Objectively Measured Physical Activity Patterns in Children With Overweight and (Morbid) Obesity Across Different Weight Categories, Age Groups and Gender; Baseline Data of a Multidisciplinary Tailored Intervention Program

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Research

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Abstract

Background

Reduced physical activity (PA) is associated with childhood obesity and is a target for intervention. This study aimed to assess objectively measured PA patterns in Dutch children across weight categories, age groups and gender at the start of a lifestyle intervention.

Methods

202 children with overweight and (morbid) obesity (55% girls, 12 ± 3y of age, BMI z-score +3.15 ± 0.73), referred to the Centre for Overweight Adolescents and Children's Healthcare (COACH, Maastricht UMC+) were included. Children were categorized as overweight, obese or morbidly obese according to their BMI z-score. PA was measured with the GT3X Actigraph accelerometer.

Results

PA levels in children with morbid obesity were higher compared to children with obesity, also after correction for age and gender (corrected difference (B) 118 counts per minute (cpm), p = .006). Sedentary behaviour (SB) was lower in children with morbid obesity compared to children with obesity (B -51 min/day, p = .018). Girls performed significantly less moderate to vigorous PA than boys (B -11 min/day, p < .001) and with increasing age, children performed less PA (B -46 cpm, p < .001) and SB increased (B 18 min/day, p < .001).

Conclusion

Weight category morbid obesity, lower age and male gender were positively associated with PA and negatively with SB. These findings highlight the need for tailored PA promotion.

Trial registration: The trial is registered with Clinicaltrials.gov NCT02091544. Registration date: March, 19th, 2014. (https://clinicaltrials.gov/ct2/show/NCT02091544?term=NCT02091544&draw=2&rank=1)

Introduction

Over the last few decades, childhood overweight and obesity rates have increased globally. In the Netherlands approximately 11.9% of primary school children (4–12 year-old) and 11.6% of adolescents (12–16 year-old) are overweight, of which 3.4% and 1.6% respectively are obese. Alarmingly, morbid obesity is the fastest growing subcategory of childhood obesity also in the Netherlands. Obesity in children has serious adverse cardiovascular and metabolic consequences and has been shown to track into adulthood. Therefore, it is of great importance to treat obesity in its earliest stage.

Reduced physical activity (PA) combined with increased sedentary behaviour (SB) may play an important role in childhood overweight and obesity development. The World Health Organization, as well as the Dutch government, recommend that children and adolescents should spend a minimum of 60 minutes in moderate to vigorous PA (MVPA) each day, more vigorous intensity activities should be included when possible and SB should be minimalized. Subjectively measured data showed that 45% of Dutch children (4–11 year-old) and 69% of adolescents (aged 12–18 years) do not meet these public health guidelines. It is expected that the prevalence of children and adolescents with obesity meeting the activity guidelines is lower, since research has shown that children with overweight and obesity are less frequently physically active compared to their normal-weight peers.

PA promotion plays a central role in the treatment of children with overweight and (morbid) obesity. Tailored interventions are refined and customized to an individual’s situation and needs. To develop such tailored interventions, insight in differences in PA patterns between subgroups is necessary. So far, little is known about the differences in PA across the weight categories overweight, obesity, and morbid obesity. A cross-sectional study that evaluated self-reported PA showed that children with overweight/obesity performed on average (± SD) 69 ± 53 min/day MVPA and morbid obese children performed 51 ± 42 min/day MVPA. Since subjective evaluation of PA often overestimates PA, objective measurements using accelerometry are more accurate to determine the intensity and amount of PA. Andersen et al. (2017) performed objective measurements with GT3X accelerometry and showed that children with obesity spent 39 minutes of MVPA per day. However, neither weight categories nor gender or age categories were distinguished.

Age and gender are factors that need to be taken into account when investigating PA between weight categories since previous studies in the general population showed that boys are more physically active than girls and that PA declines in both genders with age. Results of studies that included children having overweight and obesity showed similar results. According to Jago et al. (2019), levels of MVPA decreased with increasing age starting from the age of 6 years. In addition, differences in MVPA between BMI categories increase over time, i.e. PA
decreases with increasing age for children with overweight/obesity. The study of Rancourt et al. (2018) showed that boys having overweight/obesity were more physically active compared to girls with overweight/obesity.

In summary, various studies investigated PA levels in children with overweight and obesity, however, they did not investigate PA levels for the morbid obesity category specifically and did not compare these results with the overweight- and obese category. In addition, it has been suggested that age and gender differences also influence PA levels. Therefore, the current study aimed to assess objectively measured PA patterns across different weight categories, age groups, and gender in Dutch children with overweight and (morbid) obesity. It is hypothesized that there are differences in PA between weight categories. Further it is hypothesized that the variables age and gender influence the amount of PA; i.e. boys perform more PA compared to girls and that with increasing age children perform less PA. Insight in PA in different subcategories might help to improve tailored childhood obesity interventions.

