Early childhood physical activity behaviour and the development of overweight

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General introduction
CHILDHOOD OVERWEIGHT AND OBESITY

Obesity is an increasing problem in society. The World Health Organization refers to a global obesity epidemic, as obesity rates have almost tripled since 1975\(^1,2\). In 2016, around 40% of adults were affected with overweight and 13% with obesity globally. In children and adolescents (5-19 years old) 18% was affected by overweight or obesity\(^1\). During childhood, many children with obesity develop health problems that once emerged only in adults\(^3\). Cardiometabolic, pulmonary, and psychosocial complications as well as orthopaedic disorders, liver and gall bladder dysfunction, cardiovascular and endocrine problems, and cancer are seen in children with obesity\(^3,4\). In addition, approximately 30-50% of children with obesity will remain affected by obesity in adulthood\(^5,6\). As at young age the acceleration of the body mass index (BMI) is particularly high between 2 and 7 years, and overweight in childhood is likely to persist into adulthood, prevention should start at a young age\(^7,8\).

Weight gain is caused by a slightly positive energy balance. In short, weight is increasing when the energy intake chronically exceeds the total body energy expenditure, which is the sum of total physical activity, basal metabolic rate and environment- and diet-induced thermogenesis\(^9\). Thus, a lifestyle factor that plays an important role in the development of overweight and obesity is physical activity. However, in children, the association between physical activity and the development of overweight is not clear.

PHYSICAL ACTIVITY IN CHILDREN

To stimulate physical activity in children, several organizations have provided physical activity guidelines. For children aged 3-4 years they recommend to spent at least 180 min being active each day, with at least 60 min in energetic play\(^10,11\). In addition, the young children should not be restrained or sedentary for more than 1 h at a time\(^10,11\). For school-aged children and adolescents (5 – 17 years) it is recommended to spent at least 60 min in moderate-to-vigorous physical activity (MVPA) each day and sedentary time should be minimized\(^12-15\). However, many children do not meet these recommendations, putting them at greater risk of developing health problems.

Previous studies have shown that the time spent physically active appears to increase during the preschool years, and then decrease progressively over time until the age of 18\(^16-18\). Opposite patterns are observed for sedentary time\(^16-18\). A large study using data from the International Children’s Accelerometry Database (ICAD) showed that time spent physically active decreased with an average of 4.2% per year, compared to 5-year-old children\(^16\). Therefore, if we focus on the early prevention of childhood overweight, we need knowledge of the relation between early childhood physical activity and the development of overweight.
Physical activity levels in children

Physical activity is defined as any bodily movement produced by skeletal muscle that results in energy expenditure, and increases heart rate and breathing. Physical activity can be quantified into different intensity levels. In 1993, the Compendium of Physical Activities is developed to classify the intensities of different activity behaviours. The classification is based on the metabolic equivalent (MET). This is a measure of energy expenditure and refers to the ratio between the energy expenditure of a certain activity and the standard resting metabolism. The standard resting metabolic rate is 1.0 MET, and MET values can vary between 0.9 and 18 METs. Recently, a Youth Compendium of Physical Activities has been developed, because the adult MET values underestimate the basal metabolic rate of children. Compared to adults, children have a higher basal metabolic rate per unit body mass and their energy expenditure per unit body mass for activities is also generally higher. The different intensities of physical activity are, ranked from low to high, sedentary time, light physical activity, moderate physical activity and vigorous physical activity (see Table 1).

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Energy cost (METs)</th>
<th>Type of behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary time</td>
<td>&lt; 1.5</td>
<td>Sitting, reclining or lying down</td>
</tr>
<tr>
<td>Light physical activity</td>
<td>1.5 - 4.0</td>
<td>Standing and walking at low speed</td>
</tr>
<tr>
<td>Moderate physical activity*</td>
<td>4.0-6.9</td>
<td>Active walking or cycling and sports involving catching and throwing</td>
</tr>
<tr>
<td>Vigorous physical activity*</td>
<td>&gt; 7.0</td>
<td>Active games involving running and chasing, fast bicycle riding, and running</td>
</tr>
</tbody>
</table>

* Often combined into moderate-to-vigorous physical activity (MVPA)

