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Unravelling the association between accelerometer-derived physical activity and adiposity among preschool children: a systematic review and meta-analyses

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ABSTRACT

Background: Evidence on the association between physical activity (PA) and adiposity in young children is inconclusive.

Objectives: A systematic review and meta-analyses was conducted to examine associations between accelerometer-derived PA and varying adiposity outcomes in preschool children.

Methods: Searches were conducted in EMBASE, MEDLINE, and Web of Science to identify studies on the association between total PA, sedentary behaviour, or different PA intensities and adiposity in children aged 2–7 years. Separate random effects meta-analyses were performed for varying PA intensities and adiposity outcomes.

Results: Fifty-six articles were included in the review and 48 in the meta-analyses. There was substantial evidence of an inverse association between moderate-to-vigorous- or vigorous PA and body fat percentage (stdβ[SE] = -0.162[0.041]; 5 studies), weight status (r = -0.120, p<0.001; 11 studies), fat mass (stdβ[SE] = -0.103(0.051); 5 studies), fat mass index (stdβ[SE] = -0.121[0.036]; 2 studies), and skinfold thickness (stdβ[SE] = -0.145[0.036]; 4 studies). However, total PA, sedentary behaviour, and different PA intensities were not associated with body mass index (BMI) or waist circumference.

Conclusions: Adiposity levels were lower among preschool children engaged in more (moderate-to-) vigorous PA compared with their peers, but no associations between PA and BMI or waist circumference were found.

Keywords: accelerometry, body fat distribution, exercise, sedentary behaviour
INTRODUCTION

Overweight and obesity is an increasing problem in society, in adulthood as well as in childhood. In 2016, about 6.0% of the under-five age group, globally, were affected by overweight or obesity, with percentages ranging from 3.7% in Africa to 7.2% in the United States. During childhood, many children with obesity develop health problems that once emerged only in adults. 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. Furthermore, a lot of children with obesity will be affected by obesity in adulthood as well. Research on young children is important because prevention of overweight at young age is more effective compared with treatment after its onset.

Body weight increases when energy intake (nutrition) chronically exceeds total body energy expenditure. In children, this energy expenditure is the sum of physical activity (PA), growth, the basal metabolic rate, and environment- and diet-induced thermogenesis. Therefore, PA is seen as a key component in the prevention and management of obesity. However, while overweight is increasingly prevalent among preschool children, evidence of the association between PA and the development of overweight in this age group is inconclusive.

The use of different methods within studies conducted to assess the association between PA and adiposity has led to inconsistent findings. A review conducted in 2012 covered 17 studies that examined the relation between PA, sedentary behaviour, and childhood obesity. The review revealed the use of six subjective and objective methods for assessing PA and reported mixed results. Whereas some of the studies found a negative association between PA and weight status, others found that there was no association between them. In another study, 48 studies on the association between PA and adiposity in children and adolescents were reviewed. Only studies in which PA was measured objectively were included, but the results remained dependent on the instrument used to measure PA. A negative association was found in all of the studies using pedometers (n =11) and in 72% of the studies in which accelerometers were used (n=32). One review focused solely on objectively measured PA and adiposity in preschool children. In this review, no clear association was found between objectively measured PA and weight status. The authors suggest that the association between objectively measured PA and weight status in preschool children depends on the outcome measures used.

Several methods have been used to assess young children’s PA. Measurements taken with accelerometers are reliable and valid, and enable differences in frequency, duration, and PA intensity to be objectively assessed. These measurements are extremely important in the case of preschool children. Pedometers also provide objective measurements. However, the possibilities to assess differences in intensities and movement directions with these instruments are scarce. Questionnaires provide subjective responses, and their reliability and
validity are limited, especially when used for young children. Thus, whereas accelerometers also have limitations, they are potentially the most effective instruments for assessing PA in preschool children.

In the last few years, more studies measuring PA using accelerometers have been conducted. Therefore, this review focused exclusively on these studies, thereby reducing differences caused by the use of various instruments for measuring PA. Furthermore, it is possible to distinguish between different PA intensities and to conduct meta-analyses to explore heterogeneous results. The aim of the current study was to conduct a review and meta-analyses to examine whether accelerometer-derived PA is related to adiposity at preschool ages. We anticipated varying associations for different PA intensities and different adiposity outcomes. Hence, we differentiated PA intensities (total PA, sedentary behaviour, light PA, moderate PA, vigorous PA, and moderate-to-vigorous PA [MVPA]) and different adiposity outcomes (percentage body fat, body mass index [BMI], weight status, waist circumference, fat mass, and skinfold thickness). The differentiation of PA intensities and adiposity outcomes can provide researchers and policymakers with directly applicable information enabling the targeting of PA intensities to prevent increases in childhood overweight/obesity and the determination of which adiposity outcomes are related to PA.

**METHODS**

We registered the protocol of this systematic review and meta-analyses in the International Prospective Register of Systematic Reviews (PROSPERO, http://www.crd.york.ac.uk/PROSPERO/ display_record.php?ID=CRD42018082660) and adhered to the methods of the Cochrane Collaboration. We followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for reporting the findings.

**Search strategy**

Relevant studies for the systematic review were identified through a literature search in EMBASE, MEDLINE, and Web of Science. A combination of MeSH terms and keywords were used: (children or preschool or paediatrics) and (‘body mass index’ or BMI or ‘body fat’ or ‘waist circumference’ or overweight or obese or ‘weight status’ or ‘body composition’) and (‘physical activity’ or exercise or ‘activity level’ or ‘sedentary behaviour’) and (accelerometry or ‘physiologic monitoring’ or actigraph) (Appendix A). The literature search was performed on 13 August 2018. Additional studies were identified by searching the reference lists of the included studies. All identified hits (for abstracts and titles) were screened for eligibility by two independent reviewers (RW and JvB). Subsequently, the same two reviewers independently read the full text of all potentially eligible papers. Disagreements were discussed during a consensus meeting, and in case of persistent disagreement, a third reviewer (BH) was consulted.
Inclusion and exclusion criteria
Studies that met the following criteria were included in the review: (1) The study population consisted of typical developing preschool children, aged 2-7 years at the baseline (or the mean or median ages of the study population ranging between 3.0 and 6.0 years). (2) The determinant was continuous PA (total PA, light PA, moderate PA, vigorous PA or MVPA) and/or sedentary behaviour, measured objectively with an accelerometer. (3) The outcome was adiposity (e.g., percentage of body fat, BMI, weight status, waist circumference, fat mass, and skinfold thickness). (4) The studies were observational studies (cross-sectional, case control, and prospective cohort studies) in which an association between PA or sedentary behaviour and adiposity was quantitatively assessed. (5) Papers were full text, peer reviewed, irrespective of language. To ensure maximal inclusion of studies, cross-sectional studies were also included if the determinant was adiposity and the outcome was PA.

The following criteria were used to exclude studies: (1) the type of publication (e.g., study protocols, reviews, or critiques were excluded); (2) studies focusing on children with a (chronic) disease or those confined to hospitals; and (3) studies in which PA was measured only during a part of the day (e.g., during hours of childcare).

Risk of bias assessment
The risk of bias of the included studies was assessed by two reviewers, independently, using the ‘Quality of Prognosis Studies in Systematic Reviews’ tool (QUIPS) 17. QUIPS comprises six domains covering the following topics: 1) study participation, 2) study attrition, 3) PA measurement (which is considered valid and reliable if PA is measured for at least 10 h/day over 3 valid days), 4) measurement of adiposity outcomes, 5) study confounding (the risk of bias was considered high if the analyses had not been adjusted for sex), and 6) analysis and reporting. The extensive operationalization of the items is described in Appendix B.

For all of the identified articles, each domain was rated as entailing a low, moderate-, or high risk of bias by two independent reviewers (RW and BH). Disagreements were discussed in a consensus meeting, and in case of persistent disagreement, a third reviewer (EH) was consulted. The overall percentage agreement and Cohen’s kappa were calculated to assess the level of inter-rater agreement. Overall, an item was considered to entail a high risk of bias if scores of more than 50% of the total number of participants revealed a moderate- or high risk of bias.

Data extraction
The following data were extracted by two independent reviewers (RW and BH) from each of the studies: the study population characteristics; participants’ characteristics; PA assessment method (the type of accelerometer used, accelerometer cut-off points, epoch length, and minimum wear time); adiposity outcome and, if applicable, definitions applied for overweight/obesity; and statistical analyses and results.
Statistical analysis

Separate meta-analyses were performed using the Comprehensive Meta Analysis (CMA) software for varying PA intensities and adiposity outcome measures. These analyses were performed if at least two studies were identified, except when differences between studies were considered too large. If multiple articles included the same participants (e.g., children of the same cohort) and reported on the same adiposity outcome, one article was selected according to the following criteria: (1) the usefulness of the reported estimate for the meta-analysis, (2) the longest follow-up duration, (3) the largest sample size, and (4) the estimate with the largest possible effect. Estimates extracted from the articles with continuous outcomes were converted to standardized bèta (stdβ) and standard errors (SE). If multiple estimates were reported, the adjusted estimates were used for the meta-analyses. For the dichotomous outcome weight status (non-overweight vs. overweight/obesity), standardized mean differences were calculated and converted into Pearson correlation coefficients. Since our aim was to examine the effects of PA on adiposity, estimates obtained for studies in which adiposity was the determinant and PA was the outcome were transformed using unadjusted estimates, univariate analyses, or Pearson correlation coefficients prior to their inclusion in the meta-analyses.

If information required for calculating the estimates was missing, the authors of the article were contacted and requested to provide this information. Appendix C presents an overview of the extracted data from the studies used for the meta-analyses.

Random effect meta-analyses were performed. Heterogeneity was assessed using the χ² test and the I² statistic. If study results were found to be heterogeneous (I² > 50% and/or χ² test p-value < 0.05) an overall estimate was not calculated. The following subgroup analyses were performed to explore heterogeneity: (1) sex (boys, girls, adjusted for sex, and not adjusted for sex); (2) epoch length (5s, 10s, 15s, and 60s epoch length), (3) type of accelerometer (triaxial vs. uniaxial), (4) prevalence of overweight (studies with a low prevalence of overweight/obesity, i.e., < 20%, compared with studies with a high prevalence of overweight/obesity, i.e., > 20% overweight), and (5) individual QUIPS items with a moderate- or high risk of bias (studies with a low risk of bias for these items compared with studies with a moderate- or high risk of bias).

Publication bias

We conducted funnel plots (a visual inspection) and Egger’s test to assess the likelihood of publication bias if at least ten studies were identified. We created separate funnel plots for different PA intensities and adiposity outcomes. We assumed that there was potential publication bias if the p-value of the Egger’s test was < 0.10.
RESULTS

We identified 3906 articles after excluding duplicate articles (2352). We first read titles and abstracts and subsequently screened the full-text of 190 articles, leading to the inclusion of 55 articles. One article was added after we screened the reference lists of these articles. Thus, a total of 56 articles were included in the study, of which 48 were used for the meta-analyses. Figure 1 shows a flow chart of the process of selecting articles. The individual characteristics of each of the reviewed studies for each adiposity outcome are shown in Appendix D. Most studies were performed in the United States and in Western Europe. With regard to the assessment of PA, a wide variety of methods was observed (Appendix E). Triaxial, biaxial and uniaxial accelerometers were used in 20, 1, and 32 studies, respectively. In two studies, triaxial as well as uniaxial accelerometers were used. Thirty-two studies used epoch recordings ≤ 15s and 21 studies used 60s epoch recordings. With regard to the measurement of adiposity, two different methods to measure percentage of body fat or (trunk) fat mass (index) were observed (dual energy X-ray absorptiometry and air-displacement plethysmography), and various locations or numbers of measurements were observed for waist circumference and skinfold thickness (Appendix F). In addition, eight different definitions for overweight and obesity were used (Appendix D).

Risk of bias
Items with a high risk of bias (i.e. moderate/high risk of bias in more than 50% of the total number of participants) were: (2a) ‘adequate response rate’ (89%), (2c) ‘no important differences among participants who completed the study with accelerometer data and those who did not’ (72%), and (3b) ‘method of determinant measurement is adequately valid and reliable’ (87%) (Appendix G). The overall inter-rater agreement was 96% (kappa statistic of 0.94), and ranged between 82% for item 2b (‘reason for loss of data’) and 100% for several other items.
Figure 1. Flow chart of study selection process.

Association between accelerometer-derived PA and adiposity
For the association between PA and adiposity, seven longitudinal studies were selected, of which three examined the percentage of body fat, five examined BMI, one examined waist circumference, four examined the fat mass (index), and one examined skinfold thickness.

Additionally, for the cross-sectional assessment of the association between PA and adiposity, six studies were selected on body fat percentage, twenty-three studies for BMI, eighteen studies for weight status, five studies for waist circumference, six studies for (trunk) fat mass (index), and three studies for skinfold thickness.

Outcome: Percentage body fat

Longitudinal studies
Three longitudinal studies examined the association between different PA intensities and percentages of body fat. Although the number of longitudinal studies was sufficient, no
meta-analysis was performed because of wide variations among the studies. One study found that children who spent more time engaged in moderate PA, vigorous PA, or MVPA had a lower percentage of body fat compared with their peers 12 months later 20. Another study did not find an association between total PA, moderate PA, or vigorous PA with changes in the percentage of body fat being evident after 9 months 21. The third study did not find any relation between total PA, sedentary behaviour, or MVPA and one-year changes in the percentage of body fat 22.

Cross-sectional studies
The association between different PA intensities and the percentage of body fat was examined in six cross-sectional studies 21–26. The total sample comprised 1555 children, with 100-434 children per study. The prevalence of overweight ranged between 8.5% and 20.1%.

Pooled estimates indicated that there was an association between total PA, moderate PA, vigorous PA, or MVPA and percentage body fat (Figure 2). No association was found between time spent in sedentary behaviour and the percentage of body fat (Figure 2b). Furthermore, one study showed that children who spent more time engaged in light PA had a lower percentage of body fat compared with their peers 25. In sum, children who spent more time engaged in total PA, light PA, moderate PA, vigorous PA, or MVPA had a lower percentage of body fat compared with their peers.

Outcome: BMI
Longitudinal studies
Five longitudinal studies examined the association between different PA intensities and BMI. Although the number of longitudinal studies was sufficient, no meta-analysis was performed because of wide variations among the studies. One study showed that children who spent more time engaged in MVPA exhibited greater changes in BMI after 1 year compared with their peers 22. Another study reported that a 5% increase in total PA or light PA resulted in decreased zBMI in heavier boys 1 year later 27. A 5% increase in MVPA resulted in decreased zBMI in normal weight and heavier boys and heavier girls 1 year later 27. A third study indicated that children who spent more time engaged in vigorous PA had a higher BMI 12 months later compared with their peers 20. The fourth study did not find any differences in BMI gain for low/medium and high MVPA 28. The final study did not find any correlations between minutes spent in MVPA and changes in BMI 29.

Cross-sectional studies
Twenty-three cross-sectional studies investigated the association between different PA intensities and BMI. Fifteen studies provided sufficient data to be included in the meta-analyses 22,23,26,30–41, and two studies provided additional data on request 42,43. Of the two studies that used the same sample 35,44, one was chosen according to our pre-defined criteria for the meta-analysis 35. The authors of three studies informed us that the data were no longer available 45–47 and we failed to contact the authors of two other studies. The total sample
comprised 3502 children, with 46-394 children per study. The prevalence of overweight ranged from 8.5% to 28.0%.

Pooled estimates showed no associations between total PA, light PA, moderate PA, or vigorous PA and BMI (Figure 3). By contrast, there was an association between time spent in sedentary behaviour and BMI (Figure 3b). Notably, children who spent less time being sedentary had a higher BMI compared with their peers.

The overall result for the association between MVPA and BMI was heterogeneous (p = 0.027). In subgroup analyses, heterogeneity could be explained by sex, type of accelerometer, epoch length, PA assessment, and missing data (Table 1). Pooled estimates in the subgroup analyses for sex showed that boys who spent more time in MVPA had a higher BMI compared with their peers. However, no association was observed for boys and girls together (Figure 3f).

**Outcome: Weight status**

*Cross-sectional studies*

Nineteen cross-sectional studies reported on the association between different PA intensities and weight status (non-overweight vs. overweight/obesity) 48–66. Sixteen studies provided sufficient data and were therefore included in the meta-analyses 48,49,61–66,67,50–52,55–58,60, and for one study, we requested and obtained additional data 65. We failed to contact the authors of one study. The same sample was used in two studies 59,67, one of which was chosen for the meta-analysis 67. The total sample comprised 4327 children, with 50-540 children per study. The overweight percentage ranged from 7.1% to 43.0%.

Pooled estimates showed that children with overweight spent less time engaged in vigorous PA compared with children who were not overweight (Figure 4e). Time spent in sedentary behaviour, light PA, and moderate PA were not associated with weight status (Figure 4).

The overall results for the association between total PA or MVPA and weight status were heterogeneous ($I^2 = 70\%$ and $60\%$, respectively). Sex, accelerometer types, missing data, response rates, and the prevalence of overweight all explained heterogeneity within subgroup analyses (Table 1). The pooled estimates in the subgroup analyses for sex showed a negative association between MVPA and the weight status of boys and girls considered together (Figure 4f). Moreover, pooled estimates showed no association between total PA and the weight status for girls (Figure 4a).

**Outcome: Waist circumference**

*Longitudinal study*

One longitudinal study examined the association between MVPA and waist circumference. No relation was found between minutes in MVPA and 1-3 year changes in waist circumference 29.
Figure 2. Forest plots of the association between physical activity and body fat percentage, differentiated by physical activity intensities.

