# Evidence Portfolio – Youth Subcommittee, Question 1

## In children younger than age 6 years, is physical activity related to health outcomes?

a. What is the relationship between physical activity and adiposity/weight status?
b. What is the relationship between physical activity and bone health?
c. What is the relationship between physical activity and cardiometabolic health?
d. Are there dose-response relationships? If so, what are the shapes of those relationships?
e. Do the relationships vary by age, sex, race/ethnicity, weight status, or socio-economic status?

**Source of Evidence:** Original Research

### Conclusion Statements and Grades

Strong evidence demonstrates that higher amounts of physical activity are associated with more favorable indicators of bone health and with reduced risk for excessive increases in body weight and adiposity in children ages 3 to 6 years. **PAGAC Grade: Strong.**

Strong evidence demonstrates that higher amounts of physical activity are associated with a reduced risk of excessive increases in body weight and adiposity in children ages 3 to 6 years. **PAGAC Grade: Strong.**

Strong evidence demonstrates that higher amounts of physical activity are associated with favorable indicators of bone health in children ages 3 to 6 years. **PAGAC Grade: Strong.**

Insufficient evidence is available to determine the effects of physical activity on cardiometabolic risk factors in children under 6 years of age. **PAGAC Grade: Not assignable.**

Insufficient evidence is available to determine the dose-response relationship between physical activity and health effects in children younger than 6 years of age. **PAGAC Grade: Not assignable.**

insufficient evidence is available to determine whether the relationship between physical activity and health effects in children younger than 6 years of age is moderated by age, sex, race/ethnicity, weight status, or socioeconomic status. **PAGAC Grade: Not assignable.**

### Description of the Evidence

An initial search for systematic reviews, meta-analyses, pooled analyses, and reports did not identify sufficient literature to answer the research question as determined by the Youth Subcommittee. A complete de novo search of original research was conducted.

## BODY WEIGHT AND ADIPOSITY

### Original Research

*Overview*

Fourteen prospective cohort studies that assessed the relationship between physical activity and adiposity/weight status were included as sources of evidence.[1-14]

The analytical sample size ranged from 18[11] to 8,170.[13] Of the studies that reported location, 5 were conducted in the United States,[2-5, 8] 2 in England,[7, 11] 1 in the Netherlands,[10] 1 in the United Kingdom,[14] 1 in Japan,[13] and 1 in Finland.[12]

*Exposures*

The included studies examined physical activity levels using different types of data collection instruments, including self-reported, device-measured, and direct observation measures. Four studies used self-reported measures, mainly parental reports.[10, 12-14] Of the studies that assessed physical activity using devices, 5 studies used accelerometers,[4, 7-10] and 2 used heart rate monitors.[2, 3] Berkowitz et al[1] used an infant activity monitor to measure physical activity at birth and a motion sensor to assess activity counts at age 4 to 8 years. Three studies used direct observation instruments such as the Children's Activity Rating Scale,[2, 3, 6] and 1 assessed total energy expenditure using doubly labeled water technique.[11]

*Outcomes*

All the studies examined changes in body composition using different types of measurements including height, weight, body mass index, and percentage of body fat.

## BONE HEALTH

### Original Research

*Overview*

Ten original studies that assessed the relationship between physical activity and bone health were included as sources of evidence. Of these, 7 were prospective cohort studies[15-21] and 3 were randomized trials.[22-24]

The analytical sample size ranged from 69[22] to 530.[21] Of the studies that reported location, 5 were conducted in the United States[18-22] and 3 in Canada.[15-17]

*Exposures*

The included studies examined physical activity levels using different types of data collection instruments, including self-reported and device-based measures. Of the prospective cohort studies, 4 used accelerometers to assess the impact of moderate-to-vigorous physical activity[18-21] and 3[15-17] used self-reported measures, mainly parental reports, to examine the effect of childhood recreational gymnastics. Of the randomized trials, 1 assessed the impact of a gross motor activity intervention focused on bone-loading activities,[22] and 2 assessed the effect of moderate and vigorous intensity physical activity.[23, 24]

*Outcomes*

All the included studies examined bone mineral content measured with dual energy x-ray absorptiometry (DXA). Bone structural geometry outcomes, including bone stress index and bone cross sectional area, were also assessed by some studies. Bone mineral density was also examined.

**CARDIOMETABOLIC HEALTH**

### Original Research

*Overview*

Three prospective cohort studies that assessed the relationship between physical activity and cardiometabolic health were included as sources of evidence.[2, 25, 26]

The analytical sample size ranged from 123[2] to 427.[26] The studies were conducted in the United States,[2] the Netherlands[25] and the United Kingdom.[26]

*Exposures*

The included studies examined physical activity levels using different types of data collection instruments, including device-measured, and direct observation measures. Two studies used accelerometers: 1 to assess moderate-to-vigorous physical activity[26] and the other to assess the impact of light, moderate, and vigorous activity.[25] DuRant et al[2] used heart rate monitors and the Children's Activity Rating Scale to assess physical activity through direct observation.

*Outcomes*

The outcomes assessed included serum lipid and lipoprotein levels, respiratory symptoms, and blood pressure.

## Populations Analyzed

The table below lists the populations analyzed in each article.

***Table 1. Populations Analyzed by All Sources of Evidence***

| | Sex | Race/ Ethnicity | Age | Weight Status |
|---|---|---|---|---|
| Berkowitz, 1985 | | | Infants at baseline; ages 4–8 at follow-up | |
| Driessen, 2014 | | | 2–4 years | |
| DuRant, 1993 | | | 3–5 years | |
| Erlandson, 2011 | | | 4–10 years | |
| Gruodyte-Raciene, 2013 | Male, Female | | 4–12 years | |
| Jackowski, 2015 | Male, Female | | 4–12 years | |
| Jago, 2005 | | | 3–4 years at baseline | |
| Janz, 2006 | Male, Female | | Mean baseline 5.3 years, 8.6 years at follow-up | |
| Janz, 2007 | Male, Female | | 5–11 years | |
| Janz, 2009 | Male, Female | | 5–11 years | |
| Janz, 2014 | Male, Female | | 5–17 years | |
| Janz, 2010 | Male, Female | | 5–11 years | |
| Klesges, 1995 | Male, Female | | 3–5 years | |
| Knowles, 2013 | | | 5–7 years at baseline | |
| Li, 1995 | | White | 6, 9, 12 months | |
| Metcalf, 2008 | Male, Female | | 5-8 years | |
| Moore, 2003 | | | 3–5 years at baseline, 8–13 years at follow-up | |
| Moore, 1995 | Male, Female | | 3–5 years | |
| Remmers, 2014 | Male, Female | | 4–5 years old at baseline | |
| Roberts, 1988 | | | 0–12 months | |

| | Sex | Race/ Ethnicity | Age | Weight Status |
|---|---|---|---|---|
| Sääkslahti, 2004 | Male, Female | | 4–7 years | |
| Specker, 1999 | | White | Infants 6–18 months | |
| Specker, 2003 | | | 3–5 years | |
| Specker, 2004 | | | 3–7 years | |
| Sugimori, 2004 | Male, Female | | 3–6 years | Normal/Healthy Weight (BMI: 18.5–24.9), Overweight (BMI: 25–29.9) |
| Wells, 1996 | | | 12 weeks at baseline; 2–3.5 years at follow-up | |

**Supporting Evidence**

## Original Research

***Table 2. Original Research Individual Evidence Summary Tables***

<table>
<tr><th colspan="2">Body Weight and Adiposity</th></tr>
<tr><td colspan="2">Original Research<br>Citation: Berkowitz RI, Agras WS, Korner AF, Kraemer HC, Zeanah CH. Physical activity and adiposity: a longitudinal study from birth to childhood. J Pediatr. 1985;106(5):734–738.</td></tr>
<tr><td colspan="2">Purpose: To assess physical activity in a cohort of children ages 4 to 8 whose activity levels had been assessed during the first 3 days of life, and explore the relationship between activity levels and indices of adiposity at birth in childhood.</td></tr>
<tr><td>Study Design: Prospective cohort study</td><td rowspan="5">Abstract: Physical activity was reassessed in cohort of 52 children aged 4 to 8 years whose activity had been measured during the first 3 days of life. Neonatal adiposity was not significantly correlated with parental adiposity, neonatal physical activity, or gender, nor was neonatal activity significantly correlated with adiposity in childhood. Neonatal adiposity did not predict adiposity in childhood. However, in a stepwise multiple regression, parental adiposity and the children's daytime high activity levels were significantly associated with childhood adiposity. The age or gender of the child did not significantly correlate with childhood adiposity. As parental adiposity increased or daytime high activity of a child decreased, the adiposity in a 4- to 8-year-old child was likely to increase.</td></tr>
<tr><td>Location: Not reported</td></tr>
<tr><td>Sample: 52<br>Attrition Rate: 11.86%<br>Sample Power: Not Reported</td></tr>
<tr><td>Intervention: No</td></tr>
<tr><td>Exposure Measurement<br>Device-Measured: Infant activity monitor (first days of life): movement monitor asessed intensity and frequency of movements; child physical activity monitor: physical activity monitor for 24 hours, measured counts. Activity counts categorized in day high, day low, and night low activity.<br>Measures Steps: No<br>Measures Bouts: No</td></tr>
<tr><td>Refers to Other Materials: Yes<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Infant birth weights (kg) and lengths (cm): hospital records; child height (cm), weight (kg) and skinfold (mm): standard fashion in laboratory.</td></tr>
<tr><td>Populations Analyzed: Infants at baseline; 4–8 years at follow-up</td><td>Author-Stated Funding Source: National Institutes of Health.</td></tr>
</table>

<table>
<tr><th colspan="2">Cardiometabolic Health</th></tr>
<tr><td colspan="2">Original Research<br>Citation: Driessen LM, Kiefte-de Jong JC, Jaddoe VW, et al. Physical activity and respiratory symptoms in children: the Generation R Study. Pediatr Pulmonol. 2014;49(1):36–42. doi:10.1002/ppul.22839.</td></tr>
<tr><td colspan="2">Purpose: To assess the association between accelerometer-measured physical activity at the age of 2 years and asthma-like symptoms during the preschool period.</td></tr>
<tr><td>Study Design: Prospective cohort study</td><td rowspan="5">Abstract: BACKGROUND: To assess the relationship between physical activity in second year of life and respiratory symptoms during the pre-school period. METHODS: This study was embedded in the Generation R Study, a large prospective birth-cohort study in Rotterdam, the Netherlands. Physical activity was measured in the second year of life by an Actigraph accelerometer in a subgroup of 347 children (182 boys, 165 girls; mean age 25.1 months) and data were expressed as counts per 15 sec in categories: light activity (302-614 counts/15 sec), moderate activity (615-1,230 counts/15 sec), and vigorous activity (>/=1,231 counts/15 sec). Respiratory symptoms were assessed by the International Study of Asthma and Allergies in Childhood Questionnaire in the third and fourth year of life. RESULTS: Physical activity levels were not associated with wheezing symptoms in the third and fourth year of life (OR: 0.98; 95% CI: 0.92-1.05 and OR: 0.99; 95% CI: 0.92-1.07 for total activity, respectively), nor associated with shortness of breath symptoms (OR: 0.98; 95% CI: 0.92-1.05 and OR 1.03; 95% CI: 0.96-1.11 for total activity, respectively). CONCLUSION: These results suggest that physical activity may not play an important role in the development of respiratory symptoms in pre-school children.</td></tr>
<tr><td>Location: The Netherlands</td></tr>
<tr><td>Sample: 347<br>Attrition Rate: 30.60%<br>Sample Power: Not Reported</td></tr>
<tr><td>Intervention: No</td></tr>
<tr><td>Exposure Measurement<br>Device-Measured: Accelerometer for 1 week and 1 weekend day; intervals were categorized as light, moderate, and vigorous using cutpoints.<br>Measures Steps: No<br>Measures Bouts: No</td></tr>
<tr><td>Refers to Other Materials: Yes<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Objectively measured height and weight to calculate body mass index (kg/m2) at 36 and 48 months.</td></tr>
<tr><td>Populations Analyzed: Ages 2–4 years</td><td>Author-Stated Funding Source: Erasmus Medical Center, Erasmus University Rotterdam, Netherlands Organization for Health Research and Development, Europe Container Terminals.</td></tr>
</table>

| Body Weight And Adiposity, Cardiometabolic Health | |
|---|---|
| **Original Research**<br>**Citation:** DuRant RH, Baranowski T, Rhodes T, et al. Association among serum lipid and lipoprotein concentrations and physical activity, physical fitness, and body composition in young children. *J Pediatr.* 1993;123(2):185–192. | |
| **Purpose:** To examine the relationships among indicators of physical activity (PA), physical fitness, and body composition with serum lipid and lipoprotein levels in young children. | |
| **Study Design:** Prospective cohort study<br>**Location:** United States<br>**Sample:** 123<br>**Attrition Rate:** 0%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement**<br>**Device-Measured:** Heart rate monitor to assess indexes of daily heart rate (e.g., the percentages of heart rates 25% and 50% above resting heart rate, both indexes of physical activity). Monitor attached to child for 12 hours for 4 days in the family home.<br>**Direct Observation:** Children's Activity Rating Scale. Observations were 6–12 hours in duration and occurred in conjunction with heart rate monitoring. Continuous minute-by-minute ratings of PA and PA level were recorded by the observers; an average was taken of all the levels recorded in the minute to represent activity as the mean score.<br>**Measures Steps:** No<br>**Measures Bouts:** No | **Abstract:** OBJECTIVE: To examine the relationships among indicators of physical activity, physical fitness, and body composition with serum lipid and lipoprotein levels in young children. DESIGN: Cross-sectional and 1-year prospective cohort. SETTING: Studies of Child Activity and Nutrition (SCAN) program, Galveston, Tex. SUBJECTS: One hundred twenty-three 4- or 5-year-old black, Hispanic (of Mexican origin), and white children. MEASUREMENTS: Body composition, resting heart rate, and cardiovascular fitness variables and serum lipid and lipoprotein levels were measured at age 3 or 4 years (study year 1) and at age 4 or 5 years (study year 2), and day-long heart rate was measured and the Children's Activity Rating Scale was administered between study years 1 and 2. RESULTS: Year-1 waist/hip ratios were inversely correlated with total serum cholesterol (TSC) and low-density lipoprotein (LDL) levels. Mean activity level was inversely correlated with waist/hip ratios. On the basis of multiple regression analysis, the sum of seven skin-fold measurements, height, and gender explained 15.4% of the variation in triglyceride levels. The sum of seven skin-fold measurements was inversely correlated with the high-density lipoprotein (HDL) level. Resting heart rate, waist/hip ratio, and the slope of the exercise heart rate during fitness testing explained 19.5% of the variation in the concentration of an HDL subclass, HDL2. These children's levels of physical activity were associated with higher fitness levels. Year-1 waist/hip ratios and year-2 sum of seven skin-fold measurements were positively correlated with the LDL/HDL and TSC/HDL ratios. CONCLUSION: Higher levels of cardiovascular fitness and lower levels of fatness were associated with more favorable serum lipid and lipoprotein levels in these young children. Physical activity appeared to have an indirect association with serum lipid and lipoprotein values through its relationship with higher fitness levels and lower levels of fatness. |
| **Refers to Other Materials:** No<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Changes in serum lipids and lipoprotein levels (mg/dL) with a Technicon RA-500 analyzer. Fitness assessed with a submaximal walking treadmill test. Seven site body composition using skinfold calipers. |
| **Populations Analyzed:** Ages 3–5 years | **Author-Stated Funding Source:** Not Reported. |

| Bone Health | |
|---|---|
| **Original Research**<br>**Citation:** Erlandson MC, Kontulainen SA, Chilibeck PD, Arnold CM, Baxter-Jones AD. Bone mineral accrual in 4- to 10-year-old precompetitive, recreational gymnasts: a 4-year longitudinal study. *J Bone Miner Res*. 2011;26(6):1313–1320. doi:10.1002/jbmr.338. | |
| **Purpose:** To investigate whether the differences previously reported in the skeleton of competitive adolescent female gymnasts are also demonstrated in young children with a current or past participation history in recreational or pre-competitive gymnastics. | |
| **Study Design:** Prospective cohort study<br>**Location:** Canada<br>**Sample:** 163<br>**Attrition Rate:** 8.43%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement**<br>**Self-Reported:** Netherlands Physical Activity Questionnaire (NPAQ) via parents reporting child's physical activity (PA) preferences; responses range from 7 (low PA) to 35 (high PA); gymnasts, nongymnasts, and ex-gymnasts (gymnasts at baseline who quit sometime in follow-up) compared.<br>**Measures Steps:** No<br>**Measures Bouts:** No | **Abstract:** Competitive female gymnasts have greater bone mineral measures than nongymnasts. However, less is known about the effect of recreational and/or precompetitive gymnastics participation on bone development. The purpose of this study was to investigate whether the differences previously reported in the skeleton of competitive female gymnasts are also demonstrated in young children with a current or past participation history in recreational or precompetitive gymnastics. One hundred and sixty-three children (30 gymnasts, 61 ex-gymnasts, and 72 nongymnasts) between 4 and 6 years of age were recruited and measured annually for 4 years (not all participants were measured at every occasion). Total-body (TB), lumbar spine (LS), and femoral neck (FN) bone mineral content (BMC) were measured by dual-energy X-ray absorptiometry (DXA). Multilevel random-effects models were constructed and used to predict differences in TB, LS, and FN BMC between groups while controlling for differences in body size, physical activity, and diet. Gymnasts had 3% more TB and 7% more FN BMC than children participating in other recreational sports at year 4 ($p < .05$). No differences were found at the LS between groups, and there were no differences between ex-gymnasts' and nongymnasts' bone parameters ($p > .05$). These findings suggest that recreational and precompetitive gymnastics participation is associated with greater BMC. This is important because beginner gymnastics skills are attainable by most children and do not require a high level of training. Low-level gymnastics skills can be implemented easily into school physical education programs, potentially affecting skeletal health. |
| **Refers to Other Materials:** Yes<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Height (cm): stadiometer. Weight(kg): scale. Bone mineral content (g), lean mass (kg) and fat mass (kg): DXA. |
| **Populations Analyzed:** Ages 4–10 years | **Author-Stated Funding Source:** Canadian Institute of Health Research, Saskatchewan Health Research Foundation, and CIHR doctoral regional partnership program. |

## Bone Health

**Original Research**

**Citation:** Gruodyte-Raciene R, Erlandson MC, Jackowski SA, Baxter-Jones AD. Structural strength development at the proximal femur in 4- to 10-year-old precompetitive gymnasts: a 4-year longitudinal hip structural analysis study. *J Bone Miner Res.* 2013;28(12):2592–2600. doi:10.1002/jbmr.1986.

**Purpose:** To compare bone structural strength, as assessed through geometric indices, at the hip in young children with a current or past participation history in recreational gymnastics against non-gymnastic controls. We hypothesized that young male and female gymnasts would have greater geometric indices of bone structural strength at the hip compared with children with no past history of gymnastics participation.

