendations by Choi *et al*, and cut-off points for calculating time spend in ST, LPA and MVPA was recommended by Butte *et al*. All children with wear time ≥14 hour/day were checked manually for sleeping time.[32, 33] For valid measurements in this study, wear time had to be at least 10 hours/day for at least 3 days, regardless of whether these were week or weekend days. Time spent for ST, LPA and MVPA were calculated as means over at least three wearing days. ST, LPA and MVPA together add up to the total activity of that day.

Statistical analysis

Continuous variables were presented as means with SDs, or, if data were skewed, as the median with 25th−75th percentile. Categorical variables were presented as rates in number and percentages. Dependent skewed variables were natural logarithm (ln)-transformed for linear regression. To examine the differences of characteristics between children with ActiGraph data included in the analyses to children lacking questionnaire data, t-test was used for normally distributed continuous variables and Mann-Whitney U test was used for non-normal distributed continuous variables. Differences in categorical variables were tested by χ^2 test. To determine the relationships between potential correlates and outcomes, linear regression analysis adjusted for child and family factors was used. Then all significant variables (normal distribution) and outcomes were checked by Pearson correlation, or Spearman correlation was used if data were skewed. Ordinary least square regression-based path analysis was used to estimate direct and indirect effects on ST and MVPA in mediation models with the PROCESS macro for SPSS (Hayes, 2018, http://www.afhayes.com/). The independent variable was ‘number of PA facilities’ in the model, with ‘parents taking children to play sports’ as mediator, since ‘parents taking children to play sports’ was correlated with both ‘number of PA facilities’ and outcomes of ST/MVPA. No mediation analysis was used for LPA, since it was not correlated with ‘number of PA facilities’. Besides, age, gender, having siblings, maternal age, education level, and child outdoor play were all included as covariates in the mediation models. For the indirect effects 10 000 bootstrap samples were used for bias-corrected bootstrap CIs, and a statistically significant indirect effect existed if the CI did not include zero. IBM SPSS Statistics V.22 for Windows was used for this study, with test level $\alpha = 0.05$, and analyses were conducted in 2017.

Patient and public involvement

There was no patient involvement in the development of the research question or the selection of outcome measures. Results of this study are disseminated in a newsletter and on the website.

RESULTS

A total of 940 children, aged (3.9 ± 0.2) years, had valid data on parents' perception of neighbourhood environmental correlates, while 1146 children, aged 4–7 years, had valid ActiGraph data. Combined, 505 child–parent pairs had data both for the ActiGraph and the questionnaire, and were available for analysis (figure 1). Missing data for neighbourhood characteristics were mainly attributable to logistical and organizational problems, since the Well Baby Clinics services' paper files were digitised during the data collection period (2010–2011) in Drenthe. The characteristics of the study population are presented in table 1.

When comparing children with ActiGraph data included in the analyses to children lacking questionnaire data (n = 641), the ST, LPA, and MVPA were comparable ($p > 0.05$). Meanwhile, gender distribution was comparable between this study group (n = 505, boys = 53.5%) and the total population of GECKO (n = 2874, boys = 50.3%, $p > 0.05$). However, the children included in this study showed a higher level of maternal education (42.6%) compared with the total population (34.9%, $p < 0.05$). This study showed that higher-level education mothers were more likely to finish both the questionnaire and the measurement of children's daily activities. Missing data of this study group was not imputed, due to a small proportion that was missing (less than 3%).

Table 1 Characteristics of the study population in the GECKO study, the Netherlands

Characteristics (n=505)	Total
Age of the child at questionnaire interview (years), mean (SD)	3.9 (0.2)
Age of the child at physical activity measurement (years), mean (SD)	5.6 (0.9)
Maternal age (years), mean (SD)	37.0 (4.2)
Paternal age (years), mean (SD)	39.6 (4.6)
Body mass index, median (25th; 75th)	15.7 (15.0; 16.6)
Obesity and overweight, n (%)*	53 (12.1)
Normal weight/underweight, n (%)	386 (87.9)
Ethnicity, n (%)	
Dutch	472 (94.8)
Non-Dutch	26 (5.2)
Maternal education, n (%)	
Low/middle	290 (57.4)
High	215 (42.6)
Paternal education, n (%)	
Low/middle	305 (60.4)
High	200 (39.6)
Having siblings, n (%)	
Yes	450 (89.1)
No	55 (10.9)
Single-parent family structure, n (%)	
Yes	48 (9.5)
No	457 (90.5)
Physical activity patterns (min/day)	
Sedentary time, mean (SD)	372 (54)
Light physical activity, mean (SD)	266 (39)
Moderate and vigorous physical activity, median (25th; 75th)	61 (48; 80)

* *Overweight based on Z-scores Cole 5 years, n = 66 missing.*

4

The associations of child and family factors with children's ST, LPA and MVPA by linear regression analysis are given in table 2. Girls showed less MVPA than boys. Children's age and higher maternal educational level were positively associated with ST and negatively associated with LPA. Higher paternal educational level and older parents determine children with higher ST. Children with siblings showed lower ST and higher MVPA. Single-parent household, ethnicity, and body mass index were not associated with outcomes. Thus, potential environmental correlates were analysed by adjusting for children's gender and age, maternal age and educational levels, and having siblings. Paternal age and education were not included due to collinearity with maternal factors ($r = 0.656$, $p = 0.000$; $r = 0.343$, $p = 0.000$, respectively).

Environmental correlates of children's ST, LPA and MVPA by linear regression analysis are presented in table 3. This study indicated that none of the household characteristics was related to children's ST, LPA or MVPA. From parents' perception of neighbourhood environmental correlates, no evidence was found for traffic safety or road network in relation to these outcomes. The results showed that children spent less time on ST if parents reported more PA facilities within 5 min' walking distance ($\beta = -3.6$), and showed more MVPA if parents reported more facilities within 30 min' walking distance ($\beta = 0.027$) or more facilities close to their house as summed together (distance index) ($\beta = 0.007$). For parents' behaviours, taking children to play sports was inversely related to children's ST ($\beta = -7.9$), and positively to LPA ($\beta = 5.3$), and MVPA ($\beta = 0.068$). For children's PA behaviours, more outdoor play was related to lower ST ($\beta = -1.0$) and higher LPA ($\beta = 0.8$), but not MVPA.

Correlations between significant variables and outcomes are presented in table 4. This study indicated that 'parent taking child to play sports' correlated with all variables in the table except for 'child's outdoor play'. 'Facilities within 5 min' walk' negatively correlated with children's ST ($r = -0.101$, $p < 0.05$), 'facilities within 30 min' walk' positively correlated with children's MVPA ($r = 0.105$, $p < 0.05$), and 'distance index' correlated with both ST (negatively, $r = -0.090$, $p < 0.05$) and MVPA (positively, $r = 0.094$, $p < 0.05$).

Table 2 Correlates between child and family factors, and daily activity patterns among preschoolers in the GECKO Drenthe study, the Netherlands

Child and family factors	Range	Descriptive data	ST	LPA	MVPA
		n (%)/mean (SD)	β (95% CI)	β (95% CI)	β (95% CI)
Gender	0–1	0=male, n=270 (53.5%); 1=female, n=235 (46.5%)	5.1 (−4.4 to 14.7)	1.6 (−5.1 to 8.4)	**−0.197 (−0.261 to −0.133)**
Age at PA measurement	3–7	5.6 (0.9) (years)	**20.9 (15.6 to 26.1)**	**−16.2 (−20.0 to −12.5)**	0.031 (−0.008 to 0.070)
Maternal education	0–1	0=low/middle, n=290 (57.4%); 1=high, n=215 (42.6%)	**10.7 (1.2 to 20.3)**	**−7.4 (−14.2 to −0.6)**	−0.015 (−0.082 to 0.052)
Paternal education	0–1	0=low/middle, n=305 (60.4%); 1=high, n=200 (39.6%)	**10.0 (0.3 to 19.7)**	−2.1 (−9.1 to 4.8)	−0.042 (−0.109 to 0.026)
Maternal age	26–50	37.0 (4.2) (years)	**2.2 (1.0 to 3.3)**	−0.3 (−1.1 to 0.5)	−0.004 (−0.012 to 0.004)
Paternal age	26–58	39.6 (4.6) (years)	**1.2 (0.1 to 2.2)**	−0.2 (−0.9 to 0.5)	0.000 (−0.007 to 0.008)
Having siblings	0–1	0=no, n=55 (10.9%); 1=yes, n=450 (89.1%)	**−15.9 (−31.1 to −0.7)**	8.6 (−2.3 to 19.4)	**0.174 (0.068 to 0.279)**
Single-parent family structure	0–1	0=no, n=457 (90.5%); 1=yes, n=48 (9.5%)	9.2 (−7.0 to 25.4)	−4.4 (−15.9 to 7.1)	−0.022 (−0.135 to 0.091)
Ethnicity	0–1	0=Non-Dutch, n=26 (5.2%); 1=Dutch, n=472 (94.8%)	3.3 (−18.3 to 24.8)	4.8 (−10.6 to 20.1)	−0.028 (−0.178 to 0.121)
Body mass index	13–22	15.9 (1.3), n=439 (86.9%)	−1.0 (−4.9 to 2.9)	2.3 (−0.6 to 5.1)	0.017 (−0.011 to 0.044)

For binary variables, the group with zero was defined as the reference group.
Bold: p value<0.05.
ln, natural logarithm; LPA, light physical activity, means by minutes per day; MVPA, moderate-to-vigorous physical activity, ln transformation of means by minutes per day; PA, physical activity; ST, sedentary time, means by minutes per day.

Table 3 Correlates between environmental characteristics and daily activity patterns among preschoolers in the GECKO Drenthe study, the Netherlands

Variable	Range	Descriptive data n (%)/median (25th; 75th)	ST β (95% CI)	LPA β (95% CI)	MVPA β (95% CI)
Household characteristics					
Cars	0–1	0=one car, n=184 (36.6%); 1=more than two cars, n=319 (63.4%)	−6.2 (−15.6 to 3.2)	5.5 (−1.1 to 12.2)	0.000 (−0.067 to 0.068)
Type of house: detached house	0–1	0=others, n=322 (63.9%); 1=detached house, n=182 (36.1%)	1.6 (−8.0 to 11.2)	−2.2 (−9.0 to 4.6)	0.012 (−0.056 to 0.081)
Type of house: semidetached house	0–1	0=others, n=324 (64.3%); 1=semidetached house, n=180 (35.7%)	−0.1 (−9.4 to 9.2)	−2.1 (−8.8 to 4.5)	−0.002 (−0.068 to 0.065)
Type of house: row house	0–1	0=others, n=432 (85.7%); 1= row house, n=72 (14.3%)	4.0 (−8.9 to 16.9)	2.8 (−6.3 to 11.9)	−0.027 (−0.119 to 0.065)
House ownership	0–1	0=privately owned, n=460 (93.5%); 1=rental house, n=32 (6.5%)	1.0 (−17.4 to 19.4)	−3.5 (−16.5 to 9.5)	0.073 (−0.059 to 0.206)
Dog in the house	0–1	0=no, n=404 (80.5%); 1=yes, n=98 (19.5%)	−3.7 (−15.0 to 7.6)	2.3 (−5.7 to 10.4)	0.006 (−0.076 to 0.087)
Garden	0–1	0=no, n=2 (0.4%); 1=yes, n=503 (99.6%)	–	–	–
Parents' perception of neighbourhood environment					
Traffic safety	0–1	0=less favourable, n=175 (35.1%); 1=favourable, n=324 (64.9%)	4.0 (−5.4 to 13.4)	1.1 (−5.6 to 7.8)	−0.023 (−0.091 to 0.044)
Road network	0–1	0=less favourable, n=161 (32.3%); 1=favourable, n=337 (67.7%)	0.2 (−9.4 to 9.9)	0.6 (−6.3 to 7.4)	−0.005 (−0.074 to 0.064)
Number of PA facilities		n=505 (100%)			
Within 5 min walk	0–6	2 (1; 3)	**−3.6 (−6.7 to −0.5)**	2.0 (−0.2 to 4.2)	0.022 (−0.001 to 0.044)
Within 10 min walk	0–6	3 (2; 4)	−1.5 (−4.5 to 1.4)	−0.1 (−2.2 to 2.0)	0.015 (−0.006 to 0.036)
Within 20 min walk	0–6	4 (3; 5)	−1.9 (−4.9 to 1.1)	0.5 (−1.6 to 2.7)	0.014 (−0.007 to 0.036)
Within 30 min walk	0–6	5 (4; 6)	−2.0 (−5.2 to 1.3)	0.7 (−1.6 to 3.0)	**0.027 (0.004 to 0.050)**
≥30 min walk	0–6	1 (0; 2)	1.4 (−1.8 to 4.7)	−0.4 (−2.7 to 1.9)	−0.021 (−0.044 to 0.002)

Variable	Range	Descriptive data n (%)/median (25th; 75th)	ST β (95% CI)	LPA β (95% CI)	MVPA β (95% CI)
Distance index *	6–30	20 (17; 24)	−0.8 (−1.6 to 0.1)	0.3 (−0.3 to 0.9)	**0.007 (0.001 to 0.013)**
Parents'/guardians' behaviours					
Taking child cycling	0–2	0=0–2 days/week, n=177 (35.3%); 1=3–4 days/week, n=174 (34.7%); 2=5–7 days/week, n=150 (29.9%)	1.2 (−4.4 to 6.7)	−1.1 (−5.0 to 2.9)	−0.003 (−0.042 to 0.037)
Taking child to play sports	0–2	0=0 day/week, n=296 (59.6%); 1=1 day/week, n=129 (26.0%); 2=2 or more days/week, n=72 (14.5%)	**−7.9 (−14.0 to −1.8)**	**5.3 (1.0 to 9.6)**	**0.068 (0.024 to 0.111)**
Accompanying going out	0–2	0=0–2 days/week, n=160 (31.9%); 1=3–4 days/week, n=153 (30.5%); 2=5–7 days/week, n=188 (37.5%)	1.2 (−4.2 to 6.6)	1.4 (−2.4 to 5.2)	−0.008 (−0.047 to 0.030)
Children's PA behaviours					
Outdoor play	0–17.5	9 (5.3; 12.5) (hours/week), n=503 (99.6%)	**−1.0 (−1.9 to −0.1)**	**0.8 (0.1 to 1.4)**	0.004 (−0.002 to 0.011)
Regular cycling	0–1	0=no, n=161 (32.3%); 1=yes, n=337 (67.7%)	−7.8 (−17.4 to 1.8)	0.4 (−6.4 to 7.3)	0.024 (−0.044 to 0.093)
Going out by bicycle	0–2	0=never, n=216 (42.8%); 1=sometimes, n=198 (39.2%); 2=often, n=91 (18.0%)	−1.3 (−7.3 to 4.8)	1.5 (−2.8 to 5.8)	0.031 (−0.012 to 0.074)

All correlates were adjusted for children's gender and age, maternal age and educational levels, and siblings in the family. For binary variables, the group with zero was defined as the reference group.

Bold: p value <0.05.

* *Distance index was synthesized by the six PA facilities in the neighbourhood; higher score meant these places were close to home.*

ln, natural logarithm; LPA, light physical activity, means by minutes per day; MVPA, moderate-to-vigorous physical activity, ln transformation of means by minutes per day; PA, physical activity; ST, sedentary time, means by minutes per day.

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Table 4 Correlation between variables and outcomes in the study

Variables	1.	2.	3.	4.	5.	6.	7.
1. ST							
2. LPA†	−0.709*						
3. MVPA†	−0.562*	0.297*					
4. Facilities within 5 min' walk†	−0.101*	0.067	0.081				
5. Facilities within 30 min' walk†	−0.066	0.036	0.105*	0.487*			
6. Distance index†‡	−0.090*	0.047	0.094*	0.787*	0.865*		
7. Child's outdoor play§	−0.120*	0.141*	0.111*	0.027	−0.023	0.013	
8. Parents taking child to play sports§	−0.115*	0.111*	0.128*	0.118*	0.157*	0.160*	0.083

**P*<0.05.*

†Pearson correlation was used.

‡Distance index was synthesized by the six PA facilities in the neighbourhood; higher score meant these places were close to home.

§Spearman correlation was used.

ln, natural logarithm; LPA, light physical activity, means by minutes per day; MVPA, moderate-to-vigorous physical activity, ln transformation of means by minutes per day; ST, sedentary time, means by minutes per day.

Path coefficient models were used for investigating the role of parental support acting as mediator in the associations between numbers of PA facilities and ST/MVPA. As shown in figure 2, for both of the two path models, the indirect effect of parental support between facilities and children's ST/MVPA was significant (path coefficients [95% CI] for ST: −0.4 [−1.1 to −0.0] and path coefficients [95% CI] for MVPA [ln]: 0.004 [0.001 to 0.009]). If parents perceived more PA facilities in their neighbourhood, they showed more support for 'taking children to play sports', and this was associated with less ST or more MVPA compared with children living with less PA facilities in their neighbourhood. The indirect effect of 'parent taking child to play sports' was also significant between 'distance index' and children's ST/MVPA; this data is shown in online appendix figure A.

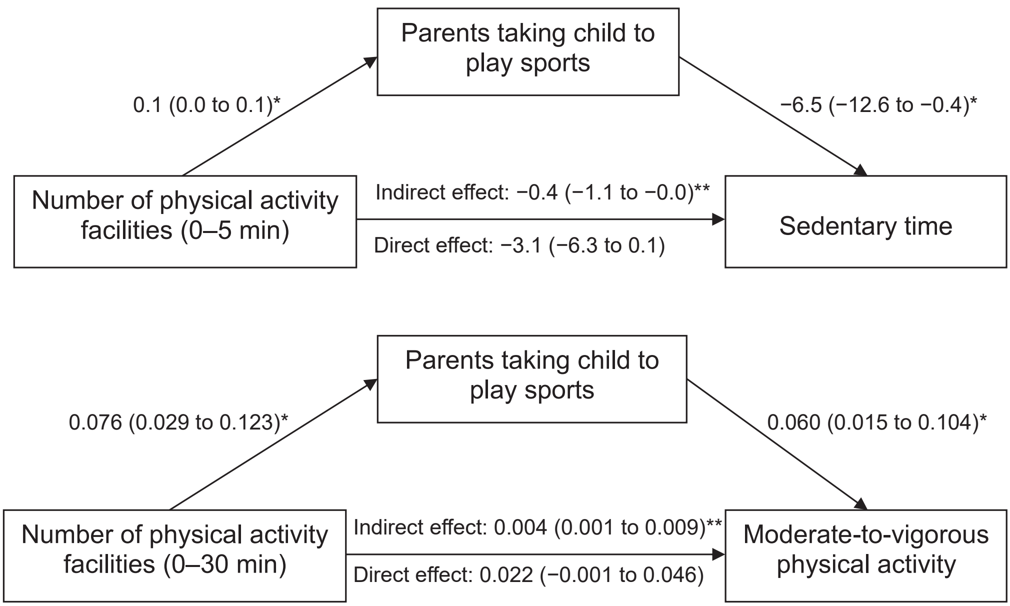

Figure 2. Direct and indirect pathways of environmental characteristics on sedentary time and moderate-to-vigorous physical activity among preschoolers in the GECKO study, the Netherlands.

Ordinary least square regression-based path analysis was used for direct and indirect effects, unstandardised β was given in the model, adjusted for child age and gender, maternal age and education, having siblings and child outdoor play.
**P<0.05. ** 95% CI does not encompass zero.*

DISCUSSION

This study examined how neighbourhood characteristics are associated with daily activity patterns in preschoolers. The results showed that parental support for participating in sports was related to less ST, more LPA and MVPA. Furthermore, parental support also acted as mediator in the associations between numbers of PA facilities and children's activities, for example, lower ST and more MVPA. Moreover, children who spent more time in outdoor play were also less sedentary and more active in LPA, though not in MVPA.

The accessibility of recreational PA facilities would seem to have an influence on daily activity patterns among preschool children, since these facilities are the most common places for children to be active. A previous review found a significant positive association between the proximity of parks and playgrounds to the home and children's PA.[34] But much of the research on the correlation of built environment characteristics and PA took place in urban area.[35] This study indicated that improving recreation facilities may be a useful strategy in developing an active neighbourhood, even in rural areas. Moreover, for PA promotion in young children, parental help is important. Parents were able to influence their children's participation in PA through a variety of mechanisms, for example, direct parental display of PA; higher maternal PA was related to more preschool children's MVPA in another study of the GECKO cohort.[10] Parental influence is most definitely important for the promotion of PA, especially when parents give their children the opportunity to be more active, for example, by encouraging playing outside or playing more sports.[12, 36] Furthermore, from the point of view of social cognitive theory, involvement of both individual factors and environmental components are essential to affect changes in health behaviour.[37] Thus, families living in a supportive neighbourhood may have more opportunities to be physically active, and active parents may be more aware of available facilities in their neighbourhoods; as a result, they are more likely to make use of these facilities for themselves and their children. Parental support should be taken into consideration, when developing active neighbourhood-targeted interventions.

In this study, traffic safety and road network were not found to be related to children's LPA or MVPA in Drenthe, the Netherlands. Thought a study reported that parental traffic safety perceptions were positively associated with MVPA in German preschoolers on weekend days.[22] Some studies found that traffic safety was an important characteristic associated with parents' reported outdoor play and children cycling.[28, 38] In this study, both a favourable situation in terms of traffic safety ($\rho = 0.144$, $p = 0.001$) and road network ($\rho = 0.090$, $p = 0.045$) were positively correlated to a higher frequency of child cycling when they went outside. Despite this, it seems that traffic safety and road network did not contribute substantially to daily LPA or MVPA in preschool children in Drenthe. However, it might be expected to be associated with transport/leisure-time PA later in school life, for example, active commuting to school.[38, 39]

The health benefits of outdoor activity, assuming that this leads to higher total PA, have been emphasized by several researchers in terms of reducing myopia, developing motor skills, and along with improving social skills, since children learn how to deal with each other.[40] More and more evidence indicates that unstructured outdoor play in 3-year to 12-year olds has declined over time and that it has nowadays been replaced by more time using electronic media indoors.[41, 42] This study indicated that more outdoor play would not contribute to the MVPA guideline but would probably contribute to the SB guideline. For example, we found that every additional hour spent outdoors per day was associated with 5.6 additional minutes of LPA and 7 min less of ST on an average day among the Dutch preschoolers in this study. For a global public health policy aimed at lower SB and at increasing LPA, encouraging outdoor play might prove to be an effective strategy in children, since outdoor play is a cheap and natural way for children to be physically active.[43]

An important strength of this study was the good representativeness of the study population with regard to socioeconomic position and a large sample size compared to similar studies.[44, 45] This study examined correlates of objectively measured ST, LPA, and MVPA separately, which provided full understanding of environmental influences on children's daily behaviours. However, due to incomplete data, a considerable number of cases could not be included in the analysis. The selection bias was small, with a slight bias towards higher-educated families but still more representative than other cohorts. An important methodological concern is that the evidence is based primarily on a cross-sectional study; therefore, children's behaviour before and after environmental changes were not evaluated. The measurements of ST, LPA, and MVPA that after data collection of household characteristics were lasting for (1.7 ± 0.9) years, and during this period, there could be some small changes of parents' reported characteristics. Thus, our hypotheses need to be tested further, and longitudinal study designs would make causality inferences between the predictors and activity outcomes more feasible to determine.

CONCLUSIONS

In conclusion, this study showed that parents' perception of neighbourhood PA facilities relates to a lower ST and higher MVPA in preschoolers, even in safe and rural communities. Convenient neighbourhood PA facilities (eg, park and playground) might be positive in encouraging children's PA through parental support for participating in sports. For the development of interventions for young children, improvement in PA facilities in the neighbourhood, promoting parents' involvement should be taken into consideration. Future studies should investigate the association between both an objective inventory (eg, via systematic environmental audits) and measurements of the perception of the effect of the environment on activity outcomes, along with using a longitudinal study design to test the influence of environmental changes.

REFERENCES

1 Hallal PC, Andersen LB, Bull FC, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects, *Lancet* 2012;380:247-57.

2 Goldfield GS, Harvey A, Grattan K, et al. Physical activity promotion in the preschool years: a critical period to intervene, *Int J Environ Res Public Health* 2012;9:1326-42.

3 Jones RA, Hinkley T, Okely AD, et al. Tracking physical activity and sedentary behavior in childhood: a systematic review, *Am J Prev Med* 2013;44:651-8.

4 Carson V, Lee EY, Hewitt L, et al. Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years), *BMC Public Health* 2017;17:854.

5 Geserick M, Vogel M, Gausche R, et al. Acceleration of BMI in Early Childhood and Risk of Sustained Obesity, *N Engl J Med* 2018;379:1303-12.

6 Carson V, Hunter S, Kuzik N, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update, *Appl Physiol Nutr Metab* 2016;41:S240-65.

7 Sallis JF, Cervero RB, Ascher W, et al. An ecological approach to creating active living communities, *Annu Rev Public Health* 2006;27:297-322.

8 Van Der Horst K, Paw MJ, Twisk JW, et al. A brief review on correlates of physical activity and sedentariness in youth, *Med Sci Sports Exerc* 2007;39:1241-50.

9 Edwardson CL, Gorely T. Parental influences on different types and intensities of physical activity in youth: A systematic review, *Psychol Sport Exerc* 2010;11:522-35.

10 Sijtsma A, Sauer PJ, Corpeleijn E. Parental correlations of physical activity and body mass index in young children--he GECKO Drenthe cohort, *Int J Behav Nutr Phys Act* 2015;12:132.

11 Maatta S, Ray C, Vepsalainen H, et al. Parental Education and Pre-School Children's Objectively Measured Sedentary Time: The Role of Co-Participation in Physical Activity, *Int J Environ Res Public Health* 2018;15:10.3390/ijerph15020366.

12 Datar A, Nicosia N, Shier V. Parent perceptions of neighborhood safety and children's physical activity, sedentary behavior, and obesity: evidence from a national longitudinal study, *Am J Epidemiol* 2013;177:1065-73.

13 Larouche R, Garriguet D, Gunnell KE, et al. Outdoor time, physical activity, sedentary time, and health indicators at ages 7 to 14: 2012/2013 Canadian Health Measures Survey, *Health Rep* 2016;27:3-13.

14 Truelove S, Bruijns BA, Vanderloo LM, et al. Physical activity and sedentary time during childcare outdoor play sessions: A systematic review and meta-analysis, *Prev Med* 2018;108:74-85.

15 Okely AD, Ghersi D, Hesketh KD, et al. A collaborative approach to adopting/adapting

guidelines - The Australian 24-Hour Movement Guidelines for the early years (Birth to 5 years): an integration of physical activity, sedentary behavior, and sleep, *BMC Public Health* 2017;17:869.

16 Talarico R, Janssen I. Compositional associations of time spent in sleep, sedentary behavior and physical activity with obesity measures in children, *Int J Obes (Lond)* 2018;42:1508-14.

17 Chastin SF, Palarea-Albaladejo J, Dontje ML, et al. Combined Effects of Time Spent in Physical Activity, Sedentary Behaviors and Sleep on Obesity and Cardio-Metabolic Health Markers: A Novel Compositional Data Analysis Approach, *PLoS One* 2015;10:e0139984.

18 Panter JR, Jones AP, van Sluijs EM. Environmental determinants of active travel in youth: a review and framework for future research, *Int J Behav Nutr Phys Act* 2008;5:34.

19 Tappe KA, Glanz K, Sallis JF, et al. Children's physical activity and parents' perception of the neighborhood environment: neighborhood impact on kids study, *Int J Behav Nutr Phys Act* 2013;10:39.

20 Carson V, Kuzik N, Hunter S, et al. Systematic review of sedentary behavior and cognitive development in early childhood, *Prev Med* 2015;78:115-22.

21 Kobes A, Kretschmer T, Timmerman G, et al. Interventions aimed at preventing and reducing overweight/obesity among children and adolescents: a meta-synthesis, *Obes Rev* 2018;19:1065-79.

22 Eichinger M, Schneider S, De Bock F. Subjectively and objectively assessed social and physical environmental correlates of preschoolers' accelerometer-based physical activity, *Int J Behav Nutr Phys Act* 2017;14:153.

23 Schmutz EA, Leeger-Aschmann CS, Radtke T, et al. Correlates of preschool children's objectively measured physical activity and sedentary behavior: a cross-sectional analysis of the SPLASHY study, *Int J Behav Nutr Phys Act* 2017;14:1.

24 Befort CA, Nazir N, Perri MG. Prevalence of obesity among adults from rural and urban areas of the United States: findings from NHANES (2005-2008), *J Rural Health* 2012;28:392-7.

25 Trivedi T, Liu J, Probst J, et al. Obesity and obesity-related behaviors among rural and urban adults in the USA, *Rural Remote Health* 2015;15:3267.

26 L'Abee C, Sauer PJ, Damen M, et al. Cohort Profile: the GECKO Drenthe study, overweight programming during early childhood, *Int J Epidemiol* 2008;37:486-9.

27 Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity, *Pediatr Obes* 2012;7:284-94.

28 Aarts MJ, de Vries SI, van Oers HA, et al. Outdoor play among children in relation to neighborhood characteristics: a cross-sectional neighborhood observation study, *Int J Behav Nutr Phys Act* 2012;9:98.

29 Aarts MJ, Wendel-Vos W, van Oers HA, et al. Environmental determinants of outdoor play in children: a large-scale cross-sectional study, *Am J Prev Med* 2010;39:212-9.

30 Brouwer SI, Kupers LK, Kors L, et al. Parental physical activity is associated with objectively measured physical activity in young children in a sex-specific manner: the GECKO Drenthe cohort, *BMC Public Health* 2018;18:1033.

31 Aadland E, Johannessen K. Agreement of objectively measured physical activity and sedentary time in preschool children, *Prev Med Rep* 2015;2:635-9.

32 Butte NF, Wong WW, Lee JS, et al. Prediction of energy expenditure and physical activity in preschoolers, *Med Sci Sports Exerc* 2014;46:1216-26.

33 Choi L, Liu Z, Matthews CE, et al. Validation of accelerometer wear and nonwear time classification algorithm, *Med Sci Sports Exerc* 2011;43:357-64.

34 Davison KK, Lawson CT. Do attributes in the physical environment influence children's physical activity? A review of the literature, *Int J Behav Nutr Phys Act* 2006;3:19.

35 Frost SS, Goins RT, Hunter RH, et al. Effects of the built environment on physical activity of adults living in rural settings, *Am J Health Promot* 2010;24:267-83.

36 Loprinzi PD, Trost SG. Parental influences on physical activity behavior in preschool children, *Prev Med* 2010;50:129-33.

37 Stokols D. Translating social ecological theory into guidelines for community health promotion, *Am J Health Promot* 1996;10:282-98.

38 Aarts MJ, Mathijssen JJ, van Oers JA, et al. Associations between environmental characteristics and active commuting to school among children: a cross-sectional study, *Int J Behav Med* 2013;20:538-55.

39 Ding D, Sallis JF, Kerr J, et al. Neighborhood environment and physical activity among youth a review, *Am J Prev Med* 2011;41:442-55.

40 McCurdy LE, Winterbottom KE, Mehta SS, et al. Using nature and outdoor activity to improve children's health, *Curr Probl Pediatr Adolesc Health Care* 2010;40:102-17.

41 Bassett DR, John D, Conger SA, et al. Trends in Physical Activity and Sedentary Behaviors of United States Youth, *J Phys Act Health* 2015;12:1102-11.

42 Russ SA, Larson K, Franke TM, et al. Associations between media use and health in US children, *Acad Pediatr* 2009;9:300-6.

43 Fuzeki E, Engeroff T, Banzer W. Health Benefits of Light-Intensity Physical Activity: A Systematic Review of Accelerometer Data of the National Health and Nutrition Examination Survey (NHANES), *Sports Med* 2017;47:1769-93.

44 Pfeiffer KA, Dowda M, McIver KL, et al. Factors related to objectively measured physical activity in preschool children, *Pediatr Exerc Sci* 2009;21:196-208.

45 Oliver M, Schofield GM, Schluter PJ. Parent influences on preschoolers' objectively assessed physical activity, *J Sci Med Sport* 2010;13:403-9.

Appendix 4.1.

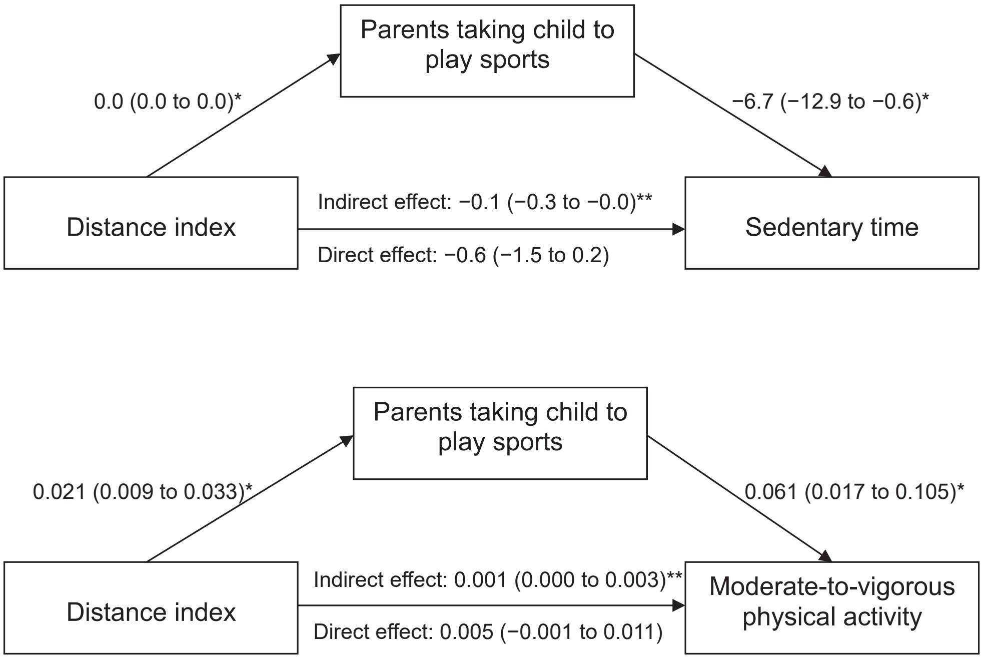

Figure A. Direct and indirect pathways of Distance index on sedentary time and moderate-to-vigorous physical activity among preschoolers in the GECKO study, the Netherlands.

Distance index was synthesized by the six PA facilities in the neighbourhood; higher score meant these places were close to home. Ordinary least square regression-based path analysis was used for direct and indirect effects, unstandardised β was given in the model, adjusted for child age and gender, maternal age and education, having siblings and child outdoor play.
**P < 0.05.*
*** 95% CI does not encompass zero.*

4

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Chapter 5

Physical activity patterns by objective measurements in preschoolers from China

Congchao Lu *, Rikstje Wiersma *,

Tong Shen, Guowei Huang, Eva Corpeleijn

(These authors contributed equally to this work.)*

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ABSTRACT

Introduction

This cross-sectional study aims to describe the objectively measured sedentary time (ST) and physical activity (PA) patterns of preschool children during the day, and to compare these patterns between non-overweight and overweight children.

Methods

Healthy children aged 3–6 years were recruited from urban preschools in Tianjin, China. Light PA (LPA), moderate-to-vigorous PA (MVPA), and ST of children were measured using ActiGraph accelerometry (at least 3 wearing days, more than 10 hours per day). Multiple adjusted, generally linear mixed models were used for statistical analysis.

Results

The time children (n = 134) spent in MVPA was 50.5 ± 17.1 min/day, and there were 28% of the children met the PA recommendation of one hour MVPA per day. Children were less active during recess (12:00–14:00) and afternoon (14:00–17:00), and more active during late afternoon (17:00–18:00) and evening (18:00–21:00). Between active and less active children, the difference of MVPA was highest in the evening (4.1 min/hour) and on weekends/holidays (42.7 min/day). Overweight children were more sedentary overall (44.6 min/day) compared to non-overweight children.

Conclusion

Chinese preschoolers have low levels of PA, especially during school days. Enhancing PA both in school and the home environment should be taken into consideration to prevent childhood obesity.

Keywords: Sedentary behaviors; obesity; accelerometry; time segments

INTRODUCTION

The increasing prevalence of childhood obesity has become one of the most important threats to public health worldwide. This is not only limited to high-income countries but is also increasingly found in low- and middle-income countries [1]. Data from the China Health and Nutrition Survey showed that the prevalence of overweight and obesity increased in boys and girls between 1997 and 2011, from 6.5% to 15.5% in boys and from 4.6% to 10.4% in girls [2]. This trend was not only found in school children but also in preschoolers (aged 3–6 years old). For example, the prevalence of obesity in Tianjin preschoolers increased from 8.8% in 2006 to 10.1% in 2010, and then remained stable until 2014 among children aged 5–6 years old [3]. Chinese people are facing huge changes in the local environment due to the rapid economic development experienced over the past three decades. As a result of urbanization, citizens' daily lives are accompanied by a lack of physical activity (PA), more sedentary lifestyles, and high-caloric diets, all contributors to the rapid rise in obesity in China [4].