Abbreviations: B, boys; G, girls; BG, boys and girls; adj, adjusted for sex; acc, accelerometer type; uni, uniaxial; bi, biaxial; tri, triaxial; epoch, epoch length (s); N, number of participants.
3a. Total physical activity - body mass index (kg/m²)

| Author (year) | Sex | Act | Epoch | N  | Statistics for each study | Point estimate | Standard error | p-Value |
|---------------|-----|-----|-------|----|---------------------------|----------------|---------------|---------|
| Cliff (2006)  | B   | Uni | 60    | 25 |                            | 0.320          | 0.200         | 0.141   |
| Hendon (2006) | B   | Uni | 60    | 48 |                            | -0.150         | 0.159         | 0.529   |
| Cliff (2009)  | G   | Uni | 60    | 48 |                            | 0.253          | 0.222         | 0.080   |
| Hendon (2006) | G   | Uni | 60    | 52 |                            | -0.170         | 0.271         | 0.530   |
| Boz (2016)    | BG  | Tri | 60    | 111|                            | -0.057         | 0.079         | 0.471   |
| Lomax (2017)  | BG  | Tri | 15   | 111|                            | 0.000          | 0.000         | 1.000   |
| Dawson (2018) | B   | Uni | 15   | 61 |                            | 0.138          | 0.100         | 0.283   |
| Fies (2002)   | B   | Uni | 60   | 218|                            | 0.052          | 0.072         | 0.470   |
| Gao (2017)    | B   | Uni | 15   | 227|                            | 0.110          | 0.175         | 0.630   |
| Jackson (2008)| B   | Uni | 60   | 104|                            | 0.190          | 0.099         | 0.041   |
| Oliver (2018) | B   | Tri | 15   | 78 |                            | -0.222         | 0.139         | 0.150   |
| Simac (2016)  | BG  | Tri | 15   | 364|                            | 0.060          | 0.045         | 0.045   |
| Tochik (2007) | BG  | Uni | 60   | 192|                            | -0.060         | 0.066         | 0.532   |

Overall: 0.059, 0.024, 0.189

Heterogeneity: F=35%, Q=14, df=2, p=0.293

3b. Sedentary behaviour - body mass index (kg/m²)

| Author (year) | Sex | Act | Epoch | N  | Statistics for each study | Point estimate | Standard error | p-Value |
|---------------|-----|-----|-------|----|---------------------------|----------------|---------------|---------|
| Bus (2011)    | B   | Uni | 15    | 169|                            | -0.149         | 0.065         | 0.100   |
| Cliff (2009)  | B   | Uni | 60    | 25 |                            | -0.369         | 0.193         | 0.071   |
| España Romero (2013) | B | Uni | 15 | 188 | -0.129 | 0.071 | 0.079 |
| Black (2012)  | G   | Uni | 15    | 188|                            | -0.183         | 0.092         | 0.050   |
| Cliff (2009)  | B   | Uni | 60    | 21 |                            | 0.034          | 0.231         | 0.883   |
| España Romero (2013) | B | Uni | 15 | 178 | 0.051 | 0.084 | 0.564 |
| Butte (2016)  | B   | Uni | 15    | 111|                            | 0.101          | 0.101         | 0.137   |
| Collings (2017) | BG  | Tri | 15   | 333|                            | -0.013         | 0.241         | 0.957   |
| Løvåsen (2016) | BG  | Tri | 10   | 307|                            | -0.365         | 0.165         | 0.137   |
| Schmidt (2017) | BG  | Tri | 15   | 294|                            | -0.156         | 0.047         | 0.003   |
| Overall       |     |     |       |    |                            | -0.080         | 0.039         | 0.030   |

Heterogeneity: F=27%, Q=12, df=4, p=0.195

3c. Light physical activity - body mass index (kg/m²)

| Author (year) | Sex | Act | Epoch | N  | Statistics for each study | Point estimate | Standard error | p-Value |
|---------------|-----|-----|-------|----|---------------------------|----------------|---------------|---------|
| Cliffs (2017) | BG  | Tri | 15    | 333|                            | -0.003         | 0.037         | 0.994   |
| Williams (2008) | BG | Uni | 15   | 198|                            | 0.010          | 0.016         | 0.530   |

Overall: 0.028, 0.015, 0.166

Heterogeneity: F=0%, Q=0, df=1, p=0.800

Figure 3. Forest plots of the association between physical activity and body mass index, differentiated by physical activity intensities.

Abbreviations: B, boys; G, girls; BG, boys and girls; adj, adjusted for sex; acc, accelerometer type; uni, uniaxial; bi, biaxial; tri, triaxial; epoch, epoch length (s); N, number of participants; NR, not reported.
Figure 4. Forest plots of the association between physical activity and weight status, differentiated by physical activity intensities.

Abbreviations: B, boys; G, girls; BG, boys and girls; acc, accelerometer type; uni, uniaxial; bi, biaxial; tri, triaxial; epoch, epoch length (s); N, number of participants; NR, not reported.
### Table 1. The results of the subgroup analyses for body mass index and weight status

#### Body mass index

|                        | Q  | df | p-value(Q) | I² | N  | Stdβ ± SE | p-value |
|------------------------|----|----|------------|----|----|-----------|---------|
| **Sex**                |    |    |            |    |    |           |         |
| Boys                   | 2  | 3  | 0.596      | 0% | 4  | 0.097 ± 0.045 | 0.032   |
| Girls                  | 11 | 3  | 0.012      | 72%| -  | -         |         |
| Adjusted for sex       | 4  | 3  | 0.305      | 17%| 4  | -0.075 ± 0.069 | 0.273   |
| Not adjusted for sex   | 0  | 1  | 0.832      | 0% | 2  | 0.130 ± 0.052 | 0.012   |
| **Accelerometer**      |    |    |            |    |    |           |         |
| Triaxial               | 3  | 3  | 0.349      | 9% | 4  | 0.044 ± 0.056 | 0.432   |
| Uniaxial               | 21 | 9  | 0.013      | 57%| -  | -         |         |
| **Epoch length**       |    |    |            |    |    |           |         |
| 10s                    | -  | -  | -          | -  | -  | -         |         |
| 15s                    | 17 | 7  | 0.016      | 59%| -  | -         |         |
| 60s                    | 4  | 4  | 0.385      | 4% | 5  | 0.000 ± 0.051 | 0.998   |
| **Physical activity assessment** |    |    |            |    |    |           |         |
| Low risk               | 3  | 2  | 0.194      | 39%| 3  | 0.049 ± 0.081 | 0.548   |
| Moderate/high risk     | 21 | 10 | 0.021      | 53%| -  | -         |         |
| **Missing data**       |    |    |            |    |    |           |         |
| Low risk               | 5  | 4  | 0.253      | 25%| 5  | 0.032 ± 0.062 | 0.607   |
| Moderate/high risk     | 19 | 8  | 0.017      | 57%| -  | -         |         |

#### Weight status

|                        | Q  | df | p-value(Q) | I² | N  | r       | p-value |
|------------------------|----|----|------------|----|----|---------|---------|
| **Sex**                |    |    |            |    |    |         |         |
| Boys                   | 13 | 1  | 0.000      | 92%| -  | -       | -       |
| Girls                  | 0  | 1  | 0.927      | 0% | 12 | -0.000  | 0.996   |
| Boys and girls         | 37 | 11 | 0.000      | 70%| -  | -       | -       |
| **Accelerometer**      |    |    |            |    |    |         |         |
| Triaxial               | 4  | 4  | 0.361      | 8% | 5  | 0.014   | 0.641   |
| Uniaxial               | 36 | 9  | 0.000      | 75%| -  | -       |         |
| Unknown                | -  | -  | -          | -  | 1  | -0.276  | 0.002   |
| **Prevalence of overweight** |    |    |            |    |    |         |         |
| Low prevalence         | 9  | 4  | 0.074      | 53%| -  | -       | -       |
| High prevalence        | 42 | 10 | <0.001     | 76%| -  | -       | -       |
| **Physical activity assessment** |    |    |            |    |    |         |         |
| Low risk               | 6  | 1  | 0.011      | 84%| -  | -       | -       |
| Moderate/high risk     | 43 | 13 | <0.001     | 70%| -  | -       | -       |
| **Missing data**       |    |    |            |    |    |         |         |
| Low risk               | 3  | 2  | 0.207      | 37%| 3  | 0.025   | 0.503   |
| Moderate/high risk     | 43 | 12 | <0.001     | 72%| -  | -       | -       |
Table 1. Continued.

| Weight status | Response rate\(^2\) | Q  | df \(^1\) | p-value(Q) | I\(^2\) | N  | Stdβ ± SE | p-value |
|---------------|----------------------|----|-----------|------------|--------|----|-----------|---------|
| Low risk      | 4                    | 2  | 0.158     | 56%        | -      | -  | -         | -       |
| Moderate/high risk | 42                | 12 | <0.001   | 71%        | -      | -  | -         | -       |

Moderate-to-vigorous physical activity

| Sex          | Boys                  | 22 | 3  | 0.000 | 86% | - | - | - |
|--------------|-----------------------|----|----|-------|-----|---|---|---|
|              | Girls                 | 7  | 3  | 0.085 | 55% | - | - | - |
|              | Boys and girls        | 8  | 7  | 0.364 | 9%  | 8 | -0.066 | 0.004 |

| Accelerometer | Triaxial              | 15 | 5  | 0.010 | 67% | - | - | - |
|---------------|-----------------------|----|----|-------|-----|---|---|---|
|               | Uniaxial              | 18 | 9  | 0.035 | 50% | - | - | - |

| Prevalence of overweight\(^3\) | Low prevalence | 5  | 4  | 0.344 | 11% | 5 | -0.056 | 0.041 |
|---------------------------------|----------------|----|----|-------|-----|---|--------|---------|
|                                 | High prevalence| 33 | 10 | <0.001 | 70% | - | - | - |

| Physical activity assessment\(^2\) | Low risk of bias | - | - | - | - | 1 | -0.096 | 0.026 |
|--------------------------------------|------------------|---|---|---|---|---|--------|---------|
| Moderate/high risk                   | 36               | 14 | 0.001 | 61% | - | - | - |

| Missing data\(^2\)                  | Low risk         | - | - | - | - | 1 | -0.096 | 0.026 |
|--------------------------------------|------------------|---|---|---|---|---|--------|---------|
| Moderate/high risk                   | 36               | 14 | 0.001 | 61% | - | - | - |

| Response rate\(^2\)                  | Low risk         | 3  | 2  | 0.274 | 23% | 3 | -0.087 | 0.066 |
|--------------------------------------|------------------|---|---|-------|-----|---|--------|---------|
| Moderate/high risk                   | 34               | 12 | 0.001 | 64% | - | - | - |

\(^1\)The results of the subgroup analyses are only shown if results were homogeneous.

\(^2\)Studies with low risk of bias on this QUIPS item compared to studies with a moderate/high risk of bias.

\(^3\)High prevalence of overweight was defined as >20% of the study sample affected by overweight or obesity.

Cross-sectional studies

Five cross-sectional studies that examined the association between different PA intensities and waist circumference were identified\(^{26,33,41,68,69}\). The total sample comprised 1198 children, with 78-357 children per study. The prevalence of overweight or a high waist circumference ranged from 8.5% to 58.0%.

Pooled estimates showed that total PA and time spent in sedentary behaviour were not associated with waist circumference (Appendix H). Single studies on the association of light PA\(^4\), moderate PA\(^26\), or vigorous PA\(^26\), respectively, with waist circumference did not indicate an association.
The results for the association between MVPA and waist circumference were heterogeneous ($I^2 = 51\%$). Epoch length, overweight prevalence, and PA assessment were factors explaining heterogeneity within subgroup analyses (Appendix I).

**Outcome: Fat mass**

**Longitudinal studies**

The association between different PA intensities and fat mass was examined in three longitudinal studies. Although the number of longitudinal studies was sufficient, no meta-analyses were performed because of wide variations among the studies. One study showed that girls with a high baseline MVPA gained less fat mass at the age of 8 years compared with their peers, but no relation was found for boys 28. In a second study, boys aged 5 years, with high MVPA levels, showed a lower fat mass at the age of 8 years compared with their peers 70. However, no such relation was found for girls. No relations between total PA, sedentary behaviour, or MVPA and 1-year changes in fat mass were found in the last study 22.

**Cross-sectional studies**

Four cross-sectional studies focused on the association between different PA intensities and fat mass 22–24,71. The total sample comprised 645 children, with 100-1080 children per study. Only one study reported on the prevalence (18%) of overweight 22.

Pooled estimates showed that children who spent more time in total PA or MVPA had a lower fat mass compared with their peers (Appendix H). One study each examined the association of sedentary behaviour 22, light PA 71, or vigorous PA 24 with fat mass. Children who spent more time engaged in vigorous PA had a lower fat mass compared with their peers 24. No associations were found for sedentary behaviour or light PA with fat mass 22,71. In addition, no study focused on moderate PA.

**Outcome: Fat mass index**

**Longitudinal studies**

One longitudinal study examined the association between different PA intensities and the fat mass index. The results showed no relations existing between sedentary behaviour, moderate PA, vigorous PA, or MVPA and fat mass index 20.

**Cross-sectional studies**

Two cross-sectional studies reported on the association between different PA intensities and the fat mass index (fat mass adjusted for height, kg/m$^2$) 25,26. The total sample comprised 693 children (295 children in one study and 398 children in the other). The prevalence of overweight in these studies was 8.5% and 20.1%, respectively.

Pooled estimates showed that children who spent less time engaged in sedentary behaviour or more time in moderate PA, vigorous PA, or MVPA had a lower fat mass index compared with their peers (Appendix H). In addition, one study which examined the association between...
light PA and fat mass index did not find an association. Furthermore, no study focused on total PA.

**Outcome: Trunk fat mass (index)**

*Cross-sectional studies*

Only one cross-sectional study examined the association between different PA intensities and trunk fat mass. Children who spent more time engaged in vigorous PA had a lower trunk fat mass compared with their peers. A similar association for total PA was only found for girls. No association was found between MVPA and trunk fat mass.

Additionally, the association between different PA intensities and trunk fat mass index (trunk fat mass adjusted for height, kg/m²) was examined in one cross-sectional study. Children who spent less time engaged in sedentary behaviour or more time in moderate PA, vigorous PA, or MVPA had a lower trunk fat mass index compared with their peers. No association were observed between light PA and trunk fat mass index.

**Outcome: Skinfold thickness**

*Longitudinal study*

The findings of one longitudinal study in which the association between MVPA and skinfold thickness was examined did not reveal any relation between minutes spent in MVPA and changes in skinfold thickness.

*Cross-sectional studies*

Three cross-sectional studies examined the association between different PA intensities and skinfold thickness. The total sample comprised 811 children, with 309-346 children per study. Only one study reported on the prevalence (19.5%) of overweight.

Pooled estimates showed that children who spent more time engaged in total PA, light PA, or MVPA had a lower skinfold thickness compared with their peers (Appendix H). One study, in which the association between sedentary behaviour and skinfold thickness was examined, showed no association between time spent in sedentary behaviour and skinfold thickness. In addition, no studies focused on moderate PA or vigorous PA.

**Other adiposity outcomes**

Two cross-sectional studies focused on other adiposity outcomes for which no meta-analyses were conducted. One study focused on central obesity and showed that boys with central obesity spent more time engaged in sedentary behaviour compared with boys who were not affected by central obesity. No differences were found for girls. The second study focused on stunted-overweight, revealing differences in sedentary behaviour, light PA, and MVPA between stunted children without overweight, stunted children with overweight, non-stunted children with overweight, and non-stunted children without overweight. Children with overweight spent more time engaged in total PA and light PA compared with
stunted children without overweight and less time engaged in sedentary behaviour compared with stunted children with and without overweight. Furthermore, stunted children with and without overweight spent less time engaged in MVPA compared with non-stunted children without overweight.

Publication bias
No indications of publication bias relating to the associations between different PA intensities and adiposity outcomes were found (all p > 0.10).

DISCUSSION

We examined the association between accelerometer-derived PA and varying adiposity outcomes in preschool children using outcome data from 56 studies. Our meta-analyses showed that the associations between PA and adiposity in preschool children are highly dependent on the intensity of PA and the type of outcome used for assessing the degree of adiposity. There was substantial evidence of an association between (moderate-to-) vigorous PA and adiposity.

PA intensity
Children who spent more time engaged in vigorous PA or MVPA showed lower levels of adiposity, revealing that high PA intensities are indicative of positive associations between PA and adiposity at young ages. These findings are in accordance with the results of a systematic review in which the relation between PA and health indicators in children aged 5-17 years was explored. The most persistent associations between PA and health indicators were found for higher PA intensities. We found that associations between PA and adiposity were highly dependent on the PA intensity. This finding highlights the importance of distinguishing between different PA intensities. For interventions among preschool children, we recommend, in accordance with the 24-hour movement guidelines from Canada and Australia, focusing on increasing (moderate-to-) vigorous PA to address the growing prevalence of overweight and obesity in young children.

The literature on light PA is scarce compared with vigorous PA and MVPA. The Advisory Committee of the 2018 US PA Guidelines decided to include light PA in their recommendations until more evidence on light PA becomes available. In our study, meta-analyses for the association between light PA and percentage of body fat, fat mass, or waist circumference were not conducted because of insufficient numbers of studies. However, an association was found between light PA and skinfold thickness, and a trend was observed for weight status. Children spent time of the day entailing the most activity engaged in light PA, which is less intensive than MVPA. It may be easier within intervention studies to increase the time spent in light PA than that spent in high intensity PA. Therefore, future studies should comprehensively examine the influence of light PA on adiposity in preschool children.
Sedentary behaviour
The studies included in this review showed no clear association between sedentary behaviour and adiposity. Associations were found between sedentary behaviour and BMI or fat mass index, but these results should be treated with caution. First, the results showed that children who were less sedentary had a higher BMI compared with their peers. This can probably be explained by the fact that BMI may not only include fat mass but also fat free mass or muscle mass. In addition, as children mature, they gain height and their motor-ability develops as well, which may have influenced the observed association as well. Second, only two studies examining the fat mass index were found. Of these studies, one study reported a positive association between sedentary behaviour and fat mass index, whereas the other study found no association. In addition, a review of studies on children and adolescents conducted in 2012 did not find any associations between accelerometer-derived sedentary behaviour and adiposity. Significant negative associations of sedentary behaviour and weight status only occurred in studies in which the former was self-reported by children and parents. This self-reported sedentary behaviour was based on reports of children's screen-time. However, screen-time and sedentary behaviour are not identical. On the one hand, screen-time is defined as the time spent engaged in screen-based behaviours, which can be performed when individuals are sedentary as well as physically active. On the other hand, sedentary behaviour is defined as sitting, reclining, or lying down and entails low energy costs (< 1.5 METs). Screen-time in children is related to a lower vegetable and fruit intake and higher snack consumption. Therefore, an alternative explanation for associations between screen-time and adiposity may be an excess of energy intake rather than a lack of energy expenditure. Consequently, future studies need to clearly distinguish between screen-time and sedentary behaviour. Although screen-time behaviour could be (indirectly) related to adiposity, we found no association between accelerometer-derived sedentary behaviour and adiposity at young ages.