**Study Design:** Prospective cohort study

**Location:** Canada

**Sample:** 165
**Attrition Rate:** 7.30%
**Sample Power:** Not Reported

**Intervention:** No

**Exposure Measurement**
**Self-Reported:** Netherlands Physical Activity Questionnaire of parental reports of child's current physical activity level and activity preferences; three comparison groups: gymnasts; ex gymnasts (gymnast at baseline not at follow-up) and nongymnasts.
**Measures Steps:** No
**Measures Bouts:** No

**Abstract:** Gymnastics, a high-impact weight-bearing physical activity, has been shown to be highly osteogenic. Previously in this cohort, bone mass development (bone mineral content accrual [BMC]) was shown to be positively associated with low-level (recreational) gymnastics exposure (1 to 2 hours per week); however, BMC is only one single component of bone strength. Bone strength is influenced not only by bone mineralization but also bone geometry, bone architecture, and the imposing loads on the bone. The aim of this study was to investigate whether low-level gymnastics training influenced the estimated structural geometry development at the proximal femur. A total of 165 children (92 gymnasts and 73 non-gymnasts) between the ages of 4 and 6 years were recruited into this study and assessed annually for 4 years. During the 4 years, 64 gymnasts withdrew from the sport and were reclassified as ex-gymnasts. A dual-energy X-ray absorptiometry (DXA) image of each child's hip was obtained. Values of cross-sectional area (CSA), section modulus (Z), and cortical thickness (CT) at the narrow neck (NN), intertrochanter (IT), and shaft (S) were estimated using the hip structural analysis (HSA) program. Multilevel random-effects models were constructed and used to develop bone structural strength development trajectories (estimate +/- SEE). Once the confounders of body size and lifestyle were controlled, it was found that gymnasts had 6% greater NN CSA than non-gymnasts controls (0.09 +/- 0.03 cm(2) , $p < 0.05$), 7% greater NN Z (0.04 +/- 0.01 cm(3) , $p < 0.05$), 5% greater IT CSA (0.11 +/- 0.04 cm(3) , $p < 0.05$), 6% greater IT Z (0.07 +/- 0.03 cm(3) , $p < 0.05$), and 3% greater S CSA (0.06 +/- 0.03 cm(3) , $p < 0.05$). These results suggest that early exposure to low-level gymnastics participation confers benefits related to geometric and bone architecture properties during childhood and, if maintained, may improve bone health in adolescence and adulthood.

**Refers to Other Materials:** Yes
**Examine Cardiorespiratory Fitness as Outcome:** No

**Outcomes Examined:** Height (cm) and weight (kg): researcher measured. Cross-sectional area (CSA, cm2), section modulus (Z, cm3), and bone mineral content (BMC, g): DXA.

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| **Populations Analyzed:** Male, Female, Ages 4–12 years | **Author-Stated Funding Source:** Canadian Institutes of Health, Saskatchewan Health Research Foundation. |

| Bone Health | |
|---|---|
| **Original Research**<br>**Citation:** Jackowski SA, Baxter-Jones AD, Gruodyte-Raciene R, Kontulainen SA, Erlandson MC. A longitudinal study of bone area, content, density, and strength development at the radius and tibia in children 4-12 years of age exposed to recreational gymnastics. *Osteoporos Int.* 2015;26(6):1677–1690. doi:10.1007/s00198-015-3041-1. | |
| **Purpose:** To investigate the relationship of exposure to recreational gymnastics on bone measures and bone strength development in normal healthy developing children, hypothesizing that recreational gymnastics would confer significant independent skeletal advantages to bone mass, content, density, and strength at both the radius and tibia once the confounders of growth, maturation, and lifestyle variables were controlled. | |
| **Study Design:** Prospective cohort study<br>**Location:** Canada<br>**Sample:** 127<br>**Attrition Rate:** 0%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement Self-Reported:** Netherlands Physical Activity Questionnaire (NPAQ) via parents reporting child's physical activity (PA) preferences; responses range from 7 (low PA) to 35 (high PA); gymnasts, nongymnasts compared.<br>**Measures Steps:** No<br>**Measures Bouts:** No<br>**Refers to Other Materials:** Yes<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Abstract:** UNLABELLED: This study investigated the long-term relationship between the exposure to childhood recreational gymnastics and bone measures and bone strength parameters at the radius and tibia. It was observed that individuals exposed to recreational gymnastics had significantly greater total bone content and area at the distal radius. No differences were observed at the tibia. INTRODUCTION: This study investigated the relationship between exposure to early childhood recreational gymnastics with bone measures and bone strength development at the radius and tibia. METHODS: One hundred twenty seven children (59 male, 68 female) involved in either recreational gymnastics (gymnasts) or other recreational sports (non-gymnasts) between 4 and 6 years of age were recruited. Peripheral quantitative computed tomography (pQCT) scans of their distal and shaft sites of the forearm and leg were obtained over 3 years, covering the ages of 4-12 years at study completion. Multilevel random effects models were constructed to assess differences in the development of bone measures and bone strength measures between those exposed and not exposed to gymnastics while controlling for age, limb length, weight, physical activity, muscle area, sex, and hours of training. RESULTS: Once age, limb length, weight, muscle area, physical activity, sex, and hours of training effects were controlled, it was observed that individuals exposed to recreational gymnastics had significantly greater total bone area (18.0 +/- 7.5 mm(2)) and total bone content (6.0 +/- 3.0 mg/mm) at the distal radius ($p < 0.05$). This represents an 8-21 % benefit in ToA and 8-15 % benefit to ToC from 4 to 12 years of age. Exposure to recreational gymnastics had no significant effect on bone measures at the radius shaft or at the tibia ($p > 0.05$). CONCLUSIONS: Exposure to early life recreational gymnastics provides skeletal benefits to distal radius bone content and area. Thus, childhood recreational gymnastics exposure may be advantageous to bone development at the wrist. |
| **Populations Analyzed:** Male, Female, Ages 4–12 years. | **Outcomes Examined:** Bone lengths (cm). Bone radius, density, and content (mg/mm): peripheral quantitative computed tomography. Weight (kg): scale. Calculated bone strength index and bone stress strain (mm3). |

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|---|---|
| | **Author-Stated Funding Source:** Canadian Institutes of Health Research, Canadian Foundation for Innovation, and Saskatchewan Research Foundation. |

<table>
<tr><th colspan="2">Body Weight And Adiposity</th></tr>
<tr><td colspan="2">Original Research<br>Citation: Jago R, Baranowski T, Baranowski JC, Thompson D, Greaves KA. BMI from 3-6 y of age is predicted by TV viewing and physical activity, not diet. Int J Obes (Lond). 2005;29(6):557–564.</td></tr>
<tr><td colspan="2">Purpose: To examine whether physical activity, TV viewing, other sedentary behaviors and dietary factors predict body mass index among a triethnic cohort of 3–4-year-old children followed over a 3-year period.</td></tr>
<tr><td>Study Design: Prospective cohort study</td><td rowspan="5">Abstract: OBJECTIVE: To investigate whether, diet, physical activity, sedentary behavior or television (TV) viewing predicted body mass index (BMI) among 3-7-y-old children. DESIGN: A triethnic cohort of 3-4-y-old children was followed for 3 y from 1986 to 1989. MEASUREMENTS: BMI was assessed at the beginning and end of each measurement year. Heart rate monitoring and observation were used to assess physical activity. Diet (calories, % calories from fat and carbohydrate), sedentary behavior and TV viewing were assessed by direct observation in each year. A repeated measures regression analysis with year as a factor and BMI at the end of each year as dependent variables was run. Nonsignificant variables were removed in a stepwise backward deletion process and significant interactions graphed. RESULTS: The interactions between minutes of TV viewing per hour and study year and minutes of physical activity per hour and study year were significant (P<0.05). There were also significant main effects for TV viewing, physical activity and BMI from the beginning of the study. The model accounted for 65% of the variance in BMI across the three study years. Plotting the significant interactions demonstrated that physical activity was positively associated with BMI in year 1, and negatively associated in years 2 and 3 with a stronger negative relationship in year 3 than 2. TV viewing became positively associated with BMI during the third study year. CONCLUSION: Physical activity and TV viewing were the only significant predictors (other than baseline BMI) of BMI among a triethnic cohort of 3-4-y-old children followed for 3 y with both physical activity (negatively associated) and TV viewing (positively associated) becoming stronger predictors as the children aged. It appears that 6 or 7 y is a critical age when TV viewing and physical activity may affect BMI. Therefore, focusing on reducing time spent watching television and increasing time spent in physical activity may be successful means of preventing obesity among this age group.</td></tr>
<tr><td>Location: United States</td></tr>
<tr><td>Sample: 133<br>Attrition Rate: 10.74%<br>Sample Power: Not Reported</td></tr>
<tr><td>Intervention: No</td></tr>
<tr><td>Exposure Measurement<br>Device-Measured: Heart rate monitor: heart rate telemetry, worn for an entire day for 4 days. Heart rate above 140: moderate-to-vigorous physical activity.<br>Direct Observation: Trained observers using Children's Activity Rating Scale, for 6–12 hours while heart rate was being measured.<br>Measures Steps: No<br>Measures Bouts: No</td></tr>
<tr><td>Refers to Other Materials: Yes<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Height (cm) and weight (kg): measured.</td></tr>
<tr><td>Populations Analyzed: Ages 3–4 years old at baseline</td><td>Author-Stated Funding Source: National Institutes of Health.</td></tr>
</table>

<table>
<tr><th colspan="2">Bone Health</th></tr>
<tr><td colspan="2">Original Research<br>Citation: Janz KF, Gilmore JM, Burns TL, et al. Physical activity augments bone mineral accrual in young children: The Iowa Bone Development study. J Pediatr. 2006;148(6):793–799.</td></tr>
<tr><td colspan="2">Purpose: To examine associations between physical activity (PA) and bone mineral content (BMC) and whether PA augments BMC accrual.</td></tr>
<tr><td>Study Design: Prospective cohort study</td><td rowspan="5">Abstract: OBJECTIVES: This 3-year follow-up study examined associations between physical activity and bone mineral content (BMC) and whether physical activity augments BMC accrual. STUDY DESIGN: Participants were 370 children (mean age baseline 5.3 years, follow-up 8.6 years). Physical activity was measured using 4-day accelerometry. BMC was measured using dual energy x-ray absorptiometry. RESULTS: After adjustment for baseline BMC, age, and body size, mean physical activity predicted follow-up BMC at the hip, trochanter, spine, and whole body in boys and at the trochanter and whole body in girls. The variability in BMC explained by physical activity was modest (1% to 2%). However, based on a general linear model with adjustment for baseline BMC and body size, children who maintained high levels of physical activity accrued, on average, 14% more trochanteric BMC and 5% more whole-body BMC relative to peers maintaining low levels of physical activity. CONCLUSIONS: This study suggests that maintaining high levels of everyday physical activity contributes to increases in BMC in young children, particularly at the trochanter.</td></tr>
<tr><td>Location: United States</td></tr>
<tr><td>Sample: 370<br>Attrition Rate: 21.28%<br>Sample Power: Not Reported</td></tr>
<tr><td>Intervention: No</td></tr>
<tr><td>Exposure Measurement<br>Device-Measured: Accelerometer for 4 days on hip. Active minutes: daily frequency of accelerometer counts per min >3,000 (equivalent to 6 metabolic equivalents); 4 PA groups by combination of baseline (high/low) and follow-up (high/low) activity.<br>Measures Steps: No<br>Measures Bouts: No</td></tr>
<tr><td>Refers to Other Materials: No<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Bone mineral content (g): DXA. Height (cm): stadiometer. Weight (kg): scale.</td></tr>
<tr><td>Populations Analyzed: Male, Female, Mean baseline 5.3 years old, 8.6 years at follow-up</td><td>Author-Stated Funding Source: National Institutes of Health.</td></tr>
</table>

| Bone Health | |
|---|---|
| **Original Research**<br>**Citation:** Janz KF, Gilmore JM, Levy SM, Letuchy EM, Burns TL, Beck TJ. Physical activity and femoral neck bone strength during childhood: the Iowa Bone Development Study. *Bone*. 2007;41(2):216–222. | |
| **Purpose:** To examine longitudinal associations between accelerometry-measured physical activity and hip geometry as children traverse middle and late childhood. Given that physical activity is anabolic to muscle, we also examined whether effects of physical activity on bone geometry seem to be mediated by muscle development. | |
| **Study Design:** Prospective cohort study<br>**Location:** United States<br>**Sample:** 468<br>**Attrition Rate:** 0%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement Device-Measured:** Accelerometer: waking hours for 4 days, including 1 weekend day, summary variable of daily minutes spent in moderate to vigorous physical activity (>3,000 ct.min-1), grouped in 10-minute intervals<br>**Measures Steps:** No<br>**Measures Bouts:** Yes | **Abstract:** Structural adaptations of bone to changing mechanical loads have recently been documented during adolescence. However, little is known about how bone adapts structurally during the earlier years. Using a longitudinal observational design spanning 6 years of growth (age range 4 to 12 years), we investigated associations between everyday physical activity and hip geometry in a cohort of healthy Midwestern children (n=468). Femoral neck (FN) cross sectional area (CSA, cm(2)) and FN section modulus (Z, cm(3)) were used to describe hip geometry. CSA and Z, indices of axial and bending strength, were assessed using dual-energy X-ray absorptiometry (DXA) scans and the hip structure analysis (HSA) program. Moderate and vigorous physical activity (MVPA) was assessed using accelerometry-based activity monitors and calculated as the number of minutes > or =3000 accelerometry movement counts. Data were analyzed using multilevel (random- and fixed-effects) regression models with adjustment for age (year), height (cm), and weight (kg) or lean mass (kg). For boys and girls, MVPA was a positive independent predictor of CSA and Z (p<0.05). On average, children who participated in 40 min of MVPA per day would be expected to have 3% to 5% greater CSA and Z than peers participating in 10 min of MVPA per day. Ten-minute increases in daily MVPA had similar effects on CSA in girls and Z in boys as did each additional 1 kg of body weight. When lean mass was substituted for weight, MVPA continued to be a positive independent predictor of CSA and Z for boys, but not girls. This study demonstrates that everyday amounts of physical activity in children are associated with indices of FN bone strength during childhood. Differences in lean mass mediate associations between physical activity and hip geometry in girls, but only somewhat in boys. These results suggest that physical activity is an important contributor to bone strength prior to adolescence and that increasing levels of physical activity during childhood are likely to enhance optimal bone strength. |
| **Refers to Other Materials:** Yes<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Lean mass (kg), bone mineral content (BMC, g), bone cross-sectional area (CSA in cm2), bone area (cm2), area bone mineral density (g/cm2):DXA. Height (cm) and weight (kg): measured by researcher. |
| **Populations Analyzed:** Male, Female, Ages 5–11 years | **Author-Stated Funding Source:** National Institutes of Health, General Clinical Research Program from the National Center for Research Resources. |

| Body Weight And Adiposity | |
|---|---|
| **Original Research**<br>**Citation:** Janz KF, Kwon S, Letuchy EM, et al. Sustained effect of early physical activity on body fat mass in older children. *Am J Prev Med.* 2009;37(1):3540. doi:10.1016/j.amepre.2009.03.012. | |
| **Purpose:** To examine whether the benefits of early childhood moderate-to-vigorous physical activity (MVPA) on fatness are sustained throughout childhood. | |
| **Study Design:** Prospective cohort study<br>**Location:** United States<br>**Sample:** 333<br>**Attrition Rate:** 23.09%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement**<br>**Device-Measured:** Waist worn accelerometer for 4 days (baseline and follow-up 1), and 5 days (follow-up 2); daily minutes of MVPA (minutes of counts >3,000); 4 groups from the combinations of high/low baseline MVPA and high/low follow-up MVPA.<br>**Measures Steps:** No<br>**Measures Bouts:** No | **Abstract:** BACKGROUND: Physical activity is assumed to reduce excessive fatness in children. This study examined whether the benefits of early childhood moderate-to-vigorous physical activity (MVPA) on fatness are sustained throughout childhood. METHODS: MVPA minutes per day (min/d) and fat mass (kilograms; kg) were measured using accelerometry and dual-energy x-ray absorptiometry in 333 children aged 5, 8, and 11 years who were participating in the Iowa Bone Development Study. Mixed regression models were used to test whether MVPA at age 5 years had an effect on fat mass at age 8 years and age 11 years, after adjustment for concurrent height, weight, age, maturity, and MVPA. The analysis was repeated to control for fat mass at age 5 years. Using mixed-model least-squares means, adjusted means of fat mass at age 8 years and age 11 years were compared between the highest and lowest quartiles of MVPA at age 5 years. Data were collected between 1998 and 2006 and analyzed in 2008. RESULTS: For boys and girls, MVPA at age 5 years was a predictor of adjusted fat mass at age 8 years and age 11 years ($p<0.05$). In girls, the effect of MVPA at age 5 years was not significant when fat mass at age 5 years was included. Boys and girls in the highest quartile of MVPA at age 5 years had a lower fat mass at age 8 years and age 11 years than children in the lowest MVPA quartile at age 5 years ($p<0.05$; mean difference 0.85 kg at age 8 years and 1.55 kg at age 11 years). CONCLUSIONS: Some effects of early-childhood MVPA on fatness appear to persist throughout childhood. Results indicate the potential importance of increasing MVPA in young children as a strategy to reduce later fat gains. |
| **Refers to Other Materials:** Yes<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Fat mass (kg): DXA. Height (cm) and sitting height(cm): stadiometer. Weight (kg): scale. |
| **Populations Analyzed:** Male, Female, Ages 5–11 years | **Author-Stated Funding Source:** National Institute of Dental and Craniofacial Research and the General Clinical Research Centers Program from the National Center for Research Resources. |

| Bone Health | |
|---|---|
| **Original Research**<br>**Citation:** Janz KF, Letuchy EM, Burns TL, Gilmore JM, Torner JC, Levy SM. Objectively measured physical activity trajectories predict adolescent bone strength: Iowa Bone Development Study. *Br J Sports Med*. 2014;48(13):1032–1036. doi:10.1136/bjsports-2014-093574. | |
| **Purpose:** To examine developmental trajectories of objectively measured physical activity from childhood to adolescence to discern if moderate-to-vigorous physical activity (MVPA) predicts bone strength. | |
| **Study Design:** Prospective cohort study<br>**Location:** United States<br>**Sample:** 530<br>**Attrition Rate:** 0%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement**<br>**Device-Measured:** Accelerometer for 3–5 days at baseline and each follow-up; MVPA defined as 2,296 or greater accelerometry counts per minute; three groups compared per gender, defined by change in MVPA from baseline to follow-up.<br>**Measures Steps:** No<br>**Measures Bouts:** No | **Abstract:** BACKGROUND: Physical activity improves bone strength and reduces the risk for osteoporotic fractures. However, there are substantial gaps in our knowledge as to when, how and how much activity is optimal for bone health. PURPOSE: In this cohort study, we examined developmental trajectories of objectively measured physical activity from childhood to adolescence to discern if moderate-and-vigorous intensity physical activity (MVPA) predicts bone strength. METHODS: Starting at age 5 and continuing at 8, 11, 13, 15 and 17 years, Iowa Bone Development Study participants (n=530) wore an accelerometer for 3-5 days. At age 17, we assessed dual X-ray energy absorptiometry outcomes of mass and estimated geometry (femoral neck cross-sectional area and section modulus). We also assessed geometric properties (bone stress index and polar moment of inertia) of the tibia using peripheral computer quantitative tomography. Latent class modelling was used to construct developmental trajectories of MVPA from childhood to late adolescence. General linear models were used to examine the trajectory groups as predictors of age 17 bone outcomes. RESULTS: Girls and boys who accumulated the most MVPA had greater bone mass and better geometry at 17 years when compared to less active peers. The proportion of participants achieving high levels of MVPA throughout childhood was very low (<6% in girls) and by late adolescence almost all girls were inactive. CONCLUSIONS: Bone health benefits of physical activity are not being realised due to low levels of activity for most youth, especially in girls. |
| **Refers to Other Materials:** Yes<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Bone mineral content (BMC, g), structural geometry, bone cross-sectional area (CSA in cm2): DXA. Tibial measures and bone stress index: peripheral quantitative CT (pQCT). Height and weight: researcher measured. Used measured sitting height and equation to calculate peak height velocity and maturity status. |
| **Populations Analyzed:** Male, Female, Ages 5–17 years | **Author-Stated Funding Source:** National Institutes of Health. |

## Bone Health

**Original Research**

**Citation:** Janz KF, Letuchy EM, Eichenberger Gilmore JM, et al. Early physical activity provides sustained bone health benefits later in childhood. *Med Sci Sports Exerc*. 2010;42(6):1072–1078. doi:10.1249/MSS.0b013e3181c619b2.