The health benefits of sufficient PA during preschool years are increasingly being recognized [5]. In addition to preventing obesity, the promotion of PA also improves physical fitness, motor skills, and psychological development [6]. A lack of PA is also a growing problem in China nowadays. A systematic review summarized the levels of PA among Chinese children and adolescents, and found a low level of PA in most studies [7]. Half of the studies reported that less than 50% of the participants were able to meet the recommendation of one-hour moderate-to-vigorous PA (MVPA) daily. However, none of these studies focused on preschoolers. The Chinese government has published PA recommendations for preschoolers in June 2018, it emphasized that preschoolers should accumulate 60 minutes MVPA per day [8]. To our knowledge, less known is about objectively measured PA patterns among preschoolers in mainland China.

Given the widespread problem of physical inactivity, and the continued growth in the prevalence of childhood obesity, promotion of regular PA among young people has become a worldwide public-health priority [9]. Future efforts to effectively promote PA in young children through policy initiatives will depend on a full understanding of PA behavior in this age group. The patterns of PA and sedentary behaviors in preschoolers are still unclear, while the associations between objective measurement of PA and Body Mass Index (BMI) remain inconclusive [10]. Identifying periods during the day, which are characterized by high levels of

PA in some children and low levels in others, will help to identify key time slots for intervening and potentially changing PA behaviors [11]. Objective measurement of PA with accelerometry can provide a reliable and valid estimate of energy/calorie expenditure in preschoolers, as well as offer the opportunity to specify the PA pattern over the day using time-stamped data [12]. The aim of this cross-sectional study is to describe the objectively measured PA and sedentary behaviors of Chinese urban preschoolers during the day, and to compare the PA patterns of non-overweight and overweight children.

METHODS

Study design

Data were derived from the Physical Activity and Health in Tianjin Chinese Children study (PATH-CC), which focuses on identifying the relationship between environmental determinants, PA, and overweight in childhood in Tianjin, China. Tianjin is the fourth largest city in northern China with over 15 million residents in 2015. Preschools generally include 3- to 6-year-old children, and most of these children attend local preschools in the urban city. Four preschools, located in four different districts, were selected at random. Healthy children aged 3–6 years of age, growing up in Tianjin, were recruited in preschools using advertising posters. There were 1031 preschool children, who, along with their parents, joined in the study from March to April 2015. The participant rate was 93.7% of the total number of 1100 children in the recruited preschools. Written informed consent was obtained from parents, and the study was approved by the Medical Ethics Committee of the Tianjin Medical University and performed in accordance with the Declaration of Helsinki.

Data collection

All children (n = 1031) in the PATH-CC study were asked to join the physical activity measurement by recruitment letters to their parents. In total, 169 parent-child pairs responded to the invitation, of which 6 children dropped out. Accelerometry data of participants were collected from June to November 2015 in Tianjin, China. The height and weight of children were measured without shoes and in light clothes by trained school nurses. Standing height was measured using a stadiometer (to the nearest 0.1 cm, SZG-180, Shanghai Zhengdahengqi Company, Shanghai, China), and weight was measured using digital scale (to the nearest 0.01 kg, TCS-60, Tianjin weighting apparatus, Tianjin, China). The standardized BMI (zBMI) of children was calculated using the LMS method; overweight and obesity were classified according to the age- and gender-specific cut-offs of Cole and colleagues (2012) [13]. Educational level of the parents (low/middle education or higher education), ethnicity, and information about children's napping in the afternoon were both addressed in questionnaires. Parents reported whether their children had a nap during the day, and the duration of napping on average, for school days as well as weekends/holidays.

Sedentary time and physical activity

Sedentary time (ST) and PA in children were assessed using ActiGraph GT3X (Actigraph, Pensacola, FL) accelerometry. Parents were instructed to have their child wear the ActiGraph on the iliac crest of the right hip with an elastic belt for seven days during all waking hours, except while bathing or swimming [14]. Data were collected using a frequency of 30 Hz. Collected data were analyzed in 15-second epochs. Non-wearing time of the ActiGraph was classified as a minimum length of 90 minutes, small window length 30 minutes, and with 2 minutes of spike tolerance [15]. Cut-off points recommended by Butte and colleagues were used to calculate the time spent on ST (≤ 819 CPM), LPA (820 – 3907 CPM), moderate physical activity (3908 – 6111 CPM), vigorous physical activity (≥ 6112 CPM) and MVPA (≥ 3908 CPM) [16]. The valid wearing period was selected as being from 6:00 until midnight. For valid measurements in this study, wearing time had to be at least 600 minutes/day for at least three days, regardless of whether these were weekdays or weekend days. Time of day, weekday or weekend day, and season were obtained from the ActiGraph output. School days and weekends/holidays were defined according to the schedule of the local government; data were not collected during summer holidays.

MVPA accrued in bouts was calculated, including sporadic sessions (1–4 minutes), short bouts (5–9 minutes, interruption periods of 1 minute), and medium-to-long bouts (≥ 10 minutes, interruption periods of 2 minutes). That is, participants were allowed an occasional rest period of 1 or 2 minutes respectively during the short and medium-to-long bouts of MVPA [17]. Another reason for allowing interruption periods is that no child had one time of medium-to-long bouts per day without any interruption in this study, and only four children had one time of short bouts per day without any interruption. Bout frequency was calculated by total number of bouts performed on valid days divided by the number of valid days [18].

The school schedule follows a five-day rotation in China, and lunch in school days for preschoolers between 11:00 and 12:00, followed by an obligatory resting time (nap time) until 14:00 or 15:00. In this study, the activity levels per segment were calculated as mean minutes per hour; incomplete hours were excluded. The incomplete hours were mainly found between 12:00 and 15:00 in nine children, since these children removed the ActiGraph for napping with an average of (105 ± 31) minutes according to parents' reports. Furthermore, the activity levels per segment were calculated for school days and for weekends/holidays as well, separately. Incomplete hours were not imputed as missing data, because no difference for napping time was found between children wearing ActiGraphs or not, either on school days or on weekend/holidays ($p > 0.05$). Adherence to the PA guidelines was defined as at least 60 minutes of MVPA daily on average (with some measurement days exceeding the recommendation and some days not) according to the World Health Organization recommendation [19], as well as the Chinese PA guidelines for preschoolers [8]. As for the seasons, summer was defined as June to August and autumn was defined as September to November. Children were also divided into active and less active groups, based on the highest (58.2 minutes/day) and lowest (41.6 minutes/day) tertile of MVPA per day, respectively.

Statistical analysis

To examine the distribution of PA and ST during the day and to identify which time slots differed from each other, a sensitivity analysis was performed, using repeated measures ANOVA with hours as dependent variables from 8:00 to 21:00, since children were not fully measured by the ActiGraph in the early morning (6:00–8:00) and late evening (21:00–24:00). To examine the differences in PA and ST of the children between school days and weekends/holidays, multiple linear mixed models, controlled for sex, age, and season, were performed, one for each segment and for the whole day (overall). School days and weekends/holidays were entered as fixed factors; gender was entered as a factor; age and season were entered as covariates; and the covariance type was set as unstructured. To compare active and less active children, and overweight and non-overweight children, multiple linear regressions were performed, one for each segment and one for the whole day, controlled for sex, age, and season. Dependent skewed variables were ln-transformed for linear regression. IBM SPSS Statistics 22 for Windows (SPSSInc., Chicago, IL) were used for this study, with test level $\alpha = 0.05$, and analyses were conducted in 2018.

RESULTS

A total of 163 children participated in the measurements of PA using ActiGraph accelerometry, and 134 children (82.2%) had valid data for analysis in this study. A flowchart of the participant recruitment is shown in Figure 1. The excluded children (n = 29) did not differ in terms of gender, age, and maternal educational levels (all $p > 0.05$) compared to the included children (n = 134). No significant differences were found between the total sample and the PA group for age, gender, BMI, ethnicity, and maternal educational levels. The time children spent in MVPA was 50.5 ± 17.1 minutes per day. The percentage of time spent in ST, LPA, and MVPA during a day was 60.8%, 32.6%, and 6.6%, respectively. The PA recommendation was met by 28% of children, and more boys (32%) than girls (22%) met the recommendation. During school days, 22% of the children were able to meet the recommendation, and 47% on weekends/holidays. The descriptive characteristics of the children for the total PATH-CC sample and PA group are shown in Table 1.

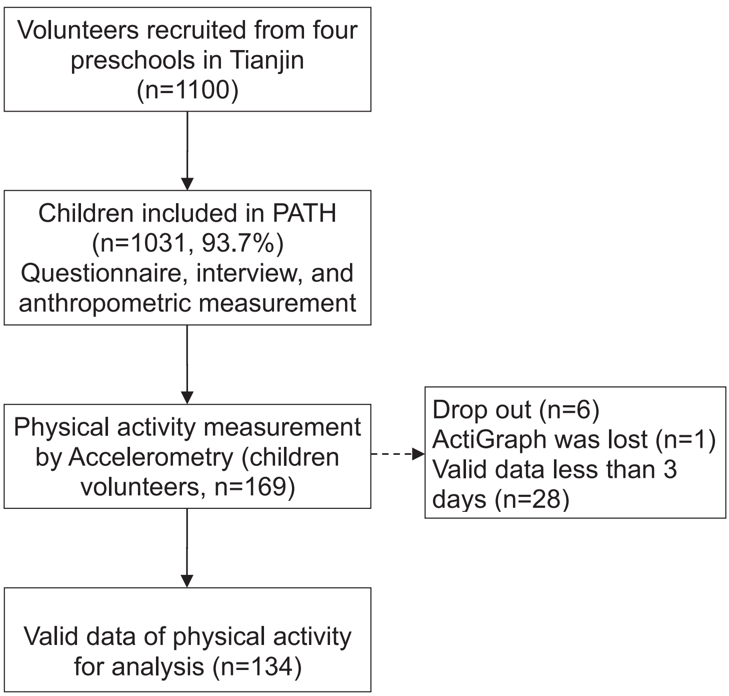


Figure 1. Flowchart of the participants from the PATH-CC study in this analysis.

Table 1. Characteristics of the study population.

Characteristics	Total (n = 1031)	Physical activity group (n = 134)
Age (years)	4.8 ± 1.1	5.4 ± 0.9
Boys	580 (56.3)	76 (56.7)
Body Mass Index	15.2 (14.4; 16.3)	15.2 (14.5; 16.3)
Obesity & overweight [a]	125 (12.2)	16 (11.9)
Normal weight & underweight	901 (87.8)	118 (88.1)
Ethnicity		
Han	969 (94.0)	127 (94.8)
Non-Han	62 (6.0)	7 (5.2)
Maternal education		
Low/middle	144 (14.3)	25 (19.1)
High	862 (85.7)	106 (80.9)
Sedentary time (min/day)	-	468.7 ± 80.5
Light physical activity (min/day)	-	249.6 ± 44.1
Moderate physical activity (min/day)	-	38.0 ± 12.7
Vigorous physical activity (min/day)	-	12.5 ± 5.4
Moderate and vigorous physical activity (min/day)	-	50.5 ± 17.1
Adherence to physical activity recommendation [b]	-	37 (27.6)

Data were presented as rates in N, and percentages as means with standard deviations, or, if data were skewed, as the median, along with the 25th to 75th percentile.

[a] *Overweight based on Z-scores Cole.*

[b] *Moderate and vigorous physical activity, 60 min/day (with some measurement days exceeding the recommendation and some days not).*

The percentage of time that children engaged in sporadic sessions (1–4 minutes), short bouts (5–9 minutes) and medium-to-long bouts (≥ 10 minutes) accounted for 31.4%, 12.7%, and 6.4%, respectively, of the total MVPA during a day. This means that 49.5% of the time in MVPA comprised of sporadic MVPA of less than one minute. A total of 7% of children engaged in at least one medium-to-long bout of MVPA on the average day, and 49% participated in at least one short bout of MVPA on the average day. During weekends/holidays, children showed a higher frequency of sporadic sessions [median and IQR, 12.0 (7.5, 17.0) bouts] compared to school days [median and IQR, 9.5 (6.6, 12.9) bouts, $p < 0.05$). Active children showed a higher frequency in bouts compared to less active children for all bout types ($p < 0.05$). There were no differences in bouts frequency between overweight and non-overweight children. These outcomes are shown in Table 2.

Table 2. Characteristics of MVPA bouts of the study population.

Bouts frequency (n/day)	Medium-to-long bout (IQR)	Short bout (IQR)	Sporadic sessions (IQR)
Physical activity group (n = 134)	0.2 (0.0, 0.5)	0.9 (0.3, 1.6)	9.8 (7.2, 14.1)
During schooldays (n = 134)	0.2 (0.0, 0.5)	0.8 (0.3, 1.5)	9.5 (6.6, 12.9)
During weekend/holidays (n = 107)	0.0 (0.0, 0.5)	1.0 (0.0, 2.3)	12.0 (7.5, 17.0)[a]
Overweight children (n = 16)	0.3 (0.0, 0.4)	0.6 (0.2, 1.4)	9.2 (4.9, 14.7)
Non-overweight children (n = 118)	0.2 (0.0, 0.5)	0.9 (0.3, 1.6)	9.9 (7.3, 14.1)
Active children (n = 44)	0.5 (0.2, 0.9)[b]	1.8 (1.0, 2.5)[b]	15.4 (13.2, 17.5)[b]
Less active children (n = 44)	0.0 (0.0, 0.2)	0.3 (0.1, 0.8)	6.5 (4.1, 7.7)

Data for bouts frequency of MVPA are presented as the median in number/day, along with the 25th and 75th percentiles.

[a] *$p < 0.05$; derived from Mann-Whitney U test assessing whether differences of bouts frequency between schooldays and weekend/holidays.*

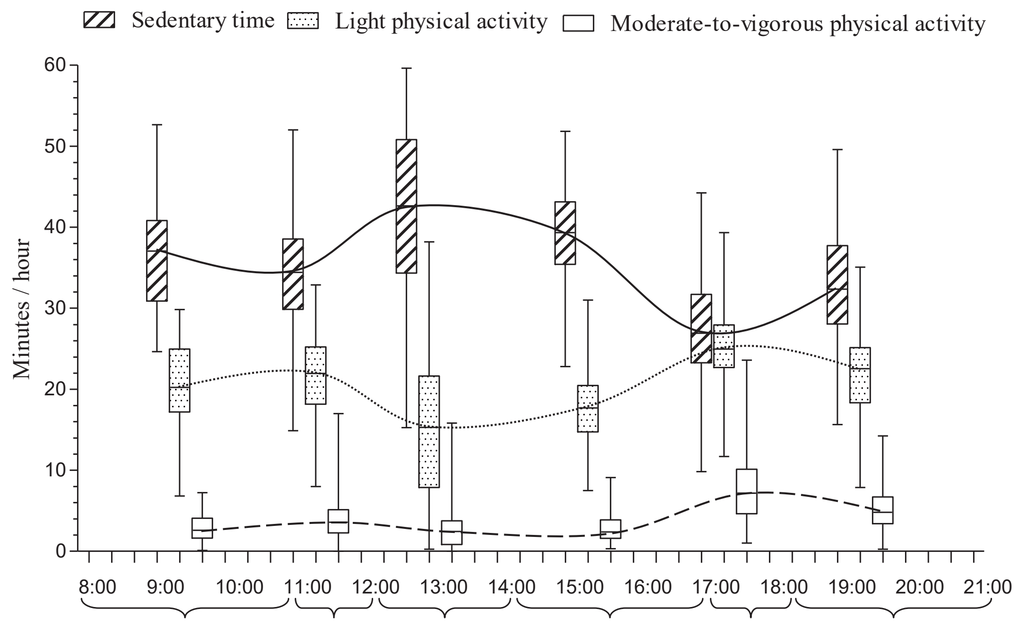
[b] *$p < 0.05$; derived from Mann-Whitney U test assessing whether differences of bouts frequency between active children and less active children.*

5

Distribution of ST and PA during the day

Time segments were chosen based on sensitivity analysis and Chinese children's daily schedules. The results of sensitivity analysis on the division of hours showed that there were significant differences between 8:00 and 9:00, 9:00 and 10:00, and 10:00 and 11:00 for LPA. However, those segments were not significantly different for ST and MVPA; therefore, these segments were combined as morning (8:00–11:00). The segments of 12:00–13:00 and 13:00–14:00 were combined as recess (12:00–14:00) since most of children would have a nap at school during this period on school days. According to parents' reports, 105 children (78%) had nap with an average of (108 ± 29) minutes in school days, and 81 children (60%) had nap with an average of (108 ± 38) minutes during weekends/holidays. Furthermore, there were no significant differences for ST, LPA, and MVPA between the segments of 14:00–15:00 and 15:00–16:00, and also no significant differences for MVPA between 15:00–16:00 and 16:00–17:00; therefore, these segments were combined as afternoon (14:00–17:00). There were no significant differences for ST, LPA, and MVPA between the segments of 18:00–19:00 and 19:00–20:00, and also no significant differences for MVPA between 19:00–20:00 and 20:00–21:00; therefore, these segments were combined as evening (18:00–21:00). Finally, six time segments were used in this study for describing the distribution of ST and PA during the day, including morning (8:00–11:00), lunch (11:00–12:00), recess (12:00–14:00), afternoon (14:00–17:00), late afternoon (17:00–18:00) and evening (18:00–21:00).

Figure 2 shows the median, the 25th and 75th percentile, and the minimum and maximum for ST, LPA, and MVPA per time segment. A main effect for differences between segments over the day was found for ST, LPA, and MVPA ($F(6) = 81.2$, $p = 0.000$; $F(6) = 60.4$, $p = 0.000$; $F(6) = 90.3$, $p = 0.000$, respectively). The contrasts for ST, LPA, and MVPA showed significant differences between all segments ($p < 0.05$). The time children spent being sedentary was highest during recess (12:00–14:00) and afternoon (14:00–17:00), which accounted for 46% of total ST daily on school days (40% of total ST daily on weekends/holidays). The time spent being sedentary was lowest in the late afternoon (17:00–18:00), and it increased again in the evening (18:00–21:00). The time children spent in LPA was lowest around recess (12:00–14:00), and increased from afternoon (14:00–17:00) to late afternoon (17:00–18:00), while in the evening it decreased again. The time children spent in MVPA was lowest around recess (12:00–14:00) and highest in late afternoon (17:00–18:00). During school days, the time children spent in MVPA during recess and afternoon (12:00–17:00) only accounted for 20% of total MVPA daily, but the late afternoon and evening (17:00–21:00) accounted for 52% of the total MVPA.



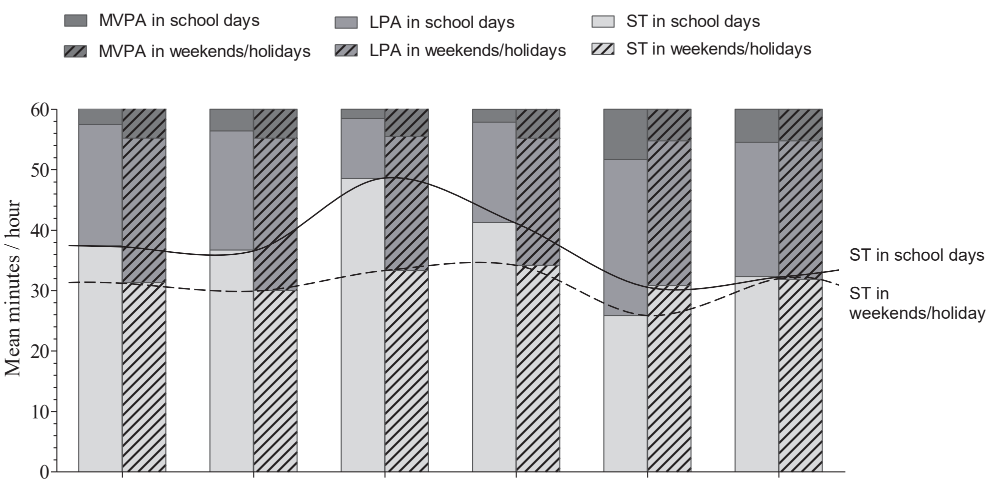
	Morning (8:00-11:00)			Lunch (11:00-12:00)			Recess (12:00-14:00)			Afternoon (14:00-17:00)			Late afternoon (17:00-18:00)			Evening (18:00-21:00)		
Median:	37.1	20.2	2.6	34.4	22.0	3.6	42.6	15.3	2.4	39.3	17.7	2.4	26.9	25.0	7.2	32.4	22.6	4.8
25th:	30.9	17.2	1.6	29.9	18.2	2.3	34.3	7.9	0.8	35.4	14.7	1.6	23.3	22.7	4.6	28.1	18.3	3.4
75th:	40.8	25.0	4.1	38.5	25.2	5.1	50.8	21.6	3.7	43.1	20.5	3.9	31.7	28.0	10.1	37.7	25.1	6.7

Figure 2. Daily physical activity patterns per time segment.

Moderate to vigorous physical activity (MVPA), light physical activity (LPA), and sedentary time (ST) are given per time segment with the median, the 25th and 75th percentile, and minimum and maximum. All time segments differed significantly ($p < 0.05$).

School days compared to weekends/holidays

During school days, children showed more ST (51.3 min/day), less LPA (45.4 min/day), and less MVPA (13.5 min/day) for the whole day (overall) compared to weekends/holidays. Data per segments indicated that children were more sedentary in daytime for each segment (8:00–17:00) compared to weekends/holidays, and the largest difference for more time spent on ST was found during recess (12:00–14:00, M_{diff} = 15.2 min/hour); however, children were more active for MVPA (M_{diff} = 3.1 min/hour) during late afternoon (17:00–18:00) on school days compared to weekends/holidays (Figure 3). No difference was found in the evening (18:00–21:00). In total, boys spent more time in MVPA (M_{diff} = 6.9 min/day, p = 0.021) than girls, the largest difference was during weekends/holidays (M_{diff} = 10.1 min/day, p = 0.020). These outcomes are shown in Table S1.



	Morning (8:00-11:00)		Lunch (11:00-12:00)		Recess (12:00-14:00)		Afternoon (14:00-17:00)		Late afternoon (17:00-18:00)		Evening (18:00-21:00)	
Mean MVPA:	2.5	4.8	3.6	4.8	1.5	4.5	2.1	4.8	8.3	5.2	5.5	5.2
LPA:	20.0	23.9	19.7	25.2	9.9	22.2	16.6	21.0	25.8	24.0	22.2	22.9
ST:	37.4	31.4	36.7	30.1	48.5	33.3	41.3	34.2	25.9	30.8	32.3	31.9

Figure 3. Daily physical activity patterns for school days and holidays.

Moderate to vigorous physical activity (MVPA), light physical activity (LPA), and sedentary time (ST) are given per time segment for school days and weekends/holidays, with the mean per behavior and per group. Only the evening (18:00–21:00) showed no significant differences for ST, LPA, and MVPA between school days and weekends/holidays (p > 0.05). P-values are based on linear mixed models and adjusted for sex, age, and season. Statistical testing for MVPA was performed using Ln-transformed MVPA.

Active children compared to less active children

When comparing active children to less active children, active children showed less ST (58.5 min/day), more LPA (57.3 min/day) and MVPA (37.3 min/day) for the whole day (overall) compared to less active children. Data per segments indicated that all segments throughout the day differed significantly for ST, LPA, and MVPA ($p < 0.05$), except for ST (17:00–18:00), and LPA (11:00–12:00, 17:00–18:00). The largest difference in time spent on MVPA per segment was found in the evening (18:00–21:00, 4.1 min/hour), between active and less active children, as shown in Figure 4. When the PA outcomes were separated into school days and weekends/holidays, this showed that the difference in time spent overall on MVPA between active and less active children was higher during weekends/holidays (42.7 min/day) compared to school days (32.9 min/day). These outcomes are shown in Table S2.

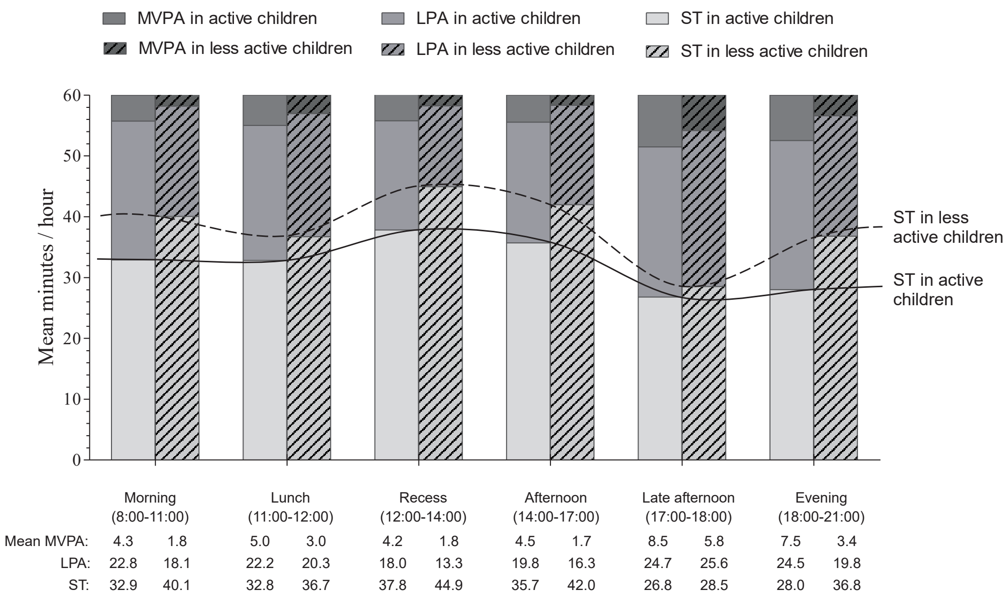
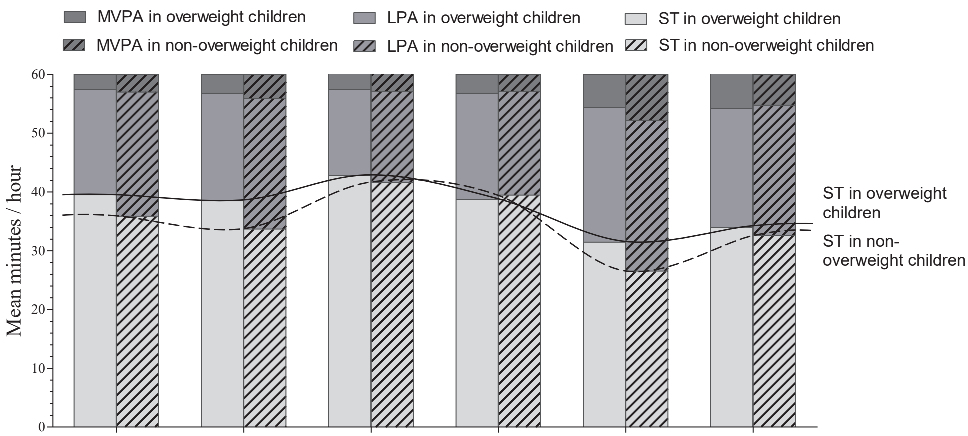


Figure 4. Daily physical activity patterns for active children and less active children.

Moderate to vigorous physical activity (MVPA), light physical activity (LPA), and sedentary time (ST) are given per time segment for active children and less active children, with the mean per behavior and per group. Only the segments of lunch (11:00–12:00) and late afternoon (17:00–18:00) for LPA, and the segment of late afternoon for ST showed no significant differences between active children and less active children (p > 0.05). P-values are based on linear mixed models and adjusted for sex, age, and season. Statistical testing for MVPA was performed using Ln-transformed MVPA.

Non-overweight children compared to overweight children

There were no differences in overall LPA and MVPA between overweight and non-overweight children. However, overweight children showed more ST overall compared to non-overweight children (44.6 min/day), especially in the morning (8:00–11:00, 3.6 min/hour) and lunch (11:00–12:00, 4.8 min/hour) and in the late afternoon (17:00–18:00, 4.9 min/hour), as shown in Figure 5. On school days, overweight children showed less time in LPA in the morning (2.9 min/hour) and evening (3.0 min/hour), and were more sedentary in the late afternoon (4.6 min/hour) compared to non-overweight children. During weekends/holidays, overweight children showed more ST (6.3 min/hour) in the morning, at the cost of less LPA (5.1 min/hour), compared to non-overweight children (Table S3).



	Morning (8:00-11:00)		Lunch (11:00-12:00)		Recess (12:00-14:00)		Afternoon (14:00-17:00)		Late afternoon (17:00-18:00)		Evening (18:00-21:00)	
Mean MVPA:	2.6	3.0	3.2	4.1	2.6	2.9	3.2	2.9	5.7	7.8	5.8	5.2
LPA:	17.9	21.1	18.3	22.2	14.6	15.4	18.0	17.7	22.9	25.6	20.2	22.2
ST:	39.5	35.9	38.5	33.7	42.8	41.6	38.7	39.5	31.4	26.5	34.0	32.5

Figure 5. Daily physical activity patterns for overweight and non-overweight children.

Moderate to vigorous physical activity (MVPA), light physical activity (LPA), and sedentary time (ST) are given per time segment for overweight and non-overweight children, with the mean per behavior and per group. Only the segments of morning (8:00–11:00) and lunch (11:00–12:00) for LPA and ST, and the segment of late afternoon (17:00–18:00) for MVPA, LPA, and ST showed significant differences between overweight and non-overweight children (p < 0.05). P-values are based on linear mixed models and adjusted for sex, age, and season. Statistical testing for MVPA was performed using Ln-transformed MVPA.

DISCUSSION

Examining time-segment-specific patterns in objectively measured PA is helpful for effective PA promotion in children [20]. In order to find the time segments, in which interventions aiming to increase the PA levels in Chinese preschoolers might enjoy the most success, different approaches were followed in this study. A low level of PA was found among Chinese preschoolers in this study, especially during afternoons in the school environment. Active children are more active than less active children outside of school hours. Children are more sedentary during school days compared to weekends/holidays, and overweight children are even more sedentary both on school days and weekends/holidays compared to non-overweight children.

This study indicated that, compared to weekends/holidays, patterns of preschoolers' activity during a day in school were more variable with more peaks and troughs. This pattern was also found in British and Belgian preschoolers, which were characterized by structured routine timetables and scheduled recesses [11,21]. For Chinese preschoolers, during school days, the percentage (22%) of children who met the PA recommendation was much lower than a worldwide systematic review reported (54%, N = 10,316, aged 2–6 years) [22]. The increased time spent on indoor activities and the lack of opportunities for outside play often comes at the price of time for PA, partly due to air pollution there is less opportunity for outdoor physical activities in Chinese children [23]. Therefore, classroom-based PA interventions such as physically active academic lessons, or providing children more opportunity for structured physical activities indoors are recommended [24]. In addition, perhaps to reduce the long duration of napping would be possible for children to gain the opportunity to be active, since cancel napping would not be culturally acceptable in China. Furthermore, literature showed that daytime naps increased sleep problems [25,26], for example, longer nap durations were found to be related to later bed time on the corresponding night in Japanese toddlers (2–5 years old) [27]. In nowadays Chinese urban cities, most preschools perform the similar timetables and scheduled recess (at school) for children, thus, implications from this study could also be considered by other cities. Effective school policies and programs are needed in China in order to fight the growing epidemic of physical inactivity and obesity; strong support from local governments is paramount [28].

Between less active and more active children, i.e. the lowest and highest tertile of MVPA, the largest differences in MVPA were found outside of school hours. For example, active children spent 4.1 min/hour more on MVPA in the evening on an average day, and spent 42.7 min/day more in MVPA during weekend/holidays than less active children. Thus, weekends/holidays or during after-school hours on school days may be a critical period for promotion of PA at preschool age, especially for less active children. We assume that transport and leisure time activities might play an important role in urban preschoolers' activity, and large improvements in PA would be gained if active commuting and sufficient active leisure-time opportunities were embedded in their daily life. Therefore, the weekends might be a good time for improving PA in less active children, since it would then be possible for parents to support children's activities efficiently by having enough time. PA-promotion strategies targeting low active children may be effectuated via parents' support at home and in neighborhood community groups [29-31]. Health education for parents is needed, both in order to learn how important adequate PA is for a child's health and development, as well as to learn strategies for stimulating children's PA [32].

This study showed that compared to non-overweight children, overweight children were more sedentary overall (44.6 min/day) and spent less time on LPA in the morning (3.6 min/hour), lunch (4.8 min/hour) and late afternoon (4.9 min/hour). A systematic review found moderate evidence for the association between television viewing and overweight in preschoolers [33]. One study in China indicated that sedentary behaviors might be positively and independently related to fat mass among Chinese children [34]. While the cross-sectional nature of this study does not allow for any conclusions vis-à-vis cause and effect, our findings are consistent with the hypothesis that ST or LPA constitutes a major contributing factor in the development and continuation of childhood obesity [35]. This study indicated that interventions should focus on both the promotion of PA and the limitation of ST. Both the school and home environments should be taken into consideration in order to promote an effective intervention. Parents' involvement is essential [36,37].

Limitations

This study has some limitations. Firstly, children included in this study were volunteers and derived from a random sample in a large city in China. Further studies are needed to confirm the results in larger sample sizes. Secondly, the participating parents were well-educated, since young parents that finished college/university are common in Chinese large urban cities nowadays, e.g. Beijing, Shanghai or Tianjin. Thirdly, not all children covered all segments during the day. However, the results were comparable when only children who covered all segments during the day were included. Furthermore, it is unknown how these results would translate to other populations in a different part of the world, since different cultures effecting different cultural habits and different school schedules play an important role in children's activity patterns.

CONCLUSION

As far as is known, this is the first study that has examined PA patterns during the day using ActiGraph along with time-stamped data in Chinese preschoolers. This study showed that Chinese preschoolers have low levels of PA, especially during school days, and overweight children are more sedentary. In this preschool age group longer bouts of MVPA are rare, but smaller bouts are common and differ greatly between active and inactive children. Results of this study indicated that enhancing PA both in school and in the home environment should be taken into consideration to prevent childhood obesity. Preschools could provide children with more opportunities to be active in the afternoon. For less active children, the weekends might be a possible time to enhance their PA, and a suitable way to promote PA should be taken into consideration by their parents. Strong support from local governments in terms of effective school policies and building a neighborhood around active living is essential.

REFERENCES

[1] Sun H, Ma Y, Han D, Pan CW, Xu Y. Prevalence and trends in obesity among China's children and adolescents, 1985-2010. PLoS One. 2014;9(8):e105469; doi:10.1371/journal.pone.0105469.

[2] Wang H, Xue H, Du S, Zhang J, Wang Y, Zhang B. Time trends and factors in body mass index and obesity among children in China: 1997-2011. Int J Obes (Lond). 2017;41(6):964-70; doi:10.1038/ijo.2017.53.

[3] Xiao Y, Qiao Y, Pan L, Liu J, Zhang T, Li N, et al. Trends in the Prevalence of Overweight and Obesity among Chinese Preschool Children from 2006 to 2014. PLoS One. 2015;10(8):e0134466; doi:10.1371/journal.pone.0134466.

[4] Bauman A, Allman-Farinelli M, Huxley R, James WP. Leisure-time physical activity alone may not be a sufficient public health approach to prevent obesity--a focus on China. Obes Rev. 2008;9 Suppl 1:119-26; doi:10.1111/j.1467-789X.2007.00452.x.

[5] Carson V, Lee EY, Hewitt L, Jennings C, Hunter S, Kuzik N, et al. Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). BMC Public Health. 2017;17(Suppl 5):854,017-4860-0; doi:10.1186/s12889-017-4860-0.

[6] Timmons BW, Leblanc AG, Carson V, Connor Gorber S, Dillman C, Janssen I, et al. Systematic review of physical activity and health in the early years (aged 0-4 years). Appl Physiol Nutr Metab. 2012;37(4):773-92; doi:10.1139/h2012-070.

[7] Lu C, Stolk RP, Sauer PJ, Sijtsma A, Wiersma R, Huang G, et al. Factors of physical activity among Chinese children and adolescents: a systematic review. Int J Behav Nutr Phys Act. 2017;14(1):36,017-0486-y; doi:10.1186/s12966-017-0486-y.

[8] National Working Committee on Children and Women under State Council. Available at: http://www.nwccw.gov.cn/2018-06/13/content_210391.htm. Accessed June 13th, 2018.

[9] Trost SG, Loprinzi PD. Parental influences on physical activity behavior in children and adolescents: a brief review. American Journal of Lifestyle Medicine. 2011;5(2):171-81; doi:10.1177/1559827610387236.

[10] Sijtsma A, Sauer PJ, Stolk RP, Corpeleijn E. Is directly measured physical activity related to adiposity in preschool children? Int J Pediatr Obes. 2011;6(5-6):389-400; doi:10.3109/17477166.2011.606323.

[11] O'Dwyer M, Fairclough SJ, Ridgers ND, Knowles ZR, Foweather L, Stratton G. Patterns of objectively measured moderate-to-vigorous physical activity in preschool children. J Phys Act Health. 2014;11(6):1233-8; doi:10.1123/jpah.2012-0163.

[12] Pate RR, O'Neill JR, Mitchell J. Measurement of physical activity in preschool children. Med Sci Sports Exerc. 2010;42(3):508-12; doi:10.1249/MSS.0b013e3181cea116.

[13] Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness,

overweight and obesity. Pediatr Obes. 2012;7(4):284-94; doi:10.1111/j.2047-6310.2012.00064.x.