PRESCOLLERS

Prevention of childhood overweight should start at a young age, but studies looking into the development of overweight in young children are scarce. Most studies on childhood overweight are conducted in school-aged children, but physical activity behaviour of school-aged children is not comparable to that of preschoolers. During the preschool years, often defined as the age period of 2 to 6.99 years, children have ample opportunity to move around freely. In these years, children are mainly dependent on their parents or caregivers, who will therefore have a major influence on the development of the child’s physical activity behaviour. Around the age of 7, children start attending school. Their physical activity behaviour becomes more restricted, and, while parental influences decrease, environmental influences will increase. In addition to these differences between preschoolers and school-aged children, it has also been shown that physical activity at a young age is an important determinant for physical activity at a later age, as it is likely to track into later life.
PHYSICAL ACTIVITY AND CHILDHOOD OVERWEIGHT

Research into physical activity in children has evolved rapidly, due to the invention of accelerometers. Until then, physical activity was mainly measured subjectively through questionnaires. These questionnaires are often filled in by the parents, and show limited reliability and validity, especially when used for young children. With accelerometers it is possible to measure physical activity objectively, which enables differences in frequency, duration, and physical activity intensity to be objectively assessed. These measurements are extremely important in the case of preschool children.

In 2011, a review including seventeen studies summarized all evidence for an association between objectively measured physical activity and overweight in early childhood. Of the seventeen studies, only two were longitudinal studies. The results were very heterogeneous and no clear relation between objectively measured physical activity and childhood overweight was found. Some studies reported a positive association between physical activity and childhood overweight, some studies observed no association and some studies found a negative association. It appeared that the results depended on the used outcome measure.

More recently, a comprehensive review in 2017 including ninety-six studies, thirty-eight of which involved objectively measured physical activity, examined the association between physical activity and health in children aged 0-4 years. Fifty-seven studies, including seven longitudinal studies, looked at adiposity as an outcome. Especially higher intensities of physical activity (at least MVPA) were related to better motor and cognitive development, psychosocial health, fitness and bone- and skeletal health, but no evident association between physical activity and adiposity was found. A review in 2016 including 162 studies summarized the evidence for an association between objectively measured physical activity and health in school-aged children and youth. The association between physical activity and adiposity was examined in seventy-two studies, and most of the studies were performed around the age of 10 years. A lack of physical activity was associated with increased adiposity in approximately 80% of the included cross-sectional studies, but longitudinal studies showed mixed results. Some of the included longitudinal studies showed a favourable influence of physical activity, but other longitudinal studies showed no association between physical activity and adiposity. For other health indicators the evidence was stronger. Especially higher intensities of physical activity (e.g. MVPA) were associated with improved physical, psychological, social and cognitive health indicators. So, although physical activity is important for children’s health, the evidence for an association with childhood overweight is inconclusive. More studies in young children, using objectively measured physical activity, considering all intensities of physical activity and with sufficient follow-up time, are needed to examine whether physical activity at a young age is related to the development of childhood overweight and obesity. This will provide insight into opportunities for the early prevention of childhood overweight.
LIFESTYLE BEHAVIOUR, THE ENVIRONMENT AND CHILDHOOD OVERWEIGHT

Next to physical activity, other lifestyle factors that may contribute to the development of overweight in children are diet, screen time and sleep. It has been shown that these lifestyle factors, together with physical activity, cluster in certain lifestyle patterns depending on age, sex and socio-economic status (SES). Therefore, to get an expanded view of the influence of early childhood physical activity on the development of childhood overweight, we should consider the complex interplay of physical activity with the other lifestyle factors in relation to the development of overweight. In addition, we should also take into account the children’s broader environment. As mentioned before, parents or caregivers play a major role in children’s behaviour, and their wider living environment can also be a determining factor. Ecological models propose that healthy or unhealthy behaviours can be explained by combining individual factors with influences from environmental- and policy levels.

Considering the young children’s lifestyle behaviours in combination with their broader living environment will provide a comprehensive view on the development of childhood overweight.

Measuring childhood overweight

In large epidemiological studies body mass index (BMI) is often used as an alternative for percentage of body fat, as estimating the percentage of body fat is rather time consuming and expensive. BMI is calculated as total body weight divided by squared height. In adults, overweight is defined as BMI ≥ 25 kg/m² and obesity as BMI ≥ 30 kg/m². In children, these definitions are more complicated. As children grow in size, their BMI should be adjusted for age and sex. Therefore, standardised BMI scores (zBMI) need to be calculated based on reference data of subjects with the same age and sex. Subsequently, children can be classified as affected by overweight or obesity using specific zBMI cut-offs that are based on growth curves. The first growth curves with appropriate cut-off values for children were developed around 1980. One of the most recent and widely used are the International Obesity Task Force (IOTF) cut-offs developed by Cole and colleagues, which are based on growth curves that correspond with cut-off points for overweight and obesity in adults (Table 2).

