General discussion
SUMMARY OF THE MAIN FINDINGS

In the prevention of overweight, physical activity is considered a key factor. However, in young children, the association between physical activity and the development of overweight is not clear. Therefore, the present thesis focused on the influence of early childhood physical activity on the development of overweight in children. In Chapter 2 we conducted a systematic review and meta-analyses to summarize the evidence of an association between different intensities of physical activity and various outcomes for adiposity. The associations differed by intensity of physical activity and the type of outcome used for assessing the degree of adiposity. Overall we found no associations between most of the intensities of physical activity and outcomes for adiposity. In Chapters 3 and 4 we explored physical activity behaviours in young Dutch and Chinese children, respectively, in great detail by looking into the different intensities of physical activity, and analysing physical activity at different moments of the day. In both countries there was a clear, but different, pattern in the children’s physical activity and sedentary time throughout the day. In addition, in the Dutch study, children affected by overweight or obesity were not less active than children without overweight (Chapter 3), but in the Chinese study they were. In the Chinese study, children with overweight or obesity were overall more sedentary and they spent less time in light physical activity in multiple segments of the day compared to their peers (Chapter 4). Subsequently, in Chapter 5, we broadened our view to examine whether early childhood physical activity was related to other components of cardiometabolic health than overweight. In this prospective study we showed that young Dutch children’s physical activity behaviour was neither related to the development of overweight, nor to abdominal overweight and hypertension five years later. Lastly, in Chapter 6, we included more lifestyle factors to consider the complex interplay of physical activity with diet, screen time, sleep and outdoor play during early childhood in relation to childhood overweight or obesity. A lifestyle pattern characterised by low screen time, high sleep and a relatively healthy diet seemed most favourable in the prevention of childhood overweight. Subsequently, we took into account the child’s broader living environment by examining the spatial clustering of the children’s lifestyle patterns and body mass index. The spatial analyses revealed spatial clustering of standardized body mass index at 10-11 years, but no spatial clustering of the early childhood lifestyle patterns. This suggested that there are likely neighbourhood factors other than children’s lifestyle behaviours that contribute to the spatial clustering of body mass index. The spatial analyses led to the suggestion that, in the prevention of childhood overweight, it could be a good approach to target the health of young children by screening for unhealthy lifestyle patterns or high body mass index on a local scale.

The current chapter provides a discussion about the association between physical activity and childhood overweight. Subsequently, we discuss the complexity of young children’s lifestyle behaviour in relation to the development and prevention of overweight and we discuss practical implications and directions for future research.
AGE-DEPENDENT INFLUENCE OF LIFESTYLE FACTORS ON CHILDHOOD OVERWEIGHT

Physical activity is seen as an important component in the prevention of overweight and obesity. However, we found only weak evidence for an association between early childhood physical activity and the development of overweight. Looking at the average number of minutes per day in different intensities of physical activity, there appears to be only a significant but small association with childhood overweight for the highest intensity levels of physical activity (i.e. [moderate-to-] vigorous physical activity) (Chapter 2). Even in more detailed analyses of physical activity patterns across the day, physical activity is not associated with childhood overweight in young Dutch children (Chapter 3). One could argue that a longer exposure is needed to see differences in overweight, but our results showed that young children’s physical activity was not related to overweight later in childhood either (Chapter 5). Furthermore, physical activity could be related to other cardiometabolic health indicators, but no evidence was found for waist circumference nor for blood pressure (Chapter 5). This shows that early childhood physical activity is not an important component in the development of childhood overweight. Other lifestyle factors like diet, sleep and screen time seem to be more important during early childhood. With regard to diet, a study conducted in Dutch children around the age of 3 years showed that children with a relatively healthy diet gained less weight in the following seven years and had a lower risk for overweight at 10 years of age 1. For sleep and screen time, a study in Dutch children aged 3-4 years showed that both sleep duration and screen time were related to body mass index during early childhood 2. In addition, a study in young children from the United Kingdom showed that, among other factors, screen time and sleep duration at age 3 were associated with an increased risk of childhood obesity 3. Lastly, a large study in European children between 2 and 11 years old showed that both high screen time and low sleep duration are related to childhood overweight 4.

The effect of physical activity behaviour on the development of overweight seems to increase with age. A large international study compared physical activity behaviours in children and youth with and without overweight. They showed no differences in physical activity behaviour between 2- to 6-year old children, however, from the age of seven, children affected by overweight were found to be less active than children without overweight 5. In addition, a longitudinal study of 9- to 15-year-olds found that spending more time sedentary during late childhood was associated with increases in body mass index over the following six years 6. That the association between physical activity behaviour and obesity is more apparent in later childhood can be explained by changes in physical activity behaviour when children become older. From infancy to approximately 5 years of age, time spent in physical activity increases, but, from the age of five years onwards, the time spent physically active declines and sedentary time starts to increase 5,7,8. However, this does not suggest that physical activity behaviour at a young age does not matter, as it determines physical activity later in life 9. Moreover, adequate physical activity during early childhood remains important, due to its importance for other health outcomes and developmental domains such as children’s motor- and cognitive development 10.
HYPOTHESIS: AVOIDING RESTRICTIONS TO MOVE AROUND FREELY COULD MATTER IN THE DEVELOPMENT OF OVERWEIGHT