[14] Cliff DP, Reilly JJ, Okely AD. Methodological considerations in using accelerometers to assess habitual physical activity in children aged 0-5 years. J Sci Med Sport. 2009;12(5):557-67; doi:10.1016/j.jsams.2008.10.008.

[15] Choi L, Liu Z, Matthews CE, Buchowski MS. Validation of accelerometer wear and nonwear time classification algorithm. Med Sci Sports Exerc. 2011;43(2):357-64; doi:10.1249/MSS.0b013e3181ed61a3.

[16] Butte NF, Wong WW, Lee JS, Adolph AL, Puyau MR, Zakeri IF. Prediction of energy expenditure and physical activity in preschoolers. Med Sci Sports Exerc. 2014;46(6):1216-26; doi:10.1249/MSS.0000000000000209.

[17] Mark AE, Janssen I. Influence of bouts of physical activity on overweight in youth. Am J Prev Med. 2009;36(5):416-21; doi:10.1016/j.amepre.2009.01.027.

[18] Brooke HL, Atkin AJ, Corder K, Brage S, van Sluijs EM. Frequency and duration of physical activity bouts in school-aged children: A comparison within and between days. Prev Med Rep. 2016;4:585-90; doi:10.1016/j.pmedr.2016.10.007.

[19] World Health Organization. Global recommendations on physical activity for health. Geneva, Switzerland: World Health Organization Press; 2010.

[20] Brooke HL, Corder K, Atkin AJ, van Sluijs EM. A systematic literature review with meta-analyses of within- and between-day differences in objectively measured physical activity in school-aged children. Sports Med. 2014;44(10):1427-38; doi:10.1007/s40279-014-0215-5.

[21] Verbestel V, Van Cauwenberghe E, De Coen V, Maes L, De Bourdeaudhuij I, Cardon G. Within- and between-day variability of objectively measured physical activity in preschoolers. Pediatr Exerc Sci. 2011;23(3):366-78.

[22] Tucker P. The physical activity levels of preschool-aged children: A systematic review. Early Childhood Res Q. 2008;23(4):547-58; doi:10.1016/j.ecresq.2008.08.005.

[23] Si Q, Cardinal BJ. The Health Impact of Air Pollution and Outdoor Physical Activity on Children and Adolescents in Mainland China. J Pediatr. 2017;180:251-5; doi:S0022-3476(16)31084-8.

[24] Martin R, Murtagh EM. Effect of Active Lessons on Physical Activity, Academic, and Health Outcomes: A Systematic Review. Res Q Exerc Sport. 2017;88(2):149-68; doi:10.1080/02701367.2017.1294244.

[25] Mindell JA, Sadeh A, Kwon R, Goh DY. Cross-cultural differences in the sleep of preschool children. Sleep Med. 2013;14(12):1283-9; doi:10.1016/j.sleep.2013.09.002.

[26] Faraut B, Andrillon T, Vecchierini MF, Leger D. Napping: A public health issue. From epidemiological to laboratory studies. Sleep Med Rev. 2017;35:85-100; doi:S1087-0792(16)30094-6.

[27] Komada Y, Asaoka S, Abe T, Matsuura N, Kagimura T, Shirakawa S, et al. Relationship between napping pattern and nocturnal sleep among Japanese nursery school children. Sleep Med. 2012;13(1):107-10; doi:10.1016/j.sleep.2011.10.017.

[28] Jia P, Li M, Xue H, Lu L, Xu F, Wang Y. School environment and policies, child eating behavior and overweight/obesity in urban China: the childhood obesity study in China megacities. Int J Obes (Lond). 2017;41(5):813-9; doi:10.1038/ijo.2017.2.

[29] Suen YN, Cerin E, Wua SL. Parental practices encouraging and discouraging physical activity in Hong Kong Chinese preschoolers. J Phys Act Health. 2015;12(3):361-9; doi:10.1123/jpah.203-0123.

[30] Oliver M, Schofield GM, Schluter PJ. Parent influences on preschoolers' objectively assessed physical activity. J Sci Med Sport. 2010;13(4):403-9; doi:10.1016/j.jsams.2009.05.008.

[31] Loprinzi PD, Trost SG. Parental influences on physical activity behavior in preschool children. Prev Med. 2010;50(3):129-33; doi:10.1016/j.ypmed.2009.11.010.

[32] Ling J, Robbins LB, Wen F, Zhang N. Lifestyle Interventions in Preschool Children: A Meta-analysis of Effectiveness. Am J Prev Med. 2017;53(1):102-12; doi:S0749-3797(17)30024-7.

[33] te Velde SJ, van Nassau F, Uijtdewilligen L, van Stralen MM, Cardon G, De Craemer M, et al. Energy balance-related behaviours associated with overweight and obesity in preschool children: a systematic review of prospective studies. Obes Rev. 2012;13 Suppl 1:56-74; doi:10.1111/j.1467-789X.2011.00960.x.

[34] Xue H, Tian G, Duan R, Quan L, Zhao L, Yang M, et al. Sedentary Behavior Is Independently Related to Fat Mass among Children and Adolescents in South China. Nutrients. 2016;8(11):667; doi:10.3390/nu8110667.

[35] Trost SG, Sirard JR, Dowda M, Pfeiffer KA, Pate RR. Physical activity in overweight and nonoverweight preschool children. Int J Obes Relat Metab Disord. 2003;27(7):834-9; doi:10.1038/sj.ijo.0802311.

[36] Hinkley T, Crawford D, Salmon J, Okely AD, Hesketh K. Preschool children and physical activity: a review of correlates. Am J Prev Med. 2008;34(5):435-41; doi:10.1016/j.amepre.2008.02.001.

[37] Adamo KB, Wasenius NS, Grattan KP, Harvey ALJ, Naylor PJ, Barrowman NJ, et al. Effects of a Preschool Intervention on Physical Activity and Body Composition. J Pediatr. 2017;188:42,49.e2; doi:S0022-3476(17)30778-3.

Appendix 5.1

Table S1-1. Comparison of PA patterns during the day between schooldays and weekends/holidays.

Segment	School days (n = 134)	Holidays (n = 107)	*p*-value
ST 8:00–11:00	37.4 [36.1; 38.7]	31.4 [29.9; 32.9]	0.000
ST 11:00–12:00	36.7 [35.1; 38.3]	30.1 [28.4; 31.7]	0.000
ST 12:00–14:00	48.5 [46.5; 50.5]	33.3 [31.4; 35.3]	0.000
ST 14:00–17:00	41.3 [40.0; 42.6]	34.2 [32.7; 35.7]	0.000
ST 17:00–18:00	25.9 [24.4; 27.4]	30.8 [29.1; 32.5]	0.000
ST 18:00–21:00	32.3 [31.0; 33.7]	31.9 [30.4; 33.4]	0.661
ST overall	478.9 [464.3; 493.4]	427.6 [411.3; 443.8]	0.000
LPA 8:00–11:00	20.0 [19.0; 21.1]	23.9 [22.7; 25.1]	0.000
LPA 11:00–12:00	19.7 [18.5; 20.9]	25.2 [23.9; 26.4]	0.000
LPA 12:00–14:00	9.9 [8.3; 11.6]	22.2 [20.6; 23.8]	0.000
LPA 14:00–17:00	16.6 [15.6; 17.6]	21.0 [19.8; 22.2]	0.000
LPA 17:00–18:00	25.8 [24.7; 26.9]	24.0 [22.7; 25.2]	0.032
LPA 18:00–21:00	22.2 [21.2; 23.2]	22.9 [21.8; 24.0]	0.379
LPA overall	238.7 [230.4; 247.1]	284.1 [274.8; 293.4]	0.000
MVPA 8:00–11:00	2.2 (1.2 – 3.4)	4.0 (2.1 – 6.0)	0.000
MVPA 11:00–12:00	3.0 (1.9 – 4.5)	3.5 (2.0 – 6.8)	0.032
MVPA 12:00–14:00	0.6 (0.1 – 2.5)	4.0 (2.4 – 5.8)	0.000
MVPA 14:00–17:00	1.8 (1.1 – 2.7)	3.8 (1.8 –7.2)	0.000
MVPA 17:00–18:00	7.4 (4.9 – 11.2)	4.1 (1.8 – 7.3)	0.000
MVPA 18:00–21:00	4.9 (3.2 – 7.2)	4.6 (2.8 – 6.9)	0.137
MVPA overall	47.4 [44.0; 50.8]	60.9 [57.1; 64.7]	0.000

Data for sedentary time (ST) overall, light physical activity (LPA) overall and moderate-to-vigorous physical activity (MVPA) overall are presented as the mean in minutes/day and with a 95% confidence interval. Data for each segment of ST and LPA per segment are presented as the mean in minutes/hour and with a 95% confidence interval. Data for MVPA per segment are presented as the median in minutes/hour, along with the 25th and 75th percentiles. P-values are based on linear mixed models and adjusted for sex, age, and season. Statistical testing for MVPA per segment was performed using Ln-transformed MVPA.

Table S1-2. Comparison of PA patterns during the day between boys and girls on school days.

Segment	Boys (n = 76)	Girls (n = 58)	*p*-value
ST 8:00–11:00	37.1[35.7; 38.6]	37.8[36.1; 39.5]	0.544
ST 11:00–12:00	36.8 [35.0; 38.6]	36.5 [34.4; 38.7]	0.828
ST 12:00–14:00	45.5 [43.2; 47.8]	46.3 [43.6; 49.0]	0.630
ST 14:00–17:00	41.0 [39.8; 42.1]	41.7 [40.3; 43.0]	0.433
ST 17:00–18:00	26.8 [25.2; 28.4]	24.7 [22.8; 26.5]	0.081
ST 18:00–21:00	32.4 [30.7; 34.1]	32.2 [30.3; 34.1]	0.864
ST overall	479.1 [459.6; 498.6]	478.5 [456.3; 500.8]	0.969
LPA 8:00–11:00	20.2 [19.0; 21.4]	19.8 [18.4; 21.2]	0.641
LPA 11:00–12:00	19.4 [18.1; 20.7]	20.2 [18.6; 21.8]	0.438
LPA 12:00–14:00	12.6 [10.6; 14.5]	11.9 [9.5; 14.2]	0.638
LPA 14:00–17:00	16.9 [15.9; 17.8]	16.2 [15.1; 17.3]	0.394
LPA 17:00–18:00	24.7 [23.6; 25.8]	27.2 [25.9; 28.5]	0.004
LPA 18:00–21:00	21.9 [20.7; 23.2]	22.6 [21.2; 24.0]	0.489
LPA overall	240.2 [230.5; 249.9]	236.9 [225.7; 248.0]	0.657
MVPA 8:00–11:00	2.4 (1.3 – 3.7)	2.0 (1.2 – 3.3)	0.350
MVPA 11:00–12:00	3.0 (2.1 – 4.6)	3.0 (1.5 – 4.5)	0.550
MVPA 12:00–14:00	1.5 (0.5 – 2.9)	0.9 (0.5 – 2.3)	0.357
MVPA 14:00–17:00	1.9 (1.0 – 2.9)	1.7 (1.2 – 2.5)	0.620
MVPA 17:00–18:00	8.1 (4.2 – 11.5)	7.3 (5.4 – 11.2)	0.750
MVPA 18:00–21:00	4.9 (3.0 – 7.7)	4.8 (3.6 – 6.6)	0.758
MVPA overall	49.7 [46.0; 53.4]	44.4 [40.2; 48.7]	0.101

Data for sedentary time (ST) overall, light physical activity (LPA) overall and moderate-to-vigorous physical activity (MVPA) overall are presented as the mean in minutes/day and with a 95% confidence interval. Data for each segment of ST and LPA per segment are presented as the mean in minutes/hour and with a 95% confidence interval. Data for MVPA per segment are presented as the median in minutes/hour, along with the 25th and 75th percentiles. P-values are based on t-test and Mann-Whitney U test.

Table S1-3. Comparison of PA patterns during the day between boys and girls on weekends/holidays.

Segment	Boys (n = 76)	Girls (n = 58)	*p*-value
ST 8:00–11:00	30.7 [28.3; 33.0]	32.3 [29.5; 35.1]	0.374
ST 11:00–12:00	29.5 [27.1; 31.9]	30.9 [28.0; 33.7]	0.478
ST 12:00–14:00	32.1 [29.7; 34.5]	35.0 [32.2; 37.8]	0.124
ST 14:00–17:00	34.1 [31.4; 36.9]	34.3 [31.2; 37.4]	0.945
ST 17:00–18:00	30.8 [28.1; 33.5]	30.9 [27.8; 34.0]	0.983
ST 18:00–21:00	30.0 [27.9; 32.2]	34.3 [31.8; 36.7]	0.011
ST overall	418.4 [396.7; 440.0]	439.7 [414.8; 464.7]	0.203
LPA 8:00–11:00	24.3 [22.5; 26.1]	23.4 [21.2; 25.5]	0.516
LPA 11:00–12:00	26.0 [24.1; 27.9]	24.0 [21.8; 26.3]	0.196
LPA 12:00–14:00	23.4 [21.4; 25.3]	20.5 [18.3; 22.8]	0.058
LPA 14:00–17:00	20.8 [18.7; 22.9]	21.3 [18.9; 23.7]	0.746
LPA 17:00–18:00	23.6 [21.6; 25.7]	24.4 [22.0; 26.7]	0.650
LPA 18:00–21:00	24.1 [22.4; 25.7]	21.4 [19.5; 23.3]	0.037
LPA overall	295.0 [281.2; 308.8]	269.7 [253.8; 285.6]	0.019
MVPA 8:00–11:00	4.3 (2.3 – 6.1)	3.9 (1.8 – 5.8)	0.416
MVPA 11:00–12:00	3.5 (2.0 – 6.2)	3.8 (1.8 – 8.0)	0.646
MVPA 12:00–14:00	4.1 (2.4 – 5.9)	3.9 (1.8 – 5.7)	0.643
MVPA 14:00–17:00	4.3 (1.9 – 7.5)	3.2 (1.7 – 6.7)	0.471
MVPA 17:00–18:00	5.0 (2.0 – 7.7)	3.3 (1.7 – 7.0)	0.411
MVPA 18:00–21:00	5.3 (3.3 – 8.3)	3.9 (2.2 – 5.3)	0.007
MVPA overall	65.3 [59.3; 71.2]	55.1 [48.3; 62.0]	0.020

Data for sedentary time (ST) overall, light physical activity (LPA) overall and moderate-to-vigorous physical activity (MVPA) overall are presented as the mean in minutes/day and with a 95% confidence interval. Data for each segment of ST and LPA per segment are presented as the mean in minutes/hour and with a 95% confidence interval. Data for MVPA per segment are presented as the median in minutes/hour, along with the 25th and 75th percentiles. P-values are based on t-test and Mann-Whitney U test.

Appendix 5.2

Table S2-1. Comparison of PA patterns during the day between active and less active children.

Segment	Active (n = 44)	Less active (n = 44)	*p*-value
ST 8:00–11:00	32.9 [31.2; 34.6]	40.1 [38.3; 41.8]	0.000
ST 11:00–12:00	32.8 [30.6; 35.0]	36.7 [34.5; 38.9]	0.015
ST 12:00–14:00	37.8 [34.7; 40.9]	44.9 [41.8; 48.0]	0.002
ST 14:00–17:00	35.7 [34.1; 37.3]	42.0 [40.3; 43.6]	0.000
ST 17:00–18:00	26.8 [24.8; 28.8]	28.5 [26.5; 30.5]	0.226
ST 18:00–21:00	28.0 [26.4; 29.6]	36.8 [35.2; 38.4]	0.000
ST overall	437.4 [413.3; 461.4]	495.8 [471.8; 519.9]	0.001
LPA 8:00–11:00	22.8 [21.4; 24.3]	18.1 [16.7; 19.6]	0.000
LPA 11:00–12:00	22.2 [20.5; 23.9]	20.3 [18.5; 22.0]	0.114
LPA 12:00–14:00	18.0 [15.4; 20.5]	13.3 [10.7; 15.9]	0.013
LPA 14:00–17:00	19.8 [18.4; 21.2]	16.3 [15.0; 17.7]	0.001
LPA 17:00–18:00	24.7 [23.2; 26.2]	25.6 [24.1; 27.2]	0.388
LPA 18:00–21:00	24.5 [23.2; 25.8]	19.8 [18.5; 21.1]	0.000
LPA overall	277.3 [265.5; 289.1]	219.9 [208.1; 231.7]	0.000
MVPA 8:00–11:00	4.6 (3.0 – 5.8)	1.7 (1.2 – 2.4)	0.000
MVPA 11:00–12:00	4.8 (3.4 – 6.3)	2.2 (1.5 – 3.2)	0.000
MVPA 12:00–14:00	3.7 (2.6 – 6.0)	0.9 (0.4 – 2.8)	0.000
MVPA 14:00–17:00	4.6 (2.7 – 5.5)	1.6 (1.1 – 2.2)	0.000
MVPA 17:00–18:00	7.8 (5.0 – 11.5)	5.4 (2.9 – 7.9)	0.002
MVPA 18:00–21:00	7.3 (5.6 – 9.5)	3.2 (2.2 – 4.3)	0.000
MVPA overall	69.8 [67.1; 72.5]	32.5 [29.8; 35.2]	0.000

Data for sedentary time (ST) overall, light physical activity (LPA) overall and moderate-to-vigorous physical activity (MVPA) overall are presented as the mean in minutes/day and with a 95% confidence interval. Data for each segment of ST and LPA per segment are presented as the mean in minutes/hour and with a 95% confidence interval. Data for MVPA per segment are presented as the median in minutes/hour, along with the 25th and 75th percentiles. P-values are based on linear mixed models and adjusted for sex, age, and season. Statistical testing for MVPA per segment was performed using Ln-transformed MVPA.

Table S2-2. Comparison of PA patterns during the day between active and less active children on school days.

Segment	Active (n = 44)	Less active (n = 44)	*p*-value
ST 8:00–11:00	34.7 [32.9; 36.5]	40.9 [39.1; 42.7]	0.000
ST 11:00–12:00	36.0 [33.4; 38.5]	39.2 [36.5; 41.8]	0.084
ST 12:00–14:00	42.9 [39.7; 46.1]	47.6 [44.3; 50.8]	0.044
ST 14:00–17:00	39.0 [37.4; 40.6]	43.2 [41.6; 44.8]	0.000
ST 17:00–18:00	25.2 [23.0; 27.5]	27.2 [25.0; 29.5]	0.217
ST 18:00–21:00	27.8 [25.9; 29.6]	36.0 [34.2; 37.9]	0.000
ST overall	453.0 [427.1; 478.9]	504.4 [478.5; 530.3]	0.006
LPA 8:00–11:00	21.6 [20.1; 23.2]	17.4 [15.9; 19.0]	0.000
LPA 11:00–12:00	19.8 [18.0; 21.7]	18.1 [16.2; 20.0]	0.196
LPA 12:00–14:00	14.1 [11.3; 16.9]	11.4 [8.6; 14.2]	0.173
LPA 14:00–17:00	18.1 [16.7; 19.4]	15.4 [14.1; 16.8]	0.007
LPA 17:00–18:00	25.1 [23.5; 26.6]	26.3 [24.7; 27.9]	0.261
LPA 18:00–21:00	24.7 [23.1; 26.2]	20.4 [18.9; 22.0]	0.000
LPA overall	263.8 [252.1; 275.5]	212.0 [200.3; 223.6]	0.000
MVPA 8:00–11:00	3.4 (2.3 – 5.1)	1.4 (0.9 – 2.2)	0.000
MVPA 11:00–12:00	4.1 (2.1 –5.5)	2.1 (1.3 – 3.0)	0.006
MVPA 12:00–14:00	2.1 (0.8 – 4.9)	0.6 (0.4 –1.5)	0.001
MVPA 14:00–17:00	2.5 (1.5 – 3.9)	1.2 (0.7 – 2.0)	0.000
MVPA 17:00–18:00	8.5 (5.3 – 14.2)	5.6 (3.5 – 10.0)	0.003
MVPA 18:00–21:00	7.1 (5.5 – 9.6)	3.4 (2.2 – 4.8)	0.000
MVPA overall	64.3 [61.2; 67.4]	31.4 [28.3; 34.5]	0.000

Data for sedentary time (ST) overall, light physical activity (LPA) overall and moderate-to-vigorous physical activity (MVPA) overall are presented as the mean in minutes/day and with a 95% confidence interval. Data for each segment of ST and LPA per segment are presented as the mean in minutes/hour and with a 95% confidence interval. Data for MVPA per segment are presented as the median in minutes/hour, along with the 25th and 75th percentiles. P-values are based on linear mixed models and adjusted for sex, age, and season. Statistical testing for MVPA per segment was performed using Ln-transformed MVPA.

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Table S2-3 Comparison of PA patterns during the day between active and less active children on weekends/holidays.

Segment	Active (n = 44)	Less active (n = 44)	*p*-value
ST 8:00–11:00	26.0 [23.4; 28.6]	35.3 [32.3; 38.4]	0.000
ST 11:00–12:00	28.6 [25.7; 31.6]	31.4 [27.9; 35.0]	0.228
ST 12:00–14:00	31.5 [28.6; 34.4]	33.9 [30.4; 37.4]	0.304
ST 14:00–17:00	30.5 [27.1; 33.9]	36.5 [32.6; 40.4]	0.024
ST 17:00–18:00	30.3 [27.0; 33.7]	32.6 [28.6; 36.5]	0.387
ST 18:00–21:00	28.0 [25.5; 30.5]	37.8 [34.9; 40.7]	0.000
ST overall	394.0 [367.9; 420.0]	451.2 [421.0; 481.4]	0.006
LPA 8:00–11:00	27.1 [25.1; 29.2]	21.9 [19.4; 24.3]	0.002
LPA 11:00–12:00	25.5 [23.2; 27.8]	24.8 [22.0; 27.6]	0.697
LPA 12:00–14:00	22.8 [20.5; 25.1]	22.7 [19.9; 25.4]	0.946
LPA 14:00–17:00	22.6 [19.9; 25.2]	20.3 [17.2; 23.4]	0.271
LPA 17:00–18:00	24.1 [21.6; 26.7]	23.6 [20.5; 26.6]	0.762
LPA 18:00–21:00	24.9 [22.9; 27.0]	19.3 [16.9; 21.7]	0.001
LPA overall	310.0 [293.9; 326.1]	258.0 [239.3; 276.6]	0.000
MVPA 8:00–11:00	5.6 (4.1 – 8.3)	1.9 (1.5 – 4.3)	0.000
MVPA 11:00–12:00	5.6 (3.4 – 8.0)	2.2 (1.6 – 3.5)	0.001
MVPA 12:00–14:00	1.5 (1.3 – 2.0)	1.0 (0.5 – 1.5)	0.006
MVPA 14:00–17:00	7.3 (3.6 – 9.2)	2.4 (1.3 – 4.1)	0.000
MVPA 17:00–18:00	5.0 (2.8 – 7.7)	2.3 (1.5 – 5.4)	0.017
MVPA 18:00–21:00	5.7 (4.3 – 9.2)	2.5 (1.6 – 3.9)	0.000
MVPA overall	81.9 [76.8; 87.0]	39.2 [33.3; 45.1]	0.000

Data for sedentary time (ST) overall, light physical activity (LPA) overall and moderate-to-vigorous physical activity (MVPA) overall are presented as the mean in minutes/day and with a 95% confidence interval. Data for each segment of ST and LPA per segment are presented as the mean in minutes/hour and with a 95% confidence interval. Data for MVPA per segment are presented as the median in minutes/hour, along with the 25th and 75th percentiles. P-values are based on linear mixed models and adjusted for sex, age, and season. Statistical testing for MVPA per segment was performed using Ln-transformed MVPA.

Appendix 5.3

Table S3-1. Comparison of PA patterns during the day between non-overweight children and overweight children.

Segment	Non-overweight (n = 118)	Overweight (n = 16)	*p*-value
ST 8:00–11:00	35.9 [34.8; 37.0]	39.5 [36.5; 42.5]	0.029
ST 11:00–12:00	33.7 [32.5; 34.9]	38.5 [35.2; 41.8]	0.009
ST 12:00–14:00	41.6 [39.7; 43.6]	42.8 [37.6; 48.0]	0.680
ST 14:00–17:00	39.5 [38.4; 40.5]	38.7 [35.8; 41.7]	0.654
ST 17:00–18:00	26.5 [25.4; 27.7]	31.4 [28.3; 34.6]	0.005
ST 18:00–21:00	32.5 [31.3; 33.8]	34.0 [30.7; 37.2]	0.427
ST overall	463.3 [448.9; 477.8]	508.0 [468.6; 547.3]	0.037
LPA 8:00–11:00	21.1 [20.2; 22.0]	17.9 [15.4; 20.4]	0.016
LPA 11:00–12:00	22.2 [21.3; 23.2]	18.3 [15.7; 20.9]	0.006
LPA 12:00–14:00	15.4 [13.8; 17.1]	14.6 [10.3; 18.9]	0.726
LPA 14:00–17:00	17.7 [16.8; 18.5]	18.0 [15.7; 20.3]	0.760
LPA 17:00–18:00	25.6 [24.8; 26.5]	22.9 [20.5; 25.3]	0.034
LPA 18:00–21:00	22.2 [21.3; 23.1]	20.2 [17.8; 22.6]	0.129
LPA overall	251.5 [243.5; 259.5]	235.5 [213.7; 257.2]	0.172
MVPA 8:00–11:00	2.6 (1.7 – 4.2)	2.2 (1.4 – 3.7)	0.498
MVPA 11:00–12:00	3.6 (2.3 – 5.3)	3.4 (2.0 – 4.2)	0.329
MVPA 12:00–14:00	2.3 (0.8 – 3.9)	2.6 (0.9 – 3.0)	0.792
MVPA 14:00–17:00	2.4 (1.6 – 3.8)	2.2 (1.7 – 5.1)	0.511
MVPA 17:00–18:00	7.4 (4.9 – 10.4)	5.0 (3.9 – 7.6)	0.039
MVPA 18:00–21:00	4.8 (3.3 – 6.8)	4.8 (4.2 – 6.3)	0.411
MVPA overall	50.5 [47.4; 53.6]	50.4 [41.9; 58.9]	0.985

Data for sedentary time (ST) overall, light physical activity (LPA) overall and moderate-to-vigorous physical activity (MVPA) overall are presented as the mean in minutes/day and with a 95% confidence interval. Data for each segment of ST and LPA per segment are presented as the mean in minutes/hour and with a 95% confidence interval. Data for MVPA per segment are presented as the median in minutes/hour, along with the 25th and 75th percentiles. P-values are based on linear mixed models and adjusted for sex, age, and season. Statistical testing for MVPA per segment was performed using Ln-transformed MVPA.

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Table S3-2. Comparison of PA patterns during the day between non-overweight children and overweight children on school days.

Segment	Non-overweight (n = 118)	Overweight (n = 16)	*p*-value
ST 8:00–11:00	37.1 [35.9; 38.2]	40.1 [37.0; 43.2]	0.074
ST 11:00–12:00	36.3 [34.8; 37.8]	39.1 [35.5; 42.8]	0.164
ST 12:00–14:00	46.1 [44.2; 48.0]	44.1 [39.6; 48.7]	0.421
ST 14:00–17:00	41.6 [40.6; 42.5]	39.1 [36.6; 41.6]	0.067
ST 17:00–18:00	25.3 [24.1; 26.6]	30.0 [26.5; 33.4]	0.014
ST 18:00–21:00	32.1 [30.7; 33.4]	34.2 [30.5; 37.8]	0.292
ST overall	473.2 [457.9; 488.6]	520.3 [478.6; 562.1]	0.038
LPA 8:00–11:00	20.4 [19.4; 21.3]	17.5 [14.9; 20.1]	0.042
LPA 11:00–12:00	20.0 [18.9; 21.1]	17.8 [15.1; 20.5]	0.132
LPA 12:00–14:00	12.1 [10.4; 13.7]	13.5 [9.6; 17.4]	0.507
LPA 14:00–17:00	16.4 [15.6; 17.1]	18.3 [16.2; 20.3]	0.097
LPA 17:00–18:00	26.0 [25.1; 27.0]	23.7 [21.2; 26.2]	0.079
LPA 18:00–21:00	22.6 [21.6; 23.6]	19.6 [16.9; 22.3]	0.045
LPA overall	240.3 [232.5; 248.1]	227.2 [206.1; 248.3]	0.253
MVPA 8:00–11:00	2.3 (1.3 – 3.4)	2.0 (1.0 – 3.3)	0.584
MVPA 11:00–12:00	3.1 (1.9 – 4.5)	2.6 (1.9 – 4.4)	0.816
MVPA 12:00–14:00	1.0 (0.5 – 2.3)	2.3 (1.0 – 3.5)	0.080
MVPA 14:00–17:00	1.7 (1.1 – 2.6)	2.2 (1.5 – 4.2)	0.074
MVPA 17:00–18:00	8.1 (5.0 – 11.6)	5.3 (4.5 – 8.3)	0.109
MVPA 18:00–21:00	4.9 (3.1 – 7.3)	4.9 (4.2 – 6.8)	0.483
MVPA overall	47.2 [44.2; 50.2]	49.0 [40.9; 57.1]	0.678

Data for sedentary time (ST) overall, light physical activity (LPA) overall and moderate-to-vigorous physical activity (MVPA) overall are presented as the mean in minutes/day and with a 95% confidence interval. Data for each segment of ST and LPA per segment are presented as the mean in minutes/hour and with a 95% confidence interval. Data for MVPA per segment are presented as the median in minutes/hour, along with the 25th and 75th percentiles. P-values are based on linear mixed models and adjusted for sex, age, and season. Statistical testing for MVPA per segment was performed using Ln-transformed MVPA.

Table S3-3. Comparison of PA patterns during the day between non-overweight children and overweight children on weekends/holidays.

Segment	Non-overweight (n = 92)	Overweight (n = 15)	*p*-value
ST 8:00–11:00	30.4 [28.5; 32.3]	36.7 [32.2; 41.2]	0.012
ST 11:00–12:00	29.0 [27.1; 31.0]	35.9 [31.2; 40.6]	0.009
ST 12:00–14:00	33.2 [31.1; 35.2]	34.4 [29.5; 39.3]	0.645
ST 14:00–17:00	34.1 [31.9; 36.3]	34.9 [29.5; 40.2]	0.795
ST 17:00–18:00	30.3 [28.1; 32.5]	33.9 [28.6; 39.3]	0.219
ST 18:00–21:00	31.7 [29.9; 33.5]	32.9 [28.5; 37.4]	0.609
ST overall	420.9 [403.5; 438.4]	468.1 [424.9; 511.3]	0.047
LPA 8:00–11:00	24.7 [23.2; 26.1]	19.5 [16.1; 23.0]	0.008
LPA 11:00–12:00	26.1 [24.5; 27.6]	20.1 [16.4; 23.8]	0.004
LPA 12:00–14:00	22.2 [20.6; 23.8]	21.9 [17.9; 25.8]	0.866
LPA 14:00–17:00	21.2 [19.5; 22.9]	19.9 [15.8; 24.0]	0.568
LPA 17:00–18:00	24.3 [22.6; 25.9]	22.0 [18.0; 26.0]	0.289
LPA 18:00–21:00	23.0 [21.7; 24.4]	22.1 [18.7; 25.4]	0.592
LPA overall	286.7 [275.2; 298.2]	268.3 [239.9; 296.7]	0.237
MVPA 8:00–11:00	4.0 (2.1 – 6.2)	3.2 (1.3 – 4.8)	0.114
MVPA 11:00–12:00	3.5 (2.0 – 6.8)	2.6 (1.6 – 7.3)	0.241
MVPA 12:00–14:00	4.1 (2.5 – 5.9)	2.8 (2.1 – 4.3)	0.721
MVPA 14:00–17:00	3.7 (1.8 – 6.8)	4.2 (1.5 – 9.3)	0.630
MVPA 17:00–18:00	4.1 (1.8 – 7.4)	3.8 (1.3 – 6.3)	0.581
MVPA 18:00–21:00	4.5 (2.8 – 7.2)	4.6 (2.8 – 6.8)	0.900
MVPA overall	61.3 [56.4; 66.3]	58.2 [46.0; 70.4]	0.640

Data for sedentary time (ST) overall， light physical activity (LPA) overall and moderate-to-vigorous physical activity (MVPA) overall are presented as the mean in minutes/day and with a 95% confidence interval. Data for each segment of ST and LPA per segment are presented as the mean in minutes/hour and with a 95% confidence interval. Data for MVPA per segment are presented as the median in minutes/hour, along with the 25th and 75th percentiles. P-values are based on linear mixed models and adjusted for sex, age, and season. Statistical testing for MVPA per segment was performed using Ln-transformed MVPA.

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Chapter 6

Physical activity around the clock: objectively measured activity patterns in young children of the GECKO Drenthe cohort

Rikstje Wiersma *, Congchao Lu *,

Esther Hartman, Eva Corpeleijn

(These authors contributed equally to this work.)*

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ABSTRACT

Background

Given the widespread problem of physical inactivity, and the continued growth in prevalence of childhood and adolescent obesity, promotion of regular physical activity (PA) among young people has become a public priority. A greater understanding of children's PA patterns throughout the day is needed to effectively encourage children to be more physically active. Hence this study looking at the distribution of PA in young children throughout the day, and its relevance to overweight.

Methods

Accelerometers (ActiGraph GT3X, weartime > 600 min/day, ≥ 3 days) were used to measure the PA of 958 children (aged 5.7 ± 0.8 years, 52% boys) enrolled in the GECKO Drenthe cohort. Levels of sedentary time (ST), light PA (LPA), and moderate-to-vigorous PA (MVPA) were recorded throughout the day and analysed in segments (07:00–09:00, 09:00–12:00, 12:00–15:00, 15:00–18:00, 18:00–21:00). Body mass index was measured by Preventive Child Healthcare nurses and Cole's (2012) definition of overweight was used. General linear mixed models, adjusted for age, sex, and season, were used to analyse patterns of PA and ST throughout the day.

Results

Children were most sedentary in the early morning (07:00–09:00) and evening (18:00–21:00), and exhibiting the most time spent engaged in LPA and MVPA in the afternoon (12:00–15:00) and late afternoon (15:00–18:00). The greatest inter-individual variation in ST, LPA, and MVPA among the children occurred in the late afternoon and evening (approximately 40, 30, and 15 min difference per time segment between 25th and 75th percentile, respectively). The most active children (highest quartile of MVPA) were found to be more active and less sedentary throughout the entire day than the least active children (lowest quartile of MVPA). Furthermore, children with overweight were no less active than children without overweight.

Conclusion

At this young age, the relevance of different PA patterns to childhood overweight was minimal. Children were most active in the afternoon and late afternoon. To encourage PA in general, ST can be reduced and PA increased in the early morning and evening. Targeted PA interventions to specifically stimulate the least active children could take place in the late afternoon or evening.

Keywords: Sedentary time; moderate-to-vigorous physical activity; accelerometry; preschool children; obesity

BACKGROUND

Physical activity (PA) is an important factor in human health. Individuals who are physically active have a lower risk of developing diseases [1,2]. Furthermore, PA is considered to be a key component in the prevention and management of overweight and obesity [3-5].

Several different organizations have provided guidelines for PA in children and young people.[6-11] It is recommended that preschool children (< 5 years old) engage in at least 180 min of activity each day. At least 60 min of this PA should be of moderate-to-vigorous intensity. Furthermore, children should not remain seated or sedentary for periods of more than 1 h at a time [6,7]. It is recommended that primary school children and young people (in the 5–17 age group) should engage in at least 60 min of moderate-to-vigorous physical activity (MVPA) per day. They should also minimize the time spent in extended periods of sedentary activity.[8-11] Nevertheless, many children are not compliant with these PA guidelines. As a result, they may be at greater risk of developing overweight, obesity or other health problems. Since the development of overweight starts at a young age, it is useful to try and support higher levels of PA early in life [12].

Most studies into children's PA behaviours are performed in children of school age. However, a large study using data from the International Children's Accelerometry Database (ICAD) showed that time spent in PA during childhood slightly increases from 2 to 5 years and then decreases progressively over time until the age of 18 [13]. An opposite pattern for sedentary time (ST) was observed [13]. Accordingly, opportunities to boost PA levels of children around the age of 5 should be examined. Furthermore, children's PA behaviours are often analysed on the basis of an average daily PA. The use of accelerometer data makes it possible to analyse PA patterns in greater detail. A recent study revealed differences in the distribution of MVPA levels during the day, even between children with the same average PA levels [14]. In Europe, there have been no previous studies of PA patterns in young children, and of their relevance to health outcomes such as overweight.

The PA behaviour of older children throughout the day has been more extensively studied. One accelerometry-based study in school-age children (7–11 year old) found that children's PA behaviour was most consistent in the school environment (07:00–15:00), whereas the greatest variation in PA levels occurred in the early evening (17:00–19:00) [15]. One study into highly active and low active children (aged 10–11) found that, in four of the five time segments, the former achieved significantly more moderate PA and vigorous PA than the latter [16].