Adiposity outcome
The findings of this review show that the association between PA and adiposity is highly dependent on the outcome measure used for adiposity. Children who spend more time engaged in PA show a lower percentage of body fat, less fat mass, and a lower weight status compared with their peers. However, more time spent in PA is not associated with a lower BMI or waist circumference regardless of PA intensity. These findings are in accordance with a review from 2011 that focused on the association between objectively measured PA and adiposity in preschool children. The review included the percentage of body fat, BMI, weight status, and fat mass as outcome measures for adiposity and partly included the same studies that we reviewed. The results depended on the outcome measure used for adiposity, with more confirmative results for percentage of body fat than for BMI. Our review and meta-analyses were more comprehensive as we also incorporated waist circumference, fat mass index, trunk fat mass (index), and skinfold thickness as adiposity outcome measures. Moreover, we included more recent literature: 38 of the studies in our review and meta-analyses were published between 2011 and 2018. More confirmative results were found for the percentage of body fat, fat mass, and weight status.
This leads to the question of which adiposity outcome should be assessed in future studies. BMI and waist circumference calculations are based on children’s anthropometry. As previously mentioned, these are not exclusive measures for fat mass. In this case, the higher BMI could indicate a higher muscle mass instead of a higher fat mass. The body fat percentage, fat mass, and skinfold thickness are more precise and may be better measures of adiposity. In addition, although no association between vigorous PA and BMI was found, children who spent more time in vigorous PA are likely to have a lower weight status compared with their less active peers. This may seem contradictory, as weight status is calculated based on BMI. BMI is a continuous measure, whereas weight status is a categorical variable. By dividing children into overweight or obesity and non-overweight groups, the distinctiveness becomes larger. It may mean that vigorous PA affects adiposity in higher ranges, preventing children to reach a threshold, but it may not affect adiposity over the whole range of BMI and all degrees of adiposity. In other words, it does not make lean children leaner. Therefore, future studies should include the percentage of body fat as outcome for adiposity, and, if BMI data are collected, children should be divided into the following categories: underweight, normal weight, overweight, and obesity to increase the distinctiveness of the outcome measure.

Assessment of PA

The reviewed studies encompassed a wide variety of methods for processing accelerometer-derived PA, which made them less comparable. Because accelerometers are now used more frequently, the development of new accelerometers and the methodological literature on accelerometers have increased, resulting in the deployment of different kinds of accelerometer cut points, and new epoch lengths. A total of 37 accelerometer cut points were used within all of the studies included in this review. A review conducted in 2017 showed 14 different cut points for sedentary behaviour and 11 different cut points for PA intensities within studies that all used the same accelerometer (ActiGraph GT3X) among preschool children. A study conducted in 2016 showed that levels of PA intensities varied significantly for different epoch lengths and for different cut points. In this study, PA was measured using ActiGraph GT3X+ accelerometers in children aged 7-11 years, and the data were processed using various methods (six different epoch lengths and five different accelerometer cut points were used). When the epoch lengths increased, sedentary behaviour, moderate PA, and vigorous PA decreased, whereas light PA increased. The use of different accelerometer cut points was shown to cause a difference of 200 minutes estimated time engaged in sedentary behaviour or light PA and approximately 50 minutes on MVPA. Thus, different epoch lengths and cut points have considerable impacts on the estimated levels of PA intensities, which potentially also influence the associations of PA with adiposity. However, in the current study, we were unable to show whether the associations between PA and adiposity were stronger or weaker if a short epoch time was used, because of heterogeneous findings in the subgroup analyses or a lack of sufficient studies using different epoch lengths. The application of one universal method to assess accelerometer-derived PA is essential to tackle the growing inconsistency reported in the literature.
Strengths and limitations
This review is the first to apply meta-analyses for assessing the association between PA and adiposity in preschool children. We used a wide age range (2-7 years) for preschool children. In general, the preschool period is described as 2-5 years of age. Nevertheless, in many countries children attend preschool until they are 7 years old. It is about the period that children receive structured educational instructions, but in the context of play, when they still have ample opportunity to move around freely. Furthermore, most studies in school-aged children start around the age of 7, leaving a gap between 5 and 7 years. Additionally, this is the first study that seeks to distinguish between different PA intensities and adiposity outcomes. Consequently, a more detailed picture of the association between PA and adiposity in preschool children emerges. Furthermore, only accelerometer-derived PA was included, making all of the included studies more comparable, even though differences in the assessment of PA still prompted variety.

A limitation of the present study is that 53 out of the 56 included studies were from high-income countries. Although this made the results from the included studies more comparable, it would be interesting to examine the association between PA and adiposity in more low- and middle-income countries as well, as part of the double burden of poor lifestyle, where low birth weight and poor growth often exist alongside a transition to more sedentary lifestyles and westernized diets. In addition, several methodological limitations should be noted. Firstly, there was a high risk of bias for most studies. About 63% of the studies had a high risk of bias on approximately 70% of the QUIPS items. Especially the QUIPS-item regarding validity and reliability of the measurement of PA scored high risk of bias. In 75% of the studies, PA was not measured according to the advised weartime (≥ 10 hours per day) or the minimum advised number of wearing days (≥3 days). Secondly, although we did not detect publication bias in our study, it is likely that some pooled estimates may be overestimated. Among observational studies, it is expected that studies with positive and strong associations are more likely to be published. We were only able to assess this likelihood of publication bias in 7 out of the 29 performed meta-analyses. For the other meta-analyses, the Egger’s test would be underpowered to detect publication bias. Lastly, meta-analyses were only performed on cross-sectional studies. Unfortunately, we were not able to conduct meta-analyses for the longitudinal studies because of a lack of comparable studies. Therefore, the pooled estimates might be overestimated and should be handled with caution. More longitudinal studies with multiple measurements taken for both PA and adiposity in young children are needed. Nevertheless, the current study has yielded detailed insights on the association between daily life PA behaviours and adiposity in young children.
**CONCLUSION**

More time spent in (moderate-to-) vigorous PA was found to be associated with a lower percentage of body fat, lower weight status, less fat mass, a lower fat mass index, and lower skinfold thickness in young children. PA was not associated with BMI or waist circumference, irrespective of PA intensity. Furthermore, sedentary behaviour does not appear to be associated with adiposity, irrespective of adiposity outcomes. In addition, light PA should be examined more extensively, and more longitudinal studies are required using multiple measurements for both PA and adiposity. Moreover, universal guidelines are needed to tackle growing inconsistencies regarding the different methods reported in the literature for assessing PA. We recommend that researchers and policymakers focus on high-intensity PA behaviours to prevent increases in childhood overweight and obesity, paying particular attention to body fat percentage or weight status as adiposity outcome measures.

**CONFLICT OF INTEREST**

None declared.

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APPENDICES

Appendix A. Search strategies used in EMBASE, MEDLINE, and Web of Science.
Appendix B. QUIPS-based criteria applied in the assessment of the risk of bias.
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Appendix D. Sample characteristics, statistical analyses, and the results of all of the reviewed studies, differentiated by adiposity outcomes.
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Appendix I. The results of the subgroup analyses for waist circumference.
Appendix A. Search strategies used in EMBASE, MEDLINE, and Web of Science.

MEDLINE:

(“Child, Preschool”[Mesh] OR child*[tiab] OR pediatr*[tiab] OR paediatr*[tiab] OR preschool[tiab])

AND

(“Body Mass Index”[Mesh] OR “Body Fat Distribution”[Mesh] OR “Waist Circumference”[Mesh] OR “Overweight”[Mesh] OR BMI[tiab] OR body mass index[tiab] OR overweight[tiab] OR obes*[tiab] OR weight status[tiab] OR body composition[tiab] OR body fat[tiab])

AND

(“Exercise”[Mesh:NoExp] OR physical activ*[tiab] OR physically activ*[tiab] OR activity level*[tiab] OR exercis*[tiab] OR sedenta*[tiab])

AND

(“Accelerometry”[Mesh] OR “Monitoring, Physiologic”[Mesh:NoExp] OR “Actigraphy”[Mesh] OR accelerom*[tiab] OR monitor*[tiab] OR actigraph[tiab])

NOT

(adolescen*[Title] OR adult*[Title])

EMBASE:

(‘preschool child’/exp OR (child* OR pediatr* OR paediatr* OR preschool):ab,ti)

AND

(‘body mass’/exp OR ‘body fat distribution’/exp OR ‘waist circumference’/exp OR ‘childhood obesity’/exp OR ‘obesity’:de OR (BMI OR ‘body mass index’ OR overweight OR obes* OR ‘weight status’ OR ‘body composition’ OR ‘body fat’):ab,ti)

AND
(‘physical activity, capacity and performance’/de OR ‘exercise’/de OR (physical activ* OR physically activ* OR activity level* OR exercis* OR sedenta*): ab,ti)

AND

(‘accelerometry’/exp OR ‘physiologic monitoring’/de OR ‘actimetry’/exp OR (accelerom* OR monitor* OR actigraph):ab,ti)

AND

(‘article’/it OR ‘conference paper’/it OR ‘review’/it)

NOT

((adolescen* OR adult*):ti)

**Web Of Science**

TS = (child* OR pediatr* OR paediatr* OR preschool)

AND

TS = (BMI OR “body mass index” OR overweight OR obes* OR “weight status” OR “body composition” OR “body fat”)

AND

TS = (“physical activ*” OR “physically activ*” OR “activity level*” OR exercis*)

AND

TS = (accelerom* OR monitor* OR actigraph)
Appendix B. QUIPS-based criteria applied in the assessment of the risk of bias.

The ‘Quality of prognosis Studies in Systematic Reviews’ (QUIPS 2013). QUIPS consists of six domain including the following topics: 1) participation, 2) attrition, 3) determinant measurement, 4) outcome measurement, 5) confounding measurement and account and 6) analysis and reporting. The operationalization of this described in the table below. For all identified articles, each domain will be rated low-, moderate- or high risk of bias by two independent reviewers (RW, BH). Disagreement will be discussed in a consensus meeting or by consulting a third reviewer (EH). The overall percentage agreement and Cohen’s kappa will be calculated.

1. Participation
   a. Description of baseline study sample (at least: age, percentage boys, measure for adiposity)
   b. Adequate description participant recruitment (how were participants recruited; e.g. well baby clinics, childcare centre or flyers. For which purpose; i.e. if recruited for intervention purposes, then 0)
   c. Description of period and place of recruitment
   d. Adequate description of inclusion and exclusion criteria

2. Attrition
   a. Adequate response rate (Response rate > 80%)
   b. Reasons for loss to follow-up or loss of (accelerometer) data are provided
   c. No important differences between participants who completed the study/with accelerometer data and those who did not.

3. Determinant measurement
   a. Clear definition or description of the determinant provided
   b. Method of measurement is adequately valid and reliable (at least 3 valid days of 10h /day of PA measurement)

4. Outcome measurement
   a. Clear definition of the outcome is provided
   b. Method of outcome measurement used is adequately valid and reliable

5. Confounding measurement and account
   a. Important confounders are accounted for in the analysis (at least: sex | preferably: SES and nutrition)

6. Analysis and reporting
   a. Sufficient presentation of data
   b. Selected statistical models is adequate for the design of the study
   c. No selective reporting of the results
| Quips domain          | Subdomains                                                                 |
|-----------------------|----------------------------------------------------------------------------|
| 1 Participation       | a. Description of baseline study sample (at least: age, percentage boys,   |
|                       |   measure for adiposity)                                                   |
|                       | b. Adequate description participant recruitment (how were participants    |
|                       |   recruited; e.g. well baby clinics, childcare centre or flyers. For which  |
|                       |   purpose; i.e. if recruited for intervention purposes, then 0)           |
|                       | c. Description of period and place of recruitment                         |
|                       | d. Adequate description of inclusion and exclusion criteria                |
| 2 Attrition           | a. Adequate response rate (Response rate > 80%)                            |
|                       | b. Reasons for loss to follow-up or loss of (accelerometer) data are provided |
|                       | c. No important differences between participants who completed the study/with accelerometer data and those who did not. |
| 3 Determinant         | a. Clear definition or description of the determinant provided           |
| measurement           | b. Method of measurement is adequately valid and reliable (at least 3 valid |
|                       |   days of 10h /day of PA measurement)                                    |
| 4 Outcome measurement | a. Clear definition of the outcome is provided                            |
|                       | b. Method of outcome measurement used is adequately valid and reliable    |
| 5 Confounding         | a. Important confounders are accounted for in the analysis (at least: sex |
| measurement and      |   preferably: SES and nutrition)                                        |
| account               | 6 Analysis and reporting                                                  |
|                       | a. Sufficient presentation of data                                        |
|                       | b. Selected statistical models is adequate for the design of the study    |
|                       | c. No selective reporting of the results                                  |
### Appendix C. Overview of the extracted data used for the meta-analyses.

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|---------------------|-------------------------|----------------------------|----------------------------|----------------------------------------|
| 1) Percentage body fat | | | | | | |
| Bürgi et al. (2011) [20] | $\beta$ (95% CI): -0.003 (-0.007; -0.0001), SD PA : 164.0, SD out : 4.8; std$\beta$ ± SE: -0.103 ± 0.050 | | $\beta$ (95% CI): -0.006 (-0.014; 0.001), SD PA: 71.0, SD out: 4.8; std$\beta$ ± SE: -0.089 ± 0.052 | $\beta$ (95% CI): -0.010 (-0.022; 0.001), SD PA: 46.0, SD out: 4.8; std$\beta$ ± SE: -0.096 ± 0.053 | |
| Butte et al. (2016) [22] | $\beta$ ± SE: -0.001 ± 0.028, SD PA : 22.7, SD out : 6.7; std$\beta$ ± SE: -0.003 ± 0.095 | $\beta$ ± SE: -0.011 ± 0.010, SD PA : 67, SD out : 6.7; std$\beta$ ± SE: -0.110 ± 0.100 | | $\beta$ ± SE: -0.066 ± 0.026, SD PA: 24.0, SD out: 6.7; std$\beta$ ± SE: -0.236 ± 0.093 | |
| Collings et al. (2013) [25] | r: 0.08, p<0.001; std$\beta$ ± SE: 0.08 ± 0.127 | r: -0.05, p<0.05; std$\beta$ ± SE: -0.05 ± 0.023 | r: -0.11, p<0.001; std$\beta$ ± SE: -0.11 ± 0.175 | r: -0.13, p<0.001; std$\beta$ ± SE: -0.13 ± 0.207 | r: -0.13, p<0.001; std$\beta$ ± SE: -0.13 ± 0.207 |
| Heelan and Eisenmann (2006) [26] | Boys, r: -0.08, p>0.05; std$\beta$ ± SE: -0.08 ± 0.127 | | | | Boys, r: -0.09, p>0.05; std$\beta$ ± SE: -0.09 ± 0.143 |
| | Girls, r: -0.06, p>0.05; std$\beta$ ± SE: -0.06 ± 0.096 | | | | Girls, r: -0.12, p>0.05; std$\beta$ ± SE: -0.12 ± 0.191 |
### Appendix C. Continued.

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|---------------------|-------------------------|---------------------------|--------------------------|---------------------------------------|
| Janz et al. (2002) [27] | Boys, $r$: -0.19, $p$: <0.01; stdβ ± SE: -0.19 ± 0.074 | | | | Boys, $r$: -0.26, $p$: <0.01; stdβ ± SE: -0.26 ± 0.101 | Boys, $r$: -0.10, $p$: >0.05; stdβ ± SE: -0.10 ± 0.159 |
| | Girls, $r$: -0.25, $p$: <0.01; stdβ ± SE: -0.25 ± 0.097 | | | | Girls, $r$: -0.30, $p$: <0.01; stdβ ± SE: -0.30 ± 0.116 | |
| Leppänen et al. (2016) [28] | | β (95% CI): 0.01 (-0.06; 0.07), SD PA: 49.6, SD out : 4.5; stdβ ± SE: 0.111 ± 0.334 | | | β (95% CI): -0.08 (-0.20; 0.04), SD PA: 22.5, SD out : 4.5; stdβ ± SE: -0.404 ± 0.303 | β (95% CI): -0.46 (-0.98; 0.06), SD PA: 4.9, SD out : 4.5; stdβ ± SE: -0.505 ± 0.286 |
| | | | | | | β (95% CI): -0.08 (-0.19; 0.02), SD PA: 25.2, SD out : 4.5; stdβ ± SE: -0.452 ± 0.283 |

2) Body mass index

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|---------------------|-------------------------|---------------------------|--------------------------|---------------------------------------|
| Buck et al. (2015) [33] | | | | | | Data no longer available |
| Butte et al. (2016) [22] | β ± SE: -0.005 ± 0.007, SD PA: 0.003, SD PA: 67, SD out : 2.0; stdβ ± SE: -0.057 ± 0.079 | | | | β ± SE: -0.005 ± 0.007, SD PA: 24.0, SD out : 2.0; stdβ ± SE: -0.060 ± 0.084 | |

Data no longer available
| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|--------------|-------------------------|--------------------|-------------------------|---------------------------|---------------------------|--------------------------------------|
| Byun et al. (2011) [34] zBMI | | Boys, r: -0.14, p < 0.1; stdβ ± SE: -0.14 ± 0.085 | | | | |
| | | Girls, r: -0.18, p < 0.05; stdβ ± SE: -0.18 ± 0.092 | | | | |
| Cliff et al. (2009) [35] zBMI | Boys, r: 0.303, p: 0.141; stdβ ± SE: -0.303 ± 0.206 | Boys, r: -0.366, p: 0.072; stdβ ± SE: -0.366 ± 0.203 | Boys, r: 0.298, p: 0.147; stdβ ± SE: 0.298 ± 0.205 | Boys, r: 0.088, p: 0.674; stdβ ± SE: 0.088 ± 0.209 | Boys, r: 0.257, p: 0.215; stdβ ± SE: 0.257 ± 0.207 | |
| | Girls, r: -0.051, p: 0.826; stdβ ± SE: -0.051 ± 0.232 | Girls, r: 0.034, p: 0.883; stdβ ± SE: 0.034 ± 0.231 | Girls, r: -0.215, p: 0.350; stdβ ± SE: -0.215 ± 0.230 | Girls, r: -0.103, p: 0.658; stdβ ± SE: -0.103 ± 0.233 | Girls, r: -0.263, p: 0.250; stdβ ± SE: -0.263 ± 0.229 | |
### Appendix C. Continued.

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|---------------------|-------------------------|---------------------------|---------------------------|----------------------------------------|
| Collings et al. (2017)[36] | β (95% CI): 0.042 (-0.037; 0.12), SD PA: 320.2, SD out: 1.7; stdβ ± SE: 0.026 ± 0.024 | β (95% CI): -0.007 (-0.040; 0.027), SD PA: 64.6, SD out: 1.7; stdβ ± SE: -0.013 ± 0.242 | β (95% CI): -0.000 (-0.043; 0.042), SD PA: 54.0, SD out: 1.7; stdβ ± SE: -0.0003 ± 0.037 | β (95% CI): 0.045 (-0.040; 0.13), SD PA: 23.5, SD out: 1.7; stdβ ± SE: 0.031 ± 0.143 |
| Dawson-Hahn et al. (2015)[38] | zBMI Stdβ: 0.118, p=0.283* | stdβ ± SE: 0.118 ± 0.110 | | Failed to contact authors. |
| España-Romero et al. (2013)[39] | Boys, β ± SE: -0.050 ± 0.028, SD PA: 3.1, SD out: 1.2; stdβ ± SE: -0.129 ± 0.072 | | | Boys, β ± SE: 0.080 ± 0.039, SD PA: 2.2, SD out: 1.2; stdβ ± SE: 0.147 ± 0.072 |
| | Girls, β ± SE: 0.014 ± 0.023, SD PA: 3.3, SD out: 0.9; stdβ ± SE: 0.051 ± 0.084 | | | Girls, β ± SE: -0.024 ± 0.036, SD PA: 2.0, SD out: 0.9; stdβ ± SE: -0.053 ± 0.080 |
### Appendix C. Continued.