Table 2. zBMI score cut-offs for overweight and obesity

<table>
<thead>
<tr>
<th>Weight status</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overweight</td>
<td>1.310</td>
<td>1.244</td>
</tr>
<tr>
<td>Obesity</td>
<td>2.288</td>
<td>2.192</td>
</tr>
</tbody>
</table>
OUTLINE OF THIS THESIS

Aim of this thesis
The main aim of this thesis is to examine the association between physical activity and the development of overweight in young children. First, we will perform detailed analyses on children’s physical activity behaviour and the association with childhood overweight, and search for windows of opportunities in order to increase physical activity levels in inactive children. Second, we will broaden our view and include diet, screen time, sleep and outdoor play as well to consider the complex interplay of children’s lifestyle behaviour in relation to the development of childhood overweight.

Cohort studies
The GECKO (Groningen Expert Center for Kids with Obesity) Drenthe birth cohort and PATH-CC (Physical Activity and Health in Tianjin Chinese Children) study were used in this thesis.

GECKO Drenthe birth cohort
The GECKO Drenthe study is a population-based birth cohort with a focus on early risk factors for overweight and obesity. Details of the GECKO Drenthe study are described elsewhere 33. In 2006, almost three-thousand pregnant women were recruited. Monitoring of the children started from the last trimester of the pregnancy and is still ongoing. This thesis mainly used data from three measurement points. For children aged 4-7 years, 1474 children participated in objective measurements of physical activity behaviour. At the age of 5-6 years, weight, height and blood pressure were collected in 2316 children by Preventive Child Healthcare nurses. At 10-11 years, 2299 children were measured for follow-up. The GECKO Drenthe study is registered at http://www.birthcohorts.net.

PATH-CC study
The PATH-CC study focuses on identifying the relationship between physical activity, overweight and environmental determinants in children living in Tianjin, China. A study protocol can be found elsewhere 34. In 2015, 1031 healthy preschool children aged 3 to 6 years and their parents were recruited in preschools by advertising posters. Similar to the GECKO Drenthe birth cohort, physical activity of the children was measured objectively by accelerometry.

Thesis outline
A graphical outline of this thesis is shown in Figure 1. In Chapter 2, we start with a systematic review and meta-analyses, to summarise the evidence of an association between objectively measured physical activity and adiposity in preschool children. We focus on different intensities of physical activity and different measures of adiposity.
Children’s physical activity is often analysed on the basis of average minutes per day or week. The use of accelerometers makes it possible to analyse physical activity patterns over the day. Looking at different moments of the day can provide more targeted advice for physical activity interventions. Therefore, in Chapter 3, we explore the physical activity behaviour of Dutch children in great detail by looking into the different intensities of physical activity, and analysing physical activity at different moments of the day. We also examine the association between the detailed physical activity and childhood overweight. As children’s physical activity behaviour may depend on the context in which children live, a comparable study was carried out in Chinese children. For example, children’s natural physical activity patterns may depend on their environment or may be affected by cultural influences. In Chapter 4, we carried out detailed analyses of physical activity behaviour and the association with childhood overweight in Chinese children.

From the detailed analyses we then shift to a broader perspective. We include more outcomes and more determinants to place the influence of physical activity during early childhood in a broader context. In Chapter 5, we add abdominal overweight and hypertension as outcomes, because these are important components of cardiometabolic health. We perform prospective analyses on the association between different intensities of physical activity and overweight, abdominal overweight and hypertension. In Chapter 6, we include more lifestyle factors to consider the complex interplay of physical activity, diet, screen time, sleep and outdoor play during early childhood. We examine the relation between young children’s lifestyle patterns and the development of childhood overweight, and take into account the child’s environment.

Finally, Chapter 7 provides a general discussion about the association between early childhood physical activity and the development of overweight in children.
The green area on the left represents the determinants and the blue area on the right represents the outcomes examined in this thesis. The numbers in the square refer to the chapters in this thesis. To illustrate, in Chapters 3 and 4 we examined the association between physical activity and childhood by looking into the different intensities of physical activity, and analysing physical activity at different moments of the day. In Chapters 2 and 5 we examined the relation between different intensities of physical activity and childhood overweight (Ch. 2) or childhood overweight and cardiovascular disease (Ch. 5). Lastly, in Chapter 6, we examined the association between children’s lifestyle behaviour and their broader environment with the development of childhood overweight.
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