**Purpose:** To examine the potential effect of early childhood moderate-to-vigorous physical activity (MVPA) on later bone health.

**Study Design:** Prospective cohort study

**Location:** United States

**Sample:** 333
**Attrition Rate:** 23.09%
**Sample Power:** Not Reported

**Intervention:** No

**Exposure Measurement**
**Device-Measured:** Waist worn accelerometer for 4 days (baseline and follow-up 1) and 5 days (follow-up 2); MVPA: minutes with >3,000 counts. Quintiles of baseline MVPA used for comparison.
**Measures Steps:** No
**Measures Bouts:** No

**Abstract:** PURPOSE: This study examined the potential effect of early childhood moderate and vigorous physical activity (MVPA) on later bone health. METHODS: Three hundred and thirty-three children, participating in the Iowa Bone Development Study, were studied at ages 5, 8, and 11 yr. MVPA (min x d(-1)) was measured using an accelerometry-based physical activity monitor. Bone mineral content (BMC; g) of the whole body, lumbar spine, and hip was measured using dual-energy x-ray absorptiometry. Mixed regression models were used to test whether MVPA at age 5 yr had an effect on BMC at ages 8 and 11 yr after adjustment for concurrent height, weight, age, maturity, and MVPA. The analysis was repeated to control for bone outcomes at age 5 yr. Mixed-model least-squares mean values at the person level of covariates for age group were used to compare the BMC at ages 8 and 11 yr of children in the highest and lowest quartiles of MVPA at age 5 yr. RESULTS: For boys and girls, MVPA at age 5 yr predicted BMC adjusted for concurrent height, weight, age, maturity, and MVPA at ages 8 and 11 yr (P < 0.05). When the analysis was repeated to also control for BMC at age 5 yr, the effect of MVPA at age 5 yr was significant for boys but not for girls. Boys and girls in the highest quartile of MVPA at age 5 yr had 4%-14% more BMC at ages 8 and 11 yr than those in the lowest quartile of MVPA at age 5 yr (P < 0.05). CONCLUSIONS: These results provide support for the benefits of early MVPA on sustained bone health during childhood especially for boys. Results indicate the importance of increasing MVPA as a strategy to improve BMC later in childhood.

**Refers to Other Materials:** Yes
**Examine Cardiorespiratory Fitness as Outcome:** No

**Outcomes Examined:** Bone mineral content (g): DXA. Height (cm): stadiometer. Weight (kg): scale.

**Populations Analyzed:** Male, Female, Ages 5–11 years

**Author-Stated Funding Source:** National Institute of Dental and Craniofacial Research and the General Clinical Research Centers Program from the National Center for Research Resources.

| Body Weight And Adiposity | |
|---|---|
| **Original Research**<br>**Citation:** Klesges RC, Klesges LM, Eck LH, Shelton ML. A longitudinal analysis of accelerated weight gain in preschool children. *Pediatrics*. 1995;95(1):126–130. | |
| **Purpose:** To investigate the extent to which largely modifiable and nonmodifiable risk factors simultaneously predicted weight gain and to determine the precise dietary, physical activity, and demographic predictors of weight change in preschool children over a 3-year period. | |
| **Study Design:** Prospective cohort study<br>**Location:** United States<br>**Sample:** 146<br>**Attrition Rate:** 28.08%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement**<br>**Direct Observation:** Parents assessed child's physical activity, including structured, leisure, and aerobic activity using Likert-type items (1 = much less, 3 = about the same, 5 = much more than others).<br>**Measures Steps:** No<br>**Measures Bouts:** No | **Abstract:** The purpose of the current investigation was to determine the dietary, physical activity, family history, and demographic predictors of relative weight change in a cohort of 146 children over a 3-year period. Results indicated that boys of normal-weight parents or who had only one parent overweight showed decreases in their body mass index (BMI) while those with two parents overweight showed increases. Girls with an overweight father showed BMI increases while others experienced decreases in BMI. Additionally, baseline intake of kilocalories from fat as well as decreases in fat intake were related to decreases in BMI. At higher levels of baseline aerobic activity, subsequent changes in BMI decreased. There was also a trend for changes in leisure activity--increases in children's leisure activity was associated with decreases in subsequent weight gain. Modifiable variables (ie, dietary intake, physical activity) accounted for more of the variance in changes in child BMI change than nonmodifiable variables (eg, number of parents obese). These results strongly suggest that encouragement of heart healthy dietary intake patterns and participation in physical activity can decrease accelerated weight gain and obesity, even in preschool children. |
| **Refers to Other Materials:** No<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Body mass index |
| **Populations Analyzed:** Male, Female, Ages 3–5 years | **Author-Stated Funding Source:** National Heart, Lung, and Blood Institute. |

| Cardiometabolic Health | |
|---|---|
| **Original Research**<br>**Citation:** Knowles G, Pallan M, Thomas GN, et al. Physical activity and blood pressure in primary school children: a longitudinal study. *Hypertension*. 2013;61(1):70–75. doi:10.1161/HYPERTENSIONAHA.112.201277. | |
| **Purpose:** To explore the cross-sectional and longitudinal association between blood pressure and objectively measured physical activity (PA) in a cohort of UK primary school children, with a high proportion of South Asians, to inform future interventions. | |
| **Study Design:** Prospective cohort study<br>**Location:** United Kingdom<br>**Sample:** 427<br>**Attrition Rate:** 16.60%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement**<br>**Device-Measured:** Accelerometer for 5 days. Total volume of PA: counts per minute, moderate-to-vigorous physical activity (min/day) calculated using 400 counts per minute cut off.<br>**Measures Steps:** No<br>**Measures Bouts:** Yes | **Abstract:** High blood pressure (BP) is becoming increasingly common during childhood. Regular physical activity (PA) reduces BP in adults, but limited studies have reported inconsistent results among children. The aim of this study is to examine, for the first time, the cross-sectional and longitudinal associations between BP and objectively measured PA in young children of predominantly South Asian background. Data from the Birmingham healthy Eating and Active lifestyle for CHildren Study were analyzed. Five hundred seventy-four children, aged 5 to 7 years, underwent a series of measures at baseline and were followed up 2 years later. PA was objectively measured using accelerometry and converted to counts per minute (total PA, cpm), and time spent in moderate-vigorous PA (minutes per day). BP was measured by trained staff using standard protocols. Data were available for 512 children at baseline (mean age 6.5 years, range 5.4-7.8 years), and 427 of these children were followed up. Baseline total PA was inversely associated with diastolic BP at both baseline (adjusted regression coefficient: -0.75 mm Hg [95% CI -1.33 to -0.18] per 20 cpm) and follow-up (-0.74 mm Hg [95% CI -1.40 to -0.08]). All associations remained unchanged after further adjustment for weight status. This study strengthens evidence of a causal association between higher PA and lower BP in children as young as 5, independent of weight status. The results provide support for development of interventions to increase PA in young children. |
| **Refers to Other Materials:** No<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Height (cm) and weight (kg): measured. Waist circumference (cm) and skinfold, 4 sites (triceps, biceps, suprailiac, and subscapular): objectively measured. Blood pressure: seated with blood pressure monitor. |
| **Populations Analyzed:** Ages 5–7 years at baseline | **Author-Stated Funding Source:** National Prevention Research Initiative. |

| Body Weight And Adiposity | |
|---|---|
| **Original Research**<br>**Citation:** Li R, O'Connor L, Buckley D, Specker B. Relation of activity levels to body fat in infants 6 to 12 months of age. *J Pediatr.* 1995;126(3):353–357. doi:10.1016/S0022-3476(95)70447-7. | |
| **Purpose:** To investigate whether the level of body fatness was related to physical activity in infants. | |
| **Study Design:** Prospective cohort study<br>**Location:** Not reported<br>**Sample:** 31<br>**Attrition Rate:** 0%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement**<br>**Direct Observation:** Modified Children's Activity Rating Scale: habitual activity was observed for the first minute of every 15 minutes for a total of 6 hours, determined activity levels for each region of the body (arms, legs, head, and trunk). Scores for the four body parts during the observation time were summed, and the average score was calculated (the sum of scores divided by number of entries).<br>**Measures Steps:** No<br>**Measures Bouts:** No | **Abstract:** We examined longitudinally the relation between body fatness and physical activity, adjusting for energy intake, in 31 healthy white infants. Measures of physical activity, dietary intake, and body composition were obtained at 6, 9, and 12 months of age. The percentage of body fat was inversely related to activity level, an association that became stronger with increasing age and remained significant after adjustment for dietary energy intake. The percentage of body fat was not related to energy consumed per lean body mass regardless of high or low activity level, nor was energy consumed related to physical activity. We conclude that the percentage of body fat in infants may be related more to their activity levels than to their energy intake. |
| **Refers to Other Materials:** No<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Body composition: measured by total body scan with the dual-energy x-ray absorptiometry; percentage of body fat was calculated as whole body fat mass divided by total body mass. |
| **Populations Analyzed:** White; Age 6, 9, and 12 months | **Author-Stated Funding Source:** National Institutes of Health grant. |

<table>
<tr><th colspan="2">Body Weight And Adiposity</th></tr>
<tr><td colspan="2">Citation: Metcalf BS, Voss LD, Hosking J, Jeffery AN, Wilkin TJ. Physical activity at the government-recommended level and obesity-related health outcomes: a longitudinal study (Early Bird 37). Arch Dis Child. 2008;93(9):772–777. doi: 10.1136/adc.2007.135012.</td></tr>
<tr><td colspan="2">Purpose: To determine the extent to which physical activity at the government-recommended intensity is associated with change in body mass/fat and metabolic health in pre-pubertal children.</td></tr>
<tr><td>Study Design: Prospective cohort study</td><td rowspan="5">Abstract: BACKGROUND: In the UK and USA, government guidelines for childhood physical activity have been set (> or =60 min/day at > or =3 metabolic equivalents of thermogenesis (METs)), and body mass index (BMI) chosen as the outcome measure. AIM: To determine the extent to which physical activity at the government-recommended intensity is associated with change in body mass/fat and metabolic health in pre-pubertal children. METHODS: Non-intervention longitudinal study of 113 boys and 99 girls (born 1995/96) recruited from 54 schools. Physical activity (Actigraph accelerometers), changes in body mass (raw and age/gender-standardised BMI), fatness (skin-fold thickness and waist circumference) and metabolic status (insulin resistance, triglycerides, cholesterol/HDL ratio and blood pressure - separately and as a composite metabolic z score) were measured on four annual occasions (5, 6, 7 and 8 years). RESULTS: Mean physical activity did not change over time in either sex. Averaging the 7-day recordings from four time points rather than one increased the reliability of characterising a child's activity from 71% to 90%. Some 42% of boys and 11% of girls met the guideline. There were no associations between physical activity and changes in any measurement of body mass or fatness over time in either sex (eg, BMI standard deviation scores: r = -0.02, p = 0.76). However, there was a small to moderate inverse association between physical activity and change in composite metabolic score (r = -0.19, p<0.01). Mixed effects modelling showed that the improvement in metabolic score among the more active compared to the less active children was linear with time (-0.08 z scores/year, p = 0.001). CONCLUSIONS: In children, physical activity above the government-recommended intensity of 3 METs is associated with a progressive improvement in metabolic health but not with a change in BMI or fatness. Girls habitually undertake less physical activity than boys, questioning whether girls in particular should be encouraged to do more, or the recommendations adjusted for girls.</td></tr>
<tr><td>Location: England</td></tr>
<tr><td>Sample: 212<br>Attrition Rate: 30.94<br>Sample Power: Not Reported</td></tr>
<tr><td>Intervention: No</td></tr>
<tr><td>Exposure Measurement<br>Self-Reported:<br>Device-Measured:<br>Accelerometer: intensity and duration of physical activity that is converted into METs (less activity group= below gender specific min/day at ≥3 METs, more active group= above the gender specific median min/day at ≥3 METs).<br>Direct Observation:<br>Other:<br>Measures Steps: No<br>Measures Bouts: No</td></tr>
<tr><td>Refers to Other Materials: Yes<br>Adverse Events Addressed:<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Body Mass Index, Body Composition: Sum of 5 skinfolds: biceps, triceps, subscapular, paraumbilical, and suprailiac, Cardiometabolic risk factors: waist circumference, Insulin resistance, Triglycerides, Cholesterol/HDL ratio, Mean arterial blood pressure.</td></tr>
<tr><td>Populations Analyzed: Male, Female, 5–8</td><td>Author-Stated Funding Source: Diabetes UK, Bright Futures Trust, Smith’s Charity, Child Growth Foundation, Diabetes Foundation, Beatrice Laing Trust, Abbott, Astra- Zeneca, GSK, Ipsen and Roche.</td></tr>
</table>

| Body Weight And Adiposity | |
|---|---|
| **Original Research**<br>**Citation:** Moore LL, Gao D, Bradlee ML, et al. Does early physical activity predict body fat change throughout childhood? *Prev Med*. 2003;37(1):10–17. | |
| **Purpose:** To examine the effects of physical activity (PA) on the change in body fat over a period of 8 years, from the preschool years to early adolescence. | |
| **Study Design:** Prospective cohort study<br>**Location:** Not reported<br>**Sample:** 103<br>**Attrition Rate:** 2.83%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement Device-Measured:** PA was measured using electronic motion sensor, Caltrac accelerometer.<br>**Measures Steps:** No<br>**Measures Bouts:** No | **Abstract:** BACKGROUND: Declining levels of physical activity in the population at large may be responsible in part for the rising rates of childhood obesity. Studies to date, however, have not consistently demonstrated such a protective effect. We used longitudinal data from the Framingham Children's Study (FCS) to address this important question. METHODS: We used 8 years of activity monitoring (Caltrac electronic motion sensors) and repeated anthropometry measures for 103 children to examine the effect of activity on body fat change from preschool to early adolescence. Longitudinal data analysis methods were employed to account for the use of repeated measures on these children. RESULTS: Children in the highest tertile of average daily activity from ages 4 to 11 years had consistently smaller gains in BMI, triceps, and sum of five skinfolds throughout childhood. By early adolescence (age 11), the sum of five skinfolds was 95.1, 94.5, and 74.1 for the low, middle, and high tertiles of activity, respectively (P for trend = 0.045). This protective effect of activity was evident for both girls and boys. CONCLUSION: This longitudinal study adds strong support for the hypothesis that higher levels of physical activity during childhood lead to the acquisition of less body fat by the time of early adolescence. |
| **Refers to Other Materials:** Yes<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Body mass index: fatness (skin-folds). |
| **Populations Analyzed:** Ages 3–5 years at baseline; 8–13 years at follow-up | **Author-Stated Funding Source:** National Heart, Lung, and Blood Institute. |

<table>
<tr><th colspan="2">Body Weight And Adiposity</th></tr>
<tr><td colspan="2">Original Research<br>Citation: Moore LL, Nguyen US, Rothman KJ, Cupples LA, Ellison RC. Preschool physical activity level and change in body fatness in young children. The Framingham Children’s Study. Am J Epidemiol. 1995;142(9):982–988.</td></tr>
<tr><td colspan="2">Purpose: To examine the effect of preschool activity on the child's changing body fatness from preschool to first grade.</td></tr>
<tr><td>Study Design: Prospective cohort study</td><td rowspan="5">Abstract: This study examined the effect of preschool physical activity on the change in body fatness from preschool to first grade. The Framingham Children's Study, a longitudinal study of childhood cardiovascular risk behaviors, began in 1987 with the enrollment of 106 children aged 3-5 years and their parents. The present analyses include 97 healthy children with complete data from study entry into first grade. Physical activity was assessed twice yearly for 5 days with an electronic motion sensor. The authors estimated change in the child's level of body fat from preschool to first grade by using the slopes of triceps and subscapular skinfolds and body mass index. On average, active girls (i.e., those with above-median activity levels) gained 1.0 mm in their triceps skinfolds from baseline to first grade, while inactive girls gained 1.75 mm. Active boys lost an average of 0.75 mm in their triceps, while inactive boys gained 0.25 mm. When age, television viewing, energy intake, baseline triceps, and parents' body mass indices were controlled for, inactive preschoolers were 3.8 (95% confidence interval 1.4-10.6) times as likely as active preschoolers to have an increasing triceps slope during follow up (rather than a stable or decreasing slope). This relative risk estimate was slightly higher for children with more body fat at baseline. In this study, preschool-aged children with low levels of physical activity gained substantially more subcutaneous fat than did more active children.</td></tr>
<tr><td>Location: United States</td></tr>
<tr><td>Sample: 97<br>Attrition Rate: 8.49%<br>Sample Power: Not Reported</td></tr>
<tr><td>Intervention: No</td></tr>
<tr><td>Exposure Measurement<br>Device-Measured: Activity counts measured with a Caltrac accelerometer. Average number of Caltrac counts per hour during the preschool years. Activity counts were averaged across all preschool monitoring periods. Accelerometer data was collected over two periods of 5 consecutive days approximately 6 months apart, from the time of arising in the morning until bedtime. Children were categorized into PA level quartiles for analysis.<br>Measures Steps: No<br>Measures Bouts: No</td></tr>
<tr><td>Refers to Other Materials: No<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Body composition: skin-fold measurements using a Lange caliper (mm). Body-mass index.</td></tr>
<tr><td>Populations Analyzed: Male, Female, Ages 3–5 years</td><td>Author-Stated Funding Source: National Heart, Lung, and Blood Institute.</td></tr>
</table>