The aim of our study was to identify segments of the day with potential for targeted PA interventions in young children. We explored patterns of different intensities of objectively measured PA and ST throughout the day to examine when young children were more sedentary and when they were more active. Secondly, since PA is an important factor in the prevention of overweight and obesity, we examined the association between the PA distribution throughout the day and childhood overweight.

METHODS

Study design

The GECKO (Groningen Expert Center for Kids with Obesity) Drenthe study is a population-based birth cohort focusing on early risk factors for overweight and obesity. Details of the GECKO Drenthe cohort are described elsewhere [17]. In 2006, almost 3000 pregnant women were recruited. The children involved are currently being monitored and have been since the last trimester of their mother's pregnancy. Written informed parental consent was obtained for participation in the study, also for any minors to take part in the study. The study was approved by the Medical Ethics Committee of the University Medical Center Groningen (UMCG), in accordance with the 1975 Declaration of Helsinki (as revised in 1983). The study has been registered at www.birthcohorts.net.

Measurements and data analysis

Physical activity

PA data was collected from May 2011 to October 2013. PA was measured using ActiGraph GT3X accelerometers (ActiGraph, Pensacola, FL). These devices have been shown to be appropriate and reliable for the measurement of PA volume and intensity in young children [18,19]. The children wore an ActiGraph (held in place by an elastic belt) on their right hip throughout their waking hours on four consecutive days, except while bathing or swimming. Data was collected at a frequency of 30 Hz and was analysed at 15-s epoch recording. Non-wearing time was defined as periods of at least 90 min with zero counts [20]. Those days on which the weartime amounted to less than 600 min were excluded from the analyses. Subsequently, any children who had fewer than three valid wear days were excluded from the analyses. When sent by post, some accelerometers generated a valid wearing day (> 10 h/day). These 'postage days' were identified by low-light activity (≤ 100 min/day) and deleted. Outcome measures were assessed using the following cut-off points: ST (≤ 819 cpm), light physical activity (LPA) (820–3907 cpm), and MVPA (≥ 3908 cpm) [21]. These cut-off points were the best fit for our age group.

Five time segments were used for the purpose of studying the distribution of MVPA and ST throughout the day. These time segments were in accordance with Dutch school schedules. They were defined as 'early morning' (07:00–09:00), 'morning' (09:00–12:00), 'afternoon' (12:00–15:00), 'late afternoon' (15:00–18:00) and 'evening' (18:00–21:00). All of the children in this study were attending kindergarten (referred to as 'Group 1' or 'Group 2' in the Dutch educational system). Here, children are given structured educational instructions – in the context of play – and they have ample opportunity to move around freely. Although the age range for preschoolers in most studies is between 2 and 5 years, we have defined the children in this study as 'preschoolers' because their behaviour is likely to be comparable with preschoolers. The activity levels per segment were expressed as the average number of minutes of activity per hour. Any incomplete hours were excluded. The cumulative activity levels were calculated as minutes per day (06:00-23:00).

To study PA patterns in general, we pooled the results for all the children in the study. In addition, to specifically stimulate the least active children, we examined differences between the most active and the least active children. Based on children's daily MVPA, the children were grouped into sex-specific quartiles, ranging from least active (Q1) to most active (Q4). Alternatively, children could be classified as 'active' if they achieved the MVPA exercise standard (≥ 60 min of MVPA per day) on more than 50% of their valid days [16,22]. If the average MVPA is used instead of this method of only counting days when the children were compliant with the standard, only 9.6% of the children would be reclassified. In view of this small difference, plus the need to maximise distinctiveness and variations in the number of valid days from one child to another, the decision was taken to use quartiles of average daily MVPA.

Weight status and additional data collection

Height and weight were measured by trained Preventive Child Healthcare nurses, according to a standardized protocol. Children were weighed while wearing light clothing, on an electronic scale with a digital read-out. Their weight was recorded to the nearest 0.1 kg. Their height was measured using a stadiometer and recorded to the nearest 0.1 cm. Each child's body mass index (BMI, kg/m^2) was converted into age- and sex-specific standardized BMI Z-scores. This involved the use of Dutch growth analysis software (Growth Analyzer 3.5; Dutch Growth Research Foundation, Rotterdam, The Netherlands), using 1997 population data as the reference [23]. Individuals were classified either as not affected by overweight (underweight and normal weight) or affected by overweight (overweight and obesity), using age- and sex-specific cut-off points for children, based on Cole et al. 2012 [24]. Questionnaires completed during pregnancy were used to obtain details of the parents' educational level (low/middle education or higher vocational education) and of the total household income. With regard to the seasons, winter was defined as December – February, spring as March – May, summer as June – August, and autumn as September – November.

Statistical analysis

The statistical analysis was performed using IBM SPSS Statistics (version 23). All MVPA variables were log-transformed, as they were not normally distributed. Independent t-tests and χ^2-tests were used to check for differences between children with and without valid PA data. Repeated measures ANOVA tests were performed – with the segments as within-subjects variables – to justify the selected time segments and to determine whether it would be useful to include an extra segment around midday (12:00–13:00). General linear mixed models were used, for each segment and for the whole day (cumulative), to examine any differences in PA and ST patterns between active and less active children and between children with and without overweight. In each of the general linear mixed models used, the participant number was entered as subject and activity group (most active vs. least active) or weight status (overweight, yes/no) was entered as fixed factor. To control for possible differences due to sex, age or season of PA measurement, we entered sex, age and season as fixed factors as well. With regard to random factors, the intercept was included and the participant number was entered. In addition, the whole-day analyses were adjusted for accelerometer weartime. The significance level was set at $p < 0.05$.

RESULTS

In total, the parents of 2276 children were asked to participate by allowing their child's PA to be measured. As a result, the PA of 1474 children was measured using ActiGraph accelerometers (response rate = 64.8%; for flow chart see Figure 1). The final sample consisted of 958 children with valid accelerometer data. The majority of these children were between 4 and 6 years of age (5^{th} – 95^{th} age percentile: age 4.4–7.0). For 847 of these children, weight status data was also available.

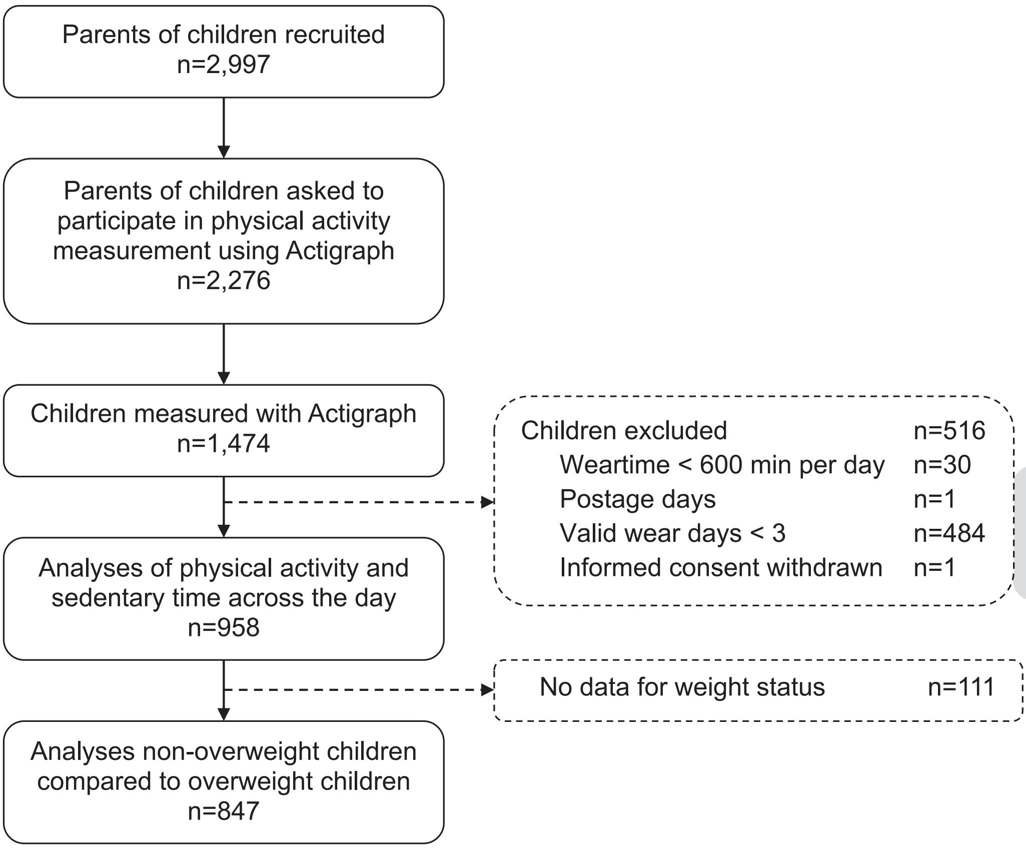

Figure 1. Flowchart showing participant recruitment in GECKO Drenthe cohort.

The characteristics of these children and their parents are shown in Table 1. Approximately 46% of the children met the PA guideline of at least 60 min per day in MVPA. There were no significant differences between children with and without valid PA data, in terms of their descriptive characteristics, except for the educational level of the father. The fathers of children with valid PA data tended to be more highly educated (41.8%) than the fathers of children without valid PA data (31.6%) ($p < 0.001$). The descriptive characteristics of children in the most active and least active groups and those of children with and without overweight are shown in Appendix A. The least active children (Q1) were significantly younger than the most active children (Q4) (aged 5.5 and 5.8, respectively). In addition, the least active children (Q1) wore their device for a shorter period than the most active children (654 and 663 min/day, respectively). With regard to the children with and without overweight, the fathers of children without overweight tended to be more highly educated than the fathers of children affected by overweight.

Distribution of physical activity and sedentary time throughout the day

Firstly, the validity of the selected time segments was assessed. For ST, LPA, and MVPA, main effects were found between segments throughout the day (all $p < 0.001$). With certain exceptions, the contrasts showed significant differences between all segments ($p < 0.001$). The exceptions were between 12:00–15:00 and 15:00–18:00 for ST ($p = 0.504$), between 09:00–12:00 and 15:00–18:00 for LPA ($p = 0.196$), and between 09:00–12:00 and 18:00–21:00 for MVPA ($p = 0.106$). This means that most segments differed significantly from each other, and that they can be regarded as separate time slots throughout the day. The option of an extra segment around midday (12:00–13:00) was explored and discarded, as it was not considered to be useful. In the case of ST and MVPA, no significant differences were found between the midday period and the 13:00–15:00 segment. In the case of LPA, there was only a small difference.

Table 1. Child characteristics.

Child characteristics	N	mean ± SD or %
Sex (boys)	500	52.2%
Age PA measurement (years)	958	5.7 ± 0.8
Age BMI measurement (years)	847	5.8 ± 0.3
BMI (kg/m^2)	847	15.9 ± 1.3
BMI Z-score	847	0.20 ± 0.78
Weight status		
Underweight	54	6.4%
Normal weight	722	85.2%
Overweight	61	7.2%
Obese	10	1.2%
Ethnicity (Dutch)	865	90.6%
Education level (low/middle)		
Mother	432	51.6%
Father	428	54.5%
Household income		
< €1150	21	2.3%
€1151–€3050	508	55.3%
€3051–€3500	163	17.8%
> €3501	124	13.5%
Unknown / not reported	102	11.1%
Weartime (min/day)	958	655.9 ± 35.3

Abbreviations: PA, physical activity; BMI, body mass index.

Sedentary time

Table 2 indicates the pattern of PA throughout the day. It gives details of the average time spent sedentary, in LPA and in MVPA for all segments throughout the day. Children are most sedentary during the early morning (07:00–09:00) and evening (18:00–21:00). Figure 2 shows the median, the 25th – 75th percentile, and the minimum and maximum values for ST, LPA, and MVPA per segment, throughout the day. This highlights the changes in PA levels throughout the day, as well as differences between the children. In terms of ST, it shows that the greatest differences between children occur in the evening (18:00–21:00). In this time segment, 25% of all children spent up to 44 min per hour in sedentary activity. However, the lowest 25% were only sedentary for 25 min per hour. Over the entire 3 h of this time segment, the most sedentary 25% of children exhibited ST for about 130 min, while the corresponding value for the least sedentary 25% of children was 75 min.

Table 2. Time spent sedentary, in light physical activity, and in moderate-to-vigorous physical activity throughout the day.

Segment	N	Sedentary time	Light PA	Moderate-to-vigorous PA
7:00–09:00	928	36.7 ± 6.3 (61.2%)	20.6 ± 5.3 (34.4%)	2.7 ± 2.0 (4.4%)
9:00–12:00	958	32.2 ± 6.2 (53.6%)	22.9 ± 4.8 (38.2%)	4.9 ± 2.5 (8.1%)
12:00–15:00	958	30.2 ± 5.5 (50.3%)	24.0 ± 4.1 (40.1%)	5.7 ± 2.7 (9.6%)
15:00–18:00	958	30.1 ± 6.3 (50.2%)	23.1 ± 4.4 (38.6%)	6.7 ± 3.2 (11.2%)
18:00–21:00	903	34.4 ± 9.6 (57.3%)	19.7 ± 6.5 (32.9%)	5.9 ± 4.9 (9.9%)
Cumulative	958	346.2 ± 55.0 (52.8%)	248.9 ± 37.3 (37.9%)	60.8 ± 24.0 (9.3%)

Data for sedentary time, light physical activity, and moderate-to-vigorous physical activity are presented as mean ± SD (%) in average minutes per hour (time segments) or per day (cumulative).

Physical activity

The PA pattern in Table 2 shows that children spent most time engaged in LPA and MVPA in the afternoon (12:00–15:00) and late afternoon (15:00–18:00), respectively. In addition, Figure 2 shows that the greatest differences between children, in terms of LPA and MVPA, occur in the late afternoon and evening (18:00–21:00). Take the average MVPA level in the late afternoon, for instance. This derives from the fact that 25% of the entire group of children spent a total of approximately 30 minutes in MVPA in the period from 15:00 to 18:00, while the least active 25% of the children spent less than 10 min in MVPA during this time segment.

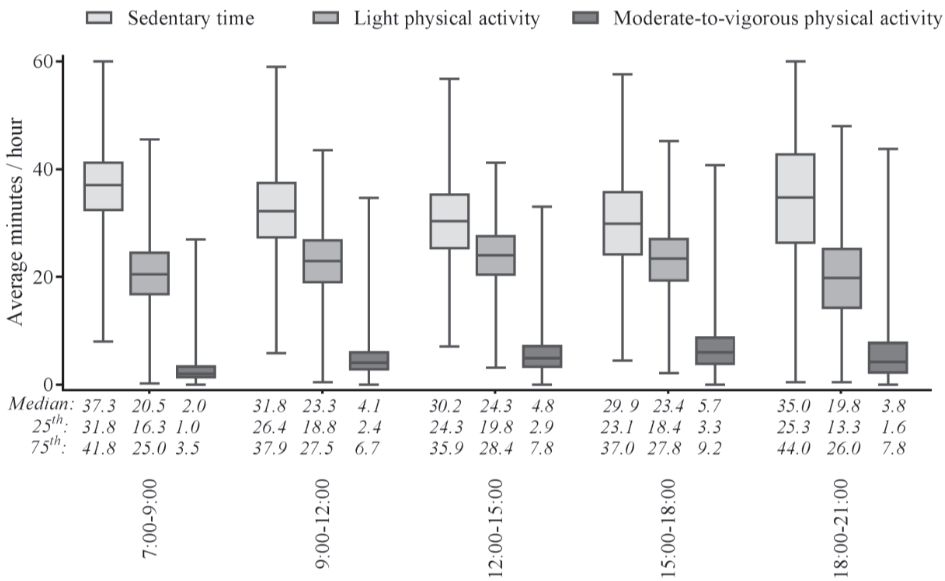

Figure 2. The flow of PA levels throughout the day.

The flow of PA levels throughout the day. Sedentary time (ST), light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA) per time segment with median, 25th – 75th percentile and minimum and maximum. For clarification, the exact numbers are given below the x-axis. Almost all time segments showed significant differences. The exceptions were for ST between 12:00–15:00 and 15:00–18:00, for LPA between 09:00–12:00 and 15:00–18:00 and for MVPA between 09:00–12:00 and 18:00–21:00.

Further looking into the differences between the most active children and the least active children, the former were more active and less sedentary than the latter throughout the entire day. Significant differences were found between the activity groups for ST, LPA, and MVPA in every time segment of the day. With regard to the average time spent in ST, LPA, and MVPA, the largest differences between the most active and least active children occurred in the late afternoon and the evening (Table 3; Figure 3).

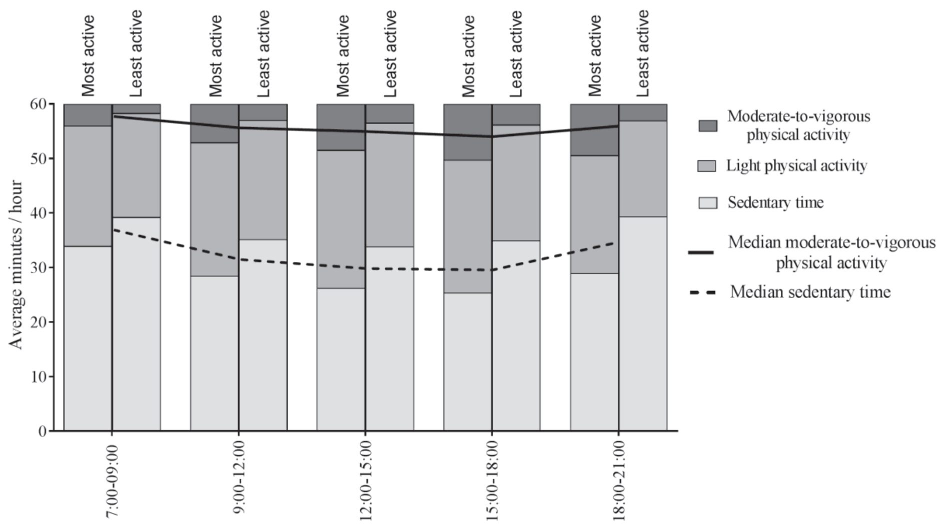

Figure 3. Daily physical activity patterns in the most active and least active children.
Daily physical activity patterns in the most active and least active children. Sedentary time, light physical activity and moderate-to-vigorous physical activity per time segment for the most active and least active children. For comparison, the lines represent the median sedentary time and moderate-to-vigorous physical activity of the entire group of children. All time segments throughout the day showed significant differences between the most active and least active children, adjusted for sex, age at physical activity measurement and season.

Table 3. Active children are more active throughout the day.

Segment	Most active (Q4) (mean minutes / hour)	Least active (Q1) (mean minutes / hour)	Estimate [95% CI] (minutes / hour)
Sedentary time (ST)			
ST 7:00–09:00	33.9 [33.1; 34.7]	39.4 [38.7; 40.2]	5.6 [4.5; 6.7]
ST 9:00–12:00	28.2 [27.5; 28.8]	35.5 [34.8; 36.2]	7.3 [6.4; 8.3]
ST 12:00–15:00	25.9 [25.3; 26.5]	34.1 [33.5; 34.8]	8.2 [7.4; 9.1]
ST 15:00–18:00	25.5 [24.9; 26.2]	35.1 [34.4; 35.7]	9.5 [8.6; 10.4]
ST 18:00–21:00	29.7 [28.6; 30.8]	39.7 [38.6; 40.8]	10.0 [8.5; 11.5]
Cumulative ST (per day) [a]	301.8 [297.1; 306.4]	393.0 [388.5; 397.6]	91.3 [84.7; 97.9]
Light physical activity (LPA)			
LPA 7:00–09:00	22.2 [21.6; 22.9]	18.9 [18.3; 19.6]	−3.3 [−4.3; −2.4]
LPA 9:00–12:00	24.8 [24.2; 25.3]	21.6 [21.0; 22.1]	−3.2 [−4.0; −2.4]
LPA 12:00–15:00	25.6 [25.1; 26.1]	22.5 [22.0; 23.0]	−3.1 [−3.8; −2.4]
LPA 15:00–18:00	24.3 [23.8; 24.9]	21.2 [20.7; 21.7]	−3.2 [−3.9; −2.4]
LPA 18:00–21:00	21.3 [20.5; 22.1]	17.3 [16.5; 18.1]	−4.0 [−5.2; −2.9]
Cumulative LPA (per day) [a]	266.5 [262.3; 270.7]	230.9 [226.8; 235.0]	−35.6 [−41.5; −29.7]
Moderate-to-vigorous physical activity (MVPA) [b]			
MVPA 7:00–09:00	3.4 (2.0 – 4.9)	1.4 (0.9 – 2.3)	−0.8 [−0.9; −0.7]
MVPA 9:00–12:00	6.8 (4.8 – 8.8)	2.9 (2.2 – 3.7)	−0.9 [−1.0; −0.8]
MVPA 12:00–15:00	8.0 (6.7 – 10.1)	3.3 (2.5 – 4.3)	−1.0 [−1.1; −0.9]
MVPA 15:00–18:00	9.5 (7.9 – 12.0)	3.6 (2.8 – 4.6)	−1.1 [−1.2; −1.0]
MVPA 18:00–21:00	8.1 (5.1 – 12.0)	2.3 (1.4 – 3.8)	−1.1 [−1.2; −0.9]
Cumulative MVPA (per day) [a]	89.8 (79.4 – 100.9)	35.2 (29.0 – 41.8)	−1.0 [−1.0; −0.9]

Descriptives of ST and LPA are presented as adjusted means and 95% confidence intervals. Descriptives of MVPA are presented as medians with 25th and 75th percentiles. Analyses were performed using linear mixed models, adjusted for sex, age at PA measurement and season. All p-values were < 0.001.

[a] *Analyses additionally adjusted for accelerometer weartime.*

[b] *Statistical testing for MVPA was performed using log-transformed MVPA.*

6

The relevance of PA distribution throughout the day to overweight

In the evening, marginal differences between children with and without overweight were found with regard to ST and LPA, but not in terms of MVPA. Children affected by overweight exhibited less ST and more LPA in the evening (18:00–21:00) than children without overweight (Table 4; Figure 4).

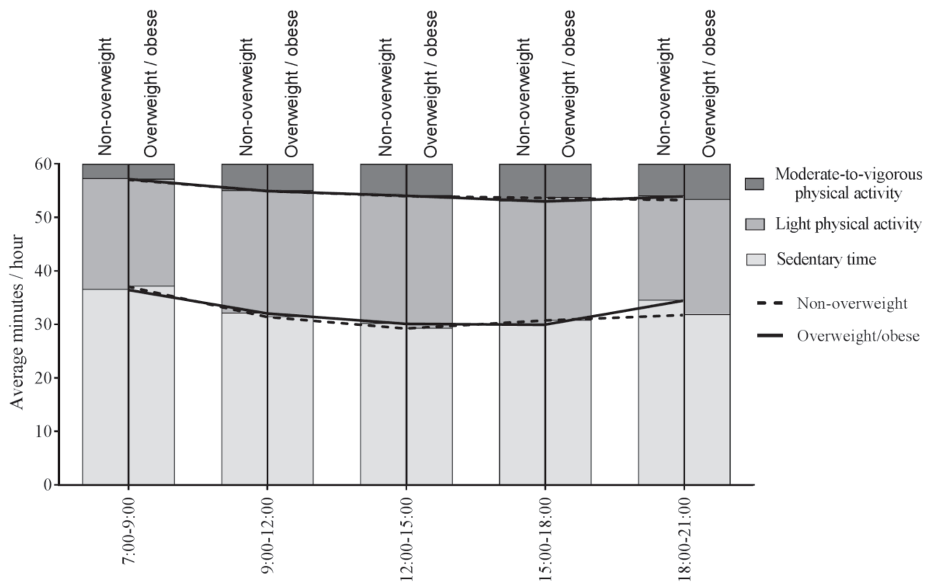

Figure 4. Daily physical activity patterns in non-overweight and overweight children.

Daily physical activity patterns in children with and without overweight. Sedentary time, light physical activity and moderate-to-vigorous physical activity per time segment for children with and without overweight, with means per behaviour and per group. There were significant differences between children with (n = 71) and without overweight (n = 776) in terms of sedentary time and light physical activity, but only in the evening (18:00–21:00). All analyses were adjusted for sex, age at physical activity and body mass index measurement and season.

Table 4. PA patterns throughout the day for children with and without overweight.

Segment	Overweight (mean minutes / hour)	Non-overweight (mean minutes / hour)	Estimate [95%CI] (minutes/hour)
Sedentary time (ST)			
ST 7:00–09:00	37.1 [35.6; 38.5]	36.6 [36.2; 37.1]	0.4 [−1.1; 2.0]
ST 9:00–12:00	31.6 [30.3; 32.9]	32.2 [31.8; 32.6]	−0.6 [−2.0; 0.7]
ST 12:00–15:00	29.4 [28.2; 30.7]	30.3 [29.9; 30.7]	−0.9 [−2.2; 0.4]
ST 15:00–18:00	31.2 [29.7; 32.6]	30.4 [29.9; 30.8]	0.8 [−0.7; 2.3]
ST 18:00–21:00	32.6 [30.5; 34.7]	35.1 [34.4; 35.8]	**−2.5 [−4.7; −0.4]**
Cumulative ST (per day) [a]	343.8 [332.8; 354.7]	348.6 [345.2; 351.9]	−4.8 [−16.2; 6.6]
Light physical activity (LPA)			
LPA 7:00–09:00	20.1 [18.8; 21.3]	20.7 [20.4; 21.1]	−0.7 [−1.9; 0.6]
LPA 9:00–12:00	23.5 [22.5; 24.5]	22.9 [22.6; 23.2]	0.6 [−0.4; 1.6]
LPA 12:00–15:00	24.7 [23.8; 25.6]	24.0 [23.7; 24.3]	0.7 [−0.2; 1.7]
LPA 15:00–18:00	22.7 [21.7; 23.7]	22.9 [22.6; 23.2]	−0.2 [−1.2; 0.8]
LPA 18:00–21:00	21.1 [19.7; 22.5]	19.2 [18.8; 19.7]	**1.8 [0.4; 3.3]**
Cumulative LPA (per day) [a]	252.5 [244.6; 260.3]	247.7 [245.3; 250.1]	4.8 [−3.4; 13.0]
Moderate-to-vigorous physical activity (MVPA)[b]			
MVPA 7:00–09:00	2.5 (1.4 – 3.8)	2.1 (1.3 – 3.4)	0.1 [−0.1; 0.2]
MVPA 9:00–12:00	4.7 (3.1 – 6.3)	4.4 (3.1 – 6.2)	−0.01 [−0.1; 0.1]
MVPA 12:00–15:00	5.2 (3.6 – 7.6)	5.4 (3.8 – 7.2)	0.02 [−0.1; 0.1]
MVPA 15:00–18:00	5.5 (3.6 – 8.4)	6.4 (4.4 – 8.7)	−0.1 [−0.2; 0.03]
MVPA 18:00–21:00	5.3 (3.2 – 8.6)	4.5 (2.5 – 8.0)	0.2 [−0.01; 0.4]
Cumulative MVPA (per day) [a]	56.7 (44.2 – 73.8)	57.5 (44.0 – 75.0)	−0.01 [−0.1; 0.1]

Descriptives of ST and LPA are presented as adjusted means and 95% confidence intervals. Descriptives of MVPA are presented as medians with 25th and 75th percentiles. Analyses were performed using linear mixed models, adjusted for sex, age at PA measurement, age at BMI measurement and season. The bold values were statistically significant (p<0.05).

[a] *Analyses additionally adjusted for accelerometer weartime.*

[b] *Statistical testing for MVPA was performed using log-transformed MVPA.*

DISCUSSION

This study shows that young children's PA and ST exhibit a distinct pattern throughout the course of the day. The highest level of ST occurred in the early morning (07:00–09:00), while the highest levels of LPA and MVPA occurred in the afternoon (12:00–15:00) and late afternoon (15:00–18:00). In terms of ST, LPA, and MVPA, the largest differences between children were found to occur in the late afternoon and evening. Active children were more active and less sedentary throughout the day, rather than being more active in one particular segment. Contrary to what might be expected, no clear association was found between PA patterns and overweight. Children affected by overweight exhibited less sedentary time and more light PA in the evening than children without overweight, but the differences were marginal.

The early morning (07:00–09:00) was the first time segment identified for targeted interventions to boost PA levels in children, since all of the children were relatively sedentary during this period. However, there is some doubt about the scope for boosting PA during this segment, as most children follow a standard routine of waking up, having breakfast and getting ready for school. Nevertheless, if PA could be integrated into this routine (e.g. by the inclusion of an active commute to school), this could be a sustainable way of structurally increasing daily PA levels. This strategy is promoted by the Comprehensive School Physical Activity Program (CSPAP), which aims to exploit all opportunities for children to be more physically active before, during, and after school [25]. Potentially, the difference between the 25th and 75th percentile is 2.5 min of MVPA per hour and 8.7 min of LPA. This means that more than 10 min per hour can be devoted to PA instead of ST. Thus, there is indeed scope for improving PA levels in the early morning, especially when such measures can be incorporated into children's morning routines.

Two other time segments with potential for targeted PA interventions were the late afternoon (15:00–18:00) and evening (18:00–21:00). With regard to MVPA, both the median and the 75th percentile were highest in the late afternoon (Figure 2). During this three hour period, the 25th and 75th percentiles of MVPA differed by approximately 18 min and the differences in terms of LPA and ST were approximately 30 and 40 min, respectively. Another study that looked at hourly activity patterns over the day in 4-year-old Swedish children, showed a slightly different pattern. They showed that children were most active and less sedentary from 9:00 to 15:00 (during preschool) compared to the rest of the day [26]. They assessed PA using the same type of accelerometer device and the same accelerometer cut-offs. However, they did not explore the variation in activity between children. The observed differences between the 25% most active and the 25% least active children in the current study show significant opportunities for increasing the PA levels of the least active children in the late afternoon. During the evening segment (18:00–21:00) the differences between the 25th and 75th percentile were even greater – almost 1 h for ST and 19 min for MVPA. These substantial differences suggest considerable variation in the range of activity exhibited by children before they go to sleep. Some children seem to prefer active forms of relaxation, whereas other children appear to favour more passive forms (ST). Indeed, studies in older children have found that the variation in activity is greatest in the late afternoon and evening. A study in 7- to 11-year-old children in northwest England found the greatest variation in PA behaviour in the early evening (17:00–19:00) [15]. Another study, into highly active and low active 10 to 11-year-old children suggested the use of structured PA programmes to promote PA in low active children during the after-school time segment (15:30–18:30) [16]. Furthermore, although the morning and late afternoon/evening seem to offer the best opportunities for changing PA levels, PA can also be promoted during school hours. PA during school time may even enhance academic engagement and performance [27,28]. The current study shows how different types of interventions may be suitable at different moments of the day, based on an analysis of young children's natural PA patterns. The children's PA patterns show the need for interventions to increase PA levels in children, as only half of the children met the PA guideline of at least 60 min per day in MVPA. Tailored PA interventions are needed to determine whether inactive children can be stimulated to become more active and to determine which types of interventions are most effective in preschool children.

There were no substantial differences between children with and without overweight in terms of their cumulative PA and ST throughout the day. However, when the day was broken down into individual time segments, we found that, during the evening segment, children affected by overweight exhibited significantly less ST and more LPA than children without overweight. Although, in absolute terms, the differences were marginal, it was clear that the children with overweight were no less active than the children without overweight. This finding may however depend on the context in which children live. In Chinese preschool children, a study using accelerometers to assess PA, comparable to ours, showed that, during some time-segments, children affected by overweight were less active compared to children without overweight [29]. The Chinese children with overweight or obesity were more sedentary from 17:00 to 18:00 and spent less time in LPA from 8:00 to 11:00 and from 17:00 to 21:00 on schooldays compared to children without overweight. A possible explanation is that the Chinese school schedule includes an obligatory nap time from 12:00 to 14:00 which probably influences, and maybe even suppresses, children's natural activity patterns across the day [30]. This was visible when looking at the average MVPA level of the Chinese children. This was visible when looking at the average MVPA level of the Chinese children, which was 47 min per day during schooldays and 61 min per day during weekends, the latter being comparable to the average of 61 minutes MVPA per day in our study. Our finding that children with overweight are no less active than children without overweight may be explained by the weartime. Children affected by overweight may have a longer weartime because they sleep less. A previous study showed a lack of sleep to be a determinant of overweight in young children [30], so it may be worthwhile to establish whether or not this might have been a factor in the present study. An analysis of the time length for which children wore their accelerometers revealed that while this was not significantly longer for children with overweight, this group did tend to stay up a little longer than their peers. Another possible explanation concerns the use of BMI to classify overweight, as BMI is not an exclusive measure of fat mass [31,32]A higher BMI could indicate a higher muscle mass rather than a higher fat mass, resulting in relatively muscular children being classified as overweight [31,32]. A recent review and meta-analyses examining the association between PA and adiposity in young children showed no association between PA and BMI, irrespective of the intensity of PA [33]. However, the review and meta-analyses did show that young children with overweight spent less time in MVPA compared to children without overweight [33]. Nevertheless, the influence of MVPA on weight status was rather small. A large study in 2015 also found no differences in PA levels between two to six-year-old children with and without overweight [13]. Only in older children, from age seven onwards, children affected by overweight were found to be less active than children without overweight [13]. Yet, even if the effect of PA does increase with age, it is still important to intervene at a relatively young age. The prevention of overweight at a young age is more effective than treatment after its onset [34]. Also, low levels of PA at a young age may make children more prone to develop overweight as they grow older, as young children's PA behaviours are likely to track into later life [35]. In summary, our results provided no evidence to suggest that PA patterns across the day are relevant to young children's weight status. It is worth remembering that PA at a young age is also important in terms of other health issues (e.g. motor development, fitness, and bone and skeletal health) [1,2]. Therefore, it is recommended that further research is carried out into the influence of PA behaviours throughout the day on other health outcomes.

Study limitations and strengths

To the best of our knowledge, this is one of only a small number of studies into varying intensities of objectively measured PA, at different times of the day, in preschool children. The use of accelerometry makes it possible to define patterns throughout the day, and to analyse them in more detail. This provides a basis for more specific recommendations concerning ways in which PA levels could be improved in preschool children. One strength of the study is that the participants of the GECKO Drenthe cohort form a highly representative sample of the general population, including children from families of both high and low socioeconomic status. Furthermore, about half of the children who were born in Drenthe between April 2006 and April 2007 were included in the GECKO Drenthe cohort. One limitation that should be mentioned is that there may have been differences in the time children spent at school and the time at which their school day ended. However, the selected time segments were found to be valid, so any effect it might have had on the results was considered negligible. We performed a sensitivity analysis, taking into account only those days in which we were certain that children were at school. The results were the same.

CONCLUSION

At this age, the relevance of different PA patterns to childhood overweight was minimal. To encourage PA in general, ST can be reduced and PA increased in the early morning and evening. Children were most active in the late afternoon. Targeted PA interventions to specifically stimulate the least active children could take place in the late afternoon or evening. This is based on the large inter-individual variation observed during these particular time segments.

REFERENCES

1. Poitras VJ, Gray CE, Borghese MM, Carson V, Chaput JP, Janssen I, et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. Appl Physiol Nutr Metab. 2016;41(6 Suppl 3):S197-239. doi: 10.1139/apnm-2015-0663.

2. Carson V, Lee EY, Hewitt L, Jennings C, Hunter S, Kuzik N, et al. Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). BMC Public Health. 2017;17(Suppl 5):854. doi: 10.1186/s12889-017-4860-0.

3. Pandita A, Sharma D, Pandita D, Pawar S, Tariq M, Kaul A. Childhood obesity: prevention is better than cure. Diabetes Metab Syndr Obes. 2016;9:83-9. doi: 10.2147/DMSO.S90783.

4. Krebs NF, Jacobson MS, American Academy of Pediatrics Committee on Nutrition. Prevention of pediatric overweight and obesity. Pediatrics. 2003;112(2):424-30. doi: 10.1542/peds.112.2.424.

5. Yanovski JA. Intensive therapies for pediatric obesity. Pediatr Clin North Am. 2001;48(4):1041-53. doi: 10.1016/s0031-3955(05)70356-4.

6. Tremblay MS, Chaput JP, Adamo KB, Aubert S, Barnes JD, Choquette L, et al. Canadian 24-Hour Movement Guidelines for the Early Years (0-4 years): An Integration of Physical Activity, Sedentary Behaviour, and Sleep. BMC Public Health. 2017;17(Suppl 5):874. doi: 10.1186/s12889-017-4859-6.

7. Okely AD, Ghersi D, Hesketh KD, Santos R, Loughran SP, Cliff DP, et al. A collaborative approach to adopting/adapting guidelines - The Australian 24-Hour Movement Guidelines for the early years (Birth to 5 years): an integration of physical activity, sedentary behavior, and sleep. BMC Public Health. 2017;17(Suppl 5):869. doi: 10.1186/s12889-017-4867-6.

8. Department of Health. Start active, stay active: A report on physical activity from the four home countries' Chief Medical Officers. London, England; 2011.

9. Institute of Medicine. Early childhood obesity prevention policies. Washington, DC: The National Academies Press; 2011. Available at: https://doi.org/10.17226/13124.