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|---------------------|-------------------------|---------------------------|---------------------------|--------------------------------------|
| Finn et al. (2002)[40] | p = 0.4; stdβ ± SE: 0.052 ± 0.072* |                      |                          |                           | p = 0.3; stdβ ± SE: 0.063 ± 0.072* |                                    |
| Fisher et al. (2005)[41] zBMI | Data no longer available |                      |                          |                           |                           |                                    |
| Guo et al. (2017)[42] zBMI | r: 0.11, p >0.05; stdβ ± SE: 0.11 ± 0.175 |                      |                          |                           |                           |                                    |
| Heelan and Eisenmann (2006) [26] | Boys, r: -0.10, p>0.05; stdβ ± SE: -0.10 ± 0.159 |                      |                          |                           | Boys, r: 0.04, p>0.05; stdβ ± SE: 0.04 ± 0.064 |                                    |
|                           | Girls, r: -0.17, p>0.05; stdβ ± SE: -0.17 ± 0.271 |                      |                          |                           | Girls, r: -0.25, p>0.05; stdβ ± SE: -0.25 ± 0.398 |                                    |
## Appendix C. Continued.

| Author (year)          | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|------------------------|-------------------------|---------------------|-------------------------|---------------------------|---------------------------|-----------------------------------------|
| Herzig et al. (2017)   | Same participants as Schmutz et al. (2017). Excluded for meta-analysis based on criteria 3. |                     |                         |                           |                           | Same participants as Schmutz et al. (2017). Excluded for meta-analysis based on criteria 3. |
| Iivonen et al. (2013)  | Failed to contact authors. |                     |                         |                           |                           | Failed to contact authors.          |
| Jackson et al. (2003)  | r: 0.19, p: 0.04; stdβ ± SE: 0.19 ± 0.093 |                     |                         |                           |                           |                                         |
| Leppänen et al. (2016)[28] | β (95% CI): -0.01 (-0.03; 0.01), SD PA: 49.6, SD out: 1.4; stdβ ± SE: -0.365 ± 0.365 |                     | β (95% CI): 0.01 (-0.02; 0.05), SD PA: 22.5, SD out: 1.4; stdβ ± SE: 0.165 ± 0.331 | β (95% CI): 0.12 (-0.03; 0.28), SD PA: 4.9, SD out: 1.4; stdβ ± SE: 0.432 ± 0.288 | β (95% CI): 0.02 (-0.02; 0.05), SD PA: 25.2, SD out: 1.4; stdβ ± SE: 0.371 ± 0.371 |                                         |
### Appendix C. Continued.

| Author (year)            | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|--------------------------|-------------------------|---------------------|-------------------------|---------------------------|---------------------------|---------------------------------------|
| Mendoza et al. (2014)[47] |                         |                     |                         |                           |                           | stdβ: -0.21, p: 0.049; stdβ ± SE: -0.21 ± 0.107 |
| Oliver et al. (2010) [48] |                         | Coefficient        |                         |                           |                           | stdβ ± SE: -0.222 ± 0.139  |
|                           |                         | (95%CI): -0.04      | (-0.08; 0.01), SD      |                           |                           |                         |
|                           |                         | BMI: 1.75, SD       |                         |                           |                           |                         |
|                           |                         | PA: 0.316*;         |                         |                           |                           |                         |
|                           |                         | stdβ ± SE: -0.222   |                         |                           |                           | ± 0.139                 |
| Pfeiffer et al. (2009)   |                         |                     |                         |                           |                           | Boys: r: 0.12, p: >0.05; stdβ ± SE: 0.12 ± 0.191 |
| zBMI                     |                         |                     |                         |                           |                           |                         |
| Schmutz et al. (2017)[50] |                         |                     |                         |                           |                           | Girls: r: 0.26, p ≤ 0.001; stdβ ± SE: 0.26 ± 0.079 |
| zBMI                     |                         | r: 0.090, p=0.045*  |                         | r: -0.155; p=0.001*       |                           | r: 0.118; p=0.009*           |
|                          |                         | stdβ ± SE: 0.090 ±  |                         | stdβ ± SE: -0.155 ±      |                           | stdβ ± SE: 0.118 ± 0.075    |
|                          |                         | 0.045               |                         | 0.047                     |                           |                         |
| Toschke et al. (2007)[52] |                         | r: -0.06, p: >0.05; |                         |                           |                           |                         |
|                          |                         | stdβ ± SE: -0.06 ±  |                         |                           |                           |                         |
|                          |                         | 0.096               |                         |                           |                           |                         |
| Williams et al. (2008)[53]|                         | r: -0.09, p: >0.05; | r: 0.01, p: >0.05;      | r: 0.13, p: >0.05;        | r: 0.14, p: <0.05;        |                         |
| zBMI                     |                         | stdβ ± SE: -0.09 ±  | stdβ ± SE: 0.01        | stdβ ± SE: 0.13 ± 0.207   | stdβ ± SE: 0.14 ± 0.071   |                         |
|                          |                         | 0.143               | ± 0.016                 |                           |                           |                         |
### Appendix C. Continued.

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|---------------------|-------------------------|-----------------------------|---------------------------|----------------------------------------|
| Yamamoto et al. (2011) [54] | | | | | | Data no longer available |
| Berglind et al. (2017) [55] | NW: 1452.0 ± 263.9 | NW: 341.1 ± 65.4 | NW: 365.2 ± 46.8 | NW: 51.5 ± 21.8 | OW: 1437.0 ± 243.8; r: -0.018 | OW: 331.1 ± 64.0; r: -0.029 |
| | OW: 341.1 ± 65.4 | OW: 338.8 ± 64.0; r: -0.018 | OW: 367.5 ± 52.2; r: 0.024 | | |
| Colley et al. (2013) [56] | NW: 349 (5) | NW: 358 (7) | NW: 281 (4) | NW: 68 (2) | OW: 350 (15); r: 0.005 | OW: 360 (9); r: 0.008 |
| | OW: 350 (15); r: 0.005 | OW: 360 (9); r: 0.008 | OW: 287 (11); r: 0.037 | OW: 63 (5); r: -0.063 | |
| Ebenegger et al. (2012) [57] | Same participants as Niederer et al. (2012). Excluded for meta-analysis based on criteria 3. | Same participants as Niederer et al. (2012). Excluded for meta-analysis based on criteria 3. | Same participants as Niederer et al. (2012). Excluded for meta-analysis based on criteria 3. | Same participants as Niederer et al. (2012). Excluded for meta-analysis based on criteria 3. | |
| Jones et al. (2009) [61] | NW: 865.7 ± 226.2 | NW: 33.0 ± 25.2 | NW: 33.0 ± 25.2 | | OW: 961.1 ± 213.1; r: 0.207 | OW: 29.0 ± 22.6; r: -0.079 |
Table

| Author and Year | Total Physical Activity | Sedentary Behaviour | Light Physical Activity | Moderate Physical Activity | Vigorous Physical Activity | Moderate-to-Vigorous Physical Activity |
|----------------|-------------------------|---------------------|-------------------------|----------------------------|---------------------------|----------------------------------------|
| Matarma et al. (2017)[62] | NW: 50.0 ± 5.1 %day | NW: 41.7 ± 4.2 %day | NW: 6.0 ± 1.8 %day | NW: 2.3 ± 1.1 %day | NW: 8.2 ± 2.6 %day |
| | OW: 51.2 ± 5.5 %day | OW: 41.3 ± 5.0 %day | OW: 5.6 ± 0.9 %day | OW: 1.9 ± 0.8 %day | OW: 7.5 ± 1.6 %day |
| | r: 0.115 | r: -0.046 | r: -0.118 | r: -0.186 | r: -0.133 |
| Matarma et al. (2018)[64] | Same participants as Matarma et al. 2017. Excluded for meta-analysis based on criteria 3. | | | | |
| Metallinos-Katsaras et al. (2007)[65] | p: 0.31, NW: 768.7, OW: 720.6; r: -0.418 | p: 0.84, NW: 412.2, OW: 415.6; r: 0.032 | p: 0.72, NW: 241.2, OW: 246.4; r: 0.050 | p: 0.06, NW: 26.8, OW: 19.9; r: -0.256 | |
## Appendix C. Continued.

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|--------------------|-------------------------|---------------------------|---------------------------|---------------------------------------|
| O’Dwyer et al. (2011)[67] | | | | | | |
| Boys, Weekday: | Boys, Weekday: | Boys, Weekday: | Boys, Weekday: | Boys, Weekday: | Boys, Weekday: | Boys, Weekday: |
| NW: 751.3 ± 146.7 | NW: 48.5 ± 15.1 | NW: 32.0 ± 16.9 | NW: 13.2 ± 4.7 | NW: 45.2 ± 20.3 | | |
| OW: 652.6 ± 168.6 | OW: 52.9 ± 11.9 | OW: 25.3 ± 5.1 | OW: 13.3 ± 3.3 | OW: 38.6 ± 8.1 | | |
| Weekend: | Weekend: | Weekend: | Weekend: | Weekend: | | |
| NW: 684.0 ± 198.1 | NW: 64.4 ± 16.2 | NW: 23.9 ± 7.6 | NW: 14.1 ± 5.5 | NW: 38.0 ± 10.4 | | |
| OW: 863.7 ± 164.4; | OW: 72.2 ± 22.1; | OW: 22.4 ± 6.8; | OW: 11.6 ± 6.0; | OW: 34.0 ± 11.9; | | |
| r: 0.112 | r: 0.167 | | | | | |
| Girls, Weekday: | Girls, Weekday: | Girls, Weekday: | Girls, Weekday: | Girls, Weekday: | Girls, Weekday: | |
| NW: 672.4 ± 117.4 | NW: 54.0 ± 16.7 | NW: 28.3 ± 12.1 | NW: 15.0 ± 7.3 | NW: 43.3 ± 17.0 | | |
| OW: 668.0 ± 150.8 | OW: 50.7 ± 10.0 | OW: 25.4 ± 7.0 | OW: 12.6 ± 4.4 | OW: 38.0 ± 10.5 | | |
| Weekend: | Weekend: | Weekend: | Weekend: | Weekend: | | |
| NW: 757.0 ± 203.0 | NW: 67.5 ± 19.7 | NW: 29.8 ± 21.0 | NW: 12.6 ± 6.5 | NW: 42.4 ± 26.4 | | |
| OW: 673.0 ± 200.4; | OW: 54.7 ± 16.6; | OW: 18.6 ± 7.4; | OW: 10.3 ± 2.3; | OW: 28.9 ± 9.5; | | |
| r: -0.129 | r: -0.249 | r: -0.201 | r: -0.254 | | | |
### Appendix C. Continued.

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|---------------------|-------------------------|--------------------------|--------------------------|----------------------------------------|
| Gutiérrez-Hervás et al. (2018)[59] | Underweight: 627 ± 118, normal weight: 627 ± 118, overweight: 563 ± 130, obese: 538 ± 114. |  |  |  |  |  |
| Niederer et al. (2012)[66] | 4 years: NW: 712 ± 139 OW: 725 ± 153 r: 0.046 |  |  |  |  |  |
| | 5 years: NW: 740 ± 181 OW: 682 ± 130; r: -0.166 |  |  |  |  |  |
| | 6 years: NW: 745 ± 165 OW: 704 ± 167; r: -0.123 |  |  |  |  |  |
| | 4 years: NW: 8.9 ± 3.4 OW: 9.1 ± 3.1 r: 0.030 |  |  |  |  |  |
| | 5 years: NW: 9.7 ± 4.1 OW: 8.4 ± 3.7 r: -0.159 |  |  |  |  |  |
| | 6 years: NW: 10.2 ± 9.1 OW: 9.1 ± 3.6 r: -0.066 |  |  |  |  |  |
### Appendix C. Continued.

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|---------------------|-------------------------|---------------------------|---------------------------|----------------------------------------|
| Pate et al. (2015)[68] | CHAMPS: NW: 14.2 (0.3) |  |  |  |  |  |
|               | Overweight: 14.9 (0.5) Obese: 15.2 (0.6); r: 0.100 |  |  |  |  |  |
|               | SHAPES: NW: 15.3 (0.4) |  |  |  |  |  |
|               | Overweight: 15.5 (0.5) Obese: 15.8 (0.5); r: 0.030 |  |  |  |  |  |
| Röttger et al. (2014)[69] |  |  |  |  |  | r: -2.89, df: 97, p: 0.044; r: -0.243 |
| Schaefer et al. (2015)[71] |  |  |  |  |  |  |
|               | p: <0.05, NW: 866.3, OW: 867.9; r: 0.015 |  |  |  |  |  |
|               |  |  |  |  |  | Boys*, NW: 83.1 ± 27.3 OW: 95.6 ± 31.4; r: 0.210 |
|               |  |  |  |  |  | Girls*, NW: 72.1 ± 27.4 OW: 62.5 ± 22.8; r: -0.184 |

* Denotes interaction with gender.
### Appendix C. Continued.

| Author (year)       | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------------|-------------------------|---------------------|-------------------------|---------------------------|----------------------------|----------------------------------------|
| Tanaka and Tanaka (2013)[72] | Thin: 1206 ± 48         | NW: 1179 ± 51       | Thin: 142 ± 28          | Thin: 18 ± 9               | Thin: 92 ± 27              | NW: 102 ± 30                           |
|                     | Thin: 1177 ± 44;        | NW: 159 ± 29        | Thin: 165 ± 24;         | NW: 22 ± 12                | NW: 102 ± 33;              | OW: 102 ± 33;                          |
|                     | r: -0.110               | OW: 20 ± 10;        | r: 0.148                |                           |                           | r: 0.059                               |
|                     |                         | r: -0.110           |                         |                           |                           |                                       |
| Trost et al. (2003)[74] | Boys,                   | NW: 60000 ± 14500   |                         | Boys,                     | NW: 6.7 ± 2.8              | NW: 33.7 ± 8.5                         |
|                     | OW: 50500 ± 14400;      |                         | Boys,                   | NW: 4.9 ± 3.1;            | OW: 27.2 ± 10.5;           | OW: 28.3 ± 10.8;                       |
|                     | r: -0.312               |                         |                         | r: -0.300                 |                           | r: -0.341                             |
|                     |                         |                         |                         |                           |                           |                                       |
|                     | Girls,                  | NW: 52100 ± 15700    |                         | Girls,                   | NW: 5.6 ± 3.7              | NW: 28.5 ± 11.1                      |
|                     | OW: 51900 ± 15800;      |                         | Girls,                   | NW: 4.7 ± 3.0;            | OW: 28.3 ± 10.8;           | OW: 28.3 ± 10.8;                      |
|                     | r: -0.006               |                         |                         | r: -0.127                 |                           | r: -0.009                             |
### Appendix C. Continued.

| Author (year)                  | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|-------------------------------|-------------------------|---------------------|-------------------------|---------------------------|---------------------------|----------------------------------------|
| Tucker et al. (2016) [75]     |                         |                     |                         |                           |                           |                                        |
| Boys, NW: 20.3 ± 3.6          |                         | Boys, NW: 39.5 ± 3.7|                         |                           |                           |                                        |
| OW: 21.7 ± 5.0; r: 0.172      |                         | OW: 38.4 ± 5.2;     |                         |                           |                           |                                        |
|                               |                         | r: 0.124            |                         |                           |                           |                                        |
| Girls, NW: 18.6 ± 3.3         |                         | Girls: NW: 41.6 ± 3.5|                         |                           |                           |                                        |
| OW: 18.6 ± 3.8; r: 0.006      |                         | OW: 41.3 ± 3.7;     |                         |                           |                           |                                        |
|                               |                         | r: -0.033           |                         |                           |                           |                                        |
| Vale et al. (2010) [76]       | NW: 134 ± 36            |                     | NW: 58 ± 14             |                           | NW: 38 ± 14               |                                        |
| OW: 133 ± 29; r: -0.014       |                         | OW: 58 ± 13;        |                         |                           | OW: 35 ± 12;              |                                        |
|                               |                         | r: 0.00             |                         |                           | r: -0.109                |                                        |
| van Cauwenberghe et al. (2012) [77] |                       | Failed to contact authors. |                       |                           |                           |                                        |
| Vorweg et al. (2013) [78]     | NW: 4.4 ± 1.8           |                     | NW: 4.4 ± 1.8           |                           |                           | NW: 4.8 ± 2.1; r: 0.108              |
| OW: 4.8 ± 2.1; r: 0.108       |                         |                     |                         |                           |                           |                                        |
### Appendix C. Continued.

| Author (year)          | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|------------------------|-------------------------|---------------------|-------------------------|----------------------------|---------------------------|----------------------------------------|
|                        |                         |                     |                         |                            |                           |                                        |
| 4) Waist circumference |                         |                     |                         |                            |                           |                                        |
| Collings et al. (2017)[36] | β (95% CI): -0.072 (-0.39; 0.24), SD PA : 320.2, SD out : 4.7; stdβ ± SE: -0.145 ± 0.094 | β (95% CI): 0.056 (-0.075; 0.19), SD PA : 64.6, SD out : 4.7; stdβ ± SE: 0.144 ± 0.017 | β (95% CI): -0.056 (-0.22; 0.11), SD PA: 54.0, SD out : 4.7; stdβ ± SE: -0.034 ± 0.010 | β (95% CI): -0.14 (-0.46; 0.19), SD PA: 23.5, SD out : 4.7; stdβ ± SE: -0.190 ± 0.033 |
| España-Romero et al. (2013)[39] | Boys, β ± SE: -0.152 ± 0.113, SD PA : 3.1, SD out : 4.7; stdβ ± SE: -0.100 ± 0.075 | Girls, β ± SE: 0.154 ± 0.117, SD PA : 3.3, SD out : 4.8; stdβ ± SE: 0.106 ± 0.080 | Boys, β ± SE: 0.233 ± 0.160, SD PA: 2.2, SD out : 4.7; stdβ ± SE: 0.109 ± 0.075 | Girls, β ± SE: -0.190 ± 0.187, SD PA: 2.0, SD out : 4.8; stdβ ± SE: -0.079 ± 0.078 |
### Appendix C. Continued.

| Author (year)          | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|------------------------|-------------------------|---------------------|-------------------------|---------------------------|---------------------------|-----------------------------------------|
| Leppänen et al. (2016)[28] | β (95% CI): -0.03 (-0.08; 0.02), SD PA: 49.6, SD out: 3.7; stdβ ± SE: -0.407 ± 0.339 | β (95% CI): 0.07 (-0.03; 0.16), SD PA: 22.5, SD out: 3.7; stdβ ± SE: 0.430 ± 0.277 | β (95% CI): 0.14 (-0.27; 0.55), SD PA: 4.9, SD out: 3.7; stdβ ± SE: 0.187 ± 0.274 | β (95% CI): 0.06 (-0.03; 0.14), SD PA: 25.2, SD out: 3.7; stdβ ± SE: 0.413 ± 0.275 |
| Oliver et al. (2010)[48] | Coefficient (95%CI): -0.01 (-0.03; 0.01), SD waist circumference: 3.95, SD PA : 0.316*; stdβ ± SE: -0.125 ± 0.125 | Failed to contact authors. | Failed to contact authors. | Failed to contact authors. |
| Oliver et al. (2013)[79] | Failed to contact authors. | Failed to contact authors. | Failed to contact authors. | Failed to contact authors. |
| Butte et al. (2016)[22] | β ± SE: -0.008 ± 0.008, SD PA: 0.003, SD out: 2.2; stdβ ± SE: -0.083 ± 0.083 | β ± SE: 0.002 ± 0.002, SD PA: 67, SD out: 2.2; stdβ ± SE: 0.061 ± 0.091 | β ± SE: -0.015 ± 0.008, SD PA: 24.0, SD out: 2.2; stdβ ± SE: -0.164 ± 0.087 |
## Appendix C. Continued.