<table>
<tr><th colspan="2">Body Weight And Adiposity</th></tr>
<tr><td colspan="2">Original Research<br>Citation: Remmers T, Sleddens EF, Gubbels JS, et al. Relationship between physical activity and the development of body mass index in children. Med Sci Sports Exerc. 2014;46(1):177–184. doi:10.1249/MSS.0b013e3182a36709.</td></tr>
<tr><td colspan="2">Purpose: To prospectively investigate the relationship, in boys and girls of the KOALA Birth Cohort study in the Netherlands, in the period of the adiposity rebound (4–9 years old). We hypothesize that the relationship between physical activity (PA) and body mass index decreases in initially heavier boys and girls.</td></tr>
<tr><td>Study Design: Prospective cohort study<br>Location: The Netherlands<br>Sample: 278<br>Attrition Rate: 24.66%<br>Sample Power: Not Reported<br>Intervention: No<br>Exposure Measurement<br>Self-Reported: Questionnaire; parents reported number of minutes their child spent cycling and swimming, categorized into 3 categories.<br>Device-Measured: Accelerometer: hip worn for 7 days; Evenson cut points used, time worn in moderate-to-vigorous physical activity and light PA.<br>Measures Steps: No<br>Measures Bouts: No</td><td>Abstract: PURPOSE: Studies estimating the contribution of physical activity (PA) to the development of body mass index (BMI) in critical periods of childhood are warranted. Therefore, we have prospectively investigated this relationship in boys and girls of the KOALA Birth Cohort study, the Netherlands, in the period around adiposity rebound (i.e., 4-9 yr old). METHODS: PA was assessed in 470 children (231 boys, 239 girls) using accelerometers at the ages of 5 and 7 yr, and height and weight were measured at 5, 7, and 9 yr. BMI z-scores were calculated to standardize for age and sex. Leaner and heavier children were classified according to the 25th and 75th percentile of our study sample. To examine longitudinal relationships between PA and BMI z-scores, generalized estimating equation analyses were performed and stratified for sex and baseline weight status (leaner, normal weight, and heavier children). RESULTS: In heavier children, an increment of 6.5 min of moderate to vigorous PA (MVPA) was related to a subsequent decrease of 0.03 BMI z-scores both in boys (95% confidence interval = -0.07 to -0.001) and girls (95% confidence interval = -0.05 to -0.002). Light PA was also associated with a decrease of BMI in heavier boys but not girls. In normal weight children, MVPA was associated with decrease of BMI in boys but not girls. CONCLUSION: Increments of MVPA were associated with decreases in BMI z-score in heavier children, both boys and girls. Promoting MVPA should remain a major prevention vehicle for improving body composition in 4- to 9-yr-old children.</td></tr>
<tr><td>Refers to Other Materials: No<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Combined objectively and parent-reported height and weight to calculate body mass index (kg/m2). All baseline and 24.6% of first follow-up measured by research assistants.</td></tr>
<tr><td>Populations Analyzed: Male, Female, Ages 4–5 years baseline</td><td>Author-Stated Funding Source: The Netherlands Heart Foundation.</td></tr>
</table>

| **Body Weight And Adiposity** | |
|---|---|
| **Original Research**<br>**Citation:** Roberts SB, Savage J, Coward WA, Chew B, Lucas A. Energy expenditure and intake in infants born to lean and overweight mothers. *N Engl J Med.* 1988;318(8):461–466. | |
| **Purpose:** To examine a prospective study of the contributions of low energy expenditure and high energy intake to excessive weight gain in infants born to overweight mothers. | |
| **Study Design:** Prospective cohort study<br>**Location:** England<br>**Sample:** 18<br>**Attrition Rate:** 0%<br>**Sample Power:** Not Reported<br>**Intervention:** No<br>**Exposure Measurement**<br>**Measures Steps:** No<br>**Measures Bouts:** No | **Abstract:** We investigated the contributions of low energy expenditure and high energy intake to excessive weight gain in infants born to overweight mothers. The subjects were infants of 6 lean and 12 overweight mothers, recruited soon after birth. Total energy expenditure and metabolizable energy intake were measured with a new doubly labeled water method over a period of seven days when the infants were 3 months of age, and the postprandial metabolic rate was measured by indirect calorimetry when the infants were 0.1 and 3 months of age. The results were related to weight gain in the first year of life. No significant difference was observed between infants who became overweight by the age of one year (50 percent of infants born to overweight mothers) and those who did not, with respect to weight, length, skinfold thicknesses, metabolic rate at 0.1 and 3 months of age, and metabolizable energy intake at 3 months. However, total energy expenditure at three months of age was 20.7 percent lower in the infants who became overweight than in the other infants (means +/- SE, 256 +/- 27 and 323 +/- 12 kJ per kilogram of body weight per day; P less than 0.05). This difference could account for the mean difference in weight gain. These data suggest that reduced energy expenditure, particularly on physical activity, was an important factor in the rapid weight gain during the first year of life in infants born to overweight mothers. |
| **Refers to Other Materials:** Yes<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Weight (kg), length/height (cm), skin folds (mm): objectively measured. Mother's pre-pregnancy weight (lean or overweight): estimated from first weight recorded by hospital, with use of correction for average weight gain in pregnancy. Child measured at 1, 3, 6, 9, and 12 months. |
| **Populations Analyzed:** Ages 0–12 months | **Author-Stated Funding Source:** Drummond Fellowship. |

<table>
<tr><th colspan="2">Body Weight And Adiposity</th></tr>
<tr><td colspan="2">Original Research<br>Citation: Sääkslahti A, Numminen P, Varstala V, et al. Physical activity as a preventive measure for coronary heart disease risk factors in early childhood. Scand J Med Sci Sports. 2004;14(3):143–149.</td></tr>
<tr><td colspan="2">Purpose: To examine longitudinally the amount of physical activity (PA) in girls and boys, and the relationships between PA and coronary heart disease risk factors in 5–7-year-old children.</td></tr>
<tr><td>Study Design: Prospective cohort study</td><td rowspan="5">Abstract: Physical activity causes acute physiological and long-term adaptive responses in the body. It is a protective factor for coronary heart disease (CHD) in adults. It has been assumed that children younger than 8 years of age may be in general active enough and there would be hardly any relationships between physical activity and CHD risk factors in early childhood. One hundred and fifty-five children (age 4-7 years) participated in this physical activity study during three consecutive years. Physical activity was examined twice a year with a special-purpose physical activity diary. CHD risk factors were measured during annual health care visits in the Specific Turku Coronary Risk-Factor Intervention Project (STRIP). We found that physical activity was related to CHD risk factors in early childhood. Among the girls, low-activity playing was related to a higher BMI. At the mean age of 6 years, high-activity playing was negatively related to serum total cholesterol (r=-0.32*) and positively to the high-density lipoprotein (HDL)/total cholesterol ratio (r=0.37**). The negative relationship between high-activity playing and triglycerides was highest (r=-0.32*) at the mean age of six. Among 4-year-old boys, playing outdoors correlated positively with serum HDL cholesterol concentration (r=0.29*) and the HDL/total ratio (r=0.35**). At the age of 5 years, physically active playing correlated positively with systolic blood pressure (r=0.25*). Playing outdoors and high-activity playing already have important health-maintaining effects in 4-7-year-old children. These positive effects differ between genders. (*P<0.05 **P<0.01)</td></tr>
<tr><td>Location: Finland</td></tr>
<tr><td>Sample: 155<br>Attrition Rate: 85.40%<br>Sample Power: Not Reported</td></tr>
<tr><td>Intervention: No</td></tr>
<tr><td>Exposure Measurement<br>Self-Reported: Special purpose PA diary filled out by parents.<br>Measures Steps: No<br>Measures Bouts: No</td></tr>
<tr><td>Refers to Other Materials: Yes<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Measured height (cm) using stadiometer and weight (kg) using an electronic scale to calculate body mass index (kg/m2). Blood pressure: systolic (mm/Hg), diastolic (mm/Hg). Cholesterol: total, HDL, HDL/total ratio, and triglycerides (mmol L-1).</td></tr>
<tr><td>Populations Analyzed: Male, Female, Ages 4–7 years</td><td>Author-Stated Funding Source: Ministry of Education, Finland; The Mannerheim League for Child Welfare; Academy of Finland; Juho Vainio Foundation; Finnish Cardiac Research Foundation; Foundation for Pediatric Research, Finland and Yrjo Janhsson Foundation.</td></tr>
</table>

**Bone Health**

**Original Research**

**Citation:** Specker BL, Mulligan L, Ho M. Longitudinal study of calcium intake, physical activity, and bone mineral content in infants 6-18 months of age. *J Bone Miner Res.* 1999;14(4):569–576.

**Purpose:** To determine whether increased load-bearing activity in young infants could alter bone mass accretion.

**Study Design:** Randomized trial

**Location:** United States

**Sample:** 69
**Attrition Rate:** 4.16%
**Sample Power:** Not Reported

**Intervention:** Yes
**Intervention Type:** Behavioral
**Intervention Length:** 1 year

**Exposure Measurement**
**Device-Measured:** Ankle and wrist miniature motion sensors for 48 hours, every 3 months; counts/hr used.
**Direct Observation:** Modified Children's Activity Rating Scale; activity and percentage of time bearing weight on legs.
**Measures Steps:** No
**Measures Bouts:** No
**Exposure**
**Frequency:** 5 times a week
**Intensity:** Moderate strain level and rate
**Time:** 15–20 minutes/day
**Type:** 15–20 minutes/day, Other Type
**Examines HIIT:** No
**Sedentary Behavior Intervention:** Comparison group: fine motor activity

**Abstract:** Although increased physical activity early in life is recommended for optimizing bone health, no controlled trials on the effect of activity on bone mass accretion during periods of rapid growth have been reported. The purpose of this study was to determine whether infants randomized to a 1 year gross motor activity program had a greater bone mass accretion than infants randomized to a fine motor activity program. The gross motor program included activities that focused on loading the skeleton and were performed for 15-20 minutes/day, 5 days/week by study personnel. Infants (n = 72) were enrolled at 6 months of age, and total body bone mineral content (BMC), 3-day diet records, and activity levels were obtained at 6, 9, 12, 15, and 18 months. BMC was associated with weight, length, and bone area at all ages and correlated with earlier calcium intakes. Calcium intake appeared to modify the effect of gross motor activity on bone mass accretion; infants in both groups had similar bone accretion at moderately high calcium intakes, but at low calcium intakes infants in the gross motor program had less bone accretion than infants in the fine motor program. Compliant infants in the gross motor group had lower BMC at 18 months compared with noncompliant infants. These results indicate that BMC in infants is related to calcium intake, and we speculate that participation in a gross motor program during rapid bone growth may lead to reduced bone accretion in the presence of a moderate to moderately low calcium intake.

**Refers to Other Materials:** No
**Adverse Events Addressed:** No
**Examine Cardiorespiratory Fitness as Outcome:** No

**Outcomes Examined:** Total body bone mineral content (BMC,g): DXA. Weight (kg) and length (cm): standardized procedures.

**Populations Analyzed:** White, Infants 6–18 months

**Author-Stated Funding Source:** National Institutes of Health and the General Clinical Research Centers Program, National Center for Research Resources, National Institutes of Health.

| Bone Health | |
|---|---|
| **Original Research**<br>**Citation:** Specker B, Binkley T. Randomized trial of physical activity and calcium supplementation on bone mineral content in 3- to 5-year-old children. *J Bone Miner Res*. 2003;18(5):885–892. | |
| **Purpose:** To determine whether calcium intake modifies the bone response to increased activity in young children. | |
| **Study Design:** Randomized trial<br>**Location:** Not reported<br>**Sample:** 178<br>**Attrition Rate:** 25.52%<br>**Sample Power:** Not Reported<br>**Intervention:** Yes<br>**Intervention Type:** Behavioral, calcium supplement or placebo<br>**Intervention Length:** 1 year<br>**Exposure Measurement**<br>**Device-Measured:** 48-hour accelerometer readings were assessed at baseline, 6 months, and 1 year; sensor counts and minutes of moderate-to-vigorous physical activity (MVPA), percentage of time in MVPA and percentage of vigorous PA.<br>**Measures Steps:** No<br>**Measures Bouts:** No<br>**Exposure**<br>**Frequency:** 5 times a week<br>**Intensity:** No reference to intensity; gross motor activities described<br>**Time:** 30 minutes/day<br>**Type:** 30 minutes/day, Other Type<br>**Examines HIIT:** No<br>**Sedentary Behavior Intervention:** Controls assigned to sitting fine motor activities. | **Abstract:** A meta-analysis of adult exercise studies and an infant activity trial show a possible interaction between physical activity and calcium intake on bone. This randomized trial of activity and calcium supplementation was conducted in 239 children aged 3-5 years (178 completed). Children were randomized to participate in either gross motor or fine motor activities for 30 minutes/day, 5 days per week for 12 months. Within each group, children received either calcium (1000 mg/day) or placebo. Total body and regional bone mineral content by DXA and 20% distal tibia measurements by peripheral quantitative computed tomography (pQCT) were obtained at 0 and 12 months. Three-day diet records and 48-h accelerometer readings were obtained at 0, 6, and 12 months. Higher activity levels were observed in gross motor versus fine motor activity groups, and calcium intake was greater in calcium versus placebo (1354 +/- 301 vs. 940 +/- 258 mg/day, $p < 0.001$). Main effects of activity and calcium group were not significant for total body bone mineral content or leg bone mineral content by DXA. However, the difference in leg bone mineral content gain between gross motor and fine motor was more pronounced in children receiving calcium versus placebo (interaction, $p = 0.05$). Children in the gross motor group had greater tibia periosteal and endosteal circumferences by pQCT compared with children in the fine motor group at study completion ($p < 0.05$). There was a significant interaction (both p < or = 0.02) between supplement and activity groups in both cortical thickness and cortical area: among children receiving placebo, thickness and area were smaller with gross motor activity compared with fine motor activity, but among children receiving calcium, thickness and area were larger with gross motor activity. These findings indicate that calcium intake modifies the bone response to activity in young children. |
| **Refers to Other Materials:** Yes<br>**Adverse Events Addressed:** No<br>**Examine Cardiorespiratory Fitness as Outcome:** No | **Outcomes Examined:** Bone mineral content (g), total body fat (kg), lean mass (kg), total body fat percent: DXA. Height (cm) and weight (kg): standard objective procedures. |
| **Populations Analyzed:** Ages 3–5 years | **Author-Stated Funding Source:** National Institutes of Health. |

<table>
<tr><th colspan="2">Bone Health</th></tr>
<tr><td colspan="2">Original Research<br>Citation: Specker B, Binkley T, Fahrenwald N. Increased periosteal circumference remains present 12 months after an exercise intervention in preschool children. Bone. 2004;35(6):1383–1388.</td></tr>
<tr><td colspan="2">Purpose: To determine whether the bone effects of calcium supplementation and physical activity (PA) persisted one year post-intervention.</td></tr>
<tr><td>Study Design: Randomized trial</td><td rowspan="5">Abstract: We previously reported that calcium intake enhanced the leg bone response to physical activity of preschool children in a 12-month randomized trial of calcium supplementation and physical activity. To determine whether the intervention-induced changes in leg bone mineral content and size were maintained through the subsequent 12-month follow-up period, total body bone measurements by DXA and 20% distal tibia pQCT bone measurements were obtained at 24 months (12 months post-intervention). Children also were measured for height and weight, and accelerometer readings were obtained in a subset of children at 18 and 24 months (6 and 12 months post-intervention). Regression analyses were performed controlling for covariates and indicated that increases from 12 to 24 months were greater in the gross motor (GM) activity group (bone loading, large muscle exercises) vs. fine motor (FM) activity group (arts and crafts program) for arm bone area (BA) (P <0.01), total body (P=0.04) and arm (P <0.01) bone mineral content (BMC). There were no differences in BA or BMC changes from 12 to 24 months by calcium supplementation. Differences in tibia periosteal circumference by pQCT persisted at 24 months (GM 51.4 +/- 0.4 mm vs. FM 50.2 +/- 0.4 mm, P=0.03) with a trend for greater endosteal circumferences in the children in the GM vs. FM groups at both 12 and 24 months (both, P=0.08). There were no significant differences in cortical area or thickness by activity or supplement group at 24 months. Children in the GM group had greater accelerometer counts/day (P=0.04) and more time in vigorous activity (P=0.05) at 18 months compared to FM group. No differences in accelerometer readings were noted at 24 months. In conclusion, we found higher activity levels in children randomized to gross motor vs. fine motor activities 6 months after the intervention program ceased. Whether the greater periosteal circumference that was observed 12 months post-intervention was a persistent biological bone effect or due to persistently higher activity levels is not known.</td></tr>
<tr><td>Location: Not reported</td></tr>
<tr><td>Sample: 161<br>Attrition Rate: 9.55%<br>Sample Power: Not Reported</td></tr>
<tr><td>Intervention: Yes<br>Intervention Type: Behavioral, supplement or placebo<br>Intervention Length: 1 year</td></tr>
<tr><td>Exposure Measurement Device-Measured: Accelerometer for 48 hours; moderate-to-vigorous PA: minutes with >3,000 counts; percent time in vigorous PA.<br>Measures Steps: No<br>Measures Bouts: No<br>Exposure<br>Frequency: 5 times a week<br>Intensity: Not specified<br>Time: 30 minutes/day<br>Type: 30 minutes/day, Other Type<br>Examines HIIT: No<br>Sedentary Behavior Intervention: Comparison group: none bone-loading fine motor activities</td></tr>
<tr><td>Refers to Other Materials: Yes<br>Adverse Events Addressed: No<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Measured weight (kg) and height (cm). Total body % fat, total body bone area (cm2), total body bone mineral content (BMC; g) arm bone area (cm2), arm BMC (g), leg bone area (cm2), and leg BMC (g) measured by DXA and peripheral quantitative computed tomography</td></tr>
</table>

| | |
|---|---|
| **Populations Analyzed:** Ages 3–7 years | **Author-Stated Funding Source:** National Institutes of Health. |