Physical activity during early childhood does not seem an important component in the development of childhood overweight overall, however the findings in the Chinese population (Chapter 4) indicate that there may be exceptions to this rule. In Chapters 3 and 4, we explored the physical activity behaviour of Dutch and Chinese children in great detail by looking into the different intensities of objectively measured physical activity, and analysing physical activity at different moments of the day. Both studies were conducted in children around the age of 5-6 years and used comparable methods by design. Figure 1 shows the physical activity patterns in children with and without overweight for both the Dutch and the Chinese study. Interestingly, we observed similarities, but also substantial differences in the physical activity patterns of the Dutch and Chinese children. Firstly, the time at which the children were most sedentary differed. The Dutch children were most sedentary in the early morning, whereas the Chinese children were the most sedentary and least active during recess (12:00 to 14:00). Secondly, the average minutes per day spent in moderate-to-vigorous physical activity was higher in the Dutch children compared to the Chinese children. The Dutch children spent on average 61 minutes per day in moderate-to-vigorous physical activity. In the Chinese children, the average time spent in moderate-to-vigorous physical activity was 47 minutes per day during schooldays compared to 61 minutes per day during weekends. Thirdly, the associations of the physical activity patterns with childhood overweight varied between the studies. In the Dutch study, children affected by overweight or obesity were no less active than children without overweight (Chapter 3). In the Chinese study, however, children with overweight or obesity were more sedentary overall and spent less time in light physical activity in multiple segments of the day compared to their peers (Chapter 4). These differences between the studies can be explained by the fact that the Chinese school schedule includes an obligatory nap time from 12:00 to 14:00 which influences, and even suppresses, children’s natural activity patterns across the day. The comparison of Chapter 3 and 4 led us to hypothesize that avoiding suppression of young children’s physical activity behaviour may be important in the prevention of childhood overweight. This example illustrates how detailed analyses of physical activity patterns across the day can provide new insights for the prevention of childhood overweight. By looking at the physical activity patterns across the day, context-specific information is obtained for possibilities for interventions to prevent obesity.

The influence of the suppression of physical activity behaviour on the development of overweight can be explained on the basis of the energy balance. As mentioned in the general introduction, weight is increasing when the energy intake chronically exceeds the total body energy expenditure. In the general introduction we defined the total body expenditure as the sum of total physical activity, basal metabolic rate and environment- and diet-induced thermogenesis. To go into more detail, the total physical activity can be divided into exercise activity and non-exercise activity. The latter is considered the most important component...
Figure 1. Comparison of physical activity patterns in children with and without overweight in Dutch and Chinese children.

of energy expenditure. Possibly, the Dutch children from Chapter 3 are able to spend more time in non-exercise activity compared to the Chinese children from Chapter 4, because their physical activity behaviour is less suppressed. Non-exercise activity comprises leisure time physical activity and posture (sitting, standing and walking). Evidence suggests that the energy balance is kept stable by endogenous regulation of the amount of this non-exercise activity. In natural situations, the non-exercise activity increases when the food intake is higher. Similarly, the non-exercise activity decreases when the food intake is lower. One underlying mechanism that regulates the amount of non-exercise activity is hypothalamic orexin. Orexin is a neuropeptide that is essential in sleep rhythms and arousal, but also in the control
of the energy metabolism, eating behaviour and physical activity. Increases in orexin should cause increase in energy expenditure by stimulating physical activity. However, when physical activity behaviour is suppressed by external factors, such as an obligatory nap during school, children will not be able to increase their physical activity levels and their weight may increase. Therefore, avoiding restrictions to move around freely during childhood can be important in the prevention of childhood overweight. This adds to the importance to offer children opportunities to be physically active during the day. This can be done, for example, through active education, as children spend a large part of their day at school. Offering physical activity during school hours may even improve academic engagement and achievement.

**COMPLEXITY OF LIFESTYLE BEHAVIOUR AND OVERWEIGHT**

The problem of childhood overweight and the influence of children’s lifestyle behaviour is complex. Several points play a role in investigating and intervening in overweight in children.

First, there is a growing awareness that lifestyle factors are interdependent. Diet, sleep, screen time and physical activity cluster in certain lifestyle patterns, depending on age, sex and socio-economic status. In Chapter 6, we considered this clustering of lifestyle factors and observed three lifestyle patterns in young Dutch children; 1) ‘high activity’ pattern, 2) ‘low screen time, high sleep and healthy diet’ pattern and 3) ‘high outdoor play’. Interestingly, only the pattern including diet, sleep and screen time was related to the development of childhood overweight. Young children with higher scores on the ‘low screen time, high sleep and healthy diet’ pattern had lower odds to become overweight and a lower standardized body mass index at 10-11 years. This demonstrates that it can be important to include all lifestyle factors in research into childhood overweight and not just focus on individual lifestyle factors, as this provides a more comprehensive view of the determinants of overweight in children.