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|---------------------|-------------------------|---------------------------|----------------------------|-----------------------------------------|
| Heelan and Eisenmann (2006)[26] | Boys, r: -0.08, p>0.05; stdβ ± SE: -0.08 ± 0.127 | Girls, r: -0.13, p>0.05; stdβ ± SE: -0.13 ± 0.207 | | | | |
| | | | | | ||
| Jackson et al. (2009)[81] | Failed to contact authors. | | | | | |
| Janz et al. (2002)[27] | Boys, r: -0.15, p<0.05; stdβ ± SE: -0.15 ± 0.077 | Girls, r: -0.19, p<0.01; stdβ ± SE: -0.19 ± 0.074 | | | | |
| | | | | | ||
| Collings et al. (2013)[25] | r: 0.058, p<0.01; stdβ ± SE: 0.058 ± 0.023 | r: -0.02, p≥0.05; stdβ ± SE: -0.02 ± 0.010 | r: -0.073, p<0.01; stdβ ± SE: -0.073 ± 0.028 | r: -0.12, p<0.001; stdβ ± SE: -0.12 ± 0.191 | | |

6) Fat mass index

| Author (year) | Fat mass index | Boys, r: -0.08, p>0.05; stdβ ± SE: -0.08 ± 0.127 | Girls, r: -0.22, p>0.05; stdβ ± SE: -0.22 ± 0.350 |
|---------------|----------------|-----------------------------------------------|-----------------------------------------------|
| Heelan and Eisenmann (2006)[26] | | | |
| | | | |
| Jackson et al. (2009)[81] | Failed to contact authors. | | |
| Janz et al. (2002)[27] | Boys, r: -0.07, p>0.05; stdβ ± SE: -0.07 ± 0.111 | Girls, r: -0.06, p>0.05; stdβ ± SE: -0.06 ± 0.096 | |
| | | | |
| Collings et al. (2013)[25] | r: -0.10, p<0.001; stdβ ± SE: -0.10 ± 0.159 | | |
### Appendix C. Continued.

| Author (year)        | Total physical activity | Sedentary behaviour   | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|----------------------|-------------------------|-----------------------|-------------------------|---------------------------|----------------------------|----------------------------------------|
| Leppänen et al.      |                         |                       |                         |                           |                            |                                        |
| (2016)[28]           | β (95% CI): 0.00        | β (95% CI): -0.01     | β (95% CI): -0.04       | β (95% CI): -0.01         |                            |                                        |
|                      | (-0.02; 0.01), SD PA: 49.6, SD out: 0.9; stdβ ± SE: 0.000 ± 0.270 | (-0.03; 0.02), SD PA: 22.5, SD out: 0.9; stdβ ± SE: -0.245 ± 0.367 | (-0.15; 0.07), SD PA: 4.9, SD out: 0.9; stdβ ± SE: -0.213 ± 0.293 | (-0.03; 0.01), SD PA: 25.2, SD out: 0.9; stdβ ± SE: -0.274 ± 0.274 |

7) Trunk fat mass

| Janz et al. (2002)   | Boys, r: -0.13, p: >0.05; stdβ ± SE: -0.13 ± 0.207 | Boys, r: -0.21, p: <0.01; stdβ ± SE: -0.21 ± 0.082 | Boys, r: -0.05, p: >0.05; stdβ ± SE: -0.05 ± 0.080 |
| [27]                 |                                       |                                                       |                                       |
|                      | Girls, r: -0.19, p: <0.01; stdβ ± SE: -0.19 ± 0.074 | Girls, r: -0.26, p: <0.01; stdβ ± SE: -0.26 ± 0.101 | Girls, r: -0.06, p: >0.05; stdβ ± SE: -0.06 ± 0.096 |

8) Trunk fat mass index

| Collings et al.      | r: 0.062, p<0.01; stdβ ± SE: 0.062 ± 0.024 | r: -0.033, p≥0.05; stdβ ± SE: -0.059 ± 0.023 | r: -0.10, p<0.001; stdβ ± SE: -0.10 ± 0.159 |
| (2013)[25]           |                                        |                                           |                                        |
|                      | r: -0.059, p<0.01; stdβ ± SE: -0.059 ± 0.023 | r: -0.10, p<0.001; stdβ ± SE: -0.10 ± 0.159 | r: -0.084, p<0.001; stdβ ± SE: -0.084 ± 0.134 |

-0.033 ± 0.017
### Appendix C. Continued.

| Author (year) | Total physical activity | Sedentary behaviour | Light physical activity | Moderate physical activity | Vigorous physical activity | Moderate-to-vigorous physical activity |
|---------------|-------------------------|---------------------|-------------------------|---------------------------|---------------------------|---------------------------------------|
| Collings et al. (2017)[36] | β (95% CI): -0.064 (-1.46; 0.19), SD PA : 320.2, SD out : 4.5; stdβ ± SE: -0.017 ± 0.037 | | β (95% CI): 0.21 (-0.12; 0.53), SD PA : 64.6, SD out : 4.5; stdβ ± SE: 0.040 ± 0.016 | β (95% CI): -0.059 (-0.47; 0.35), SD PA: 54.0, SD out : 4.5; stdβ ± SE: -0.034 ± 0.006 | β (95% CI): -0.76 (-1.43; -0.085), SD PA: 23.5, SD out : 4.5; stdβ ± SE: -0.037 ± 0.042 |
| Fang et al. (2017) [83] | | | | | | |
| | Boys: Stdβ: 0.026, p>0.05 Stdβ ± SE: 0.026 ± 0.041 | | | | | Boys: Stdβ: -0.195, p<0.05 Stdβ ± SE: -0.195 ± 0.099 |
| | Girls : Stdβ: -0.077, p>0.05 Stdβ ± SE: -0.077 ± 0.123 | | | | | Girls : Stdβ: -0.041, p>0.05 Stdβ ± SE: -0.041 ± 0.065 |
| Herzig et al. (2017) [43] | r: -0.12, p: ≤0.05; stdβ ± SE: -0.12 ± 0.061 | | | | | r: -0.13, p: ≤0.05; stdβ ± SE: -0.13 ± 0.066 |

Data presented as original from paper; standardizedβ ± SE or Pearson correlation for meta-analysis. SD out: standard deviation of the outcome (i.e. percentage of body fat, body mass index, waist circumference, fat mass or skinfold thickness).

* Data received on request.
### Appendix D. Sample characteristics, statistical analyses, and the results of all of the reviewed studies, differentiated by adiposity outcomes.

| Author (year)       | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweight\(^b\) | Statistical analysis                                                                 | Conclusion                                                                                     |
|---------------------|--------------------|-------------------------------------------------|-------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| **1) PERCENTAGE BODY FAT** |                    |                                                 |                               |                                                                                      |                                                                                               |
| **Longitudinal studies** |                    |                                                 |                               |                                                                                      |                                                                                               |
| Bürgi et al. (2011)\(^1\) | Switzerland        | Ballabeina Study n = 217, 104 boys, 113 girls; 4 - 6 years, 5.2(0.6) | 10.0% (IOTF)\(^2\)           | Mixed linear regression adjusted for age, sex, preschool clusters and baseline outcome parameters. | Total PA, moderate PA or vigorous PA was not associated with change of percentage body fat 9 months later. |
| Butte et al. (2016)\(^3\) | United States      | n = 111, 58 boys, 53 girls; 3 - 5 years, 4.6(0.9) | 18.0% (CDC)\(^4\)            | Mixed-effects linear models adjusted for age, sex, race/ethnicity, daycare hours, household size, household income, mother's age, BMI and education and awake time. | No relation between total PA, sedentary behaviour or MVPA and percentage body fat 1 year later. |
| Leppänen et al. (2017)\(^5\) | Sweden             | MINISTOP trial n = 138, 73 boys, 65 girls; 4 years, 4.5(0.2) follow-up: 5.6(0.2) | 7.2% baseline, 6.5% follow-up | Linear regression, adjusted for child’s sex, age at measurement, ActiGraph awake wearing time. | Children who spent more time engaged in moderate PA, vigorous PA or MVPA had a lower percentage of body fat 12 months later compared with their peers. No relations for sedentary behaviour. |
| **Cross-sectional studies** |                    |                                                 |                               |                                                                                      |                                                                                               |
| Bürgi et al. (2011)\(^1\) | Switzerland        | Ballabeina Study n = 217, 104 boys, 113 girls; 4 - 6 years, 5.2(0.6) | 10.0% (IOTF)\(^2\)           | Mixed linear regression adjusted for age, sex and preschool clusters.                | Children who spent more time engaged in total PA had a lower percentage body fat compared with their peers. No results for moderate PA and vigorous PA. |
### Appendix D. Continued.

| Author (year) | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweight<sup>b</sup> | Statistical analysis | Conclusion |
|---------------|--------------------|-----------------------------------------------|---------------------------------|---------------------|------------|
| Butte et al. (2016)<sup>1</sup> | United States | n = 111, 58 boys, 53 girls; 3 - 5 years, 4.6(0.9) | 18.0% (CDC)<sup>4</sup> | Mixed-effects linear models adjusted for age, sex, race/ethnicity, daycare hours, household size, household income, mother’s age, BMI and education and awake time. | Children who spent more time engaged in MVPA had a lower percentage body fat compared with their peers. No results for total PA and sedentary behaviour. |
| Collings et al. (2013)<sup>6</sup> | United Kingdom | n = 398, 202 boys, 196 girls; 4 years, 4.1(0.1) | 20.1% (Cole et al. 2000)<sup>2</sup> | Bivariate correlations. | Children who spent less time engaged in sedentary behaviour or more time engaged in light PA, moderate PA, vigorous PA or MVPA had a lower percentage of body fat compared with their peers. |
| Heelan and Eisenmann (2006)<sup>7</sup> | United States | n = 100, 48 boys, 52 girls; 4 - 7 years, 5.8(1.3) | - | Partial correlations controlling for chronological age. | No association between total PA or MVPA and percentage body fat. |
| Janz et al. (2002)<sup>8</sup> | United States IOWA-Fluoride study, IOWA-Bone Development study | n = 434, 203 boys, 231 girls; 4 - 6 years, 5.3(0.4) | - | Partial correlation coefficients adjusted for age and height. | Children who spent more time engaged in total PA or vigorous PA had a lower percentage body fat compared with their peers. No results for MVPA. |
### Appendix D. Continued.

| Author (year) | Country and cohort | Participant characteristics (sample size; age\(^a\)) | Prevalence of overweight\(^b\) | Statistical analysis | Conclusion |
|---------------|--------------------|------------------------------------------------------|-------------------------------|----------------------|------------|
| Leppänen et al. (2016)\(^9\) | Sweden MINISTOP trial | n = 295, 166 boys, 129 girls; 4.5(0.2) | 8.5% (Cole et al. 2012)\(^10\) | Multiple linear regression, adjusted for parental BMI, parental educational attainment, child's sex and age at measurement and awake wearing time. | No association between sedentary behaviour, moderate PA, vigorous PA or MVPA and percentage body fat. |

| Butte et al. (2016)\(^3\) | United States | n = 111, 58 boys, 53 girls; 3 - 5 years, 4.6(0.9) | 18.0% (CDC)\(^4\) | Mixed-effects linear models adjusted for age, sex, race/ethnicity, daycare hours, household size, household income, mother's age, BMI and education and awake time. | Children who spent more time engaged in MVPA had a larger change in BMI 1 year later. No relations between total PA or sedentary behaviour and BMI 1 year later. |

| Jáuregui et al. (2012)\(^11\) | Mexico | n = 205, 87 boys, 118 girls; 5 – 6, baseline 6.0(0.4), follow-up 8.1(0.3) | - | Multiple linear regression models adjusted by initial fat mass, energy intake and height, age, sex, socioeconomic status and changes in energy intake and height. | Children with a high baseline MVPA or who increased 10 min/d in MVPA showed no differences in BMI gain compared with their peers. |

| Leppänen et al. (2017)\(^5\) | Sweden MINISTOP trial | n = 138, 73 boys, 65 girls; 4 years, 4.5(0.2) follow-up: 5.6(0.2) | 7.2% baseline, 6.5% follow-up | Linear regression, adjusted for child’s sex, age at measurement, ActiGraph awake wearing time. | Children who spent more time engaged in vigorous PA had a higher BMI 12 months later compared with their peers. No relation for sedentary behaviour, moderate PA or MVPA. |

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2) **BODY MASS INDEX**

*Longitudinal studies*

| Butte et al. (2016)\(^3\) | United States | n = 111, 58 boys, 53 girls; 3 - 5 years, 4.6(0.9) | 18.0% (CDC)\(^4\) | Mixed-effects linear models adjusted for age, sex, race/ethnicity, daycare hours, household size, household income, mother’s age, BMI and education and awake time. | Children who spent more time engaged in MVPA had a larger change in BMI 1 year later. No relations between total PA or sedentary behaviour and BMI 1 year later. |

| Jáuregui et al. (2012)\(^11\) | Mexico | n = 205, 87 boys, 118 girls; 5 – 6, baseline 6.0(0.4), follow-up 8.1(0.3) | - | Multiple linear regression models adjusted by initial fat mass, energy intake and height, age, sex, socioeconomic status and changes in energy intake and height. | Children with a high baseline MVPA or who increased 10 min/d in MVPA showed no differences in BMI gain compared with their peers. |

| Leppänen et al. (2017)\(^5\) | Sweden MINISTOP trial | n = 138, 73 boys, 65 girls; 4 years, 4.5(0.2) follow-up: 5.6(0.2) | 7.2% baseline, 6.5% follow-up | Linear regression, adjusted for child’s sex, age at measurement, ActiGraph awake wearing time. | Children who spent more time engaged in vigorous PA had a higher BMI 12 months later compared with their peers. No relation for sedentary behaviour, moderate PA or MVPA. |
### Appendix D. Continued.

| Author (year) | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweight | Statistical analysis | Conclusion |
|---------------|--------------------|-----------------------------------------------|---------------------------|----------------------|------------|
| Metcalf et al. (2008)<sup>12</sup> | United Kingdom EarlyBird | n = 212, 113 boys, 99 girls; 5 - 8 years, follow up at 6, 7 and 8 years | - | Multiple linear regression. | No correlation between minutes in MVPA and changes in BMI. |
| Remmers et al. (2014)<sup>13</sup> | The Netherlands KOALA Birth Cohort | n = 297, 150 boys, 147 girls; T0: 4-5 years, T1: 6-7, T2: 8-9 years | - | GEE linear regression, adjusted for origin of BMI z-score, bicycling, swimming, season, recruitment group and paternal and maternal BMI. | A 5% increase in total PA or light PA resulted in decreased zBMI in heavier boys 1 year later, but not in leaner or normal weight boys or in girls. A 5% increase in MVPA resulted in decreased zBMI in normal weight and heavier boys and heavier girls 1 year later. |