<table>
<tr><th colspan="2">Body Weight And Adiposity</th></tr>
<tr><td colspan="2">Original Research<br>Citation: Sugimori H, Yoshida K, Izuno T, et al. Analysis of factors that influence body mass index from ages 3 to 6 years: a study based on the Toyama cohort study. Pediatr Int. 2004;46(3):302–310.</td></tr>
<tr><td colspan="2">Purpose: To elucidate behavioral and environmental factors influencing temporal changes in body mass index from ages 3–6 years using large cohort data from the Toyama study, and to analyze in greater detail factors promoting obesity in childhood.</td></tr>
<tr><td>Study Design: Prospective cohort study<br>Location: Japan<br>Sample: 8,170<br>Attrition Rate: 15.55%<br>Sample Power: Not Reported<br>Intervention: No<br>Exposure Measurement<br>Self-Reported: Questionnaire<br>Measures Steps: No<br>Measures Bouts: No</td><td>Abstract: BACKGROUND: The aim of the present study was to elucidate both environmental and behavioral factors that influence body mass index (BMI, kg/m2) among Japanese children from ages 3-6. METHODS: In 1992 (at age 3) and 1995 (at age 6), 8170 6-year-old children (4176 boys and 3994 girls) were surveyed using a questionnaire on both body build (height and weight) and lifestyle. The correlation between BMI for 3-year-olds and for 6-year-olds were analyzed. From the temporal changes of body build between age 3 and 6 years, we categorized children into four groups: group 1, normal at both age 3 years and 6 years (normal/normal); group 2, overweight at age 3 years and normal at age 6 years (overweight/normal); group 3, normal at age 3 years and overweight at age 6 years (normal/overweight); and group 4, overweight at both age 3 years and 6 years (overweight/overweight). The authors compared the four groups with each other according to sex, concerning frequencies of children who matched the categories of environmental and behavioral factors. Each factor was tested using the chi2 test. Overweight children were defined as those whose BMI value was age-sex specific in the 90th percentile or more. RESULTS: A significant correlation was found between body builds for children aged 3 and 6 years in both genders (boys, r = 0.559, P < 0.01; girls, r = 0.584, P < 0.01). Significant factors associated with overweight children were diet (eating rice, green tea, eggs, meat, but less breads and juice), rapid eating, short sleep duration, early bedtime, long periods of television viewing, avoidance of physical activity, and frequent bowel movement. DISCUSSION: Temporal changes in BMI from age 3 years to 6 years are significantly associated with both environmental and behavioral factors at age 6 years. The results of this study may be useful for health promotion programs designed to prevent obesity during the early stages of childhood.</td></tr>
<tr><td>Refers to Other Materials: No<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Measured height (cm) using stadiometer and weight (g) to calculate body mass index (kg/m2).</td></tr>
<tr><td>Populations Analyzed: Male, Female, Ages 3–6 years, Normal/Healthy Weight (BMI: 18.5–24.9), Overweight (BMI: 25–29.9)</td><td>Author-Stated Funding Source: Ministry of Health and Welfare of Japan.</td></tr>
</table>

<table>
<tr><th colspan="2">Body Weight And Adiposity</th></tr>
<tr><td colspan="2">Original Research<br>Citation: Wells JC, Stanley M, Laidlaw AS, Day JM, Davies PS. The relationship between components of infant energy expenditure and childhood body fatness. Int J Obes Relat Metab Disord. 1996;20(9):848–853.</td></tr>
<tr><td colspan="2">Purpose: To investigate whether any component of infant energy expenditure is related to fatness in early childhood, and whether infant fatness is related to childhood variables.</td></tr>
<tr><td>Study Design: Prospective cohort study</td><td rowspan="5">Abstract: OBJECTIVE: To investigate whether any component of infant energy expenditure is related to fatness in early childhood, and whether infant fatness is related to childhood variables. DESIGN: Longitudinal investigation of infants studied at 12 weeks and followed up at 2.5 to 3.5 years of age. SUBJECTS: 30 healthy full-term infants selected from the general population. MEASUREMENTS: Sleeping metabolic rate, total energy expenditure, anthropometry and behaviour at 12 weeks; anthropometry, body composition and behaviour in follow-up. RESULTS: Energy expenditure at 12 weeks (minimal metabolism, total energy expenditure, energy expended on physical activity, behaviour) showed no relationship with later fatness. Infant fatness (skinfold thicknesses and percentage fat) showed in contrast a strong relationship with childhood fatness. Infant fatness also predicted childhood behaviour. CONCLUSIONS: These data do not support the theory that reduced energy expenditure in early infancy is related to later fatness. However, infant fatness influences both later fatness and activity patterns.</td></tr>
<tr><td>Location: United Kingdom</td></tr>
<tr><td>Sample: 30<br>Attrition Rate: 40%<br>Sample Power: Not Reported</td></tr>
<tr><td>Intervention: No</td></tr>
<tr><td>Exposure Measurement<br>Self-Reported: Diary of behaviors (sleeping, awake and content, fussy, crying, and feeding) in hrs/day from parent at 12 weeks for 15 min periods; 2 day parental diary of activites (sleeping, awake and quiet, awake and active, watching TV, upset, feeding) at age 2–3.5 years.<br>Measures Steps: No<br>Measures Bouts: No</td></tr>
<tr><td>Refers to Other Materials: Yes<br>Examine Cardiorespiratory Fitness as Outcome: No</td><td>Outcomes Examined: Weight (kg), length (cm), skinfolds (mm): objectively measured. Body fat (%) and total energy expenditure (TEE): doubly labeled water. Fat free mass (kg), fat mass (kg) and body fat (%): total body water.</td></tr>
<tr><td>Populations Analyzed: 12 weeks baseline; 2–3.5 years old follow-up</td><td>Author-Stated Funding Source: Not Reported.</td></tr>
</table>

*Table 3. Original Research Bias Assessment Chart*

| **Nutrition Evidence Library (NEL) Bias Assessment Tool (BAT): Original Research** | | | | | | |
|---|---|---|---|---|---|---|
| | Berkowitz 1985 | Driessen, 2014 | DuRant, 1993 | Erlandson 2011 | Gruodyte -Raciene, 2013 | Jackowski 2015 |
| (???) = Can't Determine | | | | | | |
| Inclusion/exclusion criteria similar across study groups. | Yes | N/A | N/A | Yes | Yes | Yes |
| Strategy for recruiting or allocating participants similar across study groups. | Yes | N/A | N/A | Yes | Yes | Yes |
| Allocation sequence randomly generated. | N/A | N/A | N/A | N/A | N/A | N/A |
| Group allocation concealed (i.e., assignments could not be predicted). | N/A | N/A | N/A | N/A | N/A | N/A |
| Distribution of critical confounding factors similar across study groups at baseline, or analysis controlled for differences between groups. | ??? | N/A | N/A | Yes | Yes | Yes |
| Accounted for variations in execution of study from proposed protocol or research plan. | N/A | N/A | N/A | N/A | N/A | N/A |
| Adherence to study protocols similar across study groups. | Yes | N/A | N/A | Yes | Yes | Yes |
| Investigators accounted for unintended concurrent exposures that were differentially experienced by study groups and might bias results. | No | N/A | N/A | Yes | Yes | Yes |
| Participants blinded to their intervention or exposure status. | N/A | N/A | N/A | N/A | N/A | N/A |
| Investigators blinded to participants intervention or exposure status. | N/A | N/A | N/A | N/A | N/A | N/A |
| Outcome assessors blinded to participants intervention or exposure status. | N/A | N/A | N/A | N/A | N/A | N/A |
| Valid and reliable measures used consistently across study groups to assess inclusion/exclusion criteria, exposures, outcomes, and confounders. | Yes | N/A | Yes | Yes | Yes | Yes |
| Length of follow-up similar across study groups. | Yes | N/A | N/A | Yes | Yes | Yes |
| In cases of high or differential loss to follow-up, impact assessed through sensitivity analysis or other adjustment. | N/A | Yes | ??? | N/A | N/A | ??? |
| Other sources of bias taken into account in design and/or analysis of study through matching or other statistical adjustment. | Yes | Yes | Yes | Yes | Yes | Yes |
| Adequate statistical methods used to assess primary outcomes. | Yes | Yes | Yes | Yes | Yes | Yes |

| Nutrition Evidence Library (NEL) Bias Assessment Tool (BAT): Original Research | | | | | | |
|---|---|---|---|---|---|---|
| | Jago, 2005 | Janz, 2006 | Janz, 2007 | Janz, 2009 | Janz, 2014 | Janz, 2010 |
| (???) = Can't Determine | | | | | | |
| Inclusion/exclusion criteria similar across study groups. | N/A | Yes | Yes | Yes | Yes | Yes |
| Strategy for recruiting or allocating participants similar across study groups. | N/A | Yes | Yes | Yes | Yes | Yes |
| Allocation sequence randomly generated. | N/A | N/A | N/A | N/A | N/A | N/A |
| Group allocation concealed (i.e., assignments could not be predicted). | N/A | N/A | N/A | N/A | N/A | N/A |
| Distribution of critical confounding factors similar across study groups at baseline, or analysis controlled for differences between groups. | N/A | Yes | Yes | Yes | Yes | Yes |
| Accounted for variations in execution of study from proposed protocol or research plan. | N/A | N/A | N/A | N/A | N/A | N/A |
| Adherence to study protocols similar across study groups. | Yes | Yes | Yes | Yes | Yes | Yes |
| Investigators accounted for unintended concurrent exposures that were differentially experienced by study groups and might bias results. | N/A | No | No | No | No | No |
| Participants blinded to their intervention or exposure status. | N/A | N/A | N/A | N/A | N/A | N/A |
| Investigators blinded to participants intervention or exposure status. | N/A | N/A | N/A | N/A | N/A | N/A |
| Outcome assessors blinded to participants intervention or exposure status. | N/A | N/A | N/A | N/A | N/A | N/A |
| Valid and reliable measures used consistently across study groups to assess inclusion/exclusion criteria, exposures, outcomes, and confounders. | N/A | Yes | Yes | Yes | Yes | Yes |
| Length of follow-up similar across study groups. | N/A | Yes | Yes | Yes | Yes | Yes |
| In cases of high or differential loss to follow-up, impact assessed through sensitivity analysis or other adjustment. | N/A | ??? | N/A | ??? | ??? | No |
| Other sources of bias taken into account in design and/or analysis of study through matching or other statistical adjustment. | Yes | Yes | Yes | Yes | Yes | Yes |
| Adequate statistical methods used to assess primary outcomes. | Yes | Yes | Yes | Yes | Yes | Yes |

| Nutrition Evidence Library (NEL) Bias Assessment Tool (BAT): Original Research | | | | | | |
|---|---|---|---|---|---|---|
| | Klesges, 1995 | Knowles, 2013 | Li, 1995 | Metcalf, 2008 | Moore, 2003 | Moore, 1995 |
| (???) = Can't Determine | | | | | | |
| Inclusion/exclusion criteria similar across study groups. | N/A | N/A | N/A | Yes | Yes | Yes |
| Strategy for recruiting or allocating participants similar across study groups. | N/A | N/A | N/A | Yes | Yes | Yes |
| Allocation sequence randomly generated. | N/A | N/A | N/A | N/A | N/A | N/A |
| Group allocation concealed (i.e., assignments could not be predicted). | N/A | N/A | N/A | N/A | N/A | N/A |
| Distribution of critical confounding factors similar across study groups at baseline, or analysis controlled for differences between groups. | N/A | N/A | N/A | Yes | Yes | Yes |
| Accounted for variations in execution of study from proposed protocol or research plan. | N/A | N/A | N/A | Yes | N/A | N/A |
| Adherence to study protocols similar across study groups. | N/A | Yes | N/A | Yes | Yes | Yes |
| Investigators accounted for unintended concurrent exposures that were differentially experienced by study groups and might bias results. | N/A | N/A | N/A | No | Yes | Yes |
| Participants blinded to their intervention or exposure status. | N/A | N/A | N/A | N/A | N/A | N/A |
| Investigators blinded to participants intervention or exposure status. | N/A | N/A | N/A | N/A | N/A | N/A |
| Outcome assessors blinded to participants intervention or exposure status. | N/A | N/A | N/A | N/A | N/A | N/A |
| Valid and reliable measures used consistently across study groups to assess inclusion/exclusion criteria, exposures, outcomes, and confounders. | N/A | N/A | Yes | Yes | Yes | Yes |
| Length of follow-up similar across study groups. | N/A | N/A | N/A | Yes | Yes | Yes |
| In cases of high or differential loss to follow-up, impact assessed through sensitivity analysis or other adjustment. | Yes | No | N/A | No | N/A | N/A |
| Other sources of bias taken into account in design and/or analysis of study through matching or other statistical adjustment. | Yes | Yes | Yes | Yes | Yes | Yes |
| Adequate statistical methods used to assess primary outcomes. | Yes | Yes | Yes | Yes | Yes | Yes |

| Nutrition Evidence Library (NEL) Bias Assessment Tool (BAT): Original Research | | | | | |
|---|---|---|---|---|---|
| | Remmers, 2014 | Roberts, 1988 | Sääkslahti, 2004 | Specker, 1999 | Specker, 2003 |
| (???) = Can't Determine | | | | | |
| Inclusion/exclusion criteria similar across study groups. | N/A | Yes | Yes | N/A | N/A |
| Strategy for recruiting or allocating participants similar across study groups. | N/A | Yes | Yes | N/A | N/A |
| Allocation sequence randomly generated. | N/A | N/A | N/A | ??? | ??? |
| Group allocation concealed (i.e., assignments could not be predicted). | N/A | N/A | N/A | ??? | ??? |
| Distribution of critical confounding factors similar across study groups at baseline, or analysis controlled for differences between groups. | N/A | Yes | Yes | Yes | Yes |
| Accounted for variations in execution of study from proposed protocol or research plan. | N/A | Yes | No | N/A | Yes |
| Adherence to study protocols similar across study groups. | Yes | Yes | Yes | No | No |
| Investigators accounted for unintended concurrent exposures that were differentially experienced by study groups and might bias results. | N/A | Yes | N/A | Yes | Yes |
| Participants blinded to their intervention or exposure status. | N/A | N/A | N/A | No | No |
| Investigators blinded to participants intervention or exposure status. | N/A | N/A | N/A | No | No |
| Outcome assessors blinded to participants intervention or exposure status. | N/A | N/A | N/A | Yes | Yes |
| Valid and reliable measures used consistently across study groups to assess inclusion/exclusion criteria, exposures, outcomes, and confounders. | N/A | Yes | Yes | Yes | Yes |
| Length of follow-up similar across study groups. | N/A | Yes | Yes | Yes | Yes |
| In cases of high or differential loss to follow-up, impact assessed through sensitivity analysis or other adjustment. | ??? | N/A | ??? | N/A | Yes |
| Other sources of bias taken into account in design and/or analysis of study through matching or other statistical adjustment. | Yes | Yes | Yes | Yes | Yes |
| Adequate statistical methods used to assess primary outcomes. | Yes | Yes | Yes | Yes | Yes |

| Nutrition Evidence Library (NEL) Bias Assessment Tool (BAT): Original Research | | | |
|---|---|---|---|
| | Specker, 2004 | Sugimori, 2004 | Wells, 1996 |
| (???) = Can't Determine | | | |
| Inclusion/exclusion criteria similar across study groups. | N/A | Yes | N/A |
| Strategy for recruiting or allocating participants similar across study groups. | N/A | Yes | N/A |
| Allocation sequence randomly generated. | ??? | N/A | N/A |
| Group allocation concealed (i.e., assignments could not be predicted). | ??? | N/A | N/A |
| Distribution of critical confounding factors similar across study groups at baseline, or analysis controlled for differences between groups. | Yes | ??? | N/A |
| Accounted for variations in execution of study from proposed protocol or research plan. | Yes | N/A | N/A |
| Adherence to study protocols similar across study groups. | Yes | Yes | N/A |
| Investigators accounted for unintended concurrent exposures that were differentially experienced by study groups and might bias results. | Yes | Yes | N/A |
| Participants blinded to their intervention or exposure status. | No | N/A | N/A |
| Investigators blinded to participants intervention or exposure status. | No | N/A | N/A |
| Outcome assessors blinded to participants intervention or exposure status. | Yes | N/A | N/A |
| Valid and reliable measures used consistently across study groups to assess inclusion/exclusion criteria, exposures, outcomes, and confounders. | Yes | Yes | N/A |
| Length of follow-up similar across study groups. | Yes | Yes | N/A |
| In cases of high or differential loss to follow-up, impact assessed through sensitivity analysis or other adjustment. | N/A | No | No |
| Other sources of bias taken into account in design and/or analysis of study through matching or other statistical adjustment. | Yes | Yes | Yes |
| Adequate statistical methods used to assess primary outcomes. | Yes | Yes | Yes |

## Appendices

### Appendix A: Analytical Framework

**Topic Area**
Youth

**Systematic Review Questions**

In children younger than age 6 years, is physical activity related to health outcomes?

a. What is the relationship between physical activity and adiposity/weight status?
b. What is the relationship between physical activity and bone health?
c. What is the relationship between physical activity and cardiometabolic health?
d. Are there dose-response relationships? If so, what are the shapes of those relationships?
e. Do the relationships vary by age, sex, race/ethnicity, weight status, or socio-economic status?

**Population**
Children, ages 0–6

**Exposure**
All types and intensities of physical activity, including any kind of play (structured or free), sports, and other activities

**Comparison**
Least active subgroup

**Endpoint Health Outcomes**

- Adiposity
- Asthma
- Blood pressure
- Body composition
- Bone, bone mineral content, bone geometry, bone mineral density
- Cardiometabolic risk factors
- Fatness
- Gross motor movement
- Gross motor skill development
- Growth
- Motor skill competence
- Muscle mass, lean mass
- Musculoskeletal development and fitness
- Physical fitness
- Weight (underweight, normal, overweight, obese)
- Weight status
- Weight trajectory change