Second, it should be realised that the influence of certain lifestyle patterns on childhood overweight can be context-dependent. To tackle one and the same problem, in this case the obesity pandemic, different interventions may be appropriate, depending on the population or the region of interest. In Chapter 6, we illustrated that, even in a small region like Drenthe (a province in the Northern Netherlands), children’s body mass index clustered in certain areas. Subsequently looking at the clustering of their lifestyle behaviours, we suggested that lifestyle interventions may be differently effective depending on the area of interest.

Third, many different stakeholders need to be involved in tackling childhood obesity. Ecological models propose that healthy or unhealthy behaviours can be explained by looking at individual characteristics in combination with influences from environmental- and policy levels. For example, one can teach the individual, the child itself, to be more resistant to unhealthy behaviour, but parents or caregivers have a major role as well. Young children depend on the social norms of the parents or caregivers, they first will have to acknowledge
the problem and be willing to live healthier lives before the lifestyle behaviour will change. It is therefore also necessary to work on changes in the social norms and behaviour of the parents or caregivers. In addition, schools and government need to be involved to implement changes in the child’s broader environment. People may be willing to change their lifestyle behaviour, but the environment has to facilitate healthy choices too. For example, schools and the government can adopt stricter lifestyle policies, such as more sports facilities, fewer fast food outlets and more healthy advertising instead of unhealthy advertising. This shows that good cooperation between the various stakeholders, including parents and caregivers, schools and the government, is essential in the prevention of overweight in children.

**PRACTICAL IMPLICATIONS AND FUTURE RESEARCH**

In this thesis we used accelerometers to objectively assess physical activity. Objective measures are more reliable than questionnaires to measure physical activity in children. Questionnaires are often filled in by the parents, and show limited reliability and validity, especially when used for young children 21. With accelerometers it is possible to measure physical activity objectively, which enables differences in frequency, duration, and physical activity intensity to be objectively assessed 22,23. However, accelerometers measure mainly the quantity of physical activity, information about the quality is lacking. Therefore, for future research it may be best to combine accelerometer measurements with a qualitative measure. An activity diary alongside the accelerometer measurements could be a logical choice, but it is a high burden to accurately maintain an activity diary 24. Also, direct observation could be an option, as this is often considered the golden standard to measure physical activity in children and adolescents 24. However, direct observation requires highly trained observers and contains a high burden, which makes it less suitable for large studies 24,25. A better combination might be accelerometry with posture allocation. As mentioned in the previous paragraph, posture is one of the factors included in non-exercise activity, and therefore important in maintaining a healthy weight 13. Devices that enable the measurement of sedentary time and physical activity intensity together with posture allocation are the ActivPal and the ActiGraph. However, it is not yet possible to accurately assess posture in preschool children with these device, because these young children spent a lot of time in postures that are difficult to measure (e.g. kneeling and crawling) 25,26. Furthermore, for precise posture measurements the device should be placed in the thigh, however little is known about the validity of measuring physical activity with thigh-based monitors. Therefore, further developments are needed before we can combine accelerometry with posture allocation measurements. Further developments are also needed for methods related to accelerometry. For accelerometers, universal guidelines are needed to tackle growing inconsistencies regarding the different methods reported in the literature for assessing objectively measured physical activity. Lastly, it is important to note that the choice of physical activity measurements highly depends on the context. A recent review states that choosing the most appropriate measurement tool for physical activity
behaviour is balancing the validity, reliability and feasibility together with the sample size of the study, budget and resources\textsuperscript{25,27}.

Once more, we want to emphasize that we do not conclude that young children’s physical activity behaviour is not relevant for health. Physical activity at a young age is related to improved psychosocial health, increased fitness and improved bone- and skeletal health outcomes, as well as better motor and cognitive development\textsuperscript{10}. Furthermore, early childhood physical activity is likely to track into later life\textsuperscript{9}. Therefore, even though physical activity behaviours at a young age may not be one of the most important drivers in the development of childhood overweight or obesity, physical activity is important at young age.

For future research we stimulate researchers to include light physical activity in their studies, as literature is lacking and children spent much time in this intensity of physical activity. Furthermore we recommend tailored physical activity interventions to examine whether inactive children can be stimulated to become more active, and to determine which types of interventions are most effective in preschool children. One of our suggestions is to use a regional approach to target interventions more specifically to the children in need. Future intervention studies should examine whether targeting preschool children based on their lifestyle is effective in the prevention of childhood overweight, and whether this holds for all child ages, from infancy to adolescence.
REFERENCES