**Cross-sectional studies**

| Author (year) | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweight | Statistical analysis | Conclusion |
|---------------|--------------------|-----------------------------------------------|---------------------------|----------------------|------------|
| Buck et al. (2015)<sup>14</sup> | Germany IDEFICS | n = 100, 57 boys, 43 girls; 2 - <6 years, 4.2(0.8) | - | Basic log-gamma regression model. | No association between BMI and MVPA. |
| Butte et al. (2016)<sup>3</sup> | United States | n = 111, 58 boys, 53 girls; 3 - 5 years, 4.6(0.9) | 18.0% (CDC)<sup>4</sup> | Mixed-effects linear models adjusted for age, sex, race/ethnicity, daycare hours, household size, household income, mother’s age, BMI and education and awake time. | No association between total PA, sedentary behaviour or MVPA and BMI. |
| Byun et al. (2011)<sup>15</sup> | United States CHAMPS | n = 331, 168 boys, 163 girls; 2.8 - 5.7 years, 4.3(0.6) | - | Univariate analysis. | Girls who spent more time engaged in sedentary behaviour had a lower zBMI compared with their peers. No results for boys. |
| Author (year)          | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweightb | Statistical analysis                                                                 | Conclusion                                                                 |
|-----------------------|--------------------|-----------------------------------------------|--------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Cliff et al. (2009)16 | Australia PANDA   | n = 46, 25 boys, 21 girls; 3 – 5 years, 4.3(0.7) | -                        | Pearson product-moment correlations and Spearman rank-order correlations.            | No association between total PA, sedentary behaviour, moderate PA, vigorous PA or MVPA and BMI. |
| Collings et al. (2017)27 | United Kingdom BiB (HAPPY, BiB-1000, LEAP) | n = 333, 169 boys, 164 girls; 11 months – 5 years, 3.3(0.9) | 19.5% (Cole et al. 1990)18 | Multilevel models adjusted for age, sex, ethnicity, index of multiple deprivation, monitor worn time and season. | No association between total PA, sedentary behaviour, light PA or MVPA and BMI. |
| Dawson-Hahn et al. (2015)19 | United States     | n = 81, 47 boys, 34 girls; 3 - 5 years, 4.7(0.5)                       | -                        | Block linear regression analysis.                                                    | No association between BMI and total PA or MVPA.                           |
| España-Romero et al. (2013)20 | United States SHAPES | n = 357, 183 boys, 174 girls; 3 – 5 years                        | Boys: 27.9%, girls: 28.7% (CDC)4 | Linear mixed regression models adjusted for race/ethnicity, parental education and preschool. | Boys who spent more time engaged in MVPA had a higher zBMI compared with their peers. No results for girls and for sedentary behaviour. |
| Finn et al. (2002)21 | United States     | n = 214, 106 boys, 108 girls; 3 - 5 years, 3.9(0.1)                       | -                        | Forward-backward stepwise regression analysis.                                       | No association between total PA or vigorous PA and BMI.                   |
| Fisher et al. (2005)22 | United Kingdom    | n = 209, 101 boys, 108 girls; 4.8(1.2)                        | 20.0% (UK 1990)8          | Multiple regression analysis, including age, sex, zBMI and average temperature.       | No association between zBMI and total PA.                                  |
| Guo et al. (2017)23   | United States CHAMPS | n = 227, 111 boys, 116 girls; 3 – 5 years, 4.2(0.6)                       | 24.3% (CDC)4              | Pearson correlations.                                                               | No association between total PA and zBMI.                                  |
| Heelan and Eisenmann (2006)7 | United States     | n = 100, 48 boys, 52 girls; 4 – 7 years, 5.8(1.3)                       | -                        | Partial correlations controlling for chronological age.                             | No association between total PA or MVPA and BMI.                           |
| Author (year) | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweightb | Statistical analysis | Conclusion |
|--------------|-------------------|-----------------------------------------------|--------------------------|---------------------|------------|
| Herzig et al. (2017)24 | Switzerland SPLASHY | n = 309, 162 boys, 147 girls; 2 – 6 years, 3.9(0.7) | - | Pearson correlation coefficients. | No association between total PA or MVPA and BMI. |
| Iivonen et al. (2013)25 | Finland | n = 37, 17 boys, 20 girls; 4 years, 4.1(0.3) | - | Multiple regression models for fundamental motor skills, adjusted for sex, age, BMI. | No associations between BMI and total PA or MVPA. |
| Jackson et al. (2003)26 | United Kingdom SPARKLE | n = 104, 52 boys, 52 girls; 3 – 4 years, 3.7(0.4) | - | Correlation. | Children who spent more time engaged in total PA had a higher zBMI compared with their peers. |
| Kelly et al. (2006)27 | United Kingdom MAGIC study | n = 339; 4.2(0.3) | - | Analysis of variance and covariance. | No association between zBMI and total PA. |
| Leppänen et al. (2016)9 | Sweden MINISTOP trial | n = 307, 170 boys, 137 girls; 4.5(0.2) | 8.5% (Cole et al. 2012)10 | Multiple linear regression, adjusted for parental BMI, parental educational attainment, child’s sex and age at measurement and awake wearing time. | No associations between sedentary behaviour, moderate PA, vigorous PA or MVPA and BMI. |
| Mendoza et al. (2014)28 | United States | n = 96, 53 boys, 41 girls; 3 – 5 years, 4.7(0.5) | - | Block linear regression with age, sex, parent BMI and education, neighbourhood disorder, child acculturation, parent acculturation, tv viewing and MVPA added. | Children who spent more time engaged in MVPA had a lower zBMI compared with their peers. |
| Oliver et al. (2010)29 | New Zealand | n = 78, 37 boys, 41 girls; 2 – 5 years | 28.0% (IOTF)2 | Univariable GEE regression for child PA rate.3 | No association between total PA and BMI. |
### Appendix D. Continued.

| Author (year)        | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweightb | Statistical analysis                      | Conclusion                                                                 |
|----------------------|--------------------|-----------------------------------------------|---------------------------|-------------------------------------------|---------------------------------------------------------------------------|
| Pfeiffer et al. (2009)30 | United States CHAMPS | n = 331, 168 boys, 163 girls; 2.8 – 5.7 years, 4.3(0.6) | -                         | Pearson correlations.                   | Girls, and girls and boys together, who spent more time engaged in MVPA had a higher zBMI compared with their peers. No results for boys. |
| Schmutz et al. (2017)31 | Switzerland SPLASHY | n = 394, 212 boys, 182 girls; 2 - 6 years, 3.9(0.7) | 24.9% (WHO)32             | Pearson correlation coefficient received on request. | Children who spent more time engaged in total PA or MVPA and less time sedentary had a higher zBMI compared with their peers. |
| Toschke et al. (2007)33 | Germany INCA       | n = 192, 98 boys, 94 girls; 5 – 6 years         | -                         | Pearson correlation.                    | No association between total PA and BMI.                                   |
| Williams et al. (2008)34 | United States CHAMPS | n = 198, 100 boys, 98 girls; 3 - 4 years, 4.2(0.5) | -                         | Bivariate correlations.                  | Children who spent more time engaged in MVPA had a higher zBMI compared with their peers. No results for sedentary behaviour, light PA or, vigorous PA. |
| Yamamoto et al. (2011)35 | Germany Gesunde-Kinder | n = 645, 324 boys, 321 girls; 3 – 6 years | -                         | Multivariate model adjusted for age, parental education level, immigration status and siblings, parents’ BMI, children’s health and internal PA drive, daily television time and time spent outside, participation in organized sports, environmental opportunities and parents’ PA. | No association between BMI and MVPA.                                      |
### 3) WEIGHT STATUS

#### Cross-sectional studies

| Author (year) | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweight | Statistical analysis | Conclusion |
|---------------|--------------------|------------------------------------------------|--------------------------|----------------------|------------|
| Berglind et al. (2017) | Sweden | n = 540, 311 boys, 229 girls; 4 years, 4.2(0.2) | 14.6% (Cole et al. 2000) | Generalized estimating equation, adjusted for sex and maternal education. | No differences in total PA, sedentary behaviour, light PA or MVPA between children with and without overweight. |
| Colley et al. (2013) | Canada | n = 459, 232 boys, 227 girls; 3 – 5 years, 4.0(0.04) | 16.4% (IOTF) | - | No differences in total PA, sedentary behaviour, light PA or MVPA between children with and without overweight. |
| Ebenegger et al. (2012) | Switzerland | n = 600, 299 boys, 301 girls; 5.1(0.6) | 20.0% (Swiss percentiles); 11.8% (IOTF) | Linear regression analysis adjusted for sex, age and parental migrant status and educational level. | No differences in total PA, vigorous PA or MVPA between children with and without overweight. |
| Gutiérrez-Hervás et al. (2018) | Spain | n = 136, 62 boys, 74 girls; 2 – 7 years, 5.5(1.5) | 33.1% | ANOVA. | Children without overweight spent more time engaged in total PA compared with children with overweight. |
| Jones et al. (2009) | Australia | n = 58; 2 – 6 years, 4.3(0.7) | 19.6% (IOTF) | Independent samples t-test. | No differences in total PA or MVPA between children with and without overweight. |
| Matarma et al. (2017) | Finland | n = 131, 58 boys, 73 girls; 5 years, 5.6(0.3) | 16.8% | Independent variables t-tests. | No differences in sedentary behaviour, light PA, moderate PA or vigorous PA between children with and without overweight. |
### Appendix D. Continued.

| Author (year) | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweight | Statistical analysis | Conclusion |
|---------------|--------------------|-----------------------------------------------|--------------------------|----------------------|------------|
| Matarma et al. (2018) | Finland STEPS study | n = 111, 45 boys, 66 girls; 5 years, 5.6(0.4) | 17.1% | Independent variables t-tests. | No differences in sedentary behaviour or MVPA between children with and without overweight. |
| Metallinos-Katsaras et al. (2007) | United States WIC | n = 56, 26 boys, 30 girls; 2 – 5 years | 37.5% (CDC) | Multiple linear regression adjusted for age, sex, race and monitor time worn. | No differences in light PA, moderate PA or vigorous PA between children with and without overweight. |
| Niederer et al. (2012) | Switzerland | n = 613, 308 boys, 305 girls; 4 – 6 years | 20.1% (Swiss national percentiles) | ANCOVA adjusted for age-group, sex, preschool class (cluster). | No differences in total PA, vigorous PA or MVPA between 4, 5 and 6 year old children with and without overweight. |
| O’Dwyer et al. (2011) | United Kingdom Active Play | n = 50, 27 boys, 23 girls; 4.5(0.6) | boys: 26%, girls: 43% (Cole et al. 2000) | Independent t-tests. | Boys without overweight spent more time engaged in moderate PA on weekdays compared with boys affected by overweight, but no differences for girls and on weekend days. No differences in sedentary behaviour, light PA, vigorous PA or MVPA between children with and without overweight. |
| Pate et al. (2015) | United States CHAMPS, SHAPES | CHAMPS: n = 286, 122 boys, 164 girls; 3 - 5 years, 4.2(0.7) | CHAMPS: 28.3%, SHAPES: 28.5% (CDC) | Analysis of variance with sex, race/ethnicity, parent education and weight status, adjusted for preschool. | No difference in total PA between children without overweight, children with overweight and children with obesity in CHAMPS as well as SHAPES. |
| Author (year)            | Country and cohort       | Participant characteristics (sample size; age) | Prevalence of overweight | Statistical analysis | Conclusion                                                                 |
|-------------------------|--------------------------|-----------------------------------------------|--------------------------|----------------------|-----------------------------------------------------------------------------|
| Röttger et al. (2014)   | Germany, Switzerland, France |  n = 114, 48 boys, 66 girls; 5.3(0.7)          | 17.9% (Percentiles German children) | Independent t-test. | Children without overweight spent more time engaged in total PA compared with children with overweight, in both weekdays and weekend days. |
| Schaefer et al. (2015)  | United States NSFS       |  n = 134, 64 boys, 70 girls; 4 – 7 years, 5.6(1.0) | 42.3% (CDC) | .d | Children without overweight spent less time engaged in sedentary behaviour compared with children with overweight. A trend was found in MVPA, where girls without overweight spent more time in MVPA compared with girls affected by overweight or obesity, no differences for boys. |
| Tanaka and Tanaka (2013) | Japan                    |  n = 425, 223 boys, 202 girls; 5.8(0.6)        | 7.1% (Cole et al. 2000, 2007) | ANCOVA adjusted for age and sex. | Thin children spent more time engaged in sedentary behaviour and less time in light PA and MVPA compared with children with and without overweight. Thin children spent more time engaged in vigorous PA compared with children without overweight, but not compared with children with overweight. |
| Trost et al. (2003)     | United States            |  n = 245, 118 boys, 127 girls; 3 – 5 years    | Boys: 21.2%, girls 27.6% (CDC) | ANCOVA adjusted for parent education. | Boys without overweight spent more time engaged in total PA, vigorous PA or MVPA compared with boys with overweight. No differences for girls. |
### Appendix D. Continued.

| Author (year)         | Country and cohort | Participant characteristics (sample size; age\(^a\)) | Prevalence of overweight\(^b\) | Statistical analysis | Conclusion |
|-----------------------|--------------------|------------------------------------------------------|--------------------------------|----------------------|------------|
| Tucker et al. (2016)\(^{56}\) | Canada LEAPP       | n = 216, 102 boys, 114 girls; 2.5 – 5.9 years, 4.2(0.1) | 24.5% (CDC)\(^4\) | Three-way ANOVA with childcare as random factor. | No differences in total PA, vigorous PA or MVPA between children with and without overweight. |
| Vale et al. (2010)\(^{57}\) | Portugal PRESTYLE  | n = 281, 157 boys, 124 girls; 4 – 6, 5.0(0.8) | 14.6% (≥ 1 SD) | Independent t-tests. | No differences in total PA, moderate PA or vigorous PA between children with and without overweight. |
| van Cauwenbergh et al. (2012)\(^{58}\) | Australia HAPPY    | n = 703, 387 boys, 316 girls; 3 - 5 years, 4.6(0.7) | 17.5% (Cole et al. 2000)\(^2\) | Multilevel logistic regression models. | No differences in hour by hour sedentary behaviour or MVPA patterns between children with and without overweight. |
| Vorwerg et al. (2013)\(^{59}\) | Germany            | n = 92, 51 boys, 40 girls; 3 – 6 years | 14.0% (National percentiles German children)\(^{21}\) | Wilcoxon test. | No difference in total PA between children with and without overweight. |

4) WAIST CIRCUMFERENCE

**Longitudinal studies**

| Author (year)         | Country and cohort | Participant characteristics (sample size; age\(^a\)) | Statistical analysis | Conclusion |
|-----------------------|--------------------|------------------------------------------------------|----------------------|------------|
| Metcalf et al. (2008)\(^{12}\) | United Kingdom EarlyBird | n = 212, 113 boys, 99 girls; 5 – 8 years, follow up at 6, 7 and 8 years | Multiple linear regression. | No correlation between minutes in MVPA and changes in waist circumference. |

**Cross-sectional studies**

| Author (year)         | Country and cohort | Participant characteristics (sample size; age\(^a\)) | Statistical analysis | Conclusion |
|-----------------------|--------------------|------------------------------------------------------|----------------------|------------|
| Collings et al. (2017)\(^{17}\) | United Kingdom BiB (HAPPY, BiB-1000, LEAP) | n = 333, 169 boys, 164 girls; 11 months – 5 years, 3.3(0.9) | 19.5% (Cole et al. 1990)\(^{38}\) | Multilevel models adjusted for age, sex, ethnicity, index of multiple deprivation, monitor worn time, season and height. | No association between total PA, sedentary behaviour, light PA or MVPA on waist circumference. |
**Appendix D. Continued.**

| Author (year) | Country and cohort | Participant characteristics (sample size; age\(^a\)) | Prevalence of overweight\(^b\) | Statistical analysis | Conclusion |
|---------------|-------------------|--------------------------------------------------|-----------------------------|---------------------|------------|
| España-Romero et al. (2013)\(^{20}\) | United States SHAPES | n = 357, 183 boys, 174 girls; 3 – 5 years | Boys: 27.9%, girls: 28.7% (CDC)\(^4\) | Linear mixed regression models adjusted for race/ethnicity, parental education and preschool. | No association between sedentary behaviour or MVPA and waist circumference. |
| Leppänen et al. (2016)\(^9\) | Sweden MINISTOP trial | n = 304, 169 boys, 135 girls; 4.5(0.2) | 8.5% (Cole et al. 2012)\(^{10}\) | Multiple linear regression, adjusted for parental BMI, parental educational attainment, child’s sex and age at measurement, awake wearing time and height. | No association between sedentary behaviour, moderate PA, vigorous PA or MVPA and waist circumference. |
| Oliver et al. (2010)\(^{29}\) | New Zealand | n = 78, 37 boys, 41 girls; 2 – 5 years | 28.0% (IOTF)\(^2\) | Univariable GEE regression for child PA rate. | No association between total PA and waist circumference. |
| Oliver et al. (2013)\(^{60}\) | New Zealand PIF:PAC | n = 126, 52 boys, 74 girls; 5.8 – 6.7, 5.9 | 58% high waist circumference | Multiple linear regression. | No association between sedentary behaviour or MVPA and waist circumference. |

5) (TRUNK) FAT MASS (INDEX)

*Longitudinal studies*

| Author (year) | Country | Sample size; age\(^a\) | Prevalence of overweight\(^b\) | Statistical analysis | Conclusion |
|---------------|---------|------------------------|-----------------------------|---------------------|------------|
| Butte et al. (2016)\(^3\) | United States | n = 111, 58 boys, 53 girls; 3 - 5 years, 4.6(0.9) | 18.0% (CDC)\(^4\) | Mixed-effects linear models adjusted for age, sex, race/ethnicity, daycare hours, household size, household income, mother’s age, BMI and education and awake time. | No relation between total PA, sedentary behaviour or MVPA and fat mass 1 year later. |
### Appendix D. Continued.

| Author (year) | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweight | Statistical analysis | Conclusion |
|---------------|--------------------|-----------------------------------------------|--------------------------|---------------------|------------|
| Janz et al. (2009) | United States IOWA-Fluoride study, IOWA-Bone Development study | n = 333, 148 boys, 185 girls; baseline: 5 years, follow-up: 8 and 11 years. | - | Mixed regression analysis adjusted for concurrent age, height, weight, fat mass at age 5 and MVPA. | MVPA at age 5 years was a predictor of later fat mass in boys, but not in girls. |
| Jáuregui et al. (2012) | Mexico | n = 205, 87 boys, 118 girls; 5 – 6, baseline 6.0(0.4), follow-up 8.1(0.3) | - | Multiple linear regression models adjusted by initial fat mass, energy intake and height, age, sex, socioeconomic status and changes in energy intake and height. | Girls with a high baseline MVPA or girls who increased 10 min/d in MVPA had lower fat mass gain compared with their peers, but not for boys. |
| Leppänen et al. (2017) | Sweden MINISTOP trial | n = 138, 73 boys, 65 girls; 4 years, 4.5(0.2) follow-up: 5.6(0.2) | 7.2% baseline, 6.5% follow-up | Linear regression, adjusted for child’s sex, age at measurement, ActiGraph awake wearing time. | No relation between sedentary behaviour, moderate PA, vigorous PA or MVPA and fat mass index 12 months later. |