10. Department of Health and Ageing. Get up and grow: Healthy eating and physical activity for early childhood. 2010.

11. World Health Organization. Global recommendations on physical activity for health. Geneva, Switzerland; 2010.

12. Geserick M, Vogel M, Gausche R, Lipek T, Spielau U, Keller E, et al. Acceleration of BMI in early childhood and risk of sustained obesity. N Engl J Med. 2018;379(14):1303-12. doi: 10.1056/NEJMoa1803527.

13. Cooper AR, Goodman A, Page AS, Sherar LB, Esliger DW, van Sluijs EM, et al. Objectively measured physical activity and sedentary time in youth: the International children's

accelerometry database (ICAD). Int J Behav Nutr Phys Act. 2015;12:113. doi: 10.1186/s12966-015-0274-5.

14. Chinapaw M, Wang X, Andersen LB, Altenburg T. From Total Volume to Sequence Maps-Sophisticated Accelerometer Data Analysis. Med Sci Sports Exerc. 2018;51(4):814-20. doi: 10.1249/MSS.0000000000001849.

15. Fairclough SJ, Butcher ZH, Stratton G. Whole-day and segmented-day physical activity variability of northwest England school children. Prev Med. 2007;44(5):421-5. doi: 10.1016/j.ypmed.2007.01.002.

16. Fairclough SJ, Beighle A, Erwin H, Ridgers ND. School day segmented physical activity patterns of high and low active children. BMC Public Health. 2012;12:406. doi: 10.1186/1471-2458-12-406.

17. L'Abee C, Sauer PJ, Damen M, Rake JP, Cats H, Stolk RP. Cohort Profile: the GECKO Drenthe study, overweight programming during early childhood. Int J Epidemiol. 2008;37(3):486-9. doi: 10.1093/ije/dym218.

18. Hanggi JM, Phillips LR, Rowlands AV. Validation of the GT3X ActiGraph in children and comparison with the GT1M ActiGraph. J Sci Med Sport. 2013;16(1):40-4. doi: 10.1016/j.jsams.2012.05.012.

19. Sirard JR, Trost SG, Pfeiffer KA, Dowda M, Pate RR. Calibration and evaluation of an objective measure of physical activity in preschool children. Journal of physical activity and health. 2005;2(3):345-57. doi: 10.1123/jpah.2.3.345.

20. Choi L, Ward SC, Schnelle JF, Buchowski MS. Assessment of wear/nonwear time classification algorithms for triaxial accelerometer. Med Sci Sports Exerc. 2012;44(10):2009-16. doi: 10.1249/MSS.0b013e318258cb36.

21. Butte NF, Wong WW, Lee JS, Adolph AL, Puyau MR, Zakeri IF. Prediction of energy expenditure and physical activity in preschoolers. Med Sci Sports Exerc. 2014;46(6):1216-26. doi: 10.1249/MSS.0000000000000209.

22. Olds T, Ridley K, Wake M, Hesketh K, Waters E, Patton G, et al. How should activity guidelines for young people be operationalised? Int J Behav Nutr Phys Act. 2007;4:43. doi: 10.1186/1479-5868-4-43.

23. Fredriks AM, van Buuren S, Burgmeijer RJ, Meulmeester JF, Beuker RJ, Brugman E, et al. Continuing positive secular growth change in The Netherlands 1955-1997. Pediatr Res. 2000;47(3):316-23. doi: 10.1203/00006450-200003000-00006.

24. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012;7(4):284-94. doi: 10.1111/j.2047-6310.2012.00064.x.

25. Centers for Disease Control and Prevention (CDC). Comprehensive School Physical Activity Programs: A Guide for Schools. Atlanta: U.S. Department of Health and Human Services; 2013.

26. Berglind D, Tynelius P. Objectively measured physical activity patterns, sedentary time and parent-reported screen-time across the day in four-year-old Swedish children. BMC Public Health. 2017;18(1):69. doi: 10.1186/s12889-017-4600-5.

27. Mullender-Wijnsma MJ, Hartman E, de Greeff JW, Doolaard S, Bosker RJ, Visscher C. Physically Active Math and Language Lessons Improve Academic Achievement: A Cluster Randomized Controlled Trial. Pediatrics. 2016;137(3):e20152743. doi: 10.1542/peds.2015-2743.

28. Mullender-Wijnsma MJ, Hartman E, de Greeff JW, Bosker RJ, Doolaard S, Visscher C. 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. 2015;15:404. doi: 10.1186/s12889-015-1745-y.

29. Lu C, Wiersma R, Shen T, Huang G, Corpeleijn E. Physical activity patterns by objective measurements in preschoolers from China. Child and Adolescent Obesity. 2019;2(1):1-17. doi: 10.1080/2574254X.2019.1585178.

30. Monasta L, Batty GD, Cattaneo A, Lutje V, Ronfani L, Van Lenthe FJ, et al. Early-life determinants of overweight and obesity: a review of systematic reviews. Obes Rev. 2010;11(10):695-708. doi: 10.1111/j.1467-789X.2010.00735.x.

31. Sijtsma A, Sauer PJ, Stolk RP, Corpeleijn E. Is directly measured physical activity related to adiposity in preschool children? Int J Pediatr Obes. 2011;6(5-6):389-400. doi: 10.3109/17477166.2011.606323.

32. Freedman DS, Sherry B. The validity of BMI as an indicator of body fatness and risk among children. Pediatrics. 2009;124(Suppl 1):S23-34. doi: 10.1542/peds.2008-3586E.

33. Wiersma R, Haverkamp BF, van Beek JH, Riemersma AMJ, Boezen HM, Smidt N, et al. Unravelling the association between accelerometer - derived physical activity and adiposity among preschool children: a systematic review and meta-analyses. Obes Rev. 2019;doi: 10.1111/obr.12936.

34. Rodearmel SJ, Wyatt HR, Barry MJ, Dong F, Pan D, Israel RG, et al. A family-based approach to preventing excessive weight gain. Obesity (Silver Spring). 2006;14(8):1392-401. doi: 10.1038/oby.2006.158.

35. Jones RA, Hinkley T, Okely AD, Salmon J. Tracking physical activity and sedentary behavior in childhood: a systematic review. Am J Prev Med. 2013;44(6):651-8. doi: 10.1016/j.amepre.2013.03.001.

Appendix 6.1

Table A. Descriptive characteristics of the most active and least active children and children with and without overweight.

	Most active (n = 239)	Least active (n = 239)	Overweight (n = 71)	Non-overweight (n = 776)
Sex (boys)	125 (52.3%)	125 (52.3%)	32 (45.1%)	402 (51.8%)
Age PA measurement (yrs.)[a]	5.8 ± 0.8	5.5 ± 0.8	5.7 ± 0.8	5.7 ± 0.8
Age BMI measurement (yrs.)	5.8 ± 0.3	5.8 ± 0.4	5.9 ± 0.4	5.8 ± 0.3
BMI (kg/m^2)[b]	15.9 ± 1.3	15.9 ± 1.4	18.9 ± 1.0	15.7 ± 1.0
BMI Z-score[b]	0.21 ± 0.78	0.17 ± 0.80	1.73 ± 0.36	0.06 ± 0.65
Weight status				
Underweight	16 (7.5%)	13 (6.2%)	–	–
Normal weight	180 (84.1%)	182 (86.3%)	–	–
Overweight	17 (7.9%)	11 (5.2%)	–	–
Obese	1 (0.5%)	5 (2.4%)	–	–
Ethnicity (Dutch)	209 (87.8%)	217 (91.2%)	61 (85.9%)	704 (91.1%)
Education level (low/middle)				
Mother	113 (54.6%)	97 (46.9%)	33 (57.9%)	346 (50.4%)
Father[b]	104 (55.0%)	96 (47.3%)	38 (69.1%)	341 (53.3%)
Household income				
< €1150	10 (4.4%)	3 (1.3%)	1 (1.4%)	20 (2.7%)
€1151–€3050	126 (55.5%)	132 (56.7%)	41 (59.4%)	405 (54.5%)
€3051–€3500	46 (20.3%)	41 (17.6%)	7 (10.1%)	135 (18.2%)
> €3501	24 (10.6%)	31 (13.3%)	7 (10.1%)	105 (14.1%)
Unknown /not reported	21 (9.3%)	26 (11.2%)	13 (18.8%)	78 (10.5%)
Weartime (min/day)[a]	662.8 ± 36.5	654.0 ± 34.6	662.2 ± 39.7	655.2 ± 34.6

Abbreviations: PA, physical activity; BMI, body mass index. Data are presented as mean ± SD or N (%). Children were divided into activity groups based on sex-specific quartiles of their average MVPA per day. Children were classified either as affected by overweight/obesity or not affected by overweight based on the definition used by Cole et al. (2012).
** Significant differences between most active and least active children.*
[#] Significant differences between children with and without overweight or obesity.

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Chapter 7

General discussion

Physical inactivity is an important contributor to non-communicable diseases across the world.[1] Under the global concerns are the low level of physical activity (PA) and high prevalence of sedentary behaviours (SB) in children.[2] The health potential of sufficient PA and less SB during preschool years are increasingly being recognized.[3-5] Understanding the correlates of PA and SB during childhood contributes to evidence-based planning of public health interventions. The present thesis focused on PA, SB and environmental correlates in preschool children.

Built environments and physical activity

In this thesis, we have investigated a series of built environmental correlates of PA patterns in Chinese (Chapter 3) and Dutch (Chapter 4) preschool children. A summary of the studied correlates in this thesis was given in the Chapter 8 – Summary (Chapter 8 – Figure 1. Adapted ecological model of correlates on PA for preschool children). Interventions on the built environment may have the potential to provide population-wide effects and support sustained behaviour change. Our findings could be used in informing urban design to support increased PA.[6] For instance, our findings support that improving recreation facilities (e.g., parks, playgrounds) in the neighbourhood might be a useful strategy for PA promotion in the early years, whether this is in a densely-populated Chinese urban city (Chapter 3), or in a relatively rural western area, i.e. the province of Drenthe in the Netherlands (Chapter 4).

The study populations in this thesis came from two countries. Figure 1 shows the urbanization in the two countries over time, expressed as percentage of the entire population living in urban areas. The Netherlands is a developed country with a high standard of living over the past decades. The total population of the Netherlands has only slightly increased over the past decade. In 2017, 92 percent of the total population of the Netherlands lived in cities, whereas in the same year, the total population in China living in urban areas is 58%. Compared to the relatively stable urban population in the Dutch society, the Chinese society has undergone rapid urbanization and urban sprawl since the economic reforms in the early 1980s. This contributed to changes in residents' lifestyles, increased motorization and the decline in PA.[7, 8] Thus, the design of Chinese cities to promote PA is a timely issue, since China is expanding its cities at a rapid rate to accommodate enormous growth in its urban population.

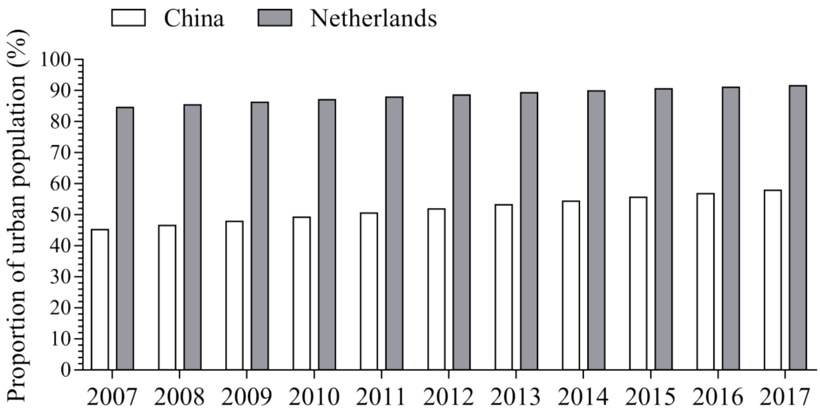


Figure 1. The degree of urbanization in China and the Netherlands from 2007 to 2017. Adapted from data of World Bank. Source: https://www.statista.com.

Over the past decade, the 'Active Living by Design' movement tried to understand and improve built environments to better support PA in developed western countries.[9] The built environment includes workplaces and schools, neighbourhoods, walking and cycling infrastructure, connectivity, transportation systems, and recreational areas. An 'Active Living by Design' environment makes it easier for individuals and families to incorporate PA into their everyday lives.[10] The influence of the environmental characteristics may vary by country and cultural context. For example, as we found in this thesis, a higher number of PA facilities located within 10 minutes walking distance would be helpful for enhancing children's leisure-time PA in a Chinese urban city, although it might not be enough to enhance their overall level of moderate-to-vigorous physical activity (MVPA), based on observational data. In the Dutch children however, it showed that PA facilities within 30 minutes walking distance in the neighbourhood were related to more a higher level of children's overall MVPA daily. These clues indicate that the activities of Chinese children may be limited to a more restricted space, closer by, compared to the Dutch children. For example, Chinese children usually do activities in their close familiar surroundings, for example in gated communities. This habit is not just found in children, it is the case for most Chinese citizens. Gated communities in China differ from gated communities in other countries, in the form of villa neighbourhoods, where it stands for a high-standard quality of life index.[11] The gated communities in China more stand for traditional values and a habitat reflecting a culture of collectivists.[12] They are closed urban residential areas where public space is legally privatized and access is restricted.[13] A growing problem of gated communities may be the restriction of spatial integration into public spaces and facilities, e.g. their wall surroundings limit the expansion of pedestrian and cyclist networks. Gated communities are also common in public school and universities, where PA facilities have the potential to improve the health of urban residents, particularly for children and the elderly.[14] Then, when aiming at PA promotion for the whole population, it should be kept in mind that the environmental characteristics that predict PA behaviours vary according to sex, age, race, and other characteristics of the target group.[1] For instance, some studies suggest that a highly connected street design is optimal for increased walking among adults, but this is not the case for children – rather, streets that are cul-de-sacs or courts-dead-ends rather than interconnectivity – are more important for children.[15, 16]

In this thesis, we have studied a series of built environmental correlates on PA patterns. Some findings were as expected, e.g. the findings that more PA facilities would be related to higher levels of PA. For other aspects we expected an association, but did not find one. For example in Chinese children, no correlation between safety and light intensity PA (LPA) or MVPA was found. We had expected an association between perceived safety, active behaviours and TPA, since parents' perceived safety may impact walking, bicycling or outdoor play, especially for children living in developing countries where traffic accidents are common.[17] Although traffic safety was not related to objectively measured PA in both Dutch and Chinese children, if Chinese parents perceived 'more safety of traffic situation' they also reported more active commuting to school ($\rho = 0.102$, $p < 0.05$). In the Dutch children, a better traffic safety was positively correlated to a higher frequency of the child cycling outside ($\rho = 0.144$, $p < 0.05$). Overall, it seems that safety is related to specific PA behaviours, but is a less strong correlate to objectively measured PA than anticipated.

Socio-cultural environment and physical activity

Another important finding of this thesis is that the socio-cultural environment was found to influence PA behaviours in preschool years. Between the two nations, daily PA patterns differed, as well as the role of child caregivers.

School schedule and child physical activity

At the population level, the prevalence of PA has declined considerably in many countries in recent decades.[18] This thesis describes patterns of PA and SB among Chinese (Chapter 5) and Dutch (Chapter 6) preschool children. The TPA levels in Chinese preschoolers are lower than the Dutch children, and also lower than a worldwide average. A systematic review reported an estimate of 54% of children adhering the at least 60 minutes of MVPA daily recommendations worldwide (N = 10,316, aged 2–6 years).[19] As it was shown in Figure 2, this recommendation to accumulate at least one hour MVPA daily was met by 53% of the Dutch children, and only 28% of Chinese children.[20] The low level of PA in general in Chinese children and adolescents has raised concerns. As shown in Chapter 2, half of the Chinese studies reported that less than 50% of the participants could meet the recommendation of one hour MVPA daily.[21] As we suspected, the lack of PA in childhood may be starting already in preschool years.

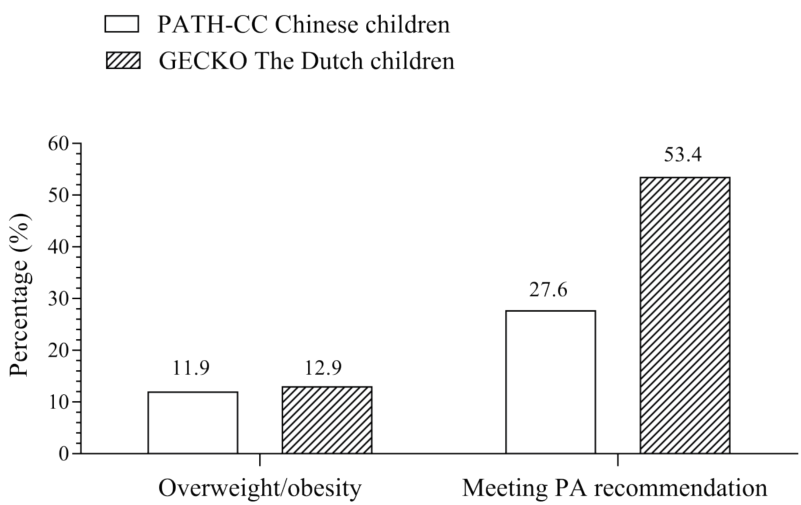


Figure 2. The percentage of overweight/obesity in this thesis and the prevalence of children meeting PA recommendations.

What's more, one reason that accounts for the low level of PA in Chinese preschoolers may be the timetables and scheduled recess compared to the Dutch children. The 24 h day is made up of sleep, sedentary time (ST) like sitting and television viewing, light physical activities like slow walking and MVPA, consisting of more intense activities like running, ball games, climbing.[22] Lifestyle behaviours do not exist in isolation, but combine in a characteristic pattern. If more time is spent in one behaviour, for example in playing sedentarily or sleep, then there must be a corresponding lower amount of time spent in other behaviours, like play in LPA or MVPA. In China, most children have a nap in the noon, therefore, in Chinese children the peak in ST was found between 12:00 and 14:00. This was not found in Dutch children, with no napping habit at age 5 to 6 in preschools. In China, exchanging nap time for active play could be an easy way to increase PA in young children. However, it should be noticed that cancelling the napping habit for children would not be culturally acceptable in Chinese society. At this time, not only the children have a nap, but also teachers can have a rest. Nevertheless, we argue that the napping time could be shorter than at present. In the PATH-CC study, 78% of the children aged 3–6 years having a napping time of on average 108 ± 29 minutes during school days.[20] Meanwhile, a population-based study from 10 cities across China reported an average napping time of 91 minutes in Chinese children of the same age.[23] Previous literature indicated that beyond the age of two years, napping is associated with later night sleep onset and both reduced sleep quality and duration [24], and napping in toddlerhood is also associated with later timing of the internal circadian clock.[25] For adults, a nap during the day of less than 30 minutes in duration could promote wakefulness and enhance performance and learning ability.[26] Perhaps we could keep the habit of napping but make it of shorter duration for preschoolers. One hour for napping, would gain half an hour for children to be active. How much time exactly is suitable for napping in preschoolers needs more support from scientific evidence.

Child caregivers and child physical activity

Especially during childhood, when behaviours are under less volitional control, parents are one of the primary providers of inhibitory and promotive opportunities whereby children can be active.[27] This thesis provides evidence to support this theory. It showed that parental support was associated with children's PA patterns. This may be explained through a variety of mechanisms. PA may be enhanced when parents are prepared to accompany their children to go to PA facilities (Chapter 3) or in doing sports (Chapter 4). PA may also be enhanced via parents engaging in exercise themselves, when their exercise habit influences older children and adolescents (chapter 2).

In contrast with the positive influence of parents on PA patterns, having grandparents as the primary caregivers was found to be associated with lower levels of MVPA and higher ST in Chinese preschoolers (Chapter 3). Grandparents raising grandchildren can be found in many parts of the world.[28] Some studies indicated that grandparents' actions may have no impact on their grandchildren's PA, e.g. in Japanese preschool children.[29] In Chinese societies, grandparents raising grandchildren is part of a long-standing cultural tradition, and this culture is more obvious since the one child-policy after 1979. The one-child generation has dramatically changed family structure and lifestyle for the last 35 years (from 1979 to 2016) in mainland China, resulting in the single child becoming the focus of the entire family.[30] It is possible that, as older adults, grandparents are seduced to spoil their only one grandchild [31], tend to be overprotective and discourage the more vigorous and encourage more sedentary indoor activities.[32] Another reason we have indicated in Chapter 3 was that these grandparents have undergone the great famine in the years 1959−1961. A study in the Netherlands has reported that women who were exposed to the Dutch famine (year 1944−1945) early in life were more often physically inactive later in life, compared to women who were not exposed.[33] Thus, these Chinese grandparents who have been exposed to the great famine in China may be of influence on children through their inactive lifestyle, although we will need more studies to confirm this suggestion.

Physical activity, sedentary behaviour and healthy weight

Globally, the number of overweight children under the age of five is estimated to be over 41 million in 2016. Almost half of all overweight children under five lived in Asia and one quarter lived in Africa.[34] The early childhood (two to six year of age) is seen as a critical window for predicting childhood weight gain.[35] Overweight and obese children are likely to become obese adolescents and adults in the future, and they are also more likely to develop non-communicable diseases like diabetes mellitus type 2 and cardiovascular diseases at a younger age.[36] In this thesis, we used the same method to measure PA via accelerometer [37] and the same standard classification [38] for overweight in the Dutch and Chinese children. In Chinese preschool children, we confirmed our hypothesis that overweight children were more sedentary and less active in LPA. In the Dutch children, however, we were not able to find this association.

A recent review has summarized papers looking at objectively measured PA and overweight, and show that PA is inversely related to percentage body fat in preschool children, but not to BMI.[39] The associations are very weak. Overall, it seems that at very young age, the variation in PA is not a strong determinant of developing overweight [40], unless perhaps when PA is really discouraged by the environment, or cultural restrictions, e.g. due to the school system, as may the case in our Chinese study. We suggest that other factors such as diet and sleep are more important predictors for overweight and obesity in this age group.[41, 42]

Implications for future physical activity promotion

Given the widespread problem of physical inactivity and the continued growth in the prevalence of childhood and adolescent obesity, promotion of regular PA should start early in life.[43] From the perspective of social cognitive theory, involvement of individual factors and environmental components are both essential for health behaviour changes.[10] To target PA promotion in preschool children, we suggest that both children and their families need education on the importance of improving PA and reducing SB for a lifelong health. Looking at the role of parents (or other caregivers) to increase PA in children, we suggest that if parents would be more active themselves, they would give their children more opportunities to be active, such as to play outside, or do more sports. Obviously older adults are facing a challenge for such a role. For future family-based interventions to increase children's PA level, questions pertaining to who should be involved, what those involved should provide, and when it should be provided need clear delineation.[44]

To avoid that children have more and more screen time in the household, support and behavioural interventions by parents are needed. Some behaviours may be easily modifiable, e.g. removing the TV from the child's bedroom, or installing rules regarding TV usage, e.g., no more than one hour per evening.[45, 46] However, it should be admitted that there are also benefits of screen time, such as children having joy or acquiring knowledge. It also leaves child caregivers with more time on house work if they let their children watch TV. With the current developments in media equipment, this will also become available for children in the home at younger age, increasing screen time by use of computers and smart phones.[47] I suggest that the potential impact on children's health should be discussed and perhaps suggestions for regulations on screen time are necessary.

Furthermore, it should be discussed how school settings could provide a good opportunity of PA promotion. For example in the United States, a Comprehensive School Physical Activity Programs (CSPAPs) are widely supported to increase PA in schools, which use all opportunities for students to be physically active.[48] As indicated in this thesis, both Chinese and Dutch children were less active on school days compared to weekend days. The school environment in the preschool years are an opportunity to make the most progress to be active that should not be missed, especially for Chinese preschool children who go to school full time. Better PA promotion should consider culture differences between nations. For example, the afternoon maybe a good opportunity for Chinese children to be active (Chapter 5), however, PA interventions for the Dutch children could take place preferably in the early morning and evening (Chapter 6).

The support and development of 'Active Living' environments could be a feasible strategy for enhancing PA. A review focused on longitudinal studies that investigated how changes in the built environment were related to PA. For example, it was studied whether creating new infrastructure for walking, cycling and public transportation could encourage active modes of transportation in citizens.[49] In our view, the local government should establish and maintain safe and convenient environments for children's active play and transportation. Overall, effective PA promotion should involve children and their families, school administrators and teachers, and also policy makers in ministries of health and education, as well as urban planners.

Methodological issues

Previous literature showed that it is not possible to conduct meta-analyses in systematic reviews of PA due to study heterogeneity, given the variation in PA assessment tools and consequently the difficulty in comparing activity levels across groups.[50] Therefore, we used the same device and post-processing procedures to measure PA in children of the same age in the Netherlands and China. This makes the studied data comparable in an absolute sense and therefore we believe the difference in PA patterns between the two nations was a real and quantifiable difference.

In this thesis we also investigated environmental characteristics and for this we relied on parental report in questionnaires. Although literature indicated that perceived neighbourhood attributes by parents might show different associations with PA than direct measurements of environments in preschoolers, the reported associations were usually stronger, maybe because parents are often the decision maker for children's activities and perceived environment is more important for behaviour than the actual environment. However, due to a lack of objective measurements of environmental characteristics, we cannot exclude the possibility that the correlations on this topic may be over-estimated in this thesis.

Another important methodological concern is that the evidence is based primarily on cross-sectional studies. Longitudinal study design would make causality inferences between the predictors and activity outcomes more feasible to determine. Thus, our hypotheses need to be tested further. For example, birth cohort studies are ideal, especially for taking long-term effects of various environmental risks in later life.

Furthermore, Asia is the most rapidly industrializing region in the world, where children are confronted by a multiplying array of health threats by rapid urbanization, unsustainable consumption, and an increase of industrial disposal such as e-waste. Currently, most of the existing birth cohorts are in high-income countries, with relatively few in low- and middle-income countries.[51] Pooling data or undertaking cross cohort comparisons supports an understanding of which aspects of children's development are unique to specific contexts and which are universal, since environmental risks or disease burdens vary from region to region. Further scientific cooperation to identify specific regional environmental threats and lifestyle choices, and the related effects of child health in Asia is needed.[52]

In conclusion, based on the studies in this thesis it is recommended that PA promotion and intervention should start in preschool years, and the effective strategy should involve children and their families, school administrators and teachers, and also policy makers in ministries of health and education, as well as urban planners. Furthermore, scientific cooperation to identify regional environmental threats and improve the health of children globally is needed, along with using a longitudinal study design to test the influence of environmental changes.

REFERENCES

1. Bauman AE, Reis RS, Sallis JF, et al. Correlates of physical activity: why are some people physically active and others not? Lancet. 2012;380(9838):258-71. doi: 10.1016/S0140-6736(12)60735-1.

2. Tremblay MS, Barnes JD, Gonzalez SA, et al. Global matrix 2.0: report card grades on the physical activity of children and youth comparing 38 countries. J Phys Act Health. 2016;13(11 Suppl 2):S343-66. doi: 10.1123/jpah.2016-0594.

3. Carson V, Lee EY, Hewitt L, et al. Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). BMC Public Health. 2017;17(Suppl 5)(854)doi: 10.1186/s12889-017-4860-0.

4. Pate RR, Hillman CH, Janz KF, et al. Physical activity and health in children younger than 6 years: a systematic review. Med Sci Sports Exerc. 2019;51(6):1282-91. doi: 10.1249/MSS.0000000000001940.

5. Carson V, Kuzik N, Hunter S, et al. Systematic review of sedentary behavior and cognitive development in early childhood. Prev Med. 2015;78:115-22. doi: 10.1016/j.ypmed.2015.07.016.

6. Hinckson EA, Duncan S, Oliver M, et al. Built environment and physical activity in New Zealand adolescents: a protocol for a cross-sectional study. BMJ Open. 2014;4(4):e004475. doi: 10.1136/bmjopen-2013-004475.

7. Ng SW, Howard AG, Wang HJ, et al. The physical activity transition among adults in China: 1991-2011. Obes Rev. 2014;15 Suppl 1:27-36. doi: 10.1111/obr.12127.

8. Qin L, Stolk RP, Corpeleijn E. Motorized transportation, social status, and adiposity: the China Health and Nutrition Survey. Am J Prev Med. 2012;43(1):1-10. doi: 10.1016/j.amepre.2012.03.022.

9. Bors P, Dessauer M, Bell R, et al. The Active Living by Design national program: community initiatives and lessons learned. Am J Prev Med. 2009;37(6 Suppl 2):S313-21. doi: 10.1016/j.amepre.2009.09.027.

10. Sallis JF, Cervero RB, Ascher W, et al. An ecological approach to creating active living communities. Annu Rev Public Health. 2006;27:297-322. doi: 10.1146/annurev.publhealth.27.021405.102100.

11. Silva de Araujo A, Pereira de Queiroz A. Spatial characterization and mapping of gated communities. ISPRS International Journal of Geo-Information. 2018;7(7):248. doi: 10.3390/ijgi7070248.

12. Pow C. Gated communities in China: class, privilege and the moral politics of the good life. London: Routledge; 2009.

13. Roitman S. Who segregates whom? The analysis of a gated community in Mendoza, Argentina. Housing studies. 2005;20(2):303-21. doi: 10.1080/026730303042000331790.

14. Kabisch N, van den Bosch M, Lafortezza R. The health benefits of nature-based solutions to urbanization challenges for children and the elderly - a systematic review. Environ Res. 2017;159:362-73. doi: 10.1016/j.envres.2017.08.004.

15. Ball K, Timperio AF, Crawford DA. Understanding environmental influences on nutrition and physical activity behaviors: where should we look and what should we count? Int J Behav Nutr Phys Act. 2006;3:33. doi: 10.1186/1479-5868-3-33.

16. Veitch J, Bagley S, Ball K, et al. Where do children usually play? A qualitative study of parents' perceptions of influences on children's active free-play. Health Place. 2006;12(4):383-93. doi: 10.1016/j.healthplace.2005.02.009.

17. Jiang B, Liang S, Peng ZR, et al. Transport and public health in China: the road to a healthy future. Lancet. 2017;390(10104):1781-91. doi: 10.1016/S0140-6736(17)31958-X.

18. Kohl HW,3rd, Craig CL, Lambert EV, et al. The pandemic of physical inactivity: global action for public health. Lancet. 2012;380(9838):294-305. doi: 10.1016/S0140-6736(12)60898-8.

19. Tucker P. The physical activity levels of preschool-aged children: a systematic review. Early Childhood Res Q. 2008;23(4):547-58. doi: 10.1016/j.ecresq.2008.08.005.

20. Lu C, Wiersma R, Shen T, et al. Physical activity patterns by objective measurements in preschoolers from China. Child and Adolescent Obesity. 2019;2(1):1-17. doi: 10.1080/2574254X.2019.1585178.

21. Lu C, Stolk RP, Sauer PJ, et al. Factors of physical activity among Chinese children and adolescents: a systematic review. Int J Behav Nutr Phys Act. 2017;14:doi: 10.1186/s12966-017-0486-y.

22. Talarico R, Janssen I. Compositional associations of time spent in sleep, sedentary behavior and physical activity with obesity measures in children. Int J Obes (Lond). 2018;42(8):1508-14. doi: 10.1038/s41366-018-0053-x.

23. Wu R, Wang GH, Zhu H, et al. Sleep patterns in Chinese preschool children: a population-based study. J Clin Sleep Med. 2018;14(4):533-40. doi: 10.5664/jcsm.7038.

24. Thorpe K, Staton S, Sawyer E, et al. Napping, development and health from 0 to 5 years: a systematic review. Arch Dis Child. 2015;100(7):615-22. doi: 10.1136/archdischild-2014-307241.

25. Akacem LD, Simpkin CT, Carskadon MA, et al. The timing of the circadian clock and sleep differ between napping and non-napping Toddlers. PLoS One. 2015;10(4):e0125181. doi: 10.1371/journal.pone.0125181.

26. Dhand R, Sohal H. Good sleep, bad sleep! The role of daytime naps in healthy adults. Curr Opin Pulm Med. 2006;12(6):379-82. doi: 10.1097/01.mcp.0000245703.92311.d0.

27. Beets MW, Cardinal BJ, Alderman BL. Parental social support and the physical activity-related behaviors of youth: a review. Health Educ Behav. 2010;37(5):621-44. doi:

10.1177/1090198110363884.

28. Lakó JH. The issues of the relationship of grandparents and grandchildren in the light of physical activity. European Journal of Mental Health. 2014;9(02):178-94. doi: 10.5708/ejmh.9.2014.2.3.

29. Watanabe E, Lee JS, Kawakubo K. Associations of maternal employment and three-generation families with pre-school children's overweight and obesity in Japan. Int J Obes (Lond). 2011;35(7):945-52. doi: 10.1038/ijo.2011.82.

30. Feng X, Poston Jr DL, Wang X. China's one-child policy and the changing family. Journal of comparative family studies. 2014;45(1):17-29.

31. Hesketh T, Lu L, Xing ZW. The effect of China's one-child family policy after 25 years. N Engl J Med. 2005;353(11):1171-6. doi: 10.1056/NEJMhpr051833.

32. Johansson E, Mei H, Xiu L, et al. Physical activity in young children and their parents-An Early STOPP Sweden-China comparison study. Sci Rep. 2016;6:29595. doi: 10.1038/srep29595.

33. Fransen HP, Peeters PH, Beulens JW, et al. Exposure to famine at a young age and unhealthy lifestyle behavior later in life. PLoS One. 2016;11(5):e0156609. doi: 10.1371/journal.pone.0156609.

34. World Health Organization. Childhood overweight and obesity. Available at: https://www.who.int/dietphysicalactivity/childhood/en/. [accessed 12.08.2019].

35. Volger S, Rigassio Radler D, Rothpletz-Puglia P. Early childhood obesity prevention efforts through a life course health development perspective: a scoping review. PLoS One. 2018;13(12):e0209787. doi: 10.1371/journal.pone.0209787.

36. Geserick M, Vogel M, Gausche R, et al. Acceleration of BMI in early childhood and risk of sustained obesity. N Engl J Med. 2018;379(14):1303-12. doi: 10.1056/NEJMoa1803527.

37. Butte NF, Wong WW, Lee JS, et al. Prediction of energy expenditure and physical activity in preschoolers. Med Sci Sports Exerc. 2014;46(6):1216-26. doi: 10.1249/MSS.0000000000000209.

38. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012;7(4):284-94. doi: 10.1111/j.2047-6310.2012.00064.x.

39. Wiersma R, Haverkamp BF, van Beek JH, et al. Unravelling the association between accelerometer - derived physical activity and adiposity among preschool children: a systematic review and meta-analyses. Obes Rev. 2019;doi: 10.1111/obr.12936.

40. Sijtsma A, Sauer PJ, Stolk RP, et al. Is directly measured physical activity related to adiposity in preschool children? Int J Pediatr Obes. 2011;6(5-6):389-400. doi: 10.3109/17477166.2011.606323.

41. Chaput JP, Gray CE, Poitras VJ, et al. Systematic review of the relationships between sleep duration and health indicators in the early years (0-4 years). BMC Public Health. 2017;17(Suppl 5):855. doi: 10.1186/s12889-017-4850-2.

42. Monasta L, Batty GD, Cattaneo A, et al. Early-life determinants of overweight and obesity: a review of systematic reviews. Obes Rev. 2010;11(10):695-708. doi: 10.1111/j.1467-789X.2010.00735.x.

43. Downing KL, Hnatiuk JA, Hinkley T, et al. Interventions to reduce sedentary behaviour in 0-5-year-olds: a systematic review and meta-analysis of randomised controlled trials. Br J Sports Med. 2018;52(5):314-21. doi: 10.1136/bjsports-2016-096634.

44. Hnatiuk JA, Brown HE, Downing KL, et al. Interventions to increase physical activity in children 0-5 years old: a systematic review, meta-analysis and realist synthesis. Obes Rev. 2019;20(1):75-87. doi: 10.1111/obr.12763.

45. Tremblay MS, Chaput JP, Adamo KB, et al. Canadian 24-Hour Movement Guidelines for the Early Years (0-4 years): An Integration of Physical Activity, Sedentary Behaviour, and Sleep. BMC Public Health. 2017;17(Suppl 5):874. doi: 10.1186/s12889-017-4859-6.

46. Okely AD, Ghersi D, Hesketh KD, et al. A collaborative approach to adopting/adapting guidelines - The Australian 24-Hour Movement Guidelines for the early years (Birth to 5 years): an integration of physical activity, sedentary behavior, and sleep. BMC Public Health. 2017;17(Suppl 5):869. doi: 10.1186/s12889-017-4867-6.

47. Wong BY, Cerin E, Ho SY, et al. Adolescents' physical activity: competition between perceived neighborhood sport facilities and home media resources. Int J Pediatr Obes. 2010;5(2):169-76. doi: 10.3109/17477160903159432.

48. Singletary CR, Weaver G, Carson RL, et al. Evaluation of a comprehensive school physical activity program: Be a Champion! Eval Program Plann. 2019;75:54-60. doi: 10.1016/j.evalprogplan.2019.04.003.

49. Karmeniemi M, Lankila T, Ikaheimo T, et al. The built environment as a determinant of physical activity: a systematic review of longitudinal studies and natural experiments. Ann Behav Med. 2018;52(3):239-51. doi: 10.1093/abm/kax043.