## Appendix B: Final Search Strategy

**Search Strategy: PubMed (Systematic Reviews, Meta-Analyses, Pooled Analyses, and High-Quality Reports)**

Database: PubMed; Date of Search: 12/6/2016; 222 results

| Set | Search Strategy |
|---|---|
| Limit: Language | (English[lang]) |
| Limit: Exclude animal only | NOT ("Animals"[Mesh] NOT ("Animals"[Mesh] AND "Humans"[Mesh])) |
| Limit: Exclude adult only | NOT (("adult"[Mesh]) NOT (("adult"[Mesh]) AND ("infant"[Mesh] OR child[Mesh]))) |
| Limit: Exclude subheadings | NOT (ad[sh] OR aa[sh] OR ci[sh] OR cn[sh] OR dh[sh] OR de[sh] OR dt[sh] OR em[sh] OR en[sh] OR es[sh] OR eh[sh] OR ge[sh] OR hi[sh] OR is[sh] OR ip[sh] OR lj[sh] OR ma[sh] OR mi[sh] OR og[sh] OR ps[sh] OR py[sh] OR pk[sh] OR pd[sh] OR po[sh] OR re[sh] OR rt[sh] OR rh[sh] OR st[sh] OR sd[sh] OR tu[sh] OR th[sh] OR tm[sh] OR tr[sh] OR us[sh] OR ut[sh] OR ve[sh] OR vi[sh]) |
| Limit: Publication Date | AND ("2006/01/01"[PDAT] : "3000/12/31"[PDAT]) |
| Limit: Publication Type Include | AND (systematic[sb] OR meta-analysis[pt] OR “systematic review”[tiab] OR “systematic literature review”[tiab] OR metaanalysis[tiab] OR "meta analysis"[tiab] OR metanalyses[tiab] OR "meta analyses"[tiab] OR "pooled analysis"[tiab] OR “pooled analyses”[tiab] OR "pooled data"[tiab]) |
| Limit: Publication Type Exclude | NOT (“comment”[Publication Type] OR “editorial”[Publication Type]) |
| Physical Activity | AND (("Active games"[tiab] OR "Active recreation"[tiab] OR "Exercise"[mh] OR "Exercise"[tiab] OR "High intensity activities"[tiab] OR "High intensity activity"[tiab] OR "Low intensity activities"[tiab] OR "Low intensity activity"[tiab] OR "Moderate to Vigorous Activities”[tiab] OR "Moderate to Vigorous Activity”[tiab] OR "Muscle-strengthening"[tiab] OR "Physical activity"[tiab] OR ("Recess"[tiab] AND ("Child"[tiab] OR "Youth"[tiab] OR Child[mh])) OR "Screen time"[tiab] OR "Sedentary lifestyle"[mh] OR "Television viewing"[tiab] OR "Television watching"[tiab] OR "Tummy time"[tiab] OR "TV viewing"[tiab] OR "TV watching"[tiab] OR "Video game"[tiab] OR "Video gaming"[tiab] OR "Vigorous Activities"[tiab] OR "Vigorous Activity"[tiab] OR "Play and Playthings"[mh]) OR (("Active play"[tiab] OR "Aerobic activities"[tiab] OR "Aerobic activity"[tiab] OR "Cardiovascular activities"[tiab] OR "Cardiovascular activity"[tiab] OR "Free Play"[tiab] OR "Outdoor Play"[tiab] OR "Physical activities"[tiab] OR "Recreational activities"[tiab] OR "Recreational activity"[tiab] OR |

| Set | Search Strategy |
| --- | --- |
| | "Sedentary"[tiab] OR "Walk"[tiab] OR "Walking"[tiab] OR "Youth sports"[tiab]) NOT medline[sb])) |
| Outcomes | AND (("Adiposity"[mh] OR "Asthma"[mh] OR "Blood glucose"[mh] OR "Blood lipids"[tiab] OR "Blood pressure"[mh] OR "Body composition"[mh] OR "Body Mass Index"[mh] OR "Bone density"[mh] OR "Cardiometabolic risk factors"[tiab] OR "Cardiometabolic risk factor"[tiab] OR "Dyslipidemias"[mh] OR "Fatness"[tiab] OR "Muscle mass"[tiab] OR "Musculoskeletal development"[mh] OR "Musculoskeletal fitness"[tiab] OR "Hyperglycemia"[mh] OR "Hypertension"[mh] OR "Insulin resistance"[mh] OR "Metabolic syndrome X"[mh] OR "Obesity"[mh] OR Diabetes Mellitus, Type 2[mh]) OR (("Adiposity"[tiab] OR "Asthma"[tiab] OR "Blood glucose"[tiab] OR "Blood pressure"[tiab] OR "Body composition"[tiab] OR "Body Mass Index"[tiab] OR BMI[tiab] OR "Dyslipidemia"[tiab] OR "Dyslipidemias"[tiab] OR "Musculoskeletal development"[tiab] OR "Hyperglycemia"[tiab] OR "Hypertension"[tiab] OR "Insulin resistance"[tiab] OR "Metabolic syndrome"[tiab] OR "Obese"[tiab] OR "Obesity"[tiab] OR "Type 2 Diabetes"[tiab] OR "Bone mineral content"[tiab] OR "Bone mineral density"[tiab] OR "Bone geometry"[tiab]) NOT medline[sb])) |
| Age | AND ((Child[mh] OR infant[mh]) OR (("Baby"[tiab] OR "Babies"[tiab] OR "Boy"[tiab] OR "Boys"[tiab] OR "Child"[tiab] OR "Children"[tiab] OR "Girl"[tiab] OR "Girls"[tiab] OR "Infant"[tiab] OR "Infants"[tiab] OR "Nursery school"[tiab] OR "Preschool"[tiab] OR "Pre school"[tiab] OR "Preschooler"[tiab] OR "Pre schooler"[tiab] OR "Pre-K"[tiab] OR "Toddler"[tiab] OR "Toddlers"[tiab]) NOT medline[sb])) |

**Search Strategy: CINAHL (Systematic Reviews, Meta-Analyses, Pooled Analyses, and High-Quality Reports)**

Database: CINAHL; Date of Search: 12/8/16; 6 results
Terms searched in title or abstract

| Set | Search Terms |
|---|---|
| Physical Activity | ("Active games" OR "Active play" OR "Active recreation" OR "Aerobic activities" OR "Aerobic activity" OR "Cardiovascular activities" OR "Cardiovascular activity" OR "Exercise" OR "Exercise" OR "Free Play" OR "High intensity activities" OR "High intensity activity" OR "Low intensity activities" OR "Low intensity activity" OR "Moderate to Vigorous Activities" OR "Moderate to Vigorous Activity" OR "Muscle-strengthening" OR "Outdoor Play" OR "Physical activity" OR "Physical activities" OR ("Recess" AND ("Child" OR "Youth")) OR "Recreational activities" OR "Recreational activity" OR "Screen time" OR "Sedentary" OR "Sedentary lifestyle" OR "Television viewing" OR "Television watching" OR "Tummy time" OR "TV viewing" OR "TV watching" OR "Video game" OR "Video gaming" OR "Vigorous Activities" OR "Vigorous Activity" OR "Walk" OR "Walking" OR "Play and Playthings" OR "Youth sports") |
| Outcomes | AND<br>("Adiposity" OR "Adiposity" OR "Asthma" OR "Asthma" OR "Blood glucose" OR "Blood glucose" OR "Blood lipids" OR "Blood pressure" OR "Blood pressure" OR "Body composition" OR "Body composition" OR "Body Mass Index" OR "Body Mass Index" OR BMI OR "Bone density" OR "Cardiometabolic risk factors" OR "Cardiometabolic risk factor" OR "Dyslipidemia" OR "Dyslipidemias" OR "Dyslipidemias" OR "Fatness" OR "Muscle mass" OR "Musculoskeletal development" OR "Musculoskeletal development" OR "Musculoskeletal fitness" OR "Hyperglycemia" OR "Hyperglycemia" OR "Hypertension" OR "Hypertension" OR "Insulin resistance" OR "Insulin resistance" OR "Metabolic syndrome" OR "Metabolic syndrome X" OR "Obese" OR "Obesity" OR "Obesity" OR "Type 2 Diabetes" OR Diabetes Mellitus, Type 2 OR "Bone mineral content" OR "Bone mineral density" OR "Bone geometry") |
| Age | AND<br>("Baby" OR "Babies" OR "Boy" OR "Boys" OR "Child" OR "Children" OR "Girl" OR "Girls" OR "Infant" OR "Infants" OR "Nursery school" OR "Preschool" OR "Pre school" OR "Preschooler" OR "Pre schooler" OR "Pre-K" OR "Toddler" OR "Toddlers" OR "Child" OR "infant") |
| Systematic Reviews and Meta-Analyses | AND<br>(“systematic review” OR “systematic literature review” OR metaanalysis OR "meta analysis" OR metanalyses OR "meta |

| Set | Search Terms |
|---|---|
| | analyses" OR "pooled analysis" OR “pooled analyses” OR "pooled data") |
| Limits | 2006–present<br>English language<br>Peer reviewed<br>Exclude Medline records<br>Human |

**Search Strategy: Cochrane (Systematic Reviews, Meta-Analyses, Pooled Analyses, and High-Quality Reports)**

Database: Cochrane; Date of Search: 12/15/16; 112 Results
Terms searched in title, abstract, or keywords

| Set | Search Terms |
|---|---|
| Physical Activity | ("Active games" OR "Active play" OR "Active recreation" OR "Aerobic activities" OR "Aerobic activity" OR "Cardiovascular activities" OR "Cardiovascular activity" OR "Exercise" OR "Exercise" OR "Free Play" OR "High intensity activities" OR "High intensity activity" OR "Low intensity activities" OR "Low intensity activity" OR "Moderate to Vigorous Activities" OR "Moderate to Vigorous Activity" OR "Muscle-strengthening" OR "Outdoor Play" OR "Physical activity" OR "Physical activities" OR ("Recess" AND ("Child" OR "Youth")) OR "Recreational activities" OR "Recreational activity" OR "Screen time" OR "Sedentary" OR "Sedentary lifestyle" OR "Television viewing" OR "Television watching" OR "Tummy time" OR "TV viewing" OR "TV watching" OR "Video game" OR "Video gaming" OR "Vigorous Activities" OR "Vigorous Activity" OR "Walk" OR "Walking" OR "Play and Playthings" OR "Youth sports") |
| Outcomes | AND<br>("Adiposity" OR "Adiposity" OR "Asthma" OR "Asthma" OR "Blood glucose" OR "Blood glucose" OR "Blood lipids" OR "Blood pressure" OR "Blood pressure" OR "Body composition" OR "Body composition" OR "Body Mass Index" OR "Body Mass Index" OR BMI OR "Bone density" OR "Cardiometabolic risk factors" OR "Cardiometabolic risk factor" OR "Dyslipidemia" OR "Dyslipidemias" OR "Dyslipidemias" OR "Fatness" OR "Muscle mass" OR "Musculoskeletal development" OR "Musculoskeletal development" OR "Musculoskeletal fitness" OR "Hyperglycemia" OR "Hyperglycemia" OR "Hypertension" OR "Hypertension" OR "Insulin resistance" OR "Insulin resistance" OR "Metabolic syndrome" OR "Metabolic syndrome X" OR "Obese" OR "Obesity" OR "Obesity" OR "Type 2 Diabetes" OR Diabetes Mellitus, Type 2 OR "Bone mineral content" OR "Bone mineral density" OR "Bone geometry") |
| Age | AND<br>("Baby" OR "Babies" OR "Boy" OR "Boys" OR "Child" OR "Children" OR "Girl" OR "Girls" OR "Infant" OR "Infants" OR "Nursery school" OR "Preschool" OR "Pre school" OR "Preschooler" OR "Pre schooler" OR "Pre-K" OR "Toddler" OR "Toddlers" OR "Child" OR "infant") |
| Limits | 2006–present<br>Word variations not searched |

| Set | Search Terms |
|---|---|
| | Cochrane Reviews and Other Reviews |

**Search Strategy: PubMed (Original Research)**

Database: PubMed; Date of Search: 2/13/2017; 363 results

| Set | Search Strategy |
|---|---|
| Limit: Language | (English[lang]) |
| Limit: Exclude animal only | NOT ("Animals"[mh] NOT ("Animals"[mh] AND "Humans"[mh])) |
| Limit: Exclude adult only | NOT (("adult"[mh] OR "adolescent"[mh]) NOT (("adult"[mh] OR "adolescent"[mh]) AND ("infant"[mh] OR “child, preschool”[mh])) |
| Limit: Exclude subheadings | NOT (ad[sh] OR aa[sh] OR ai[sh] OR ci[sh] OR cn[sh] OR dh[sh] OR de[sh] OR dt[sh] OR em[sh] OR en[sh] OR es[sh] OR eh[sh] OR ge[sh] OR hi[sh] OR is[sh] OR ip[sh] OR lj[sh] OR ma[sh] OR mi[sh] OR og[sh] OR ps[sh] OR py[sh] OR pk[sh] OR pd[sh] OR po[sh] OR re[sh] OR rt[sh] OR rh[sh] OR st[sh] OR sd[sh] OR tu[sh] OR th[sh] OR tm[sh] OR tr[sh] OR ut[sh] OR ve[sh] OR vi[sh]) |
| Limit: Publication Date | AND ("0000/00/00"[PDAT] : "3000/12/31"[PDAT]) |
| Limit: Publication Type Exclude | NOT (“comment”[Publication Type] OR “editorial”[Publication Type] OR “review”[Publication Type] OR systematic[sb] OR "meta-analysis"[publication type] OR “systematic review”[tiab] OR “systematic literature review”[tiab] OR metaanalysis[tiab] OR "meta analysis"[tiab] OR metanalyses[tiab] OR "meta analyses"[tiab] OR "pooled analysis"[tiab] OR “pooled analyses”[tiab] OR "pooled data"[tiab]) |
| Study Design | AND (“Randomized controlled trial”[Publication Type] OR “Randomized controlled”[tiab] OR “Randomised controlled”[tiab] OR “Randomized trial”[tiab] OR “Randomised trial”[tiab] OR “Controlled trial”[tiab] OR “prospective studies”[mh] OR “longitudinal studies”[mh] OR “follow-up studies”[mh] OR (“Cohort”[tiab] AND “Prospective”[tiab]) OR (“Cohort”[tiab] AND “longitudinal”[tiab]) OR (“Cohort”[tiab] AND “Concurrent”[tiab]) OR (“follow*”[tiab] AND “Prospective*”[tiab]) OR (“follow*”[tiab] AND “over time”[tiab])) |
| Physical Activity | AND (("Active games"[tiab] OR "Active recreation"[tiab] OR "Exercise"[mh] OR "Exercise"[tiab] OR "High intensity activities"[tiab] OR "High intensity activity"[tiab] OR "Low intensity activities"[tiab] OR "Low intensity activity"[tiab] OR "Moderate to Vigorous Activities”[tiab] OR "Moderate to Vigorous Activity”[tiab] OR "Muscle-strengthening"[tiab] OR "Physical activity"[tiab] OR ("Recess"[tiab] AND ("Child"[tiab] OR “Child, Preschool”[mh])) OR "Screen time"[tiab] OR "Sedentary lifestyle"[mh] OR "Television viewing"[tiab] OR "Television watching"[tiab] OR "Tummy time"[tiab] OR "TV viewing"[tiab] |

| Set | Search Strategy |
|---|---|
| | OR "TV watching"[tiab] OR "Video game"[tiab] OR "Video gaming"[tiab] OR "Vigorous Activities"[tiab] OR "Vigorous Activity"[tiab] OR "Play and Playthings"[mh]) OR (("Active play"[tiab] OR "Aerobic activities"[tiab] OR "Aerobic activity"[tiab] OR "Cardiovascular activities"[tiab] OR "Cardiovascular activity"[tiab] OR "Free Play"[tiab] OR "Outdoor Play"[tiab] OR "Physical activities"[tiab] OR "Recreational activities"[tiab] OR "Recreational activity"[tiab] OR "Sedentary"[tiab] OR "Walk"[tiab] OR "Walking"[tiab] OR "Youth sports"[tiab]) NOT medline[sb])) |
| Outcomes | AND (("Adiposity"[mh] OR "Asthma"[mh] OR "Blood glucose"[mh] OR "Blood lipids"[tiab] OR "Blood pressure"[mh] OR "Body composition"[mh] OR "Body Mass Index"[mh] OR "Bone density"[mh] OR "Cardiometabolic risk factors"[tiab] OR "Cardiometabolic risk factor"[tiab] OR "Dyslipidemias"[mh] OR "Fatness"[tiab] OR "Muscle mass"[tiab] OR "Musculoskeletal development"[mh] OR "Musculoskeletal fitness"[tiab] OR "Hyperglycemia"[mh] OR "Hypertension"[mh] OR "Insulin resistance"[mh] OR "Metabolic syndrome X"[mh] OR "Obesity"[mh] OR Diabetes Mellitus, Type 2[mh]) OR (("Adiposity"[tiab] OR "Asthma"[tiab] OR "Blood glucose"[tiab] OR "Blood pressure"[tiab] OR "Body composition"[tiab] OR "Body Mass Index"[tiab] OR BMI[tiab] OR "Dyslipidemia"[tiab] OR "Dyslipidemias"[tiab] OR "Musculoskeletal development"[tiab] OR "Hyperglycemia"[tiab] OR "Hypertension"[tiab] OR "Insulin resistance"[tiab] OR "Metabolic syndrome"[tiab] OR "Obese"[tiab] OR "Obesity"[tiab] OR "Type 2 Diabetes"[tiab] OR "Bone mineral content"[tiab] OR "Bone mineral density"[tiab] OR "Bone geometry"[tiab]) NOT medline[sb])) |
| Age | AND ((Infant[mh] OR “Child, Preschool”[mh]) OR (("Baby"[tiab] OR "Babies"[tiab] OR "Child"[tiab] OR "Children"[tiab] OR "Infant"[tiab] OR "Infants"[tiab] OR "Nursery school"[tiab] OR "Preschool"[tiab] OR "Pre school"[tiab] OR "Preschooler"[tiab] OR "Pre schooler"[tiab] OR "Pre-K"[tiab] OR "Toddler"[tiab] OR "Toddlers"[tiab] OR “pediatric”[tiab]) NOT medline[sb])) |

**Search Strategy: CINAHL (Original Research)**

Database: CINAHL; Date of Search: 2/8/2017; 21 results
Terms searched in title or abstract

| Set | Search Terms |
|---|---|
| Study Design | (“Randomized controlled” OR “Randomised controlled” OR “Randomized trial” OR “Randomised trial” OR “Controlled trial” OR “prospective study” OR “longitudinal study” OR “follow-up study” OR (“Cohort” AND “Prospective”) OR (“Cohort” AND “longitudinal”) OR (“Cohort” AND “Concurrent”) OR (“follow” AND “Prospective”) OR (“follow” AND “over time”)) |
| Physical Activity | AND ("Active games" OR "Active recreation" OR "Exercise" OR "High intensity activities" OR "High intensity activity" OR "Low intensity activities" OR "Low intensity activity" OR "Moderate to Vigorous Activities” OR "Moderate to Vigorous Activity” OR "Muscle-strengthening" OR "Physical activity" OR ("Recess" AND "Child") OR "Screen time" OR "Sedentary lifestyle" OR "Television viewing" OR "Television watching" OR "Tummy time" OR "TV viewing" OR "TV watching" OR "Video game" OR "Video gaming" OR "Vigorous Activities" OR "Vigorous Activity" OR "Play and Playthings" OR "Active play" OR "Aerobic activities" OR "Aerobic activity" OR "Cardiovascular activities" OR "Cardiovascular activity" OR "Free Play" OR "Outdoor Play" OR "Physical activities" OR "Recreational activities" OR "Recreational activity" OR "Sedentary" OR "Walk" OR "Walking" OR "Youth sports") |
| Outcomes | AND ("Adiposity" OR "Adiposity" OR "Asthma" OR "Asthma" OR "Blood glucose" OR "Blood glucose" OR "Blood lipids" OR "Blood pressure" OR "Blood pressure" OR "Body composition" OR "Body composition" OR "Body Mass Index" OR "Body Mass Index" OR BMI OR "Bone density" OR "Cardiometabolic risk factors" OR "Cardiometabolic risk factor" OR "Dyslipidemia" OR "Dyslipidemias" OR "Dyslipidemias" OR "Fatness" OR "Muscle mass" OR "Musculoskeletal development" OR "Musculoskeletal development" OR "Musculoskeletal fitness" OR "Hyperglycemia" OR "Hyperglycemia" OR "Hypertension" OR "Hypertension" OR "Insulin resistance" OR "Insulin resistance" OR "Metabolic syndrome" OR "Metabolic syndrome X" OR "Obese" OR "Obesity" OR "Obesity" OR "Type 2 Diabetes" OR Diabetes Mellitus, Type 2 OR "Bone mineral content" OR "Bone mineral density" OR "Bone geometry") |
| Age | AND (“Infant” OR “Infants” OR "Baby" OR "Babies" OR "Child" OR "Children" OR "Nursery school" OR "Preschool" OR "Pre school" OR "Preschooler" OR "Pre schooler" OR "Pre-K" OR "Toddler" OR "Toddlers" OR “pediatric”) |
| Limits | English language<br>Peer reviewed |

| Set | Search Terms |
|---|---|
| | Exclude Medline records<br>Human |

**Search Strategy: Cochrane (Original Research)**

Database: Cochrane; Date of Search: 2/10/2017; 765 results

Terms searched in title, abstract, or keywords

| Set | Search Terms |
|---|---|
| Study Design | [mh “prospective studies”] OR |
| | [mh “longitudinal studies”] OR |
| | [mh “follow-up studies”] OR |
| | (“Randomized controlled” OR “Randomised controlled” OR “Randomized trial” OR “Randomised trial” OR “Controlled trial” OR (“Cohort” AND “Prospective”) OR (“Cohort” AND “longitudinal”) OR (“Cohort” AND “Concurrent”) OR (“follow” AND “Prospective”) OR (“follow” AND “over time”)) |
| Physical Activity | [mh Exercise] OR |
| | [mh “sedentary lifestyle”] OR |
| | [mh “play and playthings”] OR |
| | ("Active games" OR "Active recreation" OR "High intensity activities" OR "High intensity activity" OR "Low intensity activities" OR "Low intensity activity" OR "Moderate to Vigorous Activities” OR "Moderate to Vigorous Activity” OR "Muscle-strengthening" OR "Physical activity" OR ("Recess" AND "Child") OR "Screen time" OR "Television viewing" OR "Television watching" OR "Tummy time" OR "TV viewing" OR "TV watching" OR "Video game" OR "Video gaming" OR "Vigorous Activities" OR "Vigorous Activity" OR "Active play" OR "Aerobic activities" OR "Aerobic activity" OR "Cardiovascular activities" OR "Cardiovascular activity" OR "Free Play" OR "Outdoor Play" OR "Physical activities" OR "Recreational activities" OR "Recreational activity" OR "Sedentary" OR "Walk" OR "Walking" OR "Youth sports") |
| Outcomes | [mh "Adiposity"] |
| | [mh "Asthma"] |
| | [mh "Blood glucose"] |
| | [mh "Blood pressure"] |
| | [mh "Body composition"] |
| | [mh "Body Mass Index"] |
| | [mh "Bone density"] |
| | [mh "Dyslipidemias"] |
| | [mh "Musculoskeletal development”] |
| | [mh "Hyperglycemia"] |