**Cross-sectional studies**

| Butte et al. (2016) | United States | n = 111, 58 boys, 53 girls; 3 – 5 years, 4.6(0.9) | 18.0% (CDC) | Mixed-effects linear models adjusted for age, sex, race/ethnicity, daycare hours, household size, household income, mother’s age, BMI and education and awaketime. | No association between total PA, sedentary behaviour or MVPA and fat mass. |
| Author (year) | Country and cohort | Participant characteristics (sample size; age) | Prevalence of overweight<sup>b</sup> | Statistical analysis | Conclusion |
|--------------|--------------------|-----------------------------------------------|----------------------------------|---------------------|------------|
| Collings et al. (2013)<sup>6</sup> | United Kingdom SWS | n = 398, 202 boys, 196 girls; 4 years, 4.1(0.1) | 20.1% (IOTF)<sup>7</sup> | Bivariate correlations. | Children who spent less time engaged in sedentary behaviour or more time in moderate PA, vigorous PA or MVPA had a lower fat mass index and trunk fat mass index compared with their peers. No results for light PA. |
| Heelan and Eisenmann (2006)<sup>7</sup> | United States | n = 100, 48 boys, 52 girls; 4 – 7 years, 5.8(1.3) | - | Partial correlations controlling for chronological age. | No association between total PA or MVPA and fat mass. |
| Jackson et al. (2009)<sup>8</sup> | United Kingdom RASCAL | n = 89, 42 boys, 47 girls; 2 – 6 years, 4.1 (1.3) | 30.6% (UK 1990)<sup>9</sup> | General linear model, adjusted for age, sex and TV viewing time. | No association between fat mass and total PA. |
| Janz et al. (2002)<sup>8</sup> | United States IOWA-Fluoride study, IOWA-Bone Development study | n = 434, 203 boys, 231 girls; 4 – 6 years, 5.3(0.4) | - | Partial correlation coefficients adjusted for age and height. | Children who spent more time engaged in vigorous PA had a lower fat mass and trunk fat mass compared with their peers. Children who spent more time engaged in total PA had a lower fat mass compared with their peers. Girls who spent more time engaged in total PA had a lower trunk fat mass compared with their peers as well. No results for MVPA. |
| Kwon et al. (2011)<sup>8</sup> | United States IOWA-Bone Development study | n = 436, 204 boys, 232 girls; 5 years, 5.3(0.4) | - | Pearson partial correlation coefficients adjusted for age, height and fat free mass. | No associations between both IW-LPA100<sup>6</sup> and IW-LPA1100<sup>6</sup> and fat mass. |
| Author (year) | Country and cohort | Participant characteristics (sample size; age\(^a\)) | Prevalence of overweight\(^b\) | Statistical analysis | Conclusion |
|--------------|---------------------|----------------------------------------------------|-----------------------------|---------------------|------------|
| Leppänen et al. (2016)\(^9\) | Sweden MINISTOP trial | n = 295, 166 boys, 129 girls; 4.5(0.2) | 8.5% (Cole et al. 2012)\(^10\) | Multiple linear regression, adjusted for parental BMI, parental educational attainment, child’s sex and age at measurement and awake wearing time. | No association between sedentary behaviour, moderate PA, vigorous PA or MVPA and fat mass index. |
| Metcalf et al. (2008)\(^12\) | United Kingdom EarlyBird | n = 212, 113 boys, 99 girls; 5 – 8 years, follow up at 6, 7 and 8 years | - | Multiple linear regression. | No correlation between minutes in MVPA and changes in skinfold thickness. |
| Collings et al. (2017)\(^17\) | United Kingdom BiB (HAPPY, BiB-1000, LEAP) | n = 333, 169 boys, 164 girls; 11 months – 5 years, 3.3(0.9) | 19.5% (Cole et al. 1990)\(^18\) | Multilevel models adjusted for age, sex, ethnicity, index of multiple deprivation, monitor worn time, season and height. | Children who spent more time engaged in MVPA had a lower skinfold thickness compared with their peers. No associations between total PA, sedentary behaviour or light PA and skinfold thickness. |
| Fang et al. (2017)\(^64\) | China | n = 346, 201 boys, 145 girls; 3.5 – 5.5 years, 4.6(0.5) | - | multiple linear regression models controlling for age, BMI, sex and valid wearing time. | Boys who spent more time engaged in MVPA had a lower triceps skinfold thickness compared with their peers. No associations for girls or for light PA. |
| Herzig et al. (2017)\(^24\) | Switzerland SPLASHY | n = 309, 162 boys, 147 girls; 2 – 6 years, 3.9(0.7) | - | Pearson correlation coefficients. | Children who spent more time engaged in total PA or MVPA had a lower sum of skinfolds compared with their peers. |

6) SKINFOLD THICKNESS

**Longitudinal studies**

**Cross-sectional studies**
### 7) OTHER ADIPOSIITY OUTCOMES

| Author (year) | Country and cohort | Participant characteristics (sample size; age\(^a\)) | Prevalence of overweight\(^b\) | Statistical analysis | Conclusion |
|---------------|--------------------|-----------------------------------------------------|-------------------------------|----------------------|------------|
| Mota et al. (2016)\(^65\) | Portugal | PRESTYLE n = 646, 312 girls, 334 boys; 2 – 6 years, 5.2(0.7) | central obesity (WHtR > 0.5\(^f\)); boys: 39.2%, girls: 52.4% | Logistic regression adjusted by age. | Boys classified as having central obesity spent more time in sedentary behaviour compared with boys who were not classified as central obesity. No statistical differences for girls. |
| Said-Mohamed et al. (2012)\(^66\) | Kameroen, central Afrika | n = 133; 2 – 6 years | 24.7% stunted, 25.3% overweight, 13.6% stunted overweight\(^e\) | ANCOVA, adjusted for sex, age and being at school. | Sedentary behaviour, light PA and MVPA were different between stunted children without overweight, stunted children with overweight, non-stunted children with overweight and non-stunted children without overweight. |

Abbreviations: PA, physical activity; MVPA, moderate-to-vigorous physical activity; BMI, body mass index; IOTF, International Obesity Task Force age- and sex-specific BMI growth charts; CDC, Centers for Disease Control and Prevention; WHO, World Health Organization; SWS, Southampton Women’s Survey; BiB, Born in Bradford study; CHMS, Canadian Health Measures Survey; WHtR, waist to height ratio.

\(^a\) Age is presented as age range, mean(SD).

\(^b\) Prevalence of overweight is presented as % overweight/obesity.

\(^c\) Weight status was defined as non-overweight compared with overweight/obesity.

\(^d\) Data received on request.

\(^e\) IW-LPA100 is the daily sum of accelerometer counts during light-intensity physical activity defined as 100 - 2999 cpm, IW-LPA1100 is the daily sum of accelerometer counts during light-intensity physical activity defined as 1100 - 2999 cpm.

\(^f\) Waist-to-height ratio was calculated as the ratio of waist (cm) and height (cm). A WHtR cutoff of <0.5 was used to define abdominal obesity (McCarthy and Ashwell, 2006). Two categories: the non-risk group (WHtR <0.5) and at risk group based on central fat (WHtR > 0.5).

\(^g\) Stunted: height-for-age (HAC) ≤ 3rd percentile, BMI < 85th percentile, weight-for-height (WHZ) > -2 z-score; Overweight: HAC > 3rd percentile, BMI ≥ 85th percentile; Stunted Overweight: HAC ≤ 3rd percentile, BMI ≥ 85th percentile; Non-Stunted-and-Non-Overweight: HAC > 3rd percentile, BMI < 85th percentile, WHZ > -2 z-score.
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### Physical activity assessment.

#### A) Studies using triaxial accelerometers

| Author (year) | Type of accelerometer | Epoch (s) | Accelerometer cutpoints | Minimum weartime |
|---------------|-----------------------|----------|--------------------------|------------------|
| Berglind et al. (2017) | ActiGraph GT3X+ | 5 | TPA: average cpm, SB: <820, LPA: 820 - 3907, MVPA: ≥ 3908 cpm | At least 3 days, 10h/day |
| Iivonen et al. (2013) | Actigraph GT3X | 5 | TPA: average cpm over monitoring period, MVPA: ≥ 196 counts/5s | At least 3 days, 8h/day |
| Leppänen et al. (2016) | ActiGraph wGT3x | 10 | SB <305, LPA 306-817, MPA 818-1968, VPA >1969, MVPA >818 VM (all per 5s) | At least 3 days, 10h/day |
| Leppänen et al. (2017) | ActiGraph wGT3x | 10 | SB <305, LPA 306-817, MPA 818-1968, VPA >1969, MVPA >818 VM (all per 5s) | At least 3 days, 10h/day |
| Buck et al. (2015) | ActiGraph GT3X+ | 15 | MVPA = 2298 cpm | At least 3 consecutive days, 1 weekend day, 8h/day |
| Collings et al. (2017) | ActiGraph GT3X+ | 15 | SB: <820, LPA: 820-3907, MVPA: ≥ 3904 cpm | At least 1 valid day, 6h/day |
| España-Romero et al. (2013) | ActiGraph GT1M and GT3X | 15 | SB: ≤ 200, MVPA: ≥ 420 counts/15s | At least 2 weekdays, 6h/day |
| Matarma et al. (2017) | ActiGraph GT3X | 15 | Cutpoints Evenson et al. (2008) | At least 4 days, 8h/day, 3 weekdays and 1 weekend day |
| Matarma et al. (2018) | ActiGraph GT3X | 15 | SB < 100cpm | At least 4 days, 8h/day, 3 weekdays and 1 weekend day |
| Oliver et al. (2010) | Actical accelerometer | 15 | TPA: daily PA rates | NR |
| Pate et al. (2015) | CHAMPS: ActiGraph 7164 SHAPES: GT1M and GT3X | 15 | TPA: ≥ 200 counts/15s | At least 2 days, 8h/day |
| Schmutz et al. (2017) | Actigraph wGT3X | 15 | TPA: mean cpm, SB: ≤ 25, MVPA: ≥ 420 counts/15s | At least 3 days, 10h/day |
### Appendix E. Continued.

| Author (year)          | Type of accelerometer | Epoch (s) | Accelerometer cutpoints                                                                 | Minimum weartime               |
|------------------------|-----------------------|-----------|----------------------------------------------------------------------------------------|--------------------------------|
| Tucker et al. (2016)   | Actical accelerometer | 15        | TPA: ≥ 50, SB < 50, MVPA ≥ 715 counts/15s<sup>19</sup>                                   | At least 3 days, 5h/day        |
| Butte et al. (2016)    | ActiGraph GT3X+       | 60        | SB: < 820, MVPA: ≥ 3908 cpm<sup>2</sup>                                                  | At least 4 valid days, 1 weekend day, 1000 min/day |
| Colley et al. (2013)   | Actical accelerometer | 60        | TPA: total cpm, SB: <100, LPA: 100 - 1149, MVPA: ≥ 1150 cpm<sup>22,23</sup>               | At least 4 days, 5h/day        |
| Jáuregui et al. (2012) | RT3 accelerometers    | 60        | MVPA: 970.2 cpm<sup>25</sup>                                                            | at least 1 valid day, 10h/day  |
| Oliver et al. (2013)   | Actical accelerometer | 60        | SB: <100, MVPA: ≥1500 cpm<sup>27</sup>                                                  | At least 3 days, 7 hours/day   |
| Tanaka and Tanaka (2013)| ActivTracer GMS      | 60        | Low-intensity activity (PAR < 2), LPA (2 < PAR < 3), MVPA (3 ≤ PAR) and VPA(PAR ≥ 4)<sup>29</sup> | At least 2 weekdays, 1 weekend day |
| Fang et al. (2017)     | Actigraph GT3X+       | NR        | LPA: 100-1679, MPA: 1680-3367, VPA ≥ 3368 cpm<sup>12</sup>                              | At least 3 days, 8h/day, 2 weekdays and 1 weekend day |
| Herzig et al. (2017)   | Actigraph wGT3x      | NR        | Cutpoints Butte et al (2014)<sup>2</sup>                                                | At least 4 days, 10h/day       |
| Rötterger et al. (2014)| AiperMotion 440      | NR        | SB: 4s resolution<sup>31</sup>                                                         | NR                             |
| Vorwerg et al. (2013)  | SensewarePro          | NR        | SB: MET ≤ 1.4, LPA: 1.5–2.9, MPA 3–5.9 , VPA ≥ 6 METs<sup>35,36</sup>                   | At least 4 consecutive days and nights, one day of the weekend |

B) Studies using biaxial accelerometers

| Author (year) | Type of accelerometer | Cutpoints | Minimum weartime |
|---------------|-----------------------|------------|------------------|
| Finn et al. (2002) | Actiwatch Model AW16 activity monitor | VPA: 1000 counts | NR |

C) Studies using uniaxial accelerometers

| Author (year) | Type of accelerometer | Epoch (s) | Cutpoints | Minimum weartime |
|---------------|-----------------------|-----------|-----------|------------------|
| Mota et al. (2016) | Actigraph GT1M | 5         | SB: ≤ 200 counts/15s<sup>11,16</sup> | At least 10h/day |
| Author (year) | Type of accelerometer | Epoch (s) | Accelerometer cutpoints | Minimum weartime |
|---------------|------------------------|-----------|--------------------------|------------------|
| O’Dwyer et al. (2011) | Actigraph GT1M | 5         | Cupoints: Sirard et al. (2005) | At least 3 days, 2 weekdays and 1 weekend |
| Vale et al. (2010) | Actigraph GT1M | 5         | TPA: ≥ 1100, MPA: >1680, VPA: >3360 cpm | At least 10h/day |
| Bürgi et al. (2011) | Actigraph GT1M | 15        | MPA: 420 - 841, VPA: ≥ 842 counts/15s | At least 3 days of recording, 2 weekdays and 1 weekend day, 6h/day |
| Byun et al. (2011) | Actigraph 7164 | 15        | SB: <37.5 counts/15s | NR |
| Dawson-Hahn et al. (2015) | Actigraph GT1M | 15        | TPA: > 37.5 cpm, MVPA: NR | at least 5 days, 3h/day |
| Ebenegger et al. (2012) | Actigraph GT1M | 15        | MVPA: ≥ 420, VPA: ≥ 842 counts/15s | At least 3 days, 2 weekdays and 1 weekend day, 6h/day |
| Guo et al. (2017) | ActiGraph 7164 | 15        | TPA: ≥ 200 counts/15s | At least 3 days, 5 – 17 h/day |
| Mendoza et al. (2014) | Actigraph GT1M | 15        | MVPA: ≥ 420 counts/15s | At least 1 day, 8h/day |
| Niederer et al. (2012) | Actigraph GT1M | 15        | TPA = total cpm, MVPA ≥ 420, VPA ≥ 842 epoch/6h | At least 3 days, 2 weekdays and 1 weekend day, 6h/day |
| Pfeiffer et al. (2009) | ActiGraph 7164 | 15        | MVPA: ≥ 420 counts/15s | At least 3 days |
| Remmers et al. (2014) | ActiGraph 7164 | 15        | SB: 0-25, LPA : 26-573, MPA : 574-1002, VPA : ≥ 1003 counts/epoch | At least 3 days, 2 weekdays and 1 weekend day, 400min/day |
| Trost et al. (2003) | ActiGraph 7164 | 15        | MVPA: ≥ 3 MET’s, VPA: ≥ 6 MET’s | At least 3 days |
| van Cauwenbergh et al. (2012) | Actigraph GT1M | 15        | SB: ≤ 25, MVPA: 3yr. >614 | At least 4 days, 4 – 9h/day counts/15s |
### Appendix E. Continued.

| Author (year)         | Type of accelerometer              | Epoch (s) | Accelerometer cutpoints                                      | Minimum weartime                  |
|-----------------------|------------------------------------|-----------|--------------------------------------------------------------|-----------------------------------|
| Williams et al. (2008) | ActiGraph 7164                     | 15        | SB: <37.5, LPA: 38-419, MVPA: ≥ 420, VPA: ≥ 842 counts/15s   | At least 3 days, 5h/day           |
| Yamamoto et al. (2011)| Actiheart                          | 15        | MVPA girls: > 105 | boys: > 118 counts/15s                                      | At least one weekend and one weekday |
| Schaefer et al. (2015)| Polar Active                        | 30        | NR                                                           | At least 3 days                   |
| Cliff et al. (2009)   | Actigraph 7164                     | 60        | SB: <1100 cpm, MPA: 3yr. 2460-4920 | 4yr. 3248-4936 | 5yr. 3564-5016, VPA: 3yr. >4920 | 4yr. >4936 | > 5016, MVPA: 3yr. > 2460 | 4yr. > 3248 | 5yr. > 3564 cpm | At least three days, 6h/day |
| Collings et al. (2013)| Actiheart combined heart rate and movement sensor | 60        | SB: < 37.5, LPA: 38 - 419, MPA: 420 - 841, VPA: ≥ 842 counts | At least one valid day, 600 min/day |
| Fisher et al. (2005)  | CSA                                | 60        | TPA: average cpm over monitoring period                      | At least 3 days, 6h/day           |
| Heelan and Eisenmann (2006) | Actigraph 7164                  | 60        | MPA: 615-2971, VPA: > 2972 cpm                              | At least 3 weekdays, 8h/day       |
| Jackson et al. (2003) | Actigraph 7164/CSA                 | 60        | TPA: average over 3 day period                               | At least 3 days, 2weekdays, 1 weekend day, 6h/day |
| Jackson et al. (2009) | Actiwatch-L                        | 60        | NR                                                           | NR                               |
| Janz et al. (2002)    | CSA                                | 60        | TPA: total movement counts/total time, MVPA: ≥ 615, VPA: ≥ 2972 counts | At least 3 days, minimal 8h/day   |
| Janz et al. (2009)    | Actigraph 7164                     | 60        | MVPA: > 3000 cpm                                            | At least 3 days, 8h/day           |
| Jones et al. (2009)   | Actigraph 7164                     | 60        | Total PA: mean cpm                                          | At least 3 days, 6h/day           |
| Author (year)          | Type of accelerometer | Epoch (s) | Accelerometer cutpoints                                                                 | Minimum weartime                        |
|-----------------------|-----------------------|-----------|----------------------------------------------------------------------------------------|-----------------------------------------|
| Kelly et al. (2006)   | Accelerometer         | 60        | TPA: average cpm, SB: <1100, MVPA: 3200 cpm<sup>64,73</sup>                             | At least 6 days, 6h/day                |
| Kwon et al. (2011)    | Actigraph 7164        | 60        | Daily sum of accelerometer counts at LPA (100 cpm) and LPA (1100 cpm)<sup>42,75,76</sup> | At least 3 days, 8h/day                |
| Metallinos-Katsaras et al. (2007)<sup>77</sup> | ActiGraph 7164       | 60        | LPA: <615, MPA: 615-2971, VPA: 2972-5331 cpm<sup>78</sup>                               | At least 4,5 days                      |
| Metcalf et al. (2008)<sup>79</sup> | Actigraph MTI and CSA | 60        | ≥ 3 MET’s<sup>61,80</sup>                                                            | NR                                      |
| Said-Mohamed et al. (2012)<sup>81</sup> | Actigraph GT1M      | 60        | SB: ≤ 800, LPA: ≤ 3200, MVPA: > 3201 cpm<sup>61</sup>                                 | NR                                      |
| Toschke et al. (2007)<sup>82</sup> | ActiGraph 7164       | 60        | TPA: average active cpm                                                               | At least 6h/day                        |
| D) Type of accelerometer not mentioned |
| Gutiérrez-Hervás et al. (2018)<sup>83</sup> | NR                    | 15        | TPA: total cpm                                                                        | At least 4 days, 10 h/day, 3 weekdays and 1 weekend day |

Abbreviations: TPA, total physical activity; SB, sedentary behaviour; LPA, light physical activity; MPA, moderate physical activity; VPA, vigorous physical activity; MVPA, moderate-to-vigorous physical activity; cpm, counts per minute; VM, vector magnitude; PAR, physical activity ratio; MET, metabolic equivalent; NR, not reported.
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Appendix F. Assessment of percentage of body fat, (trunk) fat mass (index), waist circumference, and skinfold thickness.

| Author (year) | Adiposity outcome(s) | Measurement / cutpoints |
|---------------|----------------------|-------------------------|
| Bürgi et al. (2011) | Percentage of body fat | Four-polar single frequency bioelectric impedance. |
| Butte et al. (2016) | Percentage of body fat | Dual energy X-ray absorptiometry. |
| Collings et al. (2013) | Percentage of body fat | Dual energy X-ray absorptiometry. |
| Collings et al. (2017) | (Trunk) fat mass index | Waist circumference: Seca anthropometrical tape at the level of the exposed naval. Skinfold thickness: single measurements of triceps and subscapular skinfolds on the left side of the body using standard procedures. |
| España-Romero et al. (2013) | Waist circumference | Tension-regulated tape, at midway between the inferior edge of the lowest rib and the superior border of iliac crest, at the end of a gentle expiration. |
| Fang et al. (2017) | Skinfold thickness | Triceps skinfolds on the right side of the body. |
| Heelan and Eisenmann (2006) | Percentage of body fat | Dual energy X-ray absorptiometry. |
| Herzig et al. (2017) | Skinfold thickness | TriPLICATE measurements at four sites (biceps, triceps, subscapular, suprailiac) on the right body side. |
| Jackson et al. (2009) | Fat mass | Dual energy X-ray absorptiometry. |
| Jänz et al. (2002) | Percentage of body fat | Dual energy X-ray absorptiometry. |
| Jänz et al. (2009) | Fat mass | Dual energy X-ray absorptiometry. |
| Jáuregui et al. (2012) | Fat mass | Air-displacement plethysmography. |
| Kwon et al. (2011) | Fat mass | Dual energy X-ray absorptiometry. |
| Leppänen et al. (2016) | Percentage of body fat | Percentage of body fat and fat mass index: Air-displacement plethysmography. Waist circumference: non-elastic tape (SECA model 200) at the umbilical location, at the end of a normal expiration. |
| Leppänen et al. (2017) | Fat mass index | Air-displacement plethysmography. |
| Metcalf et al. (2008) | Waist circumference | Waist circumference: NR. Skinfold thickness: sum of biceps, triceps, subscapular, paraumbilical and suprailiac measurements. |
| Oliver et al. (2010) | Waist circumference | Lufkin W606PM tape. |
| Oliver et al. (2013) | Waist circumference | Lufkin W606PM tape, around the waist approximately half-way between the costal border and the iliac crest, with the participant breathing quietly. |

Only the assessment of percentage of body fat, (trunk) fat mass (index), waist circumference, and skinfold thickness are shown. Body mass index was calculated as kg/m² in all included studies. The cutpoints for weight status can be found in Table 1.
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Appendix G. Overall and individual results of the risk of bias assessment using QUIPS.