50. Pate RR, O'Neill JR, Brown WH, et al. Top 10 research questions related to physical activity in preschool children. Res Q Exerc Sport. 2013;84(4):448-55. doi: 10.1080/02701367.2013.844038.

51. Lawlor DA, Andersen AM, Batty GD. Birth cohort studies: past, present and future. Int J Epidemiol. 2009;38(4):897-902. doi: 10.1093/ije/dyp240.

52. Kishi R, Zhang JJ, Ha EH, et al. Birth cohort consortium of Asia: current and future perspectives. Epidemiology. 2017;28 Suppl 1:S19-34. doi: 10.1097/EDE.0000000000000698.

Chapter 8

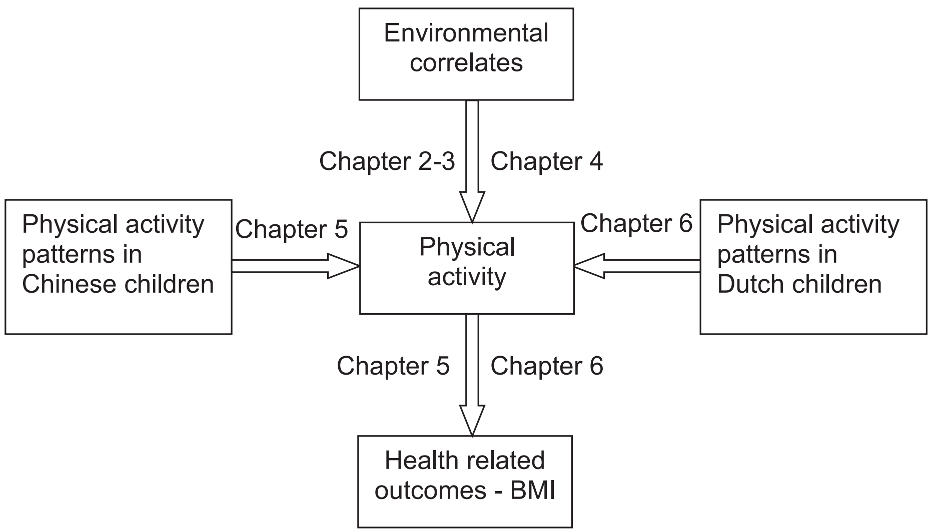
Summary

Nederlandse Samenvatting

中文摘要

Summary

The health benefits of sufficient physical activity (PA) during early years are increasingly being recognized. In addition, early life experiences have an important impact on health and lifelong behaviour. Among the global concerns is physical inactivity in children, there is a need for understanding determinants of PA and sedentary behaviours (SB) during childhood to contribute to evidence-based planning of public health interventions. As shown in the figure below (Chapter 1 - Figure 2. Overview of the thesis), the main aim of this thesis is to determine which environmental correlates are related to PA patterns in preschool children. To gain more insight in the PA behaviours in young children, we describe the daily patterns of PA based on the different intensities of PA, including light PA (LPA), moderate-to-vigorous PA (MVPA), and sedentary time (ST) both in Chinese and Dutch preschoolers. To explore the potential health relevance, we examine the correlation between PA, SB and children with overweight / obesity in their early years.



Chapter 1 - Figure 2. Overview of the thesis.

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Findings on correlates of physical activity

China owns the largest population in the world. Understanding determinants of PA in Chinese society could reduce the effect of future epidemics of inactivity and contribute to effective global prevention of non-communicable diseases. Although lack of PA is a well-known problem in Chinese adults, less is known in children and adolescents. In **Chapter 2**, a review was performed to summarize the existing literature on determinants of PA among Chinese children and adolescents. Forty two papers (published 2002 – 2016) were included, and it showed that Chinese children and adolescents had a low level of PA. It also showed that none reports focused on preschoolers. This review showed that gender, self-efficacy, parental PA, and urbanization were important factors influencing PA in Chinese children and adolescents. It also indicated that the factors influencing the PA were not yet fully understood, due to limited research quality and inconclusive findings. This review suggested future research is required to enhance the understanding of other influences, such as the physical environment, especially in early childhood.

Chapter 3 and **Chapter 4** focused on the correlation between environmental correlates, PA and ST in Chinese and the Dutch preschoolers, respectively. For better showing the correlates we investigated, a simple adapted ecological model based on Sallis' model was made, which focused on correlates of preschool children found in this thesis (Figure 1). In this thesis, we focused on parents' perceived environmental correlates and PA patterns (are shown at the centre) in preschool children. PA patterns were classified by intensity (ST, LPA and MVPA) using ActiGraph GT3X (ActiGraph, Pensacola, FL, USA) accelerometry. Environment correlates were divided into four domains: built environment (including PA facilities, traffic safety, road network and environmental quality), social culture environment (social support from family and communities, parental support and peer support), home environment (including characters of house, dog, cars, garden, lift, televisions and computers), and natural environment (including weather, temperature, and air quality). Intrapersonal factors often have a direct influence on PA and were shown within the next boundary (including child's gender, age, ethnic, social economic status, parental age and family structure). Children's behaviours were in the middle outer circle, including outdoor play and commuting activities, since children's behaviours may be changed through parental perceived neighbourhood and then affecting on their PA levels. Data of the natural environment was collected, but these results were not shown in this thesis.

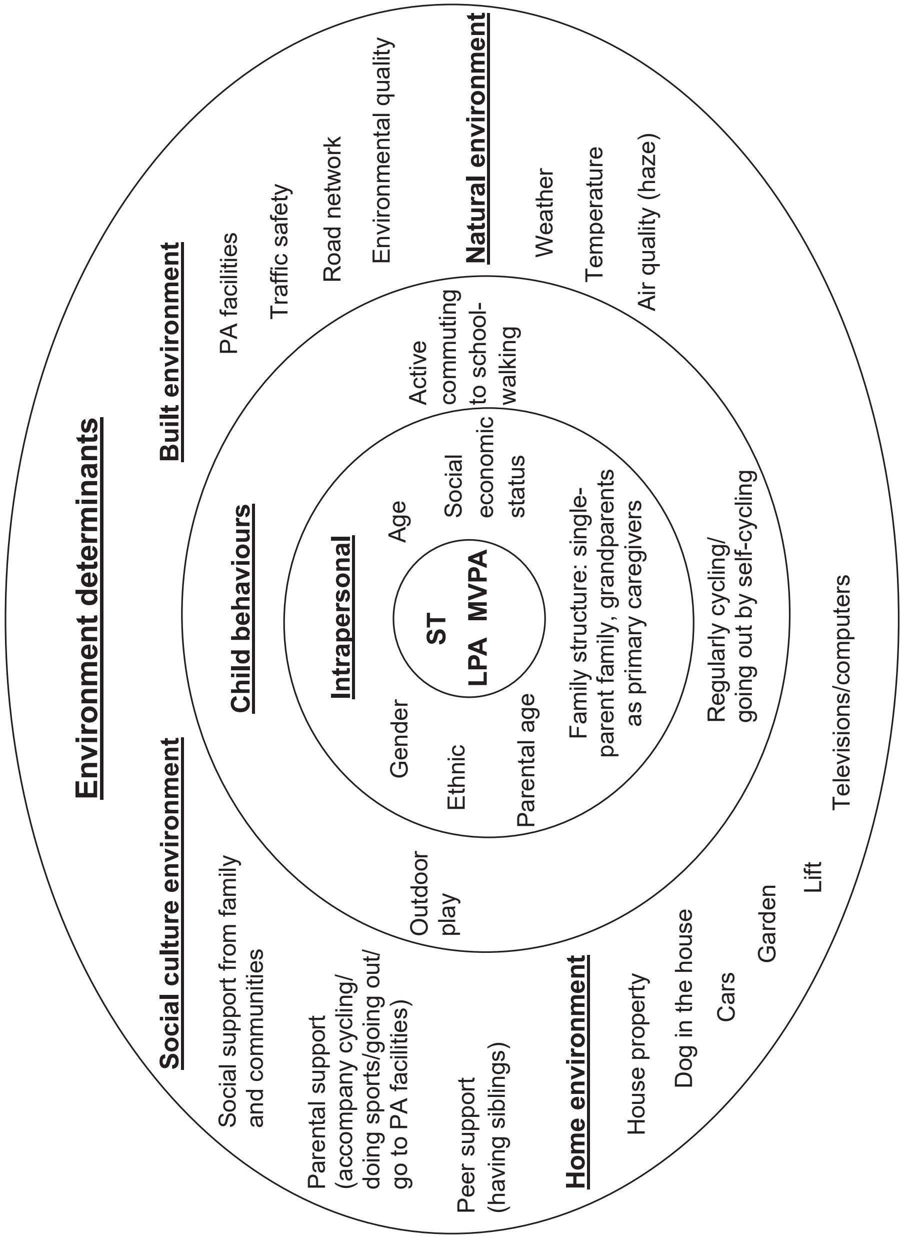

Figure 1. Adapted ecological model of correlates on PA for preschool children.

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Chapter 3 examined environmental correlates of SB and PA in preschool children in the urban area of Tianjin, China. Data were collected from the Physical Activity and Health in Tianjin Chinese Children study (PATH-CC), involving 3–6-year-olds healthy children and their families (n = 980). Results showed that 'having grandparents as the primary caregivers' was related to more time spent in SB, and less time in MVPA overall. More media exposure such as having a television or a computer in the child's bedroom was related to more time spent sedentary. Furthermore, it also indicated that built environmental correlates such as convenient PA facilities may indirectly influence children's leisure-time PA through parents' help for doing active behaviours.

Chapter 4 examined the relationship between environmental correlates and children's objectively measured ST, LPA and MVPA in the Dutch preschool children. Data were derived from the GECKO (Groningen Expert Centre for Kids with Obesity) Drenthe birth cohort. Patterns of PA of 505 children, aged 4–7 years, measured by ActiGraph accelerometry, were used. Environmental correlates were collected using a questionnaire that included household characteristics, parental and children's PA behaviours, and neighbourhood environment. This study showed that convenient neighbourhood PA facilities like parks and playgrounds had an indirect effect through parental support associated to lower children's ST and higher MVPA.

A summary of important correlates found in **Chapter 3** and **Chapter 4** is shown in Table 1. The identified association was expressed by a positive "+", negative "−", or no (coded with a "0") association. This thesis confirmed that in both the two nations, boys are more active in MVPA than girls, and older preschoolers were more sedentary.

Table 1. Important correlates of sedentary time / physical activity among preschool children found in this thesis.

Variable	Sedentary time		Light physical activity		Moderate-to-vigorous physical activity	
	PATH-CC	GECKO	PATH-CC	GECKO	PATH-CC	GECKO
Female $^{LTSB(0), LTPA(0)}$	0	0	0	0	–	–
Age $^{LTSB(+), LTPA(0)}$	0	+	0	–	0	0
Grandparents as primary caregivers $^{LTSB(+), LTPA(0)}$	+	NA	0	NA	–	NA
Outdoor play $^{LTSB(0), LTPA(+)}$	–	–	0	+	0	0
Active commuting to school by walking $^{LTSB(0), LTPA(0)}$	–	NA	0	NA	+	NA
Number of cars in the household $^{LTSB(0), LTPA(0)}$	0	0	0	0	0	0
Parental support for accompany doing sports / go to physical activity facilities $^{LTSB(0), LTPA(+)}$	0	–	0	+	0	+
Number of physical activity facilities $^{LTSB(0), LTPA(+)}$	0	–	0	0	0	+
Traffic safety $^{LTSB(0), LTPA(0)}$	0	0	0	0	0	0

Data of PATH-CC study was derived from Chapter 3. Data of GECKO study was derived from Chapter 4. The results are coded as no correlation ("0"), or positive ("+"), or negative ("–") in each study. LTPA: leisure-time physical activity; LTSB: leisure-time sedentary behaviours; NA: not applicable, the correlate was not studied in this thesis.

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For children's PA behaviours, data from the two nations both showed that 'more outdoor play' was related to less ST, but not MVPA. In Chinese children, active commuting to school by walking was related to less ST and more MVPA. Parental support for active behaviours was related to more PA in both the two nations. As shown in the table, the parental activity 'taking child to play sports' was related to less ST, more LPA and MVPA in the Dutch children, and parents 'accompanying go to PA facilities' was related to more leisure-time PA in Chinese children. Accessibility of recreational PA facilities could have an indirect positive influence on PA patterns. For example, it was related to lower ST and higher MVPA through parental support in the Dutch children, and enhanced children's leisure-time PA through parental support in Chinese children as well.

Physical activity patterns in preschool children

Future efforts to effectively promote PA in young children through policy initiatives will depend on a proper understanding of PA behaviours in this age group. Identifying periods during the day, which are characterized by high levels of PA in some children and low levels in others, will help to identify key time slots for intervening and potentially changing PA behaviours. In **Chapter 5** and **Chapter 6**, PA and ST distribution across the day in Chinese preschoolers and the Dutch preschoolers were checked, respectively.

In **Chapter 5**, objectively measured ST and PA patterns of Chinese preschoolers during the day were described. Data were derived from the PATH-CC study. ST, LPA, and MVPA of 3–6-year-olds children (n = 134) were measured using ActiGraph accelerometry. Results showed that Chinese preschoolers have low levels of PA, especially during school days. Children were less active during recess (12:00–14:00) and afternoon (14:00–17:00), and more active during late afternoon (17:00–18:00) and evening (18:00–21:00). Between active and less active children, the difference of MVPA was highest in the evening (4.1 min/hour) and on weekends/holidays (42.7 min/day). Children with overweight were more sedentary overall (44.6 min/day) compared to children without overweight. This study suggested that enhancing PA both in school and the home environment should be taken into consideration to prevent childhood obesity.

Chapter 6 examined the distribution of accelerometer-derived PA throughout the day in the Dutch children. Data were derived from the GECKO Drenthe cohort. Daily overall ST, LPA, and MVPA were measured using ActiGraph accelerometers in 4–7 years old children (n = 958). Results showed that children were most sedentary in the early morning (7:00–9:00) and evening (18:00–21:00), and most active in the afternoon (12:00–15:00) and late-afternoon (15:00–18:00). The most active children were more active and less sedentary throughout the entire day compared to the less active children. Nevertheless, children with overweight were no less active than children without overweight. This study showed that different types of interventions may be suitable at different moments of the day, based on an analysis of young children's natural PA patterns.

Chapter 7 provides a general discussion on environmental characteristics and PA patterns in preschool children, with special attention for culture differences between China and the Netherlands. This thesis indicated that the socio-cultural environment may influence the natives' PA behaviours, and the school schedule as well as the role of child caregivers might play an important role in preschool children's daily PA patterns. Furthermore, some implications for future PA promotion were given, and promotion of PA was suggested already in preschool years.

In **conclusion**, the present thesis focused on PA, SB, and environmental correlates in preschool children, both Chinese and Dutch preschoolers. For preschool children, a supportive family and a facilitating neighbourhood environment maybe important factors for the promotion of PA behaviours and lowering of SB in both the two nations. We suggest that PA promotion and intervention should start in preschool years, since it would be beneficial for keeping a healthy weight and for the development of healthy behaviours. The effective strategy should involve children and their families, school administrators and teachers, and also policy makers in ministries of health and education, as well as urban planners. We suggest that the government should take notice of the low level of PA among Chinese children and adolescents and take action. Besides, PA promotion for preschoolers should be considered as part of the local culture in different nations, and specifically target for less active children and children with obesity. Furthermore, scientific cooperation to identify regional environmental threats and improve the health of children globally is needed, along with using a longitudinal study design to test the influence of environmental changes.

Nederlandse Samenvatting

De gezondheidsvoordelen van lichamelijke activiteit tijdens de eerste levensjaren worden steeds meer erkend. Bovendien hebben ervaringen in de vroege levensfase een belangrijke invloed op gezondheid en gedrag op volwassen leeftijd. Voldoende lichamelijke activiteit bij kinderen is een wereldwijde zorg. Onderzoek naar oorzaken van lichamelijke inactiviteit en zittend gedrag (SB) op de kinderleeftijd is nodig als basis voor interventies die bijdragen aan het voorkomen van overgewicht en ziekte op latere leeftijd.

De onderzoeken die beschreven zijn in dit proefschrift richten zich op omgevingsfactoren die gerelateerd zijn aan beweegpatronen bij kleuters in Nederland en China. China heeft het hoogste aantal inwoners ter wereld. Inzicht in de determinanten van lichamelijke inactiviteit in de Chinese samenleving zal daarom bijdragen aan de wereldwijde preventie van chronische ziekten. Lichamelijke inactiviteit is uitgebreid beschreven bij Chinese volwassenen, maar er is minder bekend bij kinderen.

In hoofdstuk 2 is een literatuuroverzicht beschreven over determinanten van lichamelijke activiteit bij Chinese kinderen en adolescenten. Het laat zien dat Chinese kinderen en adolescenten een laag activiteitsniveau hebben. Er zijn geen onderzoeken gepubliceerd over kleuters. Belangrijke determinanten zijn geslacht, zelfeffectiviteit (met name bij adolescenten), lichamelijke activiteit van de ouders en mate van urbanisatie.

Omgevingsfactoren en lichamelijke activiteit

Hoofdstuk 3 en hoofdstuk 4 beschrijven de verbanden tussen omgevingsfactoren en lichamelijke activiteit in respectievelijk Chinese en Nederlands kleuters. In beide landen is de lichamelijke activiteit gemeten met behulp van drie-dimensionale accelerometrie (ActiGraph GT3X, Pensacola, FL, VS). De mate van lichamelijke activiteit is geclassificeerd naar de tijd die doorgebracht wordt op een bepaalde intensiteit: zittend gedrag (sedentair) , lichte intensiteit (rustig spelen, puzzelen, tekenen) en medium-tot-hoge intensiteit (huppelen, tikkertje, rennen, fietsen). Lichamelijke activiteit is in een grotere groep Chinese kinderen ook in kaart gebracht met vragenlijsten. Omgevingsfactoren zijn bepaald met vragenlijsten en verdeeld in vier domeinen: gebouwde omgeving (sportvoorzieningen, verkeersveiligheid, wegennet en milieukwaliteit), sociaal-culturele omgeving (sociale netwerken, ouderlijke ondersteuning), thuisomgeving (samenstelling huishouden, huisdieren, auto's, tuin, lift, televisies en computers) en natuurlijke omgeving (weer, temperatuur en luchtkwaliteit). Dit laatste domein wordt niet behandeld in dit proefschrift.

Hoofdstuk 3 is gebaseerd op onderzoek bij kleuters in het stedelijke gebied van Tianjin, China (PATH-CC studie). In deze studie deden gezonde kinderen mee van 3–6 jaar oud, samen met hun families (n = 980). Het hebben van grootouders als primaire zorgverleners gaat samen met meer tijd zitten en minder tijd met bewegen op medium-tot-hoge intensiteit. Meer mediablootstelling evenals het hebben van een televisie of een computer op de slaapkamer van het kind is gerelateerd aan meer zitten. Verder blijkt dat de gebouwde omgeving, zoals aanwezige voorzieningen voor kinderen om actief buiten te spelen, de lichamelijke activiteit van kinderen positief beïnvloedt en dat dit wordt versterkt als ouders hun kinderen begeleiden in hun activiteiten.

Hoofdstuk 4 beschrijft de relaties tussen omgevingsfactoren en de objectief gemeten lichamelijke activiteit (tijd zittend, lichte activiteit of medium-tot-hoge activiteit) van Nederlandse kleuters. De gegevens zijn ontleend aan het geboortecohort GECKO (Groningen Expert Centre for Kids with Obesity) Drenthe. Volledige data van beweegpatronen en omgevingsfactoren waren beschikbaar voor 505 kinderen in de leeftijd van 4–7 jaar. Het onderzoek laat zien dat laagdrempelige speelvoorzieningen in de buurt, zoals parken en speeltuinen, gerelateerd zijn aan minder zitten en meer activiteiten van medium-tot-hoge intensiteit, vooral als ouders hun kinderen begeleiden bij dit soort activiteiten. Dit was vergelijkbaar met de Chinese situatie.

In beide landen is ‘meer buiten spelen’ gerelateerd aan minder zittend gedrag, maar niet aan bewegen in matig-tot-hoge intensiteit. Bij Chinese kinderen is lopend ‘woon-werkverkeer’ gerelateerd aan minder zitten en meer matig-tot-hoog intensief bewegen. Ook was ouderlijke support van actief gedrag gerelateerd aan meer lichamelijke activiteit in beide landen.

Beweegpatronen bij kleuters

Voor het effectief bevorderen van lichamelijke activiteit bij jonge kinderen is een goed begrip van beweegpatronen in deze leeftijdsgroep gewenst. Het identificeren van periodes gedurende de dag waarop kinderen juist erg actief zijn, of erg sedentair, kan hierbij helpen. Hoofdstuk 5 en hoofdstuk 6 beschrijven de verdeling van lichamelijke activiteit en zittend gedrag over de dag in Chinese en Nederlandse kleuters.

In hoofdstuk 5 worden objectief gemeten beweegpatronen beschreven bij 134 Chinese kleuters (3–6 jaar) uit de PATH-CC-studie. De resultaten laten zien dat Chinese kleuters lage activiteitsniveaus hebben, lager dan die van de Nederlandse kinderen (Hoofdstuk 6), vooral tijdens schooldagen. Kinderen zijn minder actief tijdens de lunchpauze en middag, en actiever tijdens de late namiddag en avond. Tussen actieve en minder actieve kinderen is het verschil in activiteit over de hele dag zichtbaar, maar het grootst in de avond en in weekends/op feestdagen. Kinderen met overgewicht vertonen meer zittend gedrag dan kinderen zonder overgewicht. Deze studie suggereert dat het in stedelijk China zinvol is om lichamelijke activiteit zowel op school als in de thuisomgeving te stimuleren, om inactiviteit en overgewicht tegen te gaan.

Hoofdstuk 6 beschrijft de objectief gemeten beweegpatronen van 958 Nederlandse kleuters (4–7 jaar) uit het GECKO Drenthe cohort. Kinderen spenderen de meeste tijd zittend in de vroege ochtend en avond, en zijn het meest actief in de middag en namiddag. De meest actieve kinderen waren de hele dag door actiever dan de minder actieve kinderen. Echter, kinderen met overgewicht waren niet minder actief dan kinderen zonder overgewicht, zoals we dat in China wel zagen (Hoofdstuk 5). Deze studie laat zien dat er meerdere momenten op de dag zijn dat inactieve kinderen gestimuleerd kunnen worden om actiever te bewegen.

Discussie, conclusie en aanbevelingen

Het proefschrift wordt in hoofdstuk 7 afgesloten met een algemene discussie over omgevingsfactoren en lichamelijke activiteit bij kleuters, met speciale aandacht voor sociaal-culturele verschillen tussen China en Nederland. Zowel activiteiten op school als van ouders/verzorgers spelen een belangrijke rol in de dagelijkse lichamelijke activiteiten van kleuters. Er worden enkele suggesties gegeven voor het stimuleren van PA, gericht op minder actieve kinderen en kinderen met overgewicht, onder andere om hiermee te beginnen op voorschoolse leeftijd en aandacht te besteden aan een omgeving die het bewegen en actief spelen mogelijk maakt. Voor een effectieve strategie moeten kinderen en hun families, schoolbestuurders en leraren worden betrokken, maar ook beleidsmakers en stadsplanners. Wij stellen voor dat de overheid bewust wordt van het lage niveau van lichamelijke activiteit bij Chinese kinderen en adolescenten en actie onderneemt. Wetenschappelijke samenwerking kan helpen bij de identificatie van omgevingsfactoren die bijdragen aan de wereldwijde gezondheid van kinderen. Daarnaast is longitudinaal onderzoek noodzakelijk om het effect op gezondheid te bestuderen van veranderingen in omgevingsfactoren.

中文摘要

儿童期充足的体力活动对机体所产生的健康效益已逐渐被认识。此外，童年早期的生活经历，对于健康乃至终身行为习惯的养成都具有重要意义。当前儿童体力活动不足这一现状已成为全球关注的问题。了解儿童时期影响其体力活动及静态行为的决定因素，有利于对其采取以证据为支持的措施进行干预。本论文的主要目的是探讨环境因素对学龄前儿童体力活动模式的影响（见下图，第 2-4 章）。为深入了解儿童的体力活动行为，第 5 章和第 6 章分别对中国和荷兰儿童的日常体力活动（包括轻度体力活动及中重度体力活动）及静态行为模式进行了分析。同时，本文也探索了儿童的体力活动和静态行为与超重/肥胖之间的关系。

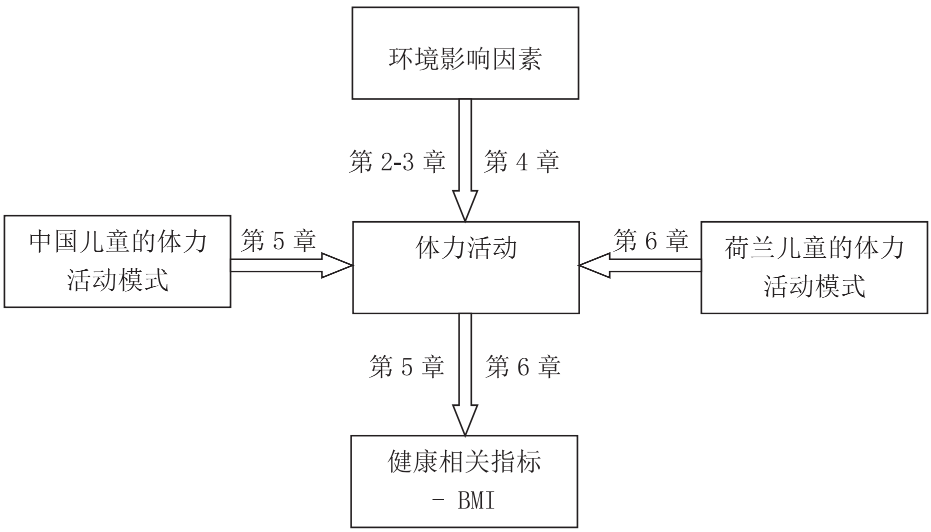

图2 论文研究概述

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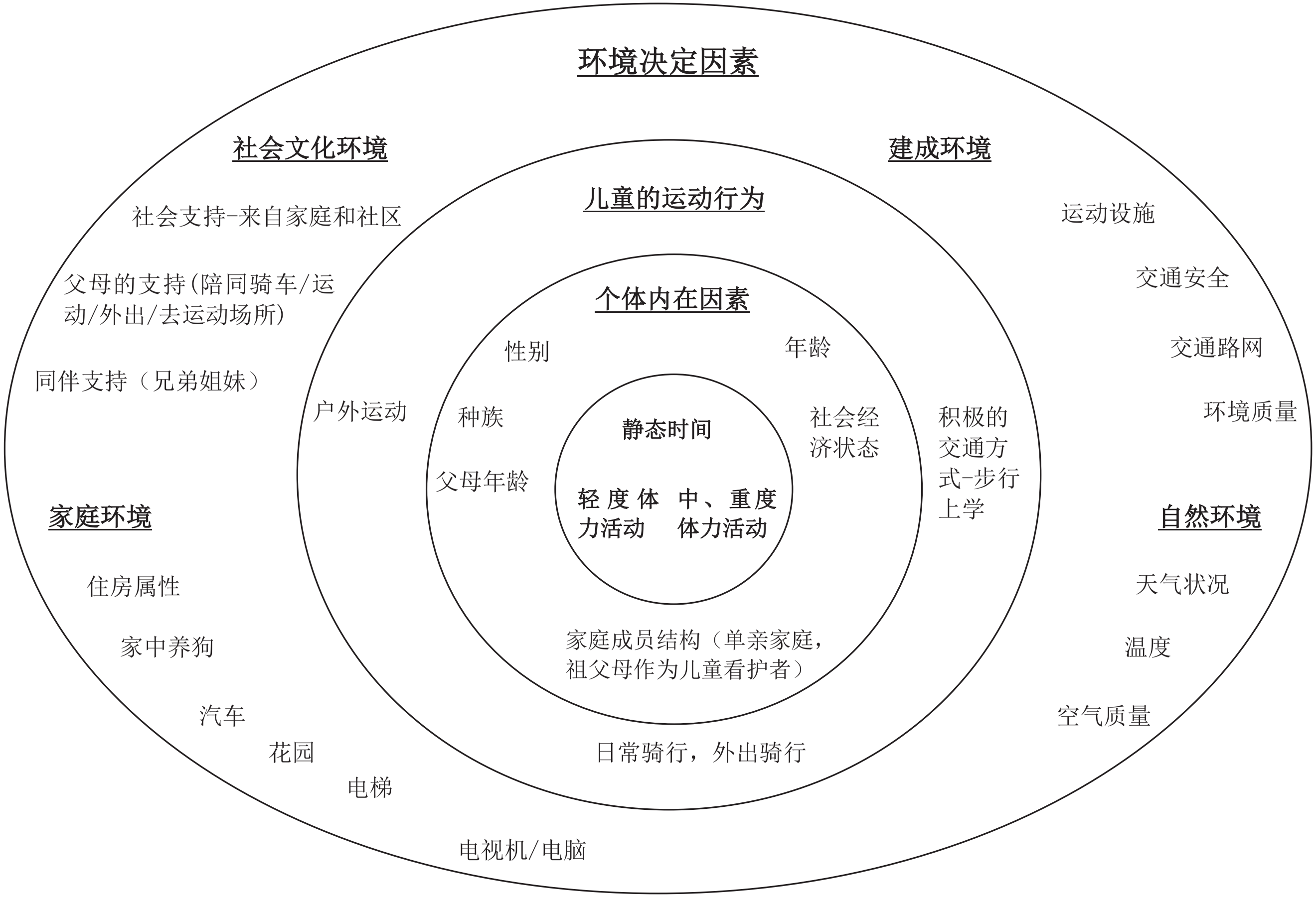

图 3 学龄前儿童体力活动的影响因素的生态学模型

体力活动影响因素研究

中国是世界上人口最多的国家，了解影响中国人群体力活动不足的决定因素，有助于缓解国民长期以来缺乏体力活动的趋势，并有利于全球慢性非传染性疾病的预防。当前，中国成年人群体力活动不足已成为广泛关注的问题，然而这一状况在儿童和青少年中尚缺乏有效的认识。本文第 2 章对中国儿童和青少年体力活动影响因素的研究进行了系统性综述。该综述共纳入了发表于 2002 年至 2016 年期间的 42 篇英文文献。综述归纳后发现多数中国儿童和青少年的体力活动处于较低水平，此外，缺乏针对学龄前儿童体力活动研究的文献报道。研究发现儿童的性别，自我效能，父母的体力活动以及都市化是中国儿童和青少年体力活动的重要影响因素。此外，由于当前纳入的研究多数为横断面研究，且对同一因素研究的数量不足等原因，很多因素的作用尚不明却。研究提示需要进一步探索其他因素对于体力活动的影响，特别是要加强儿童早期体力活动的环境因素的研究。

第3章和第4章分别在中国儿童和荷兰儿童中，研究环境因素对体力活动和静态时间的影响。图3汇总了本文所研究的学龄前儿童体力活动的影响因素。

图 3 注：本文研究父母感知的环境因素对学龄前儿童体力活动模式的影响。根据加速计测量结果将儿童的体力活动模式（位于图中核心位置）按照运动的强度分为静态时间、轻度体力活动以及中、重度体力活动。环境因素包括建成环境（如运动设施、交通安全、交通路网和环境质量），社会文化环境（来自家庭和社区的社会支持，以及父母和同伴的支持），家庭环境（房屋属性、家中是否养狗、家庭是否拥有的汽车、花园、电梯、电视机和电脑）以及自然环境（天气状况、温度及空气质量）。个体内在因素对儿童的体力活动模式有直接影响，在此图中显示在内环位置，包括儿童的性别、年龄、种族、社会经济状态、父母的年龄和家庭结构。由于父母感知的环境会影响到儿童的行为，从而影响儿童体力活动水平，因此运动行为位于中环，包括户外运动、日常交通方式等。部分研究结果如自然环境等相关数据并未在本论文中呈现。

第 3 章调查环境因素对中国天津城市学龄前儿童体力活动和静态行为的影响。数据来自于天津儿童体力活动与健康研究（PATH-CC），包括 980 名 3 至 6 周岁的健康儿童和他们的家庭。结果显示，祖父母作为儿童的主要看护者与儿童静态行为的增加以及中重度体力活动的降低有关。家庭中的媒体暴露如儿童的卧室摆放电视机或者电脑，与儿童闲暇时间静态的延长有关。此外，建成环境因素如居住社区周边便利的运动设施，可通过促进家长陪伴儿童去该场所的频率增加或者是儿童长时间的户外运动，间接促进儿童闲暇时间运动量的提高。

第 4 章调查环境因素对荷兰儿童体力活动及静态时间的影响。研究对象来自荷兰格罗宁根儿童肥胖出生队列（GECKO）。研究采用加速计测量 4 至 7 岁儿童的体力活动及静态时间（n = 505）。对家长通过问卷调查收集环境影响因素，包括家庭因素、父母和儿童的行为，以及居住环境因素。研究发现，即便是在荷兰远离城市的地区，居住地社区周边便利的运动设施，同样有助于家长陪同儿童进行运动，从而间接降低儿童的静态时间，并提高儿童的中重度体力活动水平。

对第3、4章研究中重要因素汇总后发现（见Table1），两国儿童中男孩的中重强度的体力活动水平均高于女孩，并且年龄大的儿童静态时间更长。两组数据均显示儿童长时间的户外运动与降低其静态时间有关，但未发现户外运动与中重度体力活动之间的关系。研究发现中国儿童步行上学有利于降低其静态时间并增加重度体力活动时间。两组数据均表明，父母对儿童运动的积极支持有助于提高儿童的运动水平，此外，在父母的协助下，社区便利的运动设施有助于间接提高儿童的运动量。

学龄前儿童体力活动模式研究

从决策者角度出发，为制定有效措施提高儿童的体力活动水平，需要全面了解儿童的体力活动模式。因此，识别哪些儿童在一天中的某个特定时段处于高（或低）水平的活动状态，有助于在对应时间采取针对性的措施进行干预，从而改善儿童的行为模式。第5章和第6章分别对中国儿童及荷兰儿童的日常体力活动模式进行了分析。

第5章采用客观评价的方法,对中国城市学龄前儿童的日常体力活动模式进行分析。数据来自于天津儿童体力活动与健康研究（PATH-CC），采用加速计客观测量3至6周岁儿童（n = 134）的日常静态时间，轻度体力活动及中重度体力活动时间。结果表明该组学龄前儿童的体力活动水平较低，尤其是在上学日。在一天当中，儿童在中午（12:00–14:00）和下午（14:00–17:00）的活动水平最低，在傍晚（17:00–18:00）和晚上（18:00–21:00）处于较高的活动水平。在活跃和欠活跃的儿童中，中重度体力活动最大的差距出现在晚上（4.1分/小时）和周末/节假日（42.7分/天）。受超重（或肥胖）影响的儿童比体重正常的儿童静态时间更长（44.6分/天）。研究建议早期预防儿童期肥胖，在学校和在家庭环境中均需采取措施来提高儿童的体力活动水平。

第6章对荷兰儿童的体力活动模式进行了分析。研究对象来自荷兰GECKO出生队列，采用加速计对4至7岁的儿童（n = 958）的日常体力活动进行测评，包括静态时间，轻度体力活动及中重度体力活动时间。结果显示，荷兰儿童在一天中的早上（7:00–9:00）和傍晚（18:00–21:00）静态时间较长，而在下午（12:00–15:00）和（15:00–18:00）期间最为活跃。跟欠活跃的儿童相比，活跃的儿童在各个时间段都表现出较多的体力活动以及较少的静态时间。研究发现在学龄前阶段，儿童期超重（肥胖）受体力活动模式的影响较小。研究提示对儿童体力活动的干预，应该在基于分析其活动模式的基础上，在不同的时间采用与之相应的干预方式。

第7章针对环境因素与学龄前儿童体力活动模式之间的关系，就中国和荷兰两国民族间文化背景的差异进行了深入探讨。文中指出社会文化环境会对当地居民的体力活动行为产生影响，如学校的作息制度和儿童看护者或许在儿童的日常体力活动模式的形成中发挥了重要作用。此外，本文探讨了在未来体力活动干预中应注意的问题，建议早期干预应从学龄前阶段开始。

小结

本文就环境影响因素与学龄前儿童体力活动模式之间的关系，分别在中国儿童及荷兰儿童中进行了探讨。研究发现在中国和荷兰学龄前儿童中，有利的家庭和社区环境可能是提高儿童体力活动并降低其静态时间的重要因素。为便于儿童健康体重和良好行为习惯的早期养成，本文建议应从学龄前阶段开始对儿童进行体力活动的健康促进和干预。有效的协作需要儿童和其家庭，以及学校管理人员、教师，和卫生及教育部门决策者的共同参与。建议相关部门及时关注中国儿童和青少年体力活动不足这一现状，并采取相应措施。此外，对学龄前儿童体力活动的健康促进，应在考虑不同民族间文化背景差异的基础上，对特定人群如不爱运动的儿童或是受肥胖影响的儿童采取针对性的措施。为促进全球儿童的健康，今后的研究需要地区间的合作来识别不同区域特定的环境风险，推荐采用纵向的队列研究设计，并监测环境的改变对于健康的影响。

Chapter 9

A protocol of PATH-CC study

Physical activity and psychosocial functioning

Acknowledgements

About the author

Chapter 9.1

Physical Activity and Health in Tianjin Chinese Children (PATH-CC): a protocol for a cross-sectional study

Congchao Lu, Ronald P. Stolk, Eva Corpeleijn

INTRODUCTION

Physical activity (PA) is an acknowledged component of energy-balance-related behaviours. More PA at the cost of sedentary time (ST) may improve energy balance as well as fitness. From a global perspective, a lack of PA has been identified to be the fourth leading risk factor for mortality.[1] Available data showed that globally one third of adults and four out of five adolescents do not reach public health guidelines on recommended levels of PA. This is not only limited to high-income countries, but is also increasingly found in low- and middle-income countries [2], for example, a developing country like China. Living in an increasingly urbanized country with rapid economic development, Chinese people have been and will be facing huge changes in the local environment.[3] As a result of urbanization, citizens' daily lives are accompanied by crowdedness, passive commuting [4], and air pollution [5], in parallel with a rapidly increasing rate of inactivity.[6] Physical inactivity is already a key factor in adult health in Chinese society.[4, 7] It contributes between 12% and 19% to the risks associated with the five major non-communicable diseases in China, namely coronary heart disease, stroke, hypertension, cancer, and type 2 diabetes.[8]

China owns the largest number of population in the world, with more than 13 billion people. Understanding determinants of PA in Chinese society could reduce the effect of future epidemics of inactivity and contribute to effective global prevention of non-communicable diseases. Published literature showed a growing number of studies on determinants of PA among Chinese, but mainly on adults, and less on school-age children, and none focused on preschoolers. The health benefits of sufficient PA during preschool years are increasingly being recognized, e.g., prevention of obesity, and improved physical fitness, motor skills, and psychological development.[9, 10] Besides, literature indicated that PA tracks from early childhood to school age, and a stable level is maintained from school age years to adulthood.[11, 12] Early life experiences have an important impact on lifelong behaviour and health.[13] To make PA promotion programs from early childhood effective, it is necessary to know more about the determinants of PA, for example, characteristics of the social family environment, built environment, and school environment.[14]

Research about correlates (factors associated with activity) or determinants (those with a causal relationship) of PA mostly focused on individual-level factors in high-income countries in the past two decades.[15] It is shown that age, sex, health status, self-efficacy, and motivation are associated with PA. Literature on western countries showed that environmental characteristics can play an important role in children's PA. Factors such as walkability, traffic speed/volume, access/proximity to recreation facilities, land-use mix, and residential density were correlated to PA in children.[16] Chinese citizen's PA environment is limited by a series of factors, such as closed communities, high-density neighbourhoods, mixed vehicles and bicycle roads. Since the Chinese society may know other determinants of PA in children than western societies, this information is also needed to design effective interventions and public health programs in China.