Methods

Setting and subjects

This study was designed and conducted within the setting of the Centre for Overweight Adolescent and Children's Health Care (COACH) at the Maastricht University Medical Centre (Maastricht, the Netherlands). Children were referred to COACH by the Child Health Clinics and general practitioners. Within COACH, the children and their families receive a personalized ambulatory and interdisciplinary care program. All children and their families were offered individual guidance with focus on lifestyle changes as published previously. The present study involves a cross-sectional analysis of PA data at intervention onset. Periods of recruitment were from November 2013 until September 2015, and from January 2017 until April 2019. The ActiGraph GT3X (Actigraph, Corp, USA) accelerometer was provided to a random group of 286 participants (89% of the total population), aged 4–18 years. Children suffering from any musculoskeletal condition that would prevent the subject from performing PA or children that were wheelchair dependent did not receive an accelerometer. Figure 1 provides an overview of the inclusion procedure of the study. Subsequently written informed consent was obtained from children aged > 12 years and their parents. The study is registered at ClinicalTrial.gov (registration number: NCT02091544).

Measurements

Accelerometry

The Actigraph GT3X is a triaxial accelerometer. The participants were asked to wear the accelerometer attached via a waistband on the right hip bone for seven consecutive days during waking hours, except during water activities (e.g. showering, swimming) and contact sports (e.g. judo). Accelerometry data were downloaded using 10 s epochs using Actilife software (Actigraph, Corp, USA). Valid wear time was defined as a minimum of 4 days, consisting of at least 480 minutes per day of recording, including one weekend day. Derived data was expressed as mean counts per minute (cpm).

To establish time spent in different intensity categories, the cut-off points developed by Everson et al. (2008) were used; i.e. SB = 0–99 cpm, light intensity PA (LPA) = 100–2295 cpm, and MVPA ≥ 2296 cpm.

Anthropometrics

Anthropometric data were collected in the morning after an overnight fast, barefoot and wearing only underwear. Body mass was determined using digital scales (Seca, Chino, CA, USA) to the nearest 0.1 kg and height was measured to the nearest 0.1 cm using a digital stadiometer (De Grood Metaaltechniek, Nijmegen, The Netherlands). BMI (weight [kg] / height [m]²) was calculated and BMI z-scores were obtained using a growth analyser (Growth Analyzer VE, Rotterdam, The Netherlands), to adjust for age and gender. Children were categorized as overweight, obese or morbidly obese based on International Obesity Task Force (IOTF) criteria, corresponding to the 90th, 99th and 99.8th percentile respectively. Body composition was measured with the BodPod System (Life Measurement Corporation, Inc.), an air displacement plethysmograph that uses the principle of whole-body densitometry. Lohman's equation was used to determine fat mass (FM) and fat free mass (FFM) from measured body density. All anthropometric measurements were performed by trained health care personnel.

Statistical analysis

Differences between groups (IOTF: overweight, obesity, morbid obesity; gender: male, female; age: <12, ≥ 12 years) were assessed using ANOVA or independent-samples t-tests for numerical variables and chi-square tests for categorical variables. Multivariable linear regression analyses were used to evaluate the associations between PA and weight categories, gender, and age. As additional analyses, age was also dichotomized to distinguish primary school children (4–12 y) and secondary school children (≥ 12 y). Assumptions were checked using plots (scatterplots for linearity, P-P-plots and histograms for normality, residual plots for homoscedasticity), where Cook’s distance > 1 was used to define influential outliers. As sensitivity analyses, the multivariable linear regression analyses performed were repeated for weekend- and weekdays separately. A
p-value ≤ .05 was considered statistically significant. All analyses were performed using IBM SPSS Statistics for Windows version 25.0 (IBM Corp., Armonk, NY, USA).

Results

A total of 202 children were eligible for this study, of which 29% presented with overweight, 46% with obesity and 25% with morbid obesity (Table 1). The wear-time of the accelerometer was on average (± SD) 851 ± 132 min/day. There were no significant differences in wear-time between the different weight categories. Children spent on average 589 ± 142 min/day in SB which corresponds to 69% of the day (based on wear-time). In addition, children spent on average 221 ± 63 min/day of LPA per day and 41 ± 19 min/day of MVPA. Sixteen percent (n = 32) of the children reached the PA guideline of a minimum 60 minutes of MVPA per day.

Table 1
participant characteristics and outcomes; observed values

| Total | Overweight | Obese | Morbidly obese | Boys | Girls | P | Primary school age (< 12y) | Secondary school age (≥ 12y) | P |
|-------|------------|-------|----------------|------|-------|---|--------------------------|-----------------------------|---|
| N = 202 | N = 58 | N = 93 | N = 51 | N = 90 | N = 112 | | N = 98 | N = 104 | |

Demographics

Age, years Mean ± SD 12 ± 3 12 ± 3 12 ± 4 .729 12 ± 3 12 ± 3 .222 9 ± 2 15 ± 2 < .001

Gender, M/F % 45/55 50/50 43/57 .604 47/53 42/58 .530

Anthropometry

BMI z-score Mean ± SD 3.15 ± .73c 2.39 ± .33d 3.16 ± .44d,e 4.00 ± .53e < .001 3.3 ± .8f 3.0 ± .7f .010 3.13 ± .73 3.17 ± .74 .701

FM, %a Mean ± SD 41.6 ± 5.9 38.4 ± 5.2d 41.4 ± 5.2d,e 45.9 ± 5.7d,e < .001 41.5 ± 5.8 41.7 ± 6.0 .880 40.4 ± 5.3 42.8 ± 6.3 .009

PA

Total PA, CPM