I. Overall risk of bias scores for each QUIPS item, shown as a percentage of the total number of participants.
II. The results of the risk of bias assessment based on QUIPS for each study.

| Author, year          | 1. Participation | 2. Attrition | 3. Determinant | 4. Outcome | 5. Confounding | 6. Analysis |
|-----------------------|-------------------|--------------|----------------|------------|----------------|-------------|
| Berglind et al. 2017  |                   |              |                |            |                |             |
| Buck et al. 2015      |                   |              |                |            |                |             |
| Bürgi et al. 2011     |                   |              |                |            |                |             |
| Butte et al. 2016     |                   |              |                |            |                |             |
| Byun et al. 2011      |                   |              |                |            |                |             |
| Cliff et al. 2009     |                   |              |                |            |                |             |
| Colley et al. 2013    |                   |              |                |            |                |             |
| Collings et al. 2013  |                   |              |                |            |                |             |
| Collings et al. 2017  |                   |              |                |            |                |             |
| Dawson-Hahn et al. 2015 |                 |              |                |            |                |             |
| Ebenegger et al. 2012 |                   |              |                |            |                |             |
| España-Romero et al. 2013 |               |              |                |            |                |             |
| Fang et al. 2017      |                   |              |                |            |                |             |
| Finn et al. 2002      |                   |              |                |            |                |             |
| Fisher et al. 2005    |                   |              |                |            |                |             |
| Guo et al. 2017       |                   |              |                |            |                |             |
| Gutiérrez-Hervás et al. 2018 |             |              |                |            |                |             |
| Heelan and Eisenmann 2006 |               |              |                |            |                |             |
| Herrig et al. 2017    |                   |              |                |            |                |             |
| Ivonen et al. 2013    |                   |              |                |            |                |             |
| Jackson et al. 2003   |                   |              |                |            |                |             |
| Jackson et al. 2009   |                   |              |                |            |                |             |
| Janz et al. 2002      |                   |              |                |            |                |             |
| Janz et al. 2009      |                   |              |                |            |                |             |
| Jäuregui et al. 2012  |                   |              |                |            |                |             |
| Jones et al. 2009     |                   |              |                |            |                |             |
II. The results of the risk of bias assessment based on QUIPS for each study (continued).

| Author, year          | a. Description of baseline sample | b. Participant recruitment | c. Period and place of recruitment mentioned | d. In- and exclusion criteria reported | e. Adequate response rate (>80%) | f. Reason for loss of data | g. Differences participants without data | h. Clear description of physical activity | i. Measurement is valid and reliable | j. Clear definition of the adiposity outcome | k. Measurement is valid and reliable | l. Analyses adjusted for sex | m. Sufficient presentation of the data | n. Selected statistical models are adequate | o. No selective reporting of the results |
|-----------------------|----------------------------------|-----------------------------|---------------------------------------------|--------------------------------------|-------------------------------|---------------------------|---------------------------------------------|------------------------------------------|------------------------------------------|---------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|
| Kelly et al. 2006     | - - - - +/- + + +/ - - - - - - |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Kwon et al. 2011      | - - - - +/- + + + - - - - - -   |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Leppänen et al. 2016  | - - - - +/- + + + - - - - - -   |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Leppänen et al. 2017  | - - - - + - + + - - - - - -    |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Matarma et al. 2017   | - - - - + - + + - - - - - -    |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Matarma et al. 2018   | - - - - + - + + - - - - - -    |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Mendoza et al. 2014   | - - - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Metallinos-Katsaras et al. 2007 | - - - - +/- + + + - - - - - - |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Metcalf et al. 2008   | - - - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Mota et al. 2016      | - + - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Niederer et al. 2012  | - + - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| O’Dwyer et al. 2011   | - + - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Oliver et al. 2010    | - + - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Oliver et al. 2013    | - + - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Pate et al. 2015      | - + - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Pfeiffer et al. 2009  | - + - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Remmers et al. 2014   | - + - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Röttger et al. 2014   | - + - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Said-Mohammed et al. 2012 | - + - - +/- + + + - - - - - - |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Schaefer et al. 2015  | - - - - +/- - + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Schmutz et al. 2017   | - - - - +/- + + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Tanaka and Tanaka 2013 | - - - - +/- - + + - - - - - - |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Toschke et al. 2007   | + - - - +/- - + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Trost et al. 2003     | - + - - +/- - + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Tucker et al. 2016    | - + - - +/- - + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Vale et al. 2010      | - + - - +/- - + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Van Cauwenbergh et al. 2012 | - + - - +/- - + + - - - - - - |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Vorwerk et al. 2013   | - + - - +/- - + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Williams et al. 2008  | - + - - +/- - + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
| Yamamoto et al. 2011  | + + - - +/- - + + - - - - - -  |                            |                                             |                                      |                               |                           |                                             |                                          |                                          |                                             |                                          |                                          |                                          |                                          |                                          |
Appendix H: Forest plots of the association between physical activity and waist circumference, fat mass (index), and skinfold thickness, differentiated by physical activity intensities.

### Total physical activity - waist circumference(cm)

| Author (year) | Sex | Acc | Epoch | N | Statistics for each study | Point estimate | Standard error | p-Value |
|---------------|-----|-----|-------|---|---------------------------|----------------|----------------|---------|
| Collings (2017) | BG, adj | Tri | 15 | 310 | -0.017, 0.037, 0.644 | | | |
| Oliver (2012) | BG | Tri | 15 | 78 | -0.126, 0.135, 0.917 | | | |
| Overall | | | | | -0.036, 0.025, 0.467 | -0.50, -0.25, 0.00, 0.25, 0.50 | |

Heterogeneity: I²=0%, Q=1, df=1, p=0.048

### Moderate-to-vigorous physical activity - waist circumference(cm)

| Author (year) | Sex | Acc | Epoch | N | Statistics for each study | Point estimate | Standard error | p-Value |
|---------------|-----|-----|-------|---|---------------------------|----------------|----------------|---------|
| España Romero (2013) | G | Tri | 15 | 174 | 0.106, 0.006, 0.006 | | | |
| Collings (2017) | BG, adj | Tri | 15 | 310 | 0.040, 0.016, 0.013 | | | |
| Lønnerås (2016) | BG, adj | Tri | 10 | 304 | -0.407, 0.039, 0.203 | | | |
| Overall | | | | | 0.012, 0.046, 0.013 | -0.50, -0.25, 0.00, 0.25, 0.50 | |

Heterogeneity: I²=49%, Q=6, df=3, p=0.118

### Sedentary behaviour - waist circumference(cm)

| Author (year) | Sex | Acc | Epoch | N | Statistics for each study | Point estimate | Standard error | p-Value |
|---------------|-----|-----|-------|---|---------------------------|----------------|----------------|---------|
| Español Romero (2013) | G | Tri | 15 | 174 | -0.079, 0.076, 0.310 | | | |
| Collings (2017) | BG, adj | Tri | 15 | 310 | -0.037, 0.042, 0.379 | | | |
| Lønnerås (2016) | BG, adj | Tri | 10 | 304 | 0.413, 0.275, 0.133 | | | |

Heterogeneity: I²=51%, Q=6, df=3, p=0.107

* The overall estimates are not shown because of heterogeneity.

### Total physical activity - fat mass(kg)

| Author (year) | Sex | Acc | Epoch | N | Statistics for each study | Point estimate | Standard error | p-Value |
|---------------|-----|-----|-------|---|---------------------------|----------------|----------------|---------|
| Heelan (2006) | B | Uni | 60 | 48 | -0.080, 0.127, 0.530 | | | |
| Janz (2002) | B | Uni | 60 | 203 | -0.150, 0.077, 0.050 | | | |
| Heelan (2006) | G | Uni | 60 | 52 | -0.130, 0.207, 0.550 | | | |
| Janz (2002) | G | Uni | 60 | 231 | -0.190, 0.074, 0.010 | | | |
| Butte (2016) | BG, adj | Tri | 60 | 111 | -0.083, 0.083, 0.317 | | | |
| Overall | | | | | -0.137, 0.041, 0.001 | -0.50, -0.25, 0.00, 0.25, 0.50 | |

Heterogeneity: I²=0%, Q=1, df=1, p=0.881

### Moderate-to-vigorous physical activity - fat mass index(kg/m2)

| Author (year) | Sex | Acc | Epoch | N | Statistics for each study | Point estimate | Standard error | p-Value |
|---------------|-----|-----|-------|---|---------------------------|----------------|----------------|---------|
| Heelan (2006) | B | Uni | 60 | 48 | -0.060, 0.137, 0.530 | | | |
| Janz (2002) | B | Uni | 60 | 203 | -0.150, 0.077, 0.050 | | | |
| Heelan (2006) | G | Uni | 60 | 52 | -0.130, 0.207, 0.550 | | | |
| Janz (2002) | G | Uni | 60 | 231 | -0.190, 0.074, 0.010 | | | |
| Butte (2016) | BG, adj | Tri | 60 | 111 | -0.083, 0.083, 0.317 | | | |
| Overall | | | | | -0.137, 0.041, 0.001 | -0.50, -0.25, 0.00, 0.25, 0.50 | |

Heterogeneity: I²=0%, Q=0, df=1, p=0.640

### Sedentary behaviour - fat mass index(kg/m2)

| Author (year) | Sex | Acc | Epoch | N | Statistics for each study | Point estimate | Standard error | p-Value |
|---------------|-----|-----|-------|---|---------------------------|----------------|----------------|---------|
| Collings (2013) | BG, adj | Uni | 60 | 398 | -0.073, 0.028, 0.010 | | | |
| Lønnerås (2016) | BG, adj | Tri | 10 | 256 | 0.046, 0.367, 0.584 | | | |
| Overall | | | | | -0.074, 0.028, 0.009 | -0.50, -0.25, 0.00, 0.25, 0.50 | |

Heterogeneity: I²=60%, Q=0, df=1, p=0.000

### Vigorous physical activity - fat mass index(kg/m2)

| Author (year) | Sex | Acc | Epoch | N | Statistics for each study | Point estimate | Standard error | p-Value |
|---------------|-----|-----|-------|---|---------------------------|----------------|----------------|---------|
| Collings (2013) | BG, adj | Uni | 60 | 398 | -0.120, 0.036, 0.001 | | | |
| Lønnerås (2016) | BG, adj | Tri | 10 | 256 | -0.123, 0.293, 0.467 | | | |
| Overall | | | | | -0.121, 0.036, 0.001 | -0.50, -0.25, 0.00, 0.25, 0.50 | |

Heterogeneity: I²=0%, Q=0, df=1, p=0.753
**Appendix H:** Forest plots of the association between physical activity and waist circumference, fat mass (index), and skinfold thickness, differentiated by physical activity intensities (continued).

### Moderate-to-vigorous physical activity - fat mass index (kg/m²)

| Author (year)       | Sex | Acc  | Epoch | N  | Statistics for each study | Point estimate and 95% CI |
|---------------------|-----|------|-------|----|---------------------------|---------------------------|
|                     |     |      |       |    |                           |                           |
| Collings (2013)     | BG  | adj  | Uni   | 60 | -0.100                    | -0.40, 0.00, 0.40, 0.80   |
| Lepännen (2016)     | BG  | adj  | Tri   | 30 | -0.274                    | -0.40, 0.00, 0.40, 0.80   |
| Overall             |     |      |       |    |                           |                           |

Heterogeneity: I²=95%, Q=0, df=1, p=0.528

### Light physical activity - skinfold thickness (mm)

| Author (year)       | Sex | Acc  | Epoch | N  | Statistics for each study | Point estimate and 95% CI |
|---------------------|-----|------|-------|----|---------------------------|---------------------------|
|                     |     |      |       |    |                           |                           |
| Fang (2017)         | B   | Tri  | NR    | 201| 0.028                     | 0.041, 0.530              |
| Fang (2017)         | G   | Tri  | NR    | 145| -0.077                    | 0.123, 0.530              |
| Collings (2017)     | BG  | adj  | Tri   | 15 | -0.034                    | 0.010, 0.000              |
| Overall             |     |      |       |    |                           |                           |

Heterogeneity: I²=6%, Q=2, df=2, p=0.345

### Total physical activity - skinfold thickness (mm)

| Author (year)       | Sex | Acc  | Epoch | N  | Statistics for each study | Point estimate and 95% CI |
|---------------------|-----|------|-------|----|---------------------------|---------------------------|
|                     |     |      |       |    |                           |                           |
| Collings (2017)     | BG  | adj  | Tri   | 15 | -0.145                    | -0.25, 0.00, 0.25, 0.50   |
| Herzög (2017)       | BG  | Tri  | NR    | 309| -0.120                    | -0.25, 0.00, 0.25, 0.50   |
| Overall             |     |      |       |    |                           |                           |

Heterogeneity: I²=9%, Q=6, df=1, p=0.822

### Moderate-to-vigorous physical activity - skinfold thickness (mm)

| Author (year)       | Sex | Acc  | Epoch | N  | Statistics for each study | Point estimate and 95% CI |
|---------------------|-----|------|-------|----|---------------------------|---------------------------|
|                     |     |      |       |    |                           |                           |
| Fang (2017)         | B   | Tri  | NR    | 201| -0.106                    | 0.089, 0.050              |
| Fang (2017)         | G   | Tri  | NR    | 145| -0.041                    | 0.065, 0.530              |
| Collings (2017)     | BG  | adj  | Tri   | 15 | -0.190                    | 0.033, 0.000              |
| Herzög (2017)       | BG  | Tri  | NR    | 309| -0.130                    | 0.006, 0.050              |
| Overall             |     |      |       |    |                           |                           |

Heterogeneity: I²=32%, Q=4, df=3, p=0.217

**Abbreviations:** B, boys; G, girls; BG, boys and girls; adj, adjusted for sex; acc, accelerometer type; uni, uniaxial; bi, biaxial; tri, triaxial; epoch, epoch length (s); N, number of participants.
## Appendix I. The results of the subgroup analyses for waist circumference.\(^1\)

|                           | Q | df | p-value (Q) | I\(^2\) | N | stdβ | SE | p-value |
|---------------------------|---|----|-------------|---------|---|------|----|---------|
| **Moderate-to-vigorous physical activity – waist circumference** |   |    |             |         |   |      |    |         |
| **Sex**                   |   |    |             |         |   |      |    |         |
| Boys                      | - | -  | -           | -       | 1 | 0.109| 0.075| 0.145   |
| Girls                     | - | -  | -           | -       | 1 | -0.079| 0.078| 0.310   |
| Adjusted for sex          | 3 | 1  | 0.106       | 62%     | - | -    | -   | -       |
| **Epoch length**          |   |    |             |         |   |      |    |         |
| 10s                       | - | -  | -           | -       | 1 | 0.413| 0.275| 0.133   |
| 15s                       | 4 | 2  | 0.158       | 46%     | 3 | -0.008| 0.049| 0.868   |
| **Prevalence of overweight** |   |    |             |         |   |      |    |         |
| Low prevalence            | 1 | 1  | 0.286       | 12%     | 2 | 0.146| 0.099| 0.141   |
| High prevalence           | 0 | 1  | 0.629       | 0%      | 2 | -0.046| 0.037| 0.210   |
| **Physical activity assessment** |   |    |             |         |   |      |    |         |
| Low risk                  | - | -  | -           | -       | 1 | 0.413| 0.275| 0.133   |
| Moderate/high risk        | 4 | 2  | 0.158       | 46%     | 3 | -0.008| 0.049| 0.868   |
| **Missing data**          |   |    |             |         |   |      |    |         |
| Low risk of bias          | - | -  | -           | -       | 1 | -0.037| 0.042| 0.379   |
| Moderate/high risk        | 5 | 2  | 0.082       | 60%     | - | -    | -   | -       |

\(^1\)The results of the subgroup analyses are only shown if results were homogeneous.

\(^2\)High prevalence of overweight was defined if >20% of the study sample was overweight/obese.

\(^3\)Studies with low risk of bias on this QUIPS item compared to studies with a moderate/high risk of bias.