The trend of being obese has spread into every age group of Chinese citizens, and is very pronounced in children.[17, 18] Taking Tianjin as an example, the fourth largest city of China with over 15.2 million residents, the prevalence of overweight and obesity was 12.5% and 15.7%, respectively in school-age children in 2010.[19] A recent report showed that the prevalence of obesity in Tianjin preschoolers increased from 8.8% in 2006 to 10.1% in 2010, and then remained stable until 2014 among children aged 5–6 years old.[20] Failed experiences from obesity interventions in school-age children suggest that we may be missing the critical period of early interventions [21], and the preschool years may be a better choice.[22, 23] More and more evidence supports that promoting PA during preschool years could provide profound health benefits during the whole childhood.[9, 13, 24, 25]

Urbanization in China is a long-term strategy, lead by the government since Chinese economic reform in the late 1980s, aiming at prosperity. With large numbers of people moving into cities for jobs and better education for the next generation, large cities are expanding at an unprecedented rate. Small towns also developed quickly with more immigrants from rural regions. The proportion of the urbanized population in China has increased from 18% in 1978 to 47% in 2009, and it is expected that one billion people will live in Chinese cities by 2030.[3] Information on urban planning, transportation systems, and parks and trails are also needed for Chinese public policy makers. Especially multiple strategies are needed to develop a coordinated approach to the rapidly urbanization and its unavoidable adverse health effects.

In this study, we aim to identify the environmental correlates of PA assessed by both objective and subjective methods in preschool children living in the urban city of Tianjin, China. For a proper understanding of PA behaviours in preschoolers, patterns of ST and PA will be described. Besides, the relationship between ST, PA and weight-related health outcomes will be identified.

These results will support key strategies for urban design and development in china to support increased PA, and deepen the understanding of the link between PA and human health.

METHODS AND ANALYSIS

Study design

Physical Activity and Health in Tianjin Chinese Children study (PATH-CC) is designed as across-sectional observational study. Approximately 1000 healthy children aged 3 to 6 years living in urban areas of Tianjin, China, are being recruited as volunteers. Data on PA, weight related health outcomes, lifestyle, social and environmental factors will be collected in the year 2015. Details are described below according to the checklist for reporting of observational studies in Epidemiology (STROBE).[26]

Setting

Data will be collected in urban areas of Tianjin. Tianjin is the fourth largest city in northern China with over 15 million residents in 2015. The city is located in Northern coastal China, and 67 miles southeast of the capital Beijing. Tianjin is a typical city representative of the Chinese urban development, and has a deep impact on surrounding cities in Bohai Economic Rimby its urban planning. Urban areas of Tianjin that are suitable for inclusion in this study are six urban districts (Heping, Hexi, Hebei, Nankai, Hedong and Hongqiao), and parts of four suburban districts (Beichen, Xiqing, Jinnan and Dongli). This is due to the urbanization, when more and more new communities are built in suburban areas and able to accommodate a large number of citizens.

Participants

Healthy children aged 3 to 6 years will be invited to join the study. Volunteer recruitment will be based on multiple sampling strategies. Four districts (two urban districts and two suburban districts) will be selected randomly. Preschools located in the neighbourhood with middle level socioeconomic status will be selected at random. If a selected preschool refuses to join the study, it will be replaced by another one.

At baseline, the health information of diseases will be provided by the school nurse according to the report of the annual physical examination of Tianjin Woman and Children Health Centre.

Children with any diseases that could seriously influence daily PA (such as incapable of movement, asthma, cardiovascular diseases) will be excluded from the study.

Procedures

A pilot study (n = 50) has been performed for validation of the questionnaires in 2014. The volunteer recruitment (n = 1000) will be launched in preschools in March of 2015, and the plan is to finish data collection in one year. At baseline, the child and family information, child's ST, PA and lifestyle information, household and environmental characteristics will be reported by parents via a questionnaire. Child health outcomes and weight will be measured in preschools. ST and PA will be measured in a subgroup of children volunteers via accelerometry. Figure 1 shows the flowchart of the data collection in this study.

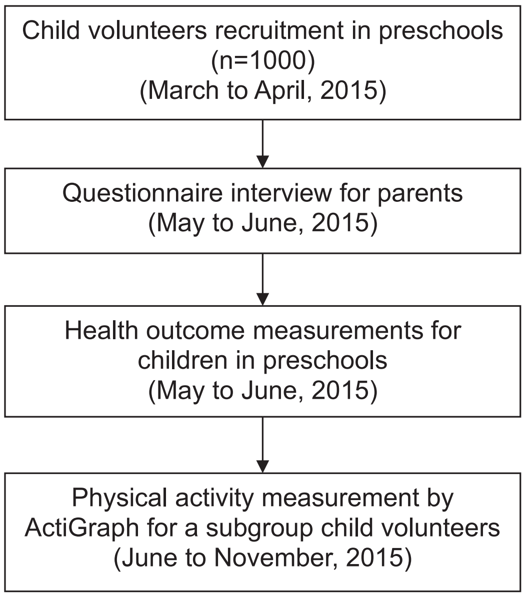

Figure 1 Flowchart of the procedure of data collection

Variables and measurement

Health outcomes

Children's health outcomes are measured in preschools by trained researchers and school nurses, including height and weight, waist and hip circumference, skinfold thickness and blood pressure measurements. Children are measured in the presence of their teachers in the nurse's office, and an additional measurement will be planned for the child who misses it. Each measurement will be taken by two researchers, one in charge of measurement and another for assisting with the right posture of the child. Each measurement (height, weight, waist and hip circumference) will be repeated twice, and an average will be computed. For skinfold thickness and blood pressure, measurements will be repeated three times, and at least two similar recordings will be taken.

Height and weight are measured without shoes and in light clothing using a stadiometer (to the nearest 0.1 cm) and digital scale (to the nearest 0.01 kg). The standardized Body Mass Index z-score (zBMI) of children is calculated using the LMS method; overweight and obesity will be classified according to the age- and gender-specific cut-offs of Cole and colleagues.[27] **Waist and hip circumference** are measured at the end of a free expiration by a non-elastic tape. Waist circumference is measured between the lower margin of the last palpable rib and the top of the iliac crest. Hip circumference is measured around the widest portion of buttocks.[28] Two right sites of body **skinfold thickness**, triceps and subscapular, are chosen as an indicator of body fat mass. The measurement is taken with a skinfold thickness caliper to the nearest 0.1 mm. Triceps skinfold thickness is measured approximately 2.0 cm above the mid-arm circumference mark. Subscapular skinfold thickness is measured at an angle of 45° to the lateral side of body roughly, at 2.0 cm above and medial to inferior angle of right scapula.[29] **Blood pressure** (BP), a risk factor of cardiovascular diseases, is measurement after the anthropometric measurements by experienced school nurses using a mercury sphygmomanometer in a quiet room. An appropriately sized cuff will be chosen for each child. The measurement of BP is followed by recommended techniques.[30] Three measurements will be taken on right arm with the child in sitting position. A child will be measured on another day if his/her blood pressure is equal to or higher than the 90^{th} percentile, or exceeding 120/80 mmHg.

Parents reported leisure time sedentary behaviour and activities

An adapted leisure time activities questionnaire for Chinese preschool children will be used in this study. The questionnaire aims to assess SB and PA among preschoolers during leisure time. In this study, leisure time was defined as time spent outside school hours on weekdays (including interest classes after school and time spent outdoors and at home, but not travel time) and entire weekend days. The items of leisure time activities were adapted from a seven-day PA questionnaire for Chinese primary school pupils, which showed a reliable estimate of the PA done during the past week in Chinese children.[31] The items of leisure time SB were adapted from the Neighbourhood Impact on Kids Survey-Sedentary Behaviours.[32] A pilot study (N = 50) has been performed to select items of activities for preschoolers by face to face interview to parents, and five sedentary behaviours and twelve physical activities are chosen for the questionnaire. The leisure time SB questionnaire included reading, writing or drawing; watching TV; playing with toys (stationary but moving arms); playing with mobile phone, tablet or electronic games; and using a computer. The leisure time PA questionnaire included running; football; climbing stairs; walking; 'Naughty castle'; playing on slide or swing; cycling; roller skating or scootering; dancing; taekwondo or other sports; climbing hills; and swimming. Parents reported the frequency and duration of these items, for example, how many minutes per day on average their children spent on each item during leisure time on schooldays in the past week (response categories ranged from 0 to 5 days) and on days over the past weekend (response categories ranged from 0 to 2 days). The average number of minutes was computed to obtain an overall average estimate for SB or PA during leisure time per day.

Objective measurement of sedentary time and physical activity

Tri-axial accelerometry (ActiGraph GT3X) will be used for objective measurement of daily ST and PA. The device is a non-invasive, water resistant, and light-weighted (19 grams) device. It provides an objective measure of intensity and duration of PA, and the frequency (bouts) of periods spent in a certain intensity of activity. It has been widely used in preschool children with a good validity.[33] The monitor will be affixed above the iliac crest of a child's right hip with an adjustable elastic belt.[34] Researchers will supervise the first time children wear the ActiGraph, for all children in classroom, with exact wear instructions. Instruction manuals for wearing the ActiGraph will be given to both main caregiver and school teacher. The school nurse, who is familiar with the school environment, accompanies the whole measurement. During the measurement, the main caregiver will fill in an ActiGraph diary with details of wearing periods for 7 days. The teacher will help children to adjust right position of monitors in preschool. The school nurse will remind parents to check children's daily wearing by sending group messages via 'Xiaoxuntong' (http://xxt.135-139.com/index.jsp). Researchers will support all participants with instruction using 'Wechat' during the whole measurement period. (https://weixin.qq.com/). Child volunteers should wear the ActiGraph during all waking hours for seven days, except while bathing or swimming.[35] Parents will send back the ActiGraph and diary to school nurse after the measurement. If the child volunteer did not wear the ActiGraph according to the manual instruction, the monitor will be send back to the child for additional measurements. Raw data of ActiGraph will be analyzed by Actilife with a standard protocol.

Outdoor play

To enhance outdoor activity may be an effective way for preschool children to be more active. The perceived child's outdoor play by parents will be asked for in this study, since it has been shown to significantly correlate to direct measurements of PA by accelerometry.[36] Questions are adapted from previous studies in the Netherlands.[37, 38] Child's outdoor play will be reported in frequency and duration for the past seven days, and given in minutes per week.

Active commuting

Parents will report their child's type and frequency of commuting to school in the previous five school days. Walking to school will be recoded into active commuting. Based on the pilot study, the question on cycling was removed from our questionnaire, as it is impracticable in urban China for preschool children. If the caregiver brings the child by car, by bike/electric bicycle, or by bus/subway, it will be recoded into inactive commuting. The distance from home to school will be measured as a confounder, both by parent' report and direct calculation of a digital map (Baidu). Commuting in leisure time will also be reported using the same method.

Environmental characteristics

Environmental characteristics were assessed using a revised and translated questionnaire. The level of internal consistency of the revised scales was acceptable in this study. Parents reported their perception of traffic safety, social support from family and communities and environmental quality in the neighbourhood. For the presence of PA facilities, parents reported their presence for six items (e.g., park, playground) within a defined distance in their neighbourhood (e.g., within a five minutes' walk or 20–30 minutes). Parents also reported their household characteristics (primary caregivers of their child, presence/absence of a lift, garden or car, the number of televisions/computers in the household, the presence of a television/computer in the child's bedroom). During the period of data collection, weather data will be collected from the Tianjin Observatory. Data of air quality will be collected from the online database of Tianjin Environmental Protection Bureau.

Covariates

Child birth characteristics and demographic factors will be collected at baseline. Child's gender, birth date, nationality and health status will be reported by parents. Parents will also report their family household address, family income, parental education levels and occupation information. Nutrition plays an important role in development of childhood overweight, and dietary information will be collected with a food frequency questionnaire.

Data analysis

For the descriptive analyses, data will be presented as rates in N and percentages, as means with standard deviations, or, if data were skewed, as the median with 25^{th} to 75^{th} percentile. To determine the relationships between potential correlates, PA patterns and ST, linear regression analysis adjusted for covariates will be conducted for each correlate. The significant variables will be analyzed by a multiple regression model. Missing values will be imputed by multiple imputations, if necessary. To examine the distribution of PA and ST of the children during the day and to identify which time slots differed from each other, a sensitivity analysis will be performed, using repeated measures ANOVA with hours as dependent variables. To examine the differences in PA and ST between groups, multiple linear mixed models, controlled for covariates will be performed.

ETHICS AND DISSEMINATION

The study will be conducted according to the principles of the Declaration of Helsinki (52^{nd} WMA General Assembly, Edinburgh Scotland, October 2000) and in accordance with the Medical Research Involving Human Subjects Act (WMO), February 1998. The study protocol has been approved by the Ethics Committee of Tianjin Medical University (TMUhMEC2014001).

Written informed consent will be obtained from parents of all participants. All data will be handled confidentially and anonymously. Each volunteer will be identified by a unique identification number during the study, which is code connected with a combination of his/her full name, birthdate and family address. The principal researcher safeguards the key to the code. Only this principal investigator will have access to the source data. All written data will be stored as a PDF version after removing personal data. These data will be kept for a maximum of five years after the end of study or the last publication on these data. The data will be used for research that is aimed at children's health. Each participant will receive a report on his/her physical examination and PA measurement. Results of the study will be presented at national and international scientific conferences, and published in international peer reviewed journals and doctoral theses.

STRENGH AND LIMITATIONS

An important strength of this study is the combination of both subjective and objective measurement of PA, which will allow adequate estimates for amount, but also type of PA. We selected participants based on differences in living environment, which are representative of an urban city's development. The preschools are chosen to be representative of the geographic, social and economic profile of the city. Limitations of the present study include its cross-sectional design, which precludes drawing conclusions on the direction or causality of the associations. The participants in this study are child volunteers. The children of parents who are more concerned about their child's health would be more likely to join in this study.

REFERENCES

1 World Health Organization. Global recommendations on physical activity for health. Geneva, Switzerland: World Health Organization 2010.

2 Hallal PC, Andersen LB, Bull FC, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects, *Lancet* 2012;380:247-57.

3 Zhu YG, Ioannidis JP, Li H, et al. Understanding and harnessing the health effects of rapid urbanization in China, *Environ Sci Technol* 2011;45:5099-104.

4 Qin L, Stolk RP, Corpeleijn E. Motorized transportation, social status, and adiposity: the China Health and Nutrition Survey, *Am J Prev Med* 2012;43:1-10.

5 Xu P, Chen Y, Ye X. Haze, air pollution, and health in China, *Lancet* 2013;382:2067.

6 Ng SW, Howard AG, Wang HJ, et al. The physical activity transition among adults in China: 1991-2011, *Obes Rev* 2014;15 Suppl 1:27-36.

7 Qin L, Corpeleijn E, Jiang C, et al. Physical activity, adiposity, and diabetes risk in middle-aged and older Chinese population: the Guangzhou Biobank Cohort Study, *Diabetes Care* 2010;33:2342-8.

8 Zhang J, Chaaban J. The economic cost of physical inactivity in China, *Prev Med* 2013;56:75-8.

9 Timmons BW, Leblanc AG, Carson V, et al. Systematic review of physical activity and health in the early years (aged 0-4 years), *Appl Physiol Nutr Metab* 2012;37:773-92.

10 Carson V, Kuzik N, Hunter S, et al. Systematic review of sedentary behavior and cognitive development in early childhood, *Prev Med* 2015;78:115-22.

11 Jones RA, Hinkley T, Okely AD, et al. Tracking physical activity and sedentary behavior in childhood: a systematic review, *Am J Prev Med* 2013;44:651-8.

12 Telama R, Yang X, Leskinen E, et al. Tracking of physical activity from early childhood through youth into adulthood, *Med Sci Sports Exerc* 2014;46:955-62.

13 Goldfield GS, Harvey A, Grattan K, et al. Physical activity promotion in the preschool years: a critical period to intervene, *Int J Environ Res Public Health* 2012;9:1326-42.

14 Sallis JF, Cervero RB, Ascher W, et al. An ecological approach to creating active living communities, *Annu Rev Public Health* 2006;27:297-322.

15 Bauman AE, Reis RS, Sallis JF, et al. Correlates of physical activity: why are some people physically active and others not? *Lancet* 2012;380:258-71.

16 Ding D, Sallis JF, Kerr J, et al. Neighborhood environment and physical activity among youth a review, *Am J Prev Med* 2011;41:442-55.

17 Gordon-Larsen P, Wang H, Popkin BM. Overweight dynamics in Chinese children and adults, *Obesity Reviews* 2014;15:37-48.

18 He W, James SA, Merli MG, et al. An Increasing Socioeconomic Gap in Childhood Overweight and Obesity in China, *Am J Public Health* 2014;104:E14-22.

19 Andegiorgish AK, Wang J, Zhang X, et al. Prevalence of overweight, obesity, and associated risk factors among school children and adolescents in Tianjin, China, *Eur J Pediatr* 2012;171:697-703.

20 Xiao Y, Qiao Y, Pan L, et al. Trends in the Prevalence of Overweight and Obesity among Chinese Preschool Children from 2006 to 2014, *PLoS One* 2015;10:e0134466.

21 Birch LL, Ventura AK. Preventing childhood obesity: what works? *Int J Obes (Lond)* 2009;33 Suppl 1:S74-81.

22 Sijtsma A, Sauer PJ, Stolk RP, et al. Is directly measured physical activity related to adiposity in preschool children? *Int J Pediatr Obes* 2011;6:389-400.

23 Bocca G, Corpeleijn E, van den Heuvel ER, et al. Three-year follow-up of 3-year-old to 5-year-old children after participation in a multidisciplinary or a usual-care obesity treatment program, *Clin Nutr* 2014;33:1095-100.

24 Pate RR, O'Neill JR, Brown WH, et al. Top 10 research questions related to physical activity in preschool children, *Res Q Exerc Sport* 2013;84:448-55.

25 Tremblay MS, Leblanc AG, Carson V, et al. Canadian Physical Activity Guidelines for the Early Years (aged 0-4 years), *Appl Physiol Nutr Metab* 2012;37:345-69.

26 Vandenbroucke JP, Von Elm E, Altman DG, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration, *Epidemiology* 2007;18:805-35.

27 Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity, *Pediatr Obes* 2012;7:284-94.

28 World Health Organization. Waist circumference and waist-hip ratio: report of a WHO expert consultation, Geneva, 8-11 December 2008. Geneva, Switzerland: World Health Organization 2011.

29 Centers for Disease Control and Prevention*National Health and Nutrition Examination Survey (NHANES) Anthropometry Procedures Manual.Atlanta, GA: CDC* 2007.

30 National Heart, Lung, and Blood Institute. A pocket guide to blood pressure

measurement in children, *National Institute of Health, US Department of Health and Human Services.NIH Publication* 2007:07-5268.

31 Liu AL, Ma GS, Zhang Q, et al. Reliability and validity of a 7-day physical activity questionnaire for elementary students, *Zhonghua Liu Xing Bing Xue Za Zhi* 2003;24:901-4.

32 Seattle Children's NIK Project. NIK Neighborhood Impact on Kids (NIK) Surveys. 2013.

33 Pate RR, O'Neill JR, Mitchell J. Measurement of physical activity in preschool children, *Med Sci Sports Exerc* 2010;42:508-12.

34 Cleland I, Kikhia B, Nugent C, et al. Optimal placement of accelerometers for the detection of everyday activities, *Sensors (Basel)* 2013;13:9183-200.

35 Cliff DP, Reilly JJ, Okely AD. Methodological considerations in using accelerometers to assess habitual physical activity in children aged 0-5 years, *J Sci Med Sport* 2009;12:557-67.

36 Burdette HL, Whitaker RC, Daniels SR. Parental report of outdoor playtime as a measure of physical activity in preschool-aged children, *Arch Pediatr Adolesc Med* 2004;158:353-7.

37 Aarts MJ, Wendel-Vos W, van Oers HA, et al. Environmental determinants of outdoor play in children: a large-scale cross-sectional study, *Am J Prev Med* 2010;39:212-9.

38 Sijtsma A, Koller M, Sauer PJ, et al. Television, sleep, outdoor play and BMI in young children: the GECKO Drenthe cohort, *Eur J Pediatr* 2015;174:631-9.

Chapter 9.2

Objectively Measured Physical Activity and Psychosocial Functioning in Young Children: The GECKO Drenthe Cohort

Esther Hartman, Dorien Ketelaar,
Congchao Lu, Eva Corpeleijn

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ABSTRACT

The global trend in inactivity in children may be related to psychosocial problems. We investigated the cross-sectional association between physical activity (PA) levels and psychosocial functioning in 3.4–7.3-year-old children. Children from the Dutch GECKO birth cohort (N = 898; 51.6% boys) had PA levels assessed objectively by accelerometry (ActiGraph GT3X) for at least three days. Linear regression analysis was used for associations with psychosocial functioning (parent report of the Strengths and Difficulties Questionnaire), controlling for gender, age and socio-economic status. Higher total and moderate-to-vigorous PA levels (MVPA) were associated with higher Total Difficulty scores, and sedentary time to lower Total Difficulty scores. More time spent in MVPA was significantly associated to "hyperactivity/inattention" in both boys (Standardized $B_{BOYS} = 0.192$) and girls ($Std.B_{GIRLS} = 0.139$) whereas for time in sedentary behaviour, a reverse association was found only in boys ($Std.B_{BOYS} = -0.230$). In boys only, more time in MVPA ($Std.B_{BOYS} = 0.154$) and less time in sedentary behaviour ($Std.B_{BOYS} = -0.147$), were significant determinants for 'behavioural problems'. When using objectively measured PA, parents report more hyperactivity/inattention and behavioural problems in the more active children, and less in the more sedentary children, most clearly for boys. High levels of PA might be an indicator for psychosocial problems in young children.

Keywords: Motor activity; mental health; child; preschool; accelerometry; questionnaires

Introduction

About 15–26% of children studied in epidemiological research regarding behaviour show notable symptoms of developing psychosocial problems (Fuchs, Klein, Otto, & von Klitzing, 2013). Problems with psychosocial functioning in young children can be defined as behavioural, emotional and social problems which could eventually result in several disorders, like conduct disorder, attention-deficit/hyperactivity disorder (ADHD), major depressive disorder, anxiety disorders or mood disorders in later childhood, adolescence and adulthood (American Psychiatric Association, 2018; Nilsen, Gustavson, Røysamb, Kjeldsen, & Karevold, 2013). In addition, psychosocial problems may affect children's learning and leisure activities, such as physical activity and participation in sports (Fuchs et al., 2013; Hasson et al., 2017; Lingineni et al., 2012). Nearly half of people display psychosocial disorders at some moment in their lives, with first onset usually early in life (Kessler et al., 2005). Therefore, early detection of psychosocial problems in young children is important, as it may contribute to prevention of more severe problems later in life.

In children and youth physical activity (PA) can provide several health benefits, and it has also been associated with psychosocial functioning (Biddle & Asare, 2011; Nijhof et al., 2018; Spruit, Assink, van Vugt, van der Put, & Stams, 2016). It has been shown that physiological effects of PA like norepinephrine and endorphins releases and larger blood supply to the brain can be related to better mental health, as cognitive functioning and mood increases and stress reduces (Spruit et al., 2016). Therefore, PA could serve as a modifiable factor in order to prevent psychosocial problems in children and youth. However, the global trend of increasing levels of physical inactivity and sedentary behaviour affects children as well, and this may result in more severe psychosocial problems during childhood and adolescence (Ahn & Fedewa, 2011; Mitchell & Steele, 2017). In children, sedentary behaviour can be characterized as TV viewing, computer time, playing video games, i.e., screen time (Hamer, Stamatakis, & Mishra, 2009), and it also includes other activities in sitting or lying posture like playing with toys, drawing or reading books (Downing, Janssen, Cliff, Okely, & Reilly, 2019).

A meta-analysis in children and youth from a wide age range (3–18y, mean age = 12.6, SD = 2.9) found that greater physical activity was related to a lesser likelihood of experiencing detrimental mental health outcomes (Ahn & Fedewa, 2011).Unfortunately, the meta-analysis did not describe the results of children from different age groups, so specific results in young children are not clear yet. A review study on early childhood (children younger than 6 years) reported that no clear conclusions could be drawn regarding relationships between physical activity and sedentary behaviour with psychosocial behaviour (Hinkley et al., 2014). The researchers warranted more studies on PA and sedentary behaviour, captured with objective measures such as accelerometry (Hinkley et al., 2014). Possibly, the lack of objective measures could have contributed to the inconsistent results, in addition to the relatively small number of studies that were found.

Taken together, identifying the unique relationships between objectively measured levels of PA and sedentary behaviour with psychosocial functioning in young children may support early identification of problems, and thereby early intervention or prevention programs to avoid the development of more serious mental health problems later in life.

The aim of the present study is to investigate the association between objectively measured levels of PA and sedentary behaviour with psychosocial functioning in young children. It is hypothesized that in these young children, high levels of PA are associated with lower scores on psychosocial problems and that high levels of sedentary behaviour are associated with more psychosocial problems.

Methods

Study design and participants

Data was derived from the GECKO Drenthe cohort, a large ongoing prospective population-based birth cohort study aimed to investigate the determinants of health in early life (Figure 1). All mothers from children born from April 2006 to April 2007 and living in Drenthe, a northern province of the Netherlands, were invited to participate during the third trimester of their pregnancy. Detailed information has been published elsewhere (L´Abée, Sauer, Damen, Rake, Cats, & Stolk, 2008). The data in the present study should be considered as cross-sectional. Age at time of data collection was defined by the date difference between moment of measurement and birth date (Sijtsma, Koller, Sauer, & Corpeleijn, 2015). Data on physical activity were collected between May 2011 and October 2013; the children were on average 5.6 years of age (5th – 95th age percentile: 4.3–6.9). Data on psychosocial functioning were collected between January 2011 and September 2013; the children were on average 5.8 years of age 5th – 95th age percentile: 5.3–6.3).

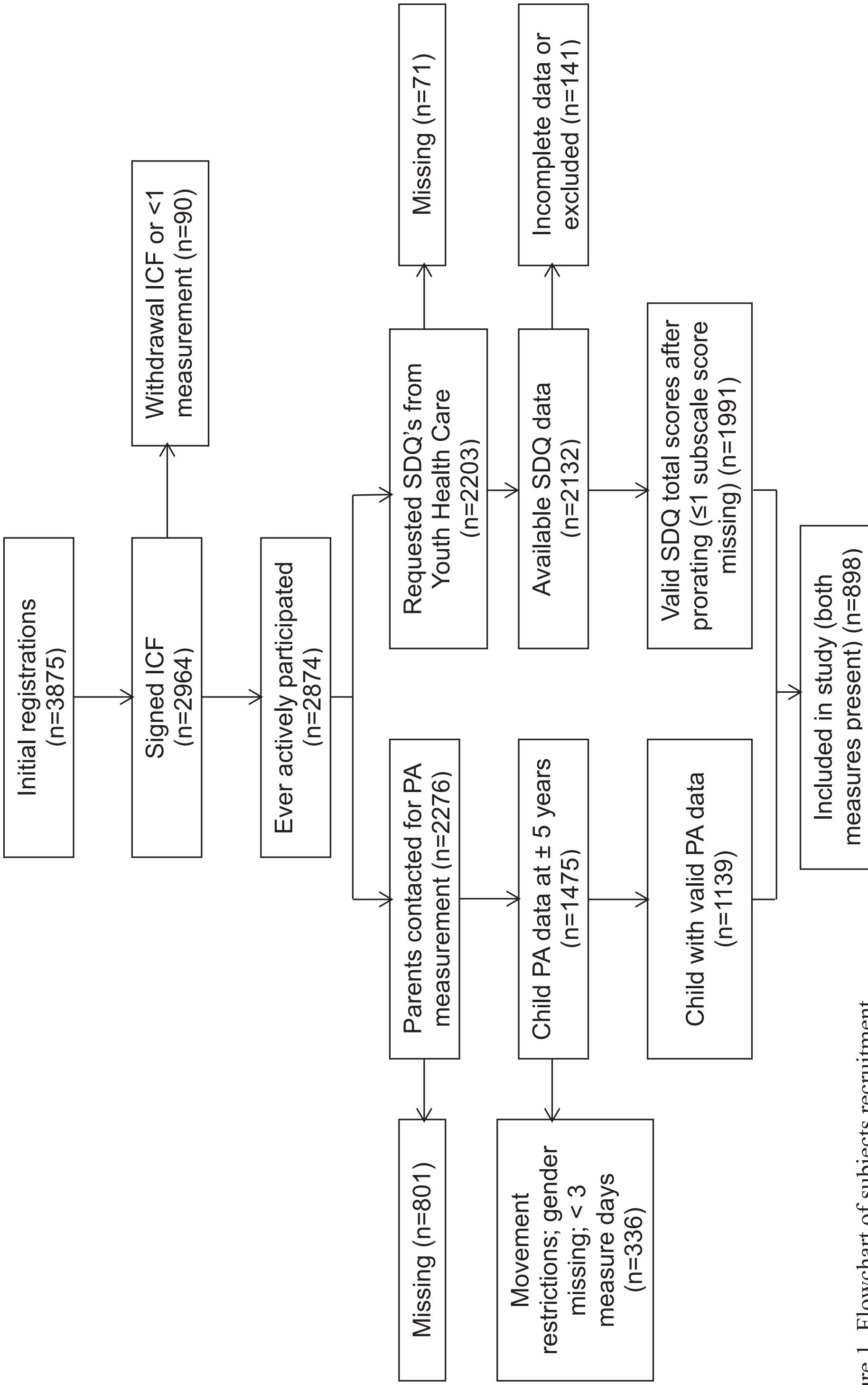

Figure 1. Flowchart of subjects recruitment.

The average age difference was 0.2 ± 0.8 months, and a 95% confidence interval of −1.3 to 1.6 years indicated that in 5% of children, psychosocial functioning was measured 1.6 years after the physical activity assessment, and that in 5% of children psychosocial functioning was measured 1.3 years before the PA assessment.

The study was approved by the Medical Ethics Committee of the University Medical Center Groningen and performed in accordance with the Declaration of Helsinki and all parents gave informed consent.

Measurements

Height, weight, and socio-economic status

At the age of six years, height and weight were measured by trained nurses from the municipal health services. Height and weight were measured by trained Youth Health Care nurses according to a standardized protocol. Weight was measured in light clothing using an electronic scale with digital reading, and recorded to the nearest 0.1 kg. Height was assessed using a stadiometer and recorded to the nearest 0.1 cm. Socio-economic status (SES) was assessed by a deprivation score based on postal code. The score has been provided by the Dutch Social and Cultural Planning Office of the Dutch government and is based on mean income, education level and unemployment rates (Dutch Social and Cultural Planning Office, 2018).

Psychosocial functioning

Psychosocial problems were assessed with the Dutch version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). Parents completed the questionnaires, which were collected and processed by the municipal health services. The SDQ is a short questionnaire (25 items), on positive attributes of the child as well as difficulties. It has good acceptability by respondents (Goodman, 2001). The items are grouped into five subscales, "prosocial behaviour" (i.e., being helpful), 'emotional problems' (i.e., unhappiness), 'behavioural problems' (i.e., conduct problems), 'peer problems' (i.e., friendless) and "hyperactivity/inattention" (i.e., restless). Every scale consists of five items that are equally weighted and scored on a 3-point scale from "not true", "somewhat true" to "certainly true". The prosocial scale is reverse scored and excluded from the total difficulties score (Goodman, 2001). When no more than one of the four subscale scores was missing the Total Difficulties score was prorated by substituting the mean. High scores indicate high symptom levels. The SDQ is considered to be a valid and reliable instrument for evaluating psychosocial functioning in children and youth. The proposed five-factor structure has a satisfactory fit in children and adolescents (aged 3–16 years) (Björnsdotter, Enebrink, & Ghaderi, 2013; Goodman, 2001; Muris, Meesters, & van den Berg, 2003). The internal consistency (Cronbach's alpha) of the SDQ parent report is moderate to high, varying between 0.50 and 0.78 for the subscales and around 0.80 for the Total Difficulties in children and adolescents. Subscales with the lowest scores are 'peer problems', 'emotional problems' and 'behavioural problems' (Björnsdotter et al., 2013; Goodman, 2001; Theunissen, Vogels, de Wolff, Crone, & Reijneveld, 2015). Concurrent validity with the Child Behaviour Checklist (CBCL) is moderate to high, around 0.70 (Pearson correlation) (Muris et al., 2003; Theunissen et al., 2015). Retest stability of the SDQ parent report is satisfactory after two months (correlations between 0.75 and 0.91) (Muris et al., 2003) and after four to six months (correlations between 0.61 and 0.72) (Goodman, 2001). In nearly all studies mentioned earlier regarding psychometric properties of the SDQ, representative community samples were used.

Physical activity

PA in children was assessed using the ActiGraph GT3X (ActiGraph, Pensacola, FL). Parents of all children participating in the GECKO Drenthe birth cohort study were contacted to collect PA data of their child. Parents were instructed to let their child wear the ActiGraph on the iliac crest with an elastic belt on the right hip for four days, of which at least one weekend day, during all waking hours except while bathing or swimming. For valid measurements, wearing time had to be at least 600 minutes/day for at least three days, regardless whether these were week or weekend days. Non-wearing time of the ActiGraph was classified as a minimum length of 90 minutes without any observed counts. Cut-points were used to calculate time spent in sedentary vs light (240 counts per minute), light vs moderate PA (2120 counts per minute), and moderate vs vigorous PA (4450 counts per minute) (Butte et al., 2014). An epoch time of 15 s was used for analyses. Data were collected using a frequency of 30 Hz. All children with wearing time ≥ 840 minutes/day (14 hours/day) were checked manually for sleeping time. Sending the accelerometers by post sometimes resulted in a valid wearing day (> 10 h/day). These postmen days were identified by low light activity (≤ 100 min/day) and deleted (Sijtsma et al., 2015).