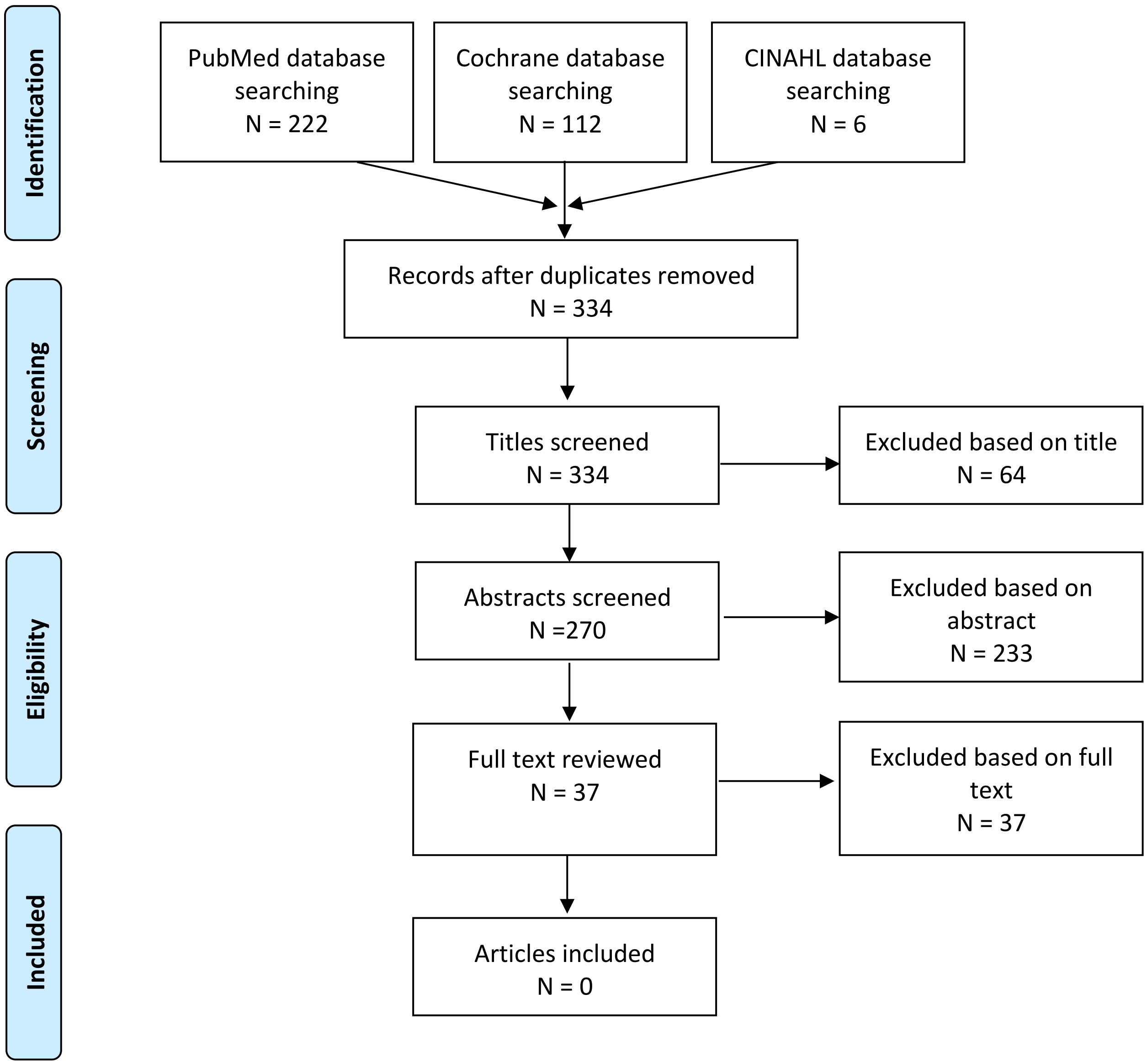
| Set | Search Terms |
|---|---|
| | [mh "Hypertension"] |
| | [mh "Insulin resistance"] |
| | [mh "Metabolic syndrome X"] |
| | [mh "Obesity"] |
| | [mh “Diabetes Mellitus, Type 2”] |
| | ("Blood lipids" OR "Blood pressure" OR "Cardiometabolic risk factors" OR "Cardiometabolic risk factor" OR "Fatness" OR "Muscle mass" OR "Musculoskeletal fitness" OR "Adiposity" OR "Asthma" OR "Blood glucose" OR "Body composition" OR "Body Mass Index" OR BMI OR "Dyslipidemia" OR "Dyslipidemias" OR "Musculoskeletal development" OR "Hyperglycemia" OR "Hypertension" OR "Insulin resistance" OR "Metabolic syndrome" OR "Obese" OR "Obesity" OR "Type 2 Diabetes" OR "Bone mineral content" OR "Bone mineral density" OR "Bone geometry") |
| Age | [mh infant] OR |
| | [mh “child, preschool”] OR |
| | “Infant” OR “Infants” OR "Baby" OR "Babies" OR "Child" OR "Children" OR "Nursery school" OR "Preschool" OR "Pre school" OR "Preschooler" OR "Pre schooler" OR "Pre-K" OR "Toddler" OR "Toddlers" OR “pediatric” |
| Limits | Trials<br>Word variations not searched |

**Supplementary Strategies:**

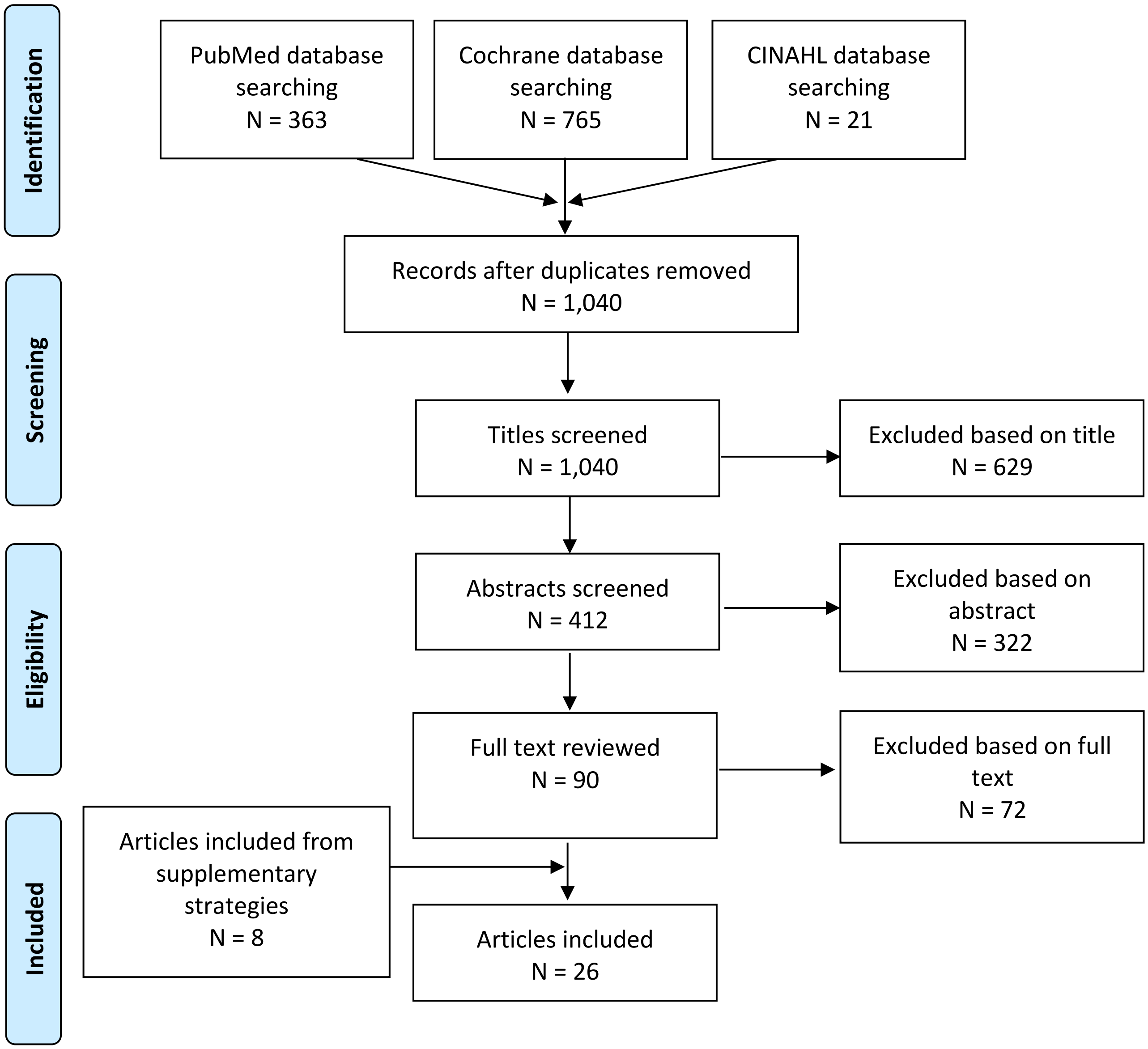
The Physical Activity Guidelines Youth Sub-committee used a supplementary search strategy—expert consultation. Members suggested relevant reviews that were not captured by the search strategies. Eight relevant articles were identified: Gruodyte-Raciene et al[16]; Janz et al[19]; Janz et al[21]; Klesges and Eck[5]; Metcalf et al[7]; Moore et al[9]; Sääkslahti et al[12]; Sugimori et al.[13]

## Appendix C: Literature Tree

***Existing Systematic Reviews, Meta-Analyses, Pooled Analyses, and Reports Literature Tree***



*Original Research Literature Tree*



## Appendix D: Inclusion/Exclusion Criteria

**Youth Subcommittee**

**Q1: In children younger than age 6 years, is physical activity related to health outcomes?**

a. What is the relationship between physical activity and adiposity/weight status?
b. What is the relationship between physical activity and bone health?
c. What is the relationship between physical activity and cardiometabolic health?
d. Are there dose-response relationships? If so, what are the shapes of those relationships?
e. Do the relationships vary by age, sex, race/ethnicity, weight status, or socio-economic status?

| Category | Inclusion/Exclusion Criteria | Notes/Rationale |
|---|---|---|
| **Publication Language** | **Include:**<br>• Studies published with full text in English | |
| **Publication Status** | **Include:**<br>• Studies published in peer-reviewed journals<br>• Reports determined to have appropriate suitability and quality by PAGAC<br><br>**Exclude:**<br>• Grey literature, including unpublished data, manuscripts, abstracts, conference proceedings | |
| **Research Type** | **Include:**<br>• Original research<br>• Meta-analyses<br>• Systematic reviews<br>• Reports determined to have appropriate suitability and quality by PAGAC | |
| **Study Subjects** | **Include:**<br>• Human subjects | |
| **Age of Study Subjects** | **Include:**<br>• Children ages 0–6<br>• Studies of preschool children<br>• When data are analyzed by age groups, only data with upper age range of 5 may be included (e.g., in a study with individuals 0–18 where data are presented for multiple age groups, only data for 5 and younger may be included). Note one exception to this: studies can be included if data have an upper age range of 6 AND are collected in the preschool setting<br>**Exclude:**<br>• Studies that only present data for children in grades K–12 regardless of age (studies that present data for preschool and K–12 are ok) | Focus must be on children ages 0–6 to be relevant to this question |

| | | |
|---|---|---|
| **Health Status of Study Subjects** | **Include:**<br>• Healthy children<br>• Overweight or obese children<br>**Exclude:**<br>• Children with disabilities<br>• Children with chronic conditions | |
| **Date of Publication** | **Include:**<br>• Original research published whenever<br>• Systematic reviews and meta-analyses published 2006–present | |
| **Study Design** | **Include:**<br>• Randomized trials<br>• Non-randomized trials<br>• Prospective cohort studies<br>• Retrospective cohort studies<br>• Case-control studies<br>• Before-After studies<br>• Time series<br>• Systematic reviews<br>• Meta-analyses<br>• Reports<br><br>**Exclude:**<br>• Narrative reviews<br>• Commentaries<br>• Editorials<br>• Cross-sectional studies<br>• Study protocol | |
| **Intervention/ Exposure** | **Include studies in which the exposure or intervention is:**<br>• All types and intensities of physical activity<br><br>**Exclude:**<br>• Studies that do not include physical activity (or the lack thereof) as the primary exposure variable or used solely as a confounding variable<br>• Studies of a specific therapeutic exercise delivered by a medical professional (e.g., physical therapist) | |
| **Outcome** | **Include studies in which the outcome is:**<br>• Adiposity<br>• Asthma<br>• Blood pressure<br>• Body composition<br>• Bone, bone mineral content, bone geometry, bone mineral density | |

| | | |
|---|---|---|
| | • Cardiometabolic risk factors<br>• Fatness<br>• Gross motor movement<br>• Gross motor skill development<br>• Growth<br>• Motor skill competence<br>• Muscle mass, lean mass<br>• Musculoskeletal development and fitness<br>• Physical fitness<br>• Weight (underweight, normal, overweight, obese)<br>• Weight status<br>• Weight trajectory change | |

## Appendix E: Rationale for Exclusion at Abstract or Full-Text Triage for Existing Systematic Reviews, Meta-Analyses, Pooled Analyses, and Reports

The table below lists the excluded articles with at least one reason for exclusion, but may not reflect all possible reasons.

| Citation | Outcome | Population | Study Design | Exposure | Not ideal fit for replacement of de novo search | Other |
|---|---|---|---|---|---|---|
| Adachi-Mejia AM, Longacre MR, Gibson JJ, Beach ML, Dalton LTTitus-ErnstoffandMA. Children with a TV in their bedroom at higher risk for being overweight. Int J Obes (Lond). 2007. 31(4):644-51 | | X | | X | | |
| Adair ET, Zioumisand LS. Childhood dual burden of under- and overnutrition in low- and middle-income countries: a critical review. Food Nutr Bull. 2014. 35(2):230-43. | | | | X | | |
| Adatia I, Haworth SG, Wegner M, et al. Clinical trials in neonates and children: report of the pulmonary hypertension academic research consortium pediatric advisory committee. *Pulm Circ.* 2013;3(1):252-266. doi:10.4103/2045-8932.109931. | | | | X | | |
| Aftosmes-Tobio A, Ganter C, Gicevic S, et al. A systematic review of media parenting in the context of childhood obesity research. *BMC Public Health.* 2016;16:320. doi:10.1186/s12889-016-2981-5. | | | | X | | |
| Aguilar Cordero MJ, Ortegon Pinero A, Mur Vilar N, Sanchez Garcia JC, Garcia Verazaluce JJ, Sanchez Lopez I, Garcia Garcia AM. Physical activity programmes to reduce overweight and obesity in children and adolescents; a systematic review. Nutr Hosp. 2014. 30(4):727-740 | | | | | | X |
| Alberdi G, McNamara AE, Lindsay KL, et al. The association between childcare and risk of childhood overweight and obesity in children aged 5 years and under: a systematic review. *Eur J Pediatr*. 2016;175(10):1277-1294. doi:10.1007/s00431-016-2768-9. | | | | X | | |
| Alexander D, Rigby MJ, Di Mattia P, Zscheppang A. Challenges in finding and measuring behavioural determinants of childhood obesity in Europe. *Z Gesundh Wiss.* 2015;23(2):87-94. | X | | | | | |
| Ansa SA, Smith B. A systematic review of lifestyle interventions for chronic diseases in rural communities. J Ga Public Health Assoc. 2016. 5(4):304-313 | X | X | | X | | |
| Antwi F, Fazylova N, Garcon MC, Lopez L, Rubiano R, Slyer JT. The effectiveness of web-based programs on the reduction of childhood obesity in school-aged children: a systematic review. *JBI Libr Syst Rev.* 2012;10(suppl 42):1-14. | | X | | | | |
| Arteburn DE. Obesity in children. *BMJ Clin Evid*. May 2007. | | | X | | | |

| Citation | Outcome | Population | Study Design | Exposure | Not ideal fit for replacement of de novo search | Other |
|---|---|---|---|---|---|---|
| Atkin AJ, Ekelund U, Moller NC, et al. Sedentary time in children: influence of accelerometer processing on health relations. *Med Sci Sports Exerc.* 2013;45(6):1097-1104. doi:10.1249/MSS.0b013e318282190e. | X | X | | | | |
| Atlantis E, Barnes EH, Singh MA. Efficacy of exercise for treating overweight in children and adolescents: a systematic review. *Int J Obest (Lond).* 2006;30(7):1027-1040. | | X | | | | |
| Azevedo LB, Ling J, Soos I, Robalino S, Ells L. Effectiveness of sedentary behaviour interventions on body mass index in children: systematic review and meta-analysis: 1410 Board #63 June 2, 9: 00 AM - 10: 30 AM. *Med Sci Sports Exerc*. 2016;48(5 suppl 1):375. | | | | | X | |
| Azevedo LB, Ling J, Soos I, Robalino S, Ells L. The effectiveness of sedentary behaviour interventions for reducing body mass index in children and adolescents: systematic review and meta-analysis. *Obes Rev*. 2016;17(7):623-635. doi:10.1111/obr.12414. | | X | | | | |
| Bäcklund C, Sundelin G, Larsson C. Effect of a 1-year lifestyle intervention on physical activity in overweight and obese children. *Adv Physiother.* 2011;13(3):87-96. | | X | | | | |
| Bäcklund C, Sundelin G, Larsson C. Effects of a 2-year lifestyle intervention on physical activity in overweight and obese children. *Adv Physiother.* 2011;13(3):97-109. | | X | | | | |
| Barr-Anderson DJ, Adams-Wynn AW, DiSantis KI, Kumanyika S. Family-focused physical activity, diet and obesity interventions in African-American girls: a systematic review. *Obes Rev.* 2013;14(1):29-51. doi:10.1111/j.1467-789X.2012.01043.x. | | | | X | | |
| Beets MW, Beighle A, Erwin HE, Huberty JL. After-school program impact on physical activity and fitness: a meta-analysis. *Am J Prev Med*. 2009;36(6):527-537. doi:10.1016/j.amepre.2009.01.033. | | X | | | | |
| Benton PM, Skouteris H, Hayden M. Does maternal psychopathology increase the risk of pre-schooler obesity? A systematic review. Appetite. 2015 Apr;87:259-82. doi: 10.1016/j.appet.2014.12.227. | X | | | X | | |
| Berge JM. A review of familial correlates of child and adolescent obesity: what has the 21st century taught us so far? *Int J Adolesc Med Health*. 2009;21(4):457-483. | X | | | | | |
| Berge JM, Everts JC. Family-based interventions targeting childhood obesity: a meta-analysis. *Child* | X | | | X | | |

| Citation | Outcome | Population | Study Design | Exposure | Not ideal fit for replacement of de novo search | Other |
|---|---|---|---|---|---|---|
| *Obes.* 2011;7(2):110-121. doi:10.1089/chi.2011.07.02.1004.berge. | | | | | | |
| Bielemann RM, Gigante JMartinez-MesaandDP. Bielemann RM, Martinez-Mesa J, Gigante DP. Physical activity during life course and bone mass: a systematic review of methods and findings from cohort studies with young adults. BMC Musculoskeletal Disorders. 2013;14:77. doi:10.1186/1471-2474-14-77. BMC Musculoskelet Disord. 2013. 14(#issue#):77 | | X | | | | |
| Birch L, Perry R, Penfold C, Beynon R, Hamilton-Shield J. What change in body mass index is needed to improve metabolic health status in childhood obesity: protocol for a systematic review. *Syst Rev.* 2016;5(1):120. doi:10.1186/s13643-016-0299-0. | | | X | | | |
| Bleich SN, Ku R, Wang YC. Relative contribution of energy intake and energy expenditure to childhood obesity: a review of the literature and directions for future research. *Int J Obes (Lond).* 2011;35(1):1-15. doi:10.1038/ijo.2010.252. | | X | | | | |
| Blewitt C, Bergmeier H, Macdonald JA, Olsson CA, Skouteris H. Associations between parent-child relationship quality and obesogenic risk in adolescence: a systematic review of recent literature. Obes Rev. 2016. 17(7):612-22 | X | | | | | |
| Blohm D, Ploch T, Apelt S. Efficacy of exercise therapy to reduce cardiometabolic risk factors in overweight and obese children and adolescents: a systematic review. *Dtsch Med Wochenschr.* 2012;137(50):2631-2636. doi:10.1055/s-0032-1327333. | | | | | | X |
| Bochner RE, Sorensen KM, Belamarich PF. The impact of active video gaming on weight in youth: a meta-analysis. *Clin Pediatr (Phila).* 2015;54(7):620-628. doi:10.1177/0009922814545165. | | X | | | | |
| Borrelli B, Tooley M, Scott-Sheldon LA. Motivational Interviewing for Parent-child Health Interventions: A Systematic Review and Meta-Analysis. Pediatr Dent. 2015. 37(3):254-65 | X | | | X | | |
| Brown EC, Buchan DS, Baker JS, Wyatt FB, Bocalini DS, Kilgore L. A systematised review of primary school whole class child obesity interventions: effectiveness, characteristics, and strategies. *Biomed Res Int.* 2016;2016:4902714. doi:10.1155/2016/4902714. | | X | | | | |
| Brown T, Summerbell C. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: an update to the | | X | | | | |

| Citation | Outcome | Population | Study Design | Exposure | Not ideal fit for replacement of de novo search | Other |
|---|---|---|---|---|---|---|
| obesity guidance produced by the National Institute for Health and Clinical Excellence. *Obes Rev.* 2009;10(1):110-141. doi:10.1111/j.1467-789X.2008.00515.x. | | | | | | |
| Bryant MJ, Lucove JC, Evenson kr, Marshall S. Measurement of television viewing in children and adolescents: a systematic review. Obes Rev. 2007. 8(3):197-209 | | | X | X | | |
| Bustamante EE, Williams CF, Davis CL. Physical Activity Interventions for Neurocognitive and Academic Performance in Overweight and Obese Youth: A Systematic Review. Pediatr Clin North Am. 2016. 63(3):459-80 | | X | | | | |
| Caleyachetty R, Echouffo-Tcheugui JB, Tait CA, Schilsky S, Forrester T, Kengne AP. Prevalence of behavioural risk factors for cardiovascular disease in adolescents in low-income and middle-income countries: an individual participant data meta-analysis. *Lancet Diabetes Endocrinol*. 2015;3(7):535-544. doi:10.1016/S2213-8587(15)00076-5. | | X | | | | |
| Cameron AJ, Spence AC, Laws R, Hesketh KD, Lioret S, Campbell KJ. A Review of the Relationship Between Socioeconomic Position and the Early-Life Predictors of Obesity. Curr Obes Rep. 2015. 4(3):350-62 | X | | | | | |
| Canoy D, Bundred P. Obesity in children. *BMJ Clin Evid.* 2011;2011. | | X | | | | |
| Carlin A, Murphy MH, Gallagher AM. Do interventions to increase walking work? A systematic review of interventions in children and adolescents. *Sports Med.* 2016;46(4):515-530. doi:10.1007/s40279-015-0432-6. | | X | | | | |
| Carson V, Hunter S, Kuzik N, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. *Appl Physiol Nutr Metab*. 2016;41(6 suppl 3):S240-S65. doi:10.1139/apnm-2015-0630. | | X | | | | |
| Carver TW. Exercise-induced asthma: critical analysis of the protective role of montelukast. J Asthma Allergy. 2009 Oct 22;2:93-103. | | | X | | | |
| Cassim R, Koplin JJ, Dharmage SC, Senaratna BC, Lodge CJ, Lowe AJ, Russell MA. The difference in amount of physical activity performed by children with and without asthma: A systematic review and meta-analysis. J Asthma. 2016. 53(9):882-92 | X | | | | | |
| Cattuzzo MT, Dos Santos Henrique R, Ré AH, et al. Motor competence and health related physical fitness in youth: a systematic review. *J Sci Med Sport.* 2016;19(2):123-129. doi:10.1016/j.jsams.2014.12.004. | | | | X | | |

| Citation | Outcome | Population | Study Design | Exposure | Not ideal fit for replacement of de novo search | Other |
|---|---|---|---|---|---|---|
| Chai LK, Burrows T, May C, Brain K, Wong See D, Collins C. Effectiveness of family-based weight management interventions in childhood obesity: an umbrella review protocol. *JBI Database System Rev Implement Rep.* 2016;14(9):32-39. | | X | | | X | |
| Chaplais E, Naughton G, Thivel D, Courteix D, Greene D. Smartphone interventions for weight treatment and behavioral change in pediatric obesity: a systematic review. *Telemed J E Health*. 2015;21(10):822-830. doi:10.1089/tmj.2014.0197. | | X | X | | X | |
| Chen SR, Chiu HW, Lee YJ, Sheen TC, Jeng C. Impact of pubertal development and physical activity on heart rate variability in overweight and obese children in Taiwan. *J Sch Nurs.* 2012;28(4):284-290. doi:10.1177/1059840511435248. | | X | | | | |
| Chen YC, Tu YK, Huang KC, Chen PC, Chu DC, Lee YL. Pathway from central obesity to childhood asthma. Physical fitness and sedentary time are leading factors. Am J Respir Crit Care Med. 2014. 189(10):1194-203 | | X | | | | |
| Chinapaw MJ, Proper KI, Brug J, van Mechelen W, Singh AS. Relationship between young peoples' sedentary behaviour and biomedical health indicators: a systematic review of prospective studies. *Obes Rev.* 2011;12(7):e621-e632. doi:10.1111/j.1467-789X.2011.00865.x. | | X | | | | |
| Ciampa PJ, Kumar D, Barkin SL, et al. Interventions aimed at decreasing obesity in children younger than 2 years: a systematic review. *Arch Pediatr Adolesc Med*. 2010;164(12):1098-1104. doi:10.1001/archpediatrics.2010.232. | | | | | X | |
| Clark JE. Does the type of intervention method really matter for combating childhood obesity? A systematic review and meta-analysis. *J Sports Med Phys Fitness.* 2014;55(12):1524-1543. | | X | | | | |
| Cliff DP, Hesketh KD, Vella SA, et al. Objectively measured sedentary behaviour and health and development in children and adolescents: systematic review and meta-analysis. *Obes Rev.* 2016;17(4):330-344. doi:10.1111/obr.12371. | | X | | | | |
| Colquitt JL, Loveman E, O'Malley C, et al. Diet, physical activity, and behavioural interventions for the treatment of overweight or obesity in preschool children up to the age of 6 years. *Cochrane Database Syst Rev.* 2016;(3):CD012105. doi:10.1002/14651858.CD012105. | | | | | X | |
| Concert CM, Burke RE, Eusebio AM, Slavin EA, Shortridge-Baggett LM. The Effectiveness of Motivational Interviewing on Glycemic Control for Adults with Type 2 Diabetes Mellitus (DM2): A | | X | | X | | |

| Citation | Outcome | Population | Study Design | Exposure | Not ideal fit for replacement of de novo search | Other |
|---|---|---|---|---|---|---|
| Systematic Review. JBI Libr Syst Rev. 2012. 10(42 Suppl):1-17 | | | | | | |
| Costa S, Adams J, Phillips V, Benjamin Neelon SE. The relationship between childcare and adiposity, body mass and obesity-related risk factors: protocol for a systematic review of longitudinal studies. Syst Rev. 2016. 5(1):141 | | | X | | | |
| Cradock AL, Barrett JL, Kenney EL, et al. Using cost-effectiveness analysis to prioritize policy and programmatic approaches to physical activity promotion and obesity prevention in childhood. *Prev Med.* 2017;95(suppl):S17-S27. doi:10.1016/j.ypmed.2016.10.017. | | | X | | | |
| Craigie AM, Lake AA, Kelly SA, Adamson AJ, Mathers JC. Tracking of obesity-related behaviours from childhood to adulthood: a systematic review. *Maturitas*. 2011;70(3):266-284. doi:10.1016/j.maturitas.2011.08.005. | X | X | | | | |
| Davison KK, Gicevic S, Aftosmes-Tobio A, Ganter C, Simon CL, Manganello S, Newlanand JA, Davison KK, Gicevic S, Aftosmes-Tobio A, et al. Fathers' Representation in Observational Studies on Parenting and Childhood Obesity: A Systematic Review and Content Analysis. American Journal of Public Health. 2016;106(11):e14-e21. doi:10.2105/AJPH.2016.303391. Am J Public Health. 2016. 106(11):1980 | X | X | | | | |
| De Bourdeaudhuij I, Van Cauwenberghe E, Spittaels H, et al. School-based interventions promoting both physical activity and healthy eating in Europe: a systematic review within the HOPE project. *Obes Rev.* 2011;12(3):205-216. doi:10.1111/j.1467-789X.2009.00711.x. | | X | | | | |
| Dellert JC, Johnson P. Interventions with children and parents to improve physical activity and body mass index: a meta-analysis. *Am J Health Promot*. 2014;28(4):259-267. doi:10.4278/ajhp.120628-LIT-313. | X | X | | | | |
| DeMattia L, Lemont L, Meurer L. Do interventions to limit sedentary behaviours change behaviour and reduce childhood obesity? A critical review of the literature. *Obes Rev*. 2007;8(1):69-81. | | X | | | | |
| Demetriou Y, Höner O. Physical activity interventions in the school setting: a systematic review. *Psychology of Sport and Exercise.* 2012;13(2):186-196. doi:10.1016/j.psychsport.2011.11.006. | | X | | | | |
| Dennison ME, Sisson SB, Lora K, Stephens LD, Copeland KC, Caudillo C. Assessment of body mass index, sugar sweetened beverage intake and time spent in physical activity of American Indian | | | X | | | |

| Citation | Outcome | Population | Study Design | Exposure | Not ideal fit for replacement of de novo search | Other |
|---|---|---|---|---|---|---|
| children in Oklahoma. *J Community Health*. 2015;40(4):808-814. doi:10.1007/s10900-015-0004-6. | | | | | | |
| Dunton GF, Kaplan J, Wolch J, Jerrett M, Reynolds KD. Physical environmental correlates of childhood obesity: a systematic review. *Obes Rev*. 2009;10(4):393-402. doi:10.1111/j.1467-789X.2009.00572.x. | | X | | | | |
| Ekelund U, Luan J, Sherar LB, Esliger DW, Griew P, Cooper A; International Children's Accelerometry Database (ICAD) Collaborators. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. JAMA. 2012;307(7):704-712. doi:10.1001/jama.2012.156. | | X | | | | |
| Escalante Y, Saavedra JM, García-Hermoso A, Domínguez AM. Improvement of the lipid profile with exercise in obese children: a systematic review. *Prev Med.* 2012;54(5):293-301. doi:0.1016/j.ypmed.2012.02.006. | | X | | | | |
| Fasanmade OA, Dagogo-Jack S. Diabetes Care in Nigeria. Ann Glob Health. 2015. 81(6):821-9 | | | | X | | |
| Fedewa MV, Gist NH, Evans EM, Dishman RK. Exercise and insulin resistance in youth: a meta-analysis. 2014;133(1):e163-e174. doi:10.1542/peds.2013-2718. | | X | | | | |
| Ferreira I, van der Horst K, Wendel-Vos W, Kremers S, van Lenthe FJ, Brug J. Environmental correlates of physical activity in youth—a review and update. *Obes Rev.* 2007;8(2):129-154. | X | X | | X | | |
| Fisberg M, Maximino P, Kain J, Kovalskys I. Obesogenic environment—intervention opportunities. *J Pediatr (Rio J).* 2016;92(3 suppl 1):S30-S39. doi:10.1016/j.jped.2016.02.007. | X | X | | X | | |
| Flak AL, Tark JY, Tinker SC, Correa A, Cogswell ME. Major, Non-Chromosomal, Birth Defects and Maternal Physical Activity: A Systematic Review. *Birth defects research Part A, Clinical and molecular teratology*. 2012;94(7):521-531. doi:10.1002/bdra.23017. | X | | | | | |
| Fleischhacker S, Roberts E, Camplain R, Evenson KR, Gittelsohn J. Promoting physical activity among Native American youth: a systematic review of the methodology and current evidence of physical activity interventions and community-wide initiatives. *J Racial Ethn Health Disparities*. 2016;3(4):608-624. | X | X | | X | | |
| Flodmark CE, Marcus C, Britton M. Interventions to prevent obesity in children and adolescents: a systematic literature review. *Int J Obes (Lond).* 2006;30(4):579-589. | | X | | | | |

| Citation | Outcome | Population | Study Design | Exposure | Not ideal fit for replacement of de novo search | Other |
|---|---|---|---|---|---|---|
| Foulds HJ, Rodgers CD, Duncan V, Ferguson LJ. A systematic review and meta-analysis of screen time behaviour among North American indigenous populations. Obes Rev. 2016. 17(5):455-66 | X | | | X | | |
| Frerichs L, Ataga O, Corbie-Smith G, Tessler Lindau S. Child and youth participatory interventions for addressing lifestyle-related childhood obesity: a systematic review. *Obes Rev.* 2016;17(12):1276-1286. doi:10.1111/obr.12468. | | | | X | | |
| Galantino ML, Galbavy R, Quinn L. Therapeutic effects of yoga for children: a systematic review of the literature. *Pediatr Phys Ther.* 2008;20(1):66-80. doi:10.1097/PEP.0b013e31815f1208. | | X | | | | |
| Gao Z, Chen S. Are field-based exergames useful in preventing childhood obesity? A systematic review. *Obes Rev.* 2014;15(8):676-691. doi:10.1111/obr.12164. | | X | | | | |
| García-Hermoso A, Carmona-López MI, Saavedra JM, Escalante Y. Physical exercise, detraining and lipid profile in obese children: a systematic review. *Arch Argent Pediatr.* 2014;112(6):519-525. doi:10.1590/S0325-00752014000600007. | | | | | | X |
| Garcia-Hermoso A, Saavedra JM, Escalante Y. Effects of exercise on resting blood pressure in obese children: a meta-analysis of randomized controlled trials. *Obes Rev.* 2013;14(11):919-928. doi:10.1111/obr.12054. | | X | | | | |
| García-Hermoso A, Sánchez-López M, Escalante Y, Saavedra JM, Martínez-Vizcaíno V. Exercise-based interventions and C-reactive protein in overweight and obese youths: a meta-analysis of randomized controlled trials. *Pediatr Res.* 2016;79(4):522-527. doi:10.1038/pr.2015.274. | | X | | | | |
| Goettems ML, Schuch HS, Hallal PC, Torriani DD, Demarco FF. Nutritional status and physical activity level as risk factor for traumatic dental injuries occurrence: a systematic review. *Dental Traumatology*. 2014;30(4):251-258. doi:10.1111/edt.12102. | X | | | | | |
| Golley RK, Hendrie GA, Slater A, Corsini N. Interventions that involve parents to improve children's weight-related nutrition intake and activity patterns—what nutrition and activity targets and behaviour change techniques are associated with intervention effectiveness? 2011;12(2):114-130. doi:10.1111/j.1467-789X.2010.00745.x. | X | X | | X | | |
| Gomes TN, Katzmarzyk PT, dos Santos FK, Souza M, Pereira S, Maia JA. Overweight and obesity in Portuguese children: prevalence and correlates. | | X | | | | |

| Citation | Outcome | Population | Study Design | Exposure | Not ideal fit for replacement of de novo search | Other |
|---|---|---|---|---|---|---|
| *Int J Environ Res Public Health*. 2014;11(11):11398-11417. doi:10.3390/ijerph111111398. | | | | | | |
| Gorga E, Regazzoni V, Bansilal S, et al. School and family-based interventions for promoting a healthy lifestyle among children and adolescents in Italy: a systematic review. *J Cardiovasc Med (Hagerstown).* 2016;17(8):547-555. doi:10.2459/JCM.0000000000000404. | X | X | | | | |
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## Rationale for Exclusion at Abstract or Full-Text Triage for Original Research

The table below lists the excluded articles with at least one reason for exclusion, but may not reflect all possible reasons.

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| Citation | Outcome | Population | Study Design | Exposure | Other |
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| Citation | Outcome | Population | Study Design | Exposure | Other |
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