Statistical Analysis

Values are presented as numbers (%), means (± standard deviations) and range (minimum-maximum). Skewed or ordinal variables are presented as median (25^{th} and 75^{th} percentile) and were ln-transformed for linear regression analysis. SES scores were used as a continuous variable in the analyses but shown in Tables as three categories: scores below −1 were considered as low SES and scores above +1 as high SES. The remaining scores were considered as "middle SES". Differences in gender were compared using non-parametric tests (Mann-Whitney U) because most PA variables were not normally distributed. The associations between PA and psychosocial functioning were investigated using Spearman correlations (r_s). When associations were significant, linear regression analyses were conducted with adjustment for age at psychosocial functioning assessment, age at PA assessment, gender and SES. If necessary, variables were ln-transformed. To investigate gender differences, interaction models for gender were studied. Standardized beta coefficients and unstandardized beta coefficients with 95% confidence intervals were shown for regression analyses. An alpha level lower than 0.05 was considered significant. Statistical analyses were conducted using IBM SPSS Statistics 23 for Windows (SPSS Inc., Chicago, IL).

Results

Descriptives

Of the 2875 children that ever participated, 2203 were seen by Youth Health Care nurses at kindergarten. Of these, 2132 parents filled in the SDQ questionnaires (97%), of which 1991 were valid. From the 1475 children with PA data, 1139 were valid. In total 898 children with valid PA and SDQ data were included in the data analysis (see Figure 1). The age range of the children was between 3.4 and 7.3 years old during the measurements (Table 1). About half (51.6%) of the children were boys, and boys were more active than girls. There was no significant difference in age, BMI and SES between boys and girls. Furthermore, boys had higher scores on SDQ Total Difficulties, and subscores "hyperactivity/inattention" and 'behavioural problems'. In the study population, an abnormal Total Difficulties score (20–40) was found in 1.3% of the sample and 1.3% was considered borderline (17–19). In boys 2.6% had an abnormal Total Difficulties score and 1.3% had a borderline score, whereas in girls 1.4% scored borderline, and no abnormal scores were found. Details are shown in Table 1.

Table 1. Descriptive characteristics of the study population.

	Total			Boys			Girls		
GENERAL	N		Min – max	N		Min – max	N		Min – max
Age at PA measurement (years)	898	5.6 ± 0.8	3.4–7.3	463	5.6 ± 0.8	3.4–7.3	435	5.6 ± 0.8	3.6–7.3
Age at SDQ (years)	898	5.8 ± 0.3	4.8–6.8	463	5.8 ± 0.3	4.8–6.8	435	5.8 ± 0.3	4.9–6.8
BMI (kg/m^2)	864	15.9 ± 1.3	13.3–22.4	446	15.9 ± 1.2	13.3–20.5	418	16.0 ± 1.4	13.2–22.4
SES	882			451			431		
Low		197 (22.3)			105 (23.3)			92 (21.3)	
Middle		566 (64.2)			287 (63.6)			279 (64.7)	
High		119 (13.5)			59 (13.1)			60 (13.9)	
PHYSICAL ACTIVITY									
Total CPM (counts)[a]	898	805 ± 220	338–2033	463	840 ± 234	397–2033	435	767 ± 198	338–1647
Sedentary time (min/day)[a]	898	373 ± 57	221–630	463	367 ± 57	243–630	435	378 ± 56	221–554
Light PA (min/day)	898	265 ± 38	155–380	463	265 ± 37	170–361	435	265 ± 39.1	155–380
Moderate PA (min/day)[a]	898	43.8 (35.6–54.7)	10–117	463	47.3 (39.5–60.1)	17–117	435	40.0 (31.4–49.3)	10–88
Vigorous PA (min/day)[a]	898	17.0 (11.4–24.5)	2–97	463	19.2 (12.9–27.0)	2–97	435	14.7 (10.2–22.2)	2–65
MVPA (min/day)[a]	898	61.4 (47.9–80.1)	12–183	463	68.3 (53.3–85.9)	20–183	435	54.8 (42.9–71.2)	12–129
SDQ									
Total Difficulties[a]	898	5 (2–7)	0–23	463	5 (3–8)	0–23	435	4 (2–7)	0–19
Hyperactivity/inattention[a]	897	2 (1–4)	0–10	462	3 (1–5)	0–10	435	1 (0–3)	0–10
Peer problems	888	0 (0–1)	0–7	459	0 (0–1)	0–7	429	0 (0–1)	0–5
Emotional problems	895	1 (0–2)	0–8	462	1 (0–2)	0–8	433	1 (0–2)	0–7
Behavioural problems[a]	891	0 (0–2)	0–8	458	1 (0–2)	0–8	433	0 (0–1)	0–7
Prosocial behaviour[a, b]	892	9 (8–10)	1–10	458	9 (7–10)	1–10	434	9 (8–10)	2–10

[a] $p < 0.05$ for gender, [b] the prosocial scale is not included in the total score; and high scores are positive. BMI, Body Mass Index; CPM, counts per minute; MVPA, moderate-to-vigorous physical activity; PA, physical activity; SDQ, Strengths and Difficulties Questionnaire; SES: Socio-economic Status (deprivation score). Data are presented as mean ± SD, N (%) or median (25^{th} – 75^{th} percentile).

Associations between PA levels and psychosocial functioning

The correlations between PA and psychosocial functioning are presented in Table 2. Higher PA levels were associated with higher scores for Total Difficulties and the subscales "hyperactivity/inattention" and 'behavioural problems', whereas time spent in sedentary behaviour was associated with lower scores for Total Difficulties and "hyperactivity/inattention". Since the associations were present for moderate PA, vigorous PA as well as for MVPA, analyses were continued with MVPA only.

Since boys and girls differed both in PA levels as well as SDQ scores, correlations were investigated for boys and girls separately. In boys, Total counts per minute (CPM) was significantly associated with Total Difficulties ($r_s = 0.115$, $p = 0.013$) and MVPA was positively associated with Total Difficulties ($r_s = 0.148$, $p = 0.001$). Time in sedentary behaviour was inversely associated with Total Difficulties ($r_s = -0.169$, $p = 0.000$). The association between Total CPM and Total difficulties was explained by association with subscale 'hyperactivity/inattention' ($r_s = 0.154$, $p = 0.001$) and subscale 'behavioural problems' ($r_s = 0.101$, $p = 0.030$).

The association between Total CPM and "hyperactivity/inattention" in boys could be explained by an inverse association of sedentary time with "hyperactivity/inattention" ($r_s = -0.233$, $p = 0.000$) and a positive association of LPA with "hyperactivity/inattention" ($r_s = 0.123$, $p = 0.008$) and MVPA with "hyperactivity/inattention" ($r_s = 0.194$, $p = 0.000$). After adjustment for exact age and SES (see Table 3), these associations remained virtually unchanged in boys (sedentary time: Std B −0.230; LPA: 0.136; MVPA: 0.192). The association between Total CPM and 'behavioural problems' in boys could be explained by time in sedentary behaviour ($r_s = -0.132$, $p = 0.005$) and MVPA ($r_s = 0.157$, p = 0.001) but not by time in LPA. The adjustments for exact age and SES (see Table 4) did not substantially change these findings (sedentary time: Std B −0.147; MVPA: 0.154).

In girls, only MVPA was associated with "hyperactivity/inattention" ($r_s = 0.139$, $p = 0.004$), whereas a trend was seen for time in sedentary behaviour and 'hyperactivity/inattention' ($r_s = -0.091$, $p = 0.059$). The adjustment for exact age and SES (see Table 3) did not change the association for MVPA (Std B 0.139), or sedentary behaviour and "hyperactivity/inattention" (Std B −0.094, $p = 0.057$).

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Table 2. Correlations between physical activity and psychosocial functioning in young children (n = 898).

	Total Difficulties	Hyperactivity/ inattention	Peer problems	Emotional problems	Behavioural problems	Prosocial behaviour[a]
Total CPM	0.080*	0.140**	−0.025	−0.040	0.054	0.000
Sedentary behaviour	−0.117**	−0.179**	0.022	−0.003	−0.059	−0.025
Light PA	0.038	0.100**	−0.025	−0.017	0.000	0.057
Moderate PA	0.149**	0.224**	−0.014	−0.042	0.117**	−0.032
Vigorous PA	0.102*	0.170**	−0.018	−0.043	0.076*	−0.063
MVPA	0.141**	0.218**	−0.014	−0.047	0.107**	−0.049

*Spearman correlation coefficients and p-values (between brackets) are given. [a] the prosocial scale is not included in the total score; and high scores are positive. * $p < 0.05$ ** $p < 0.01$ CPM, Counts per minute; MVPA, moderate to vigorous physical activity; PA, physical activity*

Table 3. Regression analysis for the PA levels and psychosocial functioning "hyperactivity/inattention" in young children for the total population and stratified by gender.

	Total			Boys			Girls		
Hyperactivity/inattention (ln)	Std. B	B	95% CI of B	Std. B	B	95% CI of B	Std. B	B	95% CI of B
Sedentary time									
Model 1: SED	**−0.170**	**−0.002**	**(−0.003; −0.001)**	**−0.206**	**−0.002**	**(−0.004; −0.001)**	−0.099	−0.001	(−0.002; 0.000)
Model 2: SED	**−0.165**	**−0.002**	**(−0.003; −0.001)**	**−0.230**	**−0.003**	**(−0.004; −0.002)**	−0.094	−0.001	(−0.002; 0.000)
Model 3: SED	**−0.316**	**−0.004**	**(−0.006; −0.001)**	-	-	-	-	-	-
SED ×Gender	0.385	0.001	(0.000; 0.003)	-	-	-	-	-	-
Light physical activity									
Model 1: LPA	**0.083**	**0.002**	**(0.000; 0.003)**	**0.108**	**0.002**	**(0.000; 0.004)**	0.065	0.001	(-0.001; 0.003)
Model 2: LPA	**0.097**	**0.002**	**(0.001; 0.003)**	**0.136**	**0.002**	**(0.001; 0.004)**	0.060	0.001	(-0.001; 0.003)
Model 3: LPA	0.187	0.003	(0.000; 0.007)	-	-	-	-	-	-
LPA ×Gender	−0.228	−0.001	(−0.003; 0.001)	-	-	-	-	-	-
Moderate-to-vigorous physical activity (ln)									
Model 1: MVPA	**0.217**	**0.397**	**(0.280; 0.515)**	**0.196**	**0.367**	**(0.198; 0.535)**	**0.136**	**0.252**	**(0.079; 0.424)**
Model 2: MVPA	**0.171**	**0.312**	**(0.190; 0.433)**	**0.192**	**0.358**	**(0.187; 0.530)**	**0.139**	**0.257**	**(0.084; 0.430)**
Model 3: MVPA	**0.242**	**0.442**	**(0.057; 0.826)**	-	-	-	-	-	-
MVPA ×Gender	−0.243	−0.086	(−0.329; 0.156)	-	-	-	-	-	-

Model 1, crude; model 2, adjusted for SES, age and gender (if applicable), model 3, adjusted for SES, age, gender and interaction with gender. Ln, ln transformation. SED, sedentary time, LPA, light physical activity, MVPA, moderate-to-vigorous activity

Table 4. Regression analysis for the PA levels and psychosocial functioning 'behavioural problems' in young children for the total population and stratified by gender.

	Total			Boys			Girls		
Behavioural problems (ln)	Std. B	B	95% CI	Std. B	B	95% CI	Std. B	B	95% CI
Sedentary time									
Model 1: SED	**−0.073**	**−0.001**	**(−0.001; 0.000)**	**−0.140**	**−0.001**	**(−0.002; 0.000)**	0.034	0.000	(−0.001; 0.001)
Model 2: SED	−0.055	−0.001	(−0.001; 0.000)	**−0.147**	**−0.001**	**(−0.002; −0.001)**	0.055	0.000	(0.000; 0.001)
Model 3: SED	**−0.308**	**−0.003**	**(−0.005; −0.001)**	-	-	-	-	-	-
SED × Gender	**0.643**	**0.002**	**(0.000; 0.003)**	-	-	-	-	-	-
Light physical activity									
Model 1: LPA	−0.007	0.000	(−0.001; 0.001)	0.065	0.001	(0.000; 0.002)	−0.085	−0.001	(−0.002; 0.000)
Model 2: LPA	−0.015	0.000	(−0.001; 0.001)	0.068	0.001	(0.000; 0.003)	**−0.105**	**−0.001**	**(−0.003; 0.000)**
Model 3: LPA	0.196	0.003	(0.000; 0.006)	-	-	-	-	-	-
LPA × Gender	**−0.533**	**−0.002**	**(−0.004; 0.000)**	-	-	-	-	-	-
Moderate-to-vigorous physical activity (ln)									
Model 1: MVPA	**0.109**	**0.155**	**(0.062; 0.248)**	**0.145**	**0.225**	**(0.084; 0.366)**	−0.012	−0.016	(−0.147; 0.115)
Model 2: MVPA	**0.073**	**0.103**	**(0.006; 0.200)**	**0.154**	**0.236**	**(0.092; 0.380)**	−0.022	−0.031	(−0.162; 0.100)
Model 3: MVPA	**0.350**	**0.496**	**(0.189; 0.803)**	-	-	-	-	-	-
MVPA × Gender	**−0.945**	**−0.261**	**(−0.454; −0.067)**	-	-	-	-	-	-

Model 1, crude; model 2, adjusted for SES, age and gender (if applicable), model 3, adjusted for SES, age, gender and interaction with gender. Ln, ln transformation. SED, sedentary time, LPA, light physical activity, MVPA, moderate-to-vigorous activity

Discussion

The aim of the present study was to investigate the association between objectively measured levels of PA and sedentary behaviour with psychosocial functioning in young children. The study showed that parents from highly active children reported higher scores on psychosocial problems. In contrast, parents from children who were more sedentary reported fewer psychosocial problems.

The present study showed that more PA was associated with more hyperactivity/inattention and behavioural problems in young children, in particular in boys. Our results were not in accordance with a meta-analysis in children and youth from a wide age range (3–18 years) showing a positive association between PA and psychosocial well-being (Ahn & Fedewa, 2011). The contrasting results from our study with those from Ahn & Fedewa (2011) could be related to the different activity patterns in young children relative to older children. Older children are more engaged in organized activities, like organized sports, whereas young children are more engaged in unorganized activities, like playing. It has been shown that physical activity patterns in younger children are more intermittent than in older children (Bailey et al., 1995; Colley, Harvey, Grattan, & Adamo, 2014). Furthermore, the increased MVPA in our study population of young children could be partly an expression of underlying behavioural problems. The intrinsic need to be active can be strong in children and increased MVPA could be perceived by parents and others as "restless behaviour". An advantage in our study is that PA was measured using an objective device, so children classified as hyperactive by their parents showed, in reality, higher activity levels than other children, it was not just their perception.

Our results add to the lack of evidence that was shown in a review regarding the relationship between PA and sedentary behaviour with psychosocial functioning in young children (< 6 years) (Hinkley et al., 2014). A possible explanation for the contrasting results with Hinkley et al. (2014) could be the lack of objectively measured physical activity in the studies that were reviewed. Only one of the 19 studies used accelerometry for measuring PA and sedentary behaviour (Ebenegger et al., 2012). Although in their study measurements of psychosocial problems were restricted to the subscale "hyperactivity/inattention", and boys and girls were not considered separately, it is interesting to mention that we also found a negative association between sedentary behaviour and hyperactivity/inattention in our total sample, but only in boys. In addition, our study extends evidence from Ebenegger et al. (2012) to the subscale ‘behavioural problems’, but again the negative association was only demonstrated in boys. Sedentary behaviour might be experienced as calm behaviour when children are sitting and watch television for example. Finally, our results confirmed results from Ebenegger et al. (2012) that more MVPA was associated with higher scores on hyperactivity/inattention, and we added similar results on behavioural problems, but only in boys. In future studies on young children, use of accelerometry and identification of different subdomains of psychosocial functioning is warranted.

An interesting finding was that the association between PA levels and psychosocial functioning was stronger in boys compared to girls. These results are in contradiction with those from the meta-analysis from Biddle & Asare (2011), showing no differential effects for gender in cross-sectional studies. Possibly, in our study, the SDQ was more suitable for investigating psychosocial problems in boys compared to girls, reflecting boys’ behaviour better than that of girls. The finding that boys had higher scores on the SDQ total and the subscales extends results from previous research in older children and adolescents (Mohammadi et al., 2014; Muris et al., 2003) to younger children. Similar, the finding that boys were more physically active than girls is in agreement with earlier studies in preschoolers (aged 2–5 years) using objective measures (Hinkley, Crawford, Salmon, Okely, & Hesketh, 2008; Jackson et al., 2003; Pate, Pfeiffer, Trost, Ziegler, & Dowda, 2004). Based on the gender differences found in our study, boys are in particular an interesting subgroup for PA-interventions aimed at improving mental health. Future studies should keep in mind that differential effects might exist in young children. In addition, it would be interesting to study possible mechanisms behind the differences between boys and girls. In summary, our study provides evidence that in young children, stronger relations exist in boys than in girls between levels of PA and sedentary behaviour with psychosocial outcomes.

The findings in our study implicate that high MVPA might be an indicator for psychosocial problems in young children. One could argue that objectively measuring PA can help to identify children who are hyperactive. In that respect, measuring PA as a supportive tool could be relevant for diagnostic and screening purposes for early identification of psychosocial problems. It may even be helpful for parental support to analyse which parts of the day these children are hyperactive in order to improve coping strategies. Interestingly, this association seemed to cover the whole range of levels of activity, and not just the extremely active children. Thus, it was also found that boys with higher levels of sedentary behaviour are perceived as having very few difficulties in the psychosocial domain. Because of the cross-sectional nature of the present study, it is not possible to draw conclusions about causality of this relation. In addition, it must be noted that sedentary behaviour is associated with negative health effects in children (Stiglic & Viner, 2019; Wu, et al., 2017).

Important strengths of this study were the representativeness of the study population with regard to SES, the young age, the large sample size and the objectively measured PA levels of the children. Objective measures of PA are hardly performed in young children, as most previous research used questionnaires for measuring PA. However, often in PA questionnaires, people tend to overestimate MVPA and underestimate sedentary behaviour (Reilly et al., 2008). Furthermore, PA levels of young children are highly variable (Pate et al., 2004) which makes it unlikely that parents can make reliable estimates. In addition, parents who perceive very active behaviour as problematic may be inclined to over report this type of behaviour.

A limitation of this study is that the associations were based on cross-sectional data, which prevents us from drawing conclusions about causal relationships. With regard to the SDQ, there is a possibility of report bias. In this study we used parent reports, but no additional teacher reports. Furthermore, although the validity of the SDQ is considered to be moderate to high (Goodman, 2001; Muris et al., 2003), the 'behavioural problems' subscale was one of the scales with low-moderate internal consistency (Björnsdotter et al., 2013; Goodman, 2001; Theunissen et al., 2015). A possible explanation for this could be that questions of this subscale reflected better boys' behaviour than that of girls. Another point is that using the Actigraph data, we cannot discern between moderate to vigorous activity like running during playing in the playground and "hyperactivity" as inappropriate high activity given the situation.

Our study infers some practical implications. Firstly, spontaneous higher levels of PA are related to higher levels of psychosocial problems as reported by parents, which in turn are expected to lead to long-term lower physical activity levels or lower sports participation. Secondly, associations between PA levels and psychosocial functioning are different for boys and girls, and associations in young children compared to those in older children or adults are not the same. These differences must be taken into account when PA-interventions are developed. And finally, objective measurements of PA may be helpful to identify children with hyperactivity/inattention and behavioural problems at young age.

In conclusion, when using objectively measured PA, parents report more hyperactivity/inattention and behavioural problems in the more active children, and less in the more sedentary children, most clearly for boys. Furthermore, very high PA might be an indicator for less psychosocial functioning in young children. These findings could be helpful in screening and diagnostics. Longitudinal research is desired to further investigate the association between PA and psychosocial functioning in young children.

References

Ahn, S., & Fedewa, A. L. (2011). A meta-analysis of the relationship between children's physical activity and mental health. *Journal of Pediatric Psychology*, *36*(4), 385-397.

American Psychiatric Association. DSM-5 development. Accessed July, 2018. http://www.dsm5.org/Pages/Default.aspx.

Bailey, R. C., Olson, J. O. D. I., Pepper, S. L., Porszasz, J. A. N. O. S., Barstow, T. J., & Cooper, D. M. (1995). The level and tempo of children's physical activities: An observational study. *Medicine and Science in Sports and Exercise*, *27*(7), 1033-1041.

Biddle, S. J., & Asare, M. (2011). Physical activity and mental health in children and adolescents: A review of reviews. *British Journal of Sports Medicine*, 45(11), 886-895.

Björnsdotter, A., Enebrink, P., & Ghaderi, A. (2013). Psychometric properties of online administered parental strengths and difficulties questionnaire (SDQ), and normative data based on combined online and paper-and-pencil administration. *Child and Adolescent Psychiatry and Mental Health*, *7*(1), 40.

Butte, N. F., Wong, W. W., Lee, J. S., Adolph, A. L., Puyau, M. R., & Zakeri, I. F. (2014). Prediction of energy expenditure and physical activity in preschoolers. *Medicine and Science in Sports and Exercise*, *46*(6), 1216.

Colley, R. C., Harvey, A., Grattan, K. P., & Adamo, K. B. (2014). Impact of accelerometer epoch length on physical activity and sedentary behaviour outcomes for preschool-aged children. *Health Reports / Statistics Canada, Canadian Centre for Health Information = Rapports Sur La Sante / Statistique Canada, Centre Canadien D'information Sur La Sante, 25(1), 3-9.*
Downing, K. L., Janssen X., Cliff D. P., Okely, A. D., & Reilly J. J. (2019) Energy expenditure associated with posture transitions in preschool children. *PLoS One, 14*(4): e0215169.

Dutch Social and Cultural Planning Office. Statusscores. Accessed July, 2018. http://www.scp.nl/Onderzoek/Lopend_onderzoek/A_Z_alle_lopende_onderzoeken/Statusscor es.

Ebenegger, V., Marques-Vidal, P. M., Munsch, S., Quartier, V., Nydegger, A., Barral, J., ... & Puder, J. J. (2012). Relationship of hyperactivity/inattention with adiposity and lifestyle characteristics in preschool children. *Journal of Child Neurology*, *27*(7), 852-858.

Fuchs, S., Klein, A. M., Otto, Y., & von Klitzing, K. (2013). Prevalence of emotional and behavioral symptoms and their impact on daily life activities in a community sample of 3 to 5-year-old children. *Child Psychiatry & Human Development*, *44*(4), 493-503.

Goodman, R. (1997). The strengths and difficulties questionnaire: A research note. *Journal of Child Psychology and Psychiatry*, *38*(5), 581-586.

Goodman, R. (2001). Psychometric properties of the strengths and difficulties questionnaire. *Journal of the American Academy of Child & Adolescent Psychiatry*, *40*(11), 1337-1345.

Hamer, M., Stamatakis, E., & Mishra, G. (2009). Psychological distress, television viewing, and physical activity in children aged 4 to 12 years. *Pediatrics*, *123*(5), 1263-1268.

Hasson, R. E., Brown, D. R., Dorn, J., Barkley, L., Torgan, C., Whitt-Glover, M., ... & Keith, N. (2017). Achieving equity in physical activity participation: ACSM experience and next steps. *Medicine and Science in Sports and Exercise*, *49*(4), 848-858.

Hinkley, T., Crawford, D., Salmon, J., Okely, A. D., & Hesketh, K. (2008). Preschool children and physical activity: A review of correlates. *American Journal of Preventive Medicine*, *34*(5), 435-441.

Hinkley, T., Teychenne, M., Downing, K. L., Ball, K., Salmon, J., & Hesketh, K. D. (2014). Early childhood physical activity, sedentary behaviors and psychosocial well-being: A systematic review. *Preventive Medicine*, *62*, 182-192.

Jackson, D. M., Reilly, J. J., Kelly, L. A., Montgomery, C., Grant, S., & Paton, J. Y. (2003). Objectively measured physical activity in a representative sample of 3-to 4-year-old children. *Obesity Research*, *11*(3), 420-425.

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the national comorbidity survey replication. *Archives of General Psychiatry*, *62*(6), 593-602.

L'Abée, C., Sauer, P. J., Damen, M., Rake, J. P., Cats, H., & Stolk, R. P. (2008). Cohort Profile: the GECKO Drenthe study, overweight programming during early childhood. International Journal of Epidemiology, *37*(3), 486-489.

Lingineni, R. K., Biswas, S., Ahmad, N., Jackson, B. E., Bae, S., & Singh, K. P. (2012). Factors associated with attention deficit/hyperactivity disorder among US children: Results from a national survey. *BMC Pediatrics*, *12*(1), 50.

Mitchell, T. B., & Steele, R. G. (2017). Latent profiles of physical activity and sedentary behavior in elementary school-age youth: Associations with health-related quality of life. *Journal of Pediatric Psychology*, *43*(7), 723-732.

Mohammadi, M. R., Salmanian, M., Ghanizadeh, A., Alavi, A., Malek, A., Fathzadeh, H., ... & Motavallian, A. (2014). Psychological problems of Iranian children and adolescents: Parent report form of Strengths and Difficulties Questionnaire. *Journal of Mental Health*, *23*(6), 287-291.

Muris, P., Meesters, C., & van Den Berg, F. (2003). The strengths and difficulties questionnaire (SDQ). *European Child & Adolescent Psychiatry*, *12*(1), 1-8.

Nijhof, S. L., Vinkers, C. H., van Geelen, S. M., Duijff, S. N., Achterberg, E. M., van der Net, J., ... & van der Brug, A. W. (2018). Healthy play, better coping: The importance of play for the development of children in health and disease. *Neuroscience & Biobehavioral Reviews*, 95, 421-429.

Nilsen, W., Gustavson, K., Røysamb, E., Kjeldsen, A., & Karevold, E. (2013). Pathways from maternal distress and child problem behavior to adolescent depressive symptoms: A prospective examination from early childhood to adolescence. *Journal of Developmental & Behavioral Pediatrics, 34*(5), 303-313.

Pate, R. R., Pfeiffer, K. A., Trost, S. G., Ziegler, P., & Dowda, M. (2004). Physical activity among children attending preschools. *Pediatrics*, *114*(5), 1258-1263.

Reilly, J. J., Penpraze, V., Hislop, J., Davies, G., Grant, S., & Paton, J. Y. (2008). Objective measurement of physical activity and sedentary behaviour: Review with new data. *Archives of Disease in Childhood, 93*, 614-619.

Sijtsma, A., Koller, M., Sauer, P. J., & Corpeleijn, E. (2015). Television, sleep, outdoor play and BMI in young children: the GECKO Drenthe cohort. *European Journal of Pediatrics*, *174*(5), 631-639.

Spruit, A., Assink, M., van Vugt, E., van der Put, C., & Stams, G. J. (2016). The effects of physical activity interventions on psychosocial outcomes in adolescents: A meta-analytic review. *Clinical Psychology Review*, *45*, 56-71.

Stiglic, N., & Viner, R. M. (2019). Effects of screentime on the health and well-being of children and adolescents: A systematic review of reviews. *BMJ Open*, *9*(1), e023191.

Theunissen, M. H., Vogels, A. G., de Wolff, M. S., Crone, M. R., & Reijneveld, S. A. (2015). Comparing three short questionnaires to detect psychosocial problems among 3 to 4-year olds. *BMC Pediatrics*, *15*(1), 84.

Wu, X. Y., Han, L. H., Zhang, J. H., Luo, S., Hu, J. W., & Sun, K. (2017). The influence of physical activity, sedentary behavior on health-related quality of life among the general population of children and adolescents: A systematic review. *PloS One*, *12*(11), e0187668.

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Dear **Rong Wang**, **Qi Cao**, **Xiang Zeng**, **Pei Meng**, **Zhijun Zeng**, **Hong Liang**, **Yiran Wang**, and **Jiani Qu**, I cherish all those nice talking we once had together, hope to see you again!

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My special thanks to all of my classmates of **Class three**, **Grade 1997**, in Baodi No.1 middle school. Thank you for being my high school classmates. It was an unforgettable memory being together with all of you during my cherished youthful years in the place *"梦开始的地方"!*

I would like to use this opportunity to pay my deep thankfulness to my families.
There is no word that could express my inner grateful for my parents. My father and my mother stand behind me forever, that's the reason I have nothing to fear all the time and wherever I am.

My deep gratitude is extended to my husband **Rui Hu**. Before I met you, I was always afraid of change, but you made me open-minded to learn something new, act actively in different situation, and keep on believing in life. No matter what, you will always hold my hand. I was so touched to have your warm accompany for going through all those tough times during the past twelve years. Your immense love and continuous support are turned me into a happy wife and a better individual. To be a father, you have enough patience to help Dudu with his homework and play with him. I admire your great curiosity of exploring new things, which set a good example for our son. As a physician, you are working with efforts to save lives in the hospital. You have earned a good reputation for our family by plenty of free consulting and helpful advices for those patients from my hometown. I'm so lucky to have you by my side!

Dear 丛杰, my young sister, I have never said "thanks" to you because it seems that I am always the older sister who has been taking care of you. You surprised me by doing a wonderful job for our family when I was abroad. You had taken good care of our parents, and you sent plenty of presents to Dudu which gave him so much joy every time. You know my weakness all the time and you always give me the frank and fair opinion. I am amazed that you are no longer a delicate girl but a lady with a bright mind and strong heart, and an impartial public prosecutor. By the way, you have given birth of the first boy in our family, so you won! I wish my cherished nephew 陈彦行 (Dandan) a bright future and all the good luck with him!

My sincere thanks to my mother-in-law 阎并, thank you for all your overwhelming support. Very special thanks to my grandma lady 孟奕. I admire your courage and wisdom in life. Thank you very much for your financial support, we are really appreciated for your generosity.

Finally, my special thanks to my dear uncle 吕守信 & aunt 曹秀英, uncle 吕守玉 & aunt 赵殿文, aunt 吕守茹 & uncle 邱立祥, aunt 吕守娟 & uncle 刘会民; my dear aunt 陈西文, uncle 陈西武 and uncle 陈西路; my dear uncle 刘道海 & aunt 李淑清; my cousins 周玉清 & 张秀霞; my uncle 吕秋生, uncle 吕守正, uncle 吕守荣, uncle 吕守勤, uncle 吕守元, uncle 吕守宽, uncle 吕学斌, uncle 吕守安, and all my family members. I am keeping on fighting for our family honour whatever hardship it is and I have never given up. Because all your contributions for our family inspired me in the progress of my growing up! Thanks for all of your loyalty guarding for our big family in decades. All of you have my deep respect and gratitude! Best wishes to all of you!

Dear Dudu,

I remembered the first day that I hold you in my arms after a difficult labour, it was Saint Valentine's Day in 2014. The moment of your birth changed my later life, I was so satisfied and appreciated it. In the first years after your birth, you waken me up by crying three times per night, I was so tired but really enjoyed. Each moment after feeding you full before dawn, I watched the sunrise peacefully and believed that we could get through all of this.

Time goes fast, when you were a toddler and you were always standing in front of the window at dusk, waiting for my car showing up. You became my best friend and made me happy ever after. I am so sorry that I owe you one year accompany. It was a heartbroken decision I had to made that I left you when you were two years old. I missed you so much when I was alone far away in the Europe. I put your little sock under my pillow and it comforted me gently in those sleepless nights. One day you could understand this. Well, there is responsibility on my shoulder, because it's a family honour so I have to finish my work. It took me a while, finally I accomplished this book of scientific researches on the age of 37.

Dudu, now you are six and you are curious of oceans and creatures. You shared with me your crazy ideas excitedly and you were especially good at lively descriptions of stories. Dudu, everyone has his dream, encounter with suffering when he purses it. One day, you may encounter with difficulties and start to worry about the future. Hey, my boy, even talent, he has to work hard on his idea and develop his skills. For what it's worth, it's never too late.

Dudu, when the stars are strung across the velvety night, cast your eyes to the starry sky and think of me. Do not let the fear of the unknown get in your way! Time is fleeting and everything will be fine! Find something interesting to work on, do it a hundred percent and make your life spectacular!

Love, Mom

致 谢

时光荏苒，七年的博士生涯，若白驹过隙！回首这些年走过的路，从 30 岁到 37 岁，在这段人生最美好的时光里，我经历着挫折和奋斗，感受过磨砺与喜悦，体验了生命的诞生和亲人的分离，并始终坚守着自己的初心和使命！这期间我得到了许多人真诚的关怀和帮助，在此衷心地向他们表达我最诚挚的谢意。

感谢我的母校天津医科大学和荷兰格罗宁根大学为我提供这次学习的宝贵机会！诚挚感谢公共卫生学院的诸位领导和老师对我近二十年的悉心培养，以及各部门同事给与我的支持和帮助！由衷地感谢我的博士生导师黄国伟教授，Ronald P. Stolk 教授和 Eva Corpeleijn 教授, 本论文的顺利完成离不开三位导师的大力支持。特别感谢黄国伟教授这些年对我工作提供的无私帮助！十分感谢 Stolk 教授为我提供此次接受格罗宁根大学博士生教育的机会！尤其感谢 Eva 在整个博士期间对我的全面指导！同时感谢求学路上遇到的善良的朋友们，事隔多年回想起和在你们一起的岁月，时光深处依旧温暖如初！

“读书学习是一辈子的事!”，这是我少年时代就铭记于心的教诲。现今，知识共享和科技进步，引导着人类文明的发展，成就了我们的美好生活。借此机会郑重地向我少年时代的母校致以最诚挚的敬意：八门城杨岗庄小学（1988.秋 - 1990.夏），保定市惠阳航空螺旋桨制造厂子弟小学/中学（1990.秋 - 1994），宝坻三中（1995.春 - 1997.夏），宝坻一中（1997.秋 - 2000.夏）。衷心感谢恩师们悉心的教诲和无私奉献！

岁月如梭，回想 30 岁那年只身赴荷兰读书，那是我第一次离开家远行，后来得知母亲在机场外看到飞机起飞那一刻已泣不成声。很多年过去了，我还清楚的记得：90 年代的夏天，我们一家四口骑车去龙门水库野餐，下坡时，我紧紧地贴在父亲背后，耳边呼啸着风声，山崖边有成簇绽放的野菊花，在归来的夕阳下，全家依偎在余辉里遥望着铁轨绵延的远方……那时父母还那么年轻，全家在一起的日子是如此地清澈明朗！曾经以为老去是很遥远的事，突然有一天，看到父母陪着嘟嘟写作业，才发现，时光已然悄悄斑驳了岁月！寸草难报春晖，感恩我的父亲和我的母亲对我始终温馨的守护！惟愿岁月平安，家人康健！感谢所有亲朋好友这些年对家人的悉心关照！

最后藉此告慰已故的祖父祖母：山河无恙，家安勿念！

吕丛超

June 18th, 2020

About the author

* Congchao Lu（吕丛超）was born on 7th October, 1982, in Tianjin, China.
* Congchao spent her happy childhood living with her grandparents. Congchao's grandfather（吕活, 1928 - 2014）had served for Peoples Liberation Army since his 18 years old. In times of peace, her grandfather worked as a village teacher in his rest of life.
* When Congchao was nine years old, she moved to living with her parents. Congchao's father（吕守明）graduated from Northwestern Polytechnical University, China. Her father worked as an engineer in a secret military factory which made propeller.
* In July 2000, Congchao graduated from Baodi No.1 middle school, Tianjin. She started undergraduate education in Preventive Medicine in Tianjin Medical University (TMU).
* In July 2005, Congchao obtained her bachelor degree of Medicine and started her three years' graduate education in Epidemiology and Health Statistics in TMU.
* In July 2008, Congchao obtained her MSc degree and started work as a teacher in TMU.
* In December 16th, 2011, Congchao married Rui Hu（胡睿）in Tianjin.
* In November 2012, Congchao got her Ph.D. position of University of Groningen, the Netherlands. She worked under supervision of Prof. Ronald P. Stolk and Dr. Eva Corpeleijn at Department of Epidemiology, University Medical Centre of Groningen (UMCG). She took part in the research of birth cohort study and finished her Ph.D. research plan during six months' stay in the Netherlands.
* In April 2013, Congchao attended the 48th Annual Meeting of the European Diabetes Epidemiology Group in Potsdam, Germany.
* In May 2013, Congchao went back to Tianjin and continued her teaching in TMU, China. In the meantime, she went on with her research works and initiated pilot study in Tianjin.
* In February 14th, 2014, Congchao's baby boy Dudu（胡俸铭）was born in Tianjin.
* From March, 2015, Congchao started her research project the PATH-CC study.
* In March 2016, Congchao returned to the Netherlands and continued her research in UMCG. During her 1.5 years' study, she was eager to attend trained courses which made her credits more than a full time three years' PhD student should have.

* In March 2017, her first English scientific paper was published on an open access, peer-reviewed international journal.
* In April 2017, Congchao gave her first international oral presentation on the Netherlands Association for the Study of Obesity (NASO) Scientific spring meeting in Utrecht, the Netherlands.
* In June 2017, Congchao attended the UMCG summer school: Fundamentals of Biobanking and Cohort Research, this course thrilled Congchao in her future research.

* In August 2017, Congchao was back home to China and continued her work in the TMU.
* In September 2019, Congchao was invited to attend the 2019 European Association for the Study of Obesity (EASO), New Investigators United Autumn School in Naples, Italy. This meeting is about hot topics in obesity. She gave an oral presentation on the meeting.
* In December 2019, Congchao handed this thesis to the reading committee. Her original PhD Ceremony was decided to be hold on April 15th, 2020. However, she had to postpone her ceremony to September 16th, 2020 due to the pandemic of COVID-19.
* Here is the final PhD dissertation of Congchao Lu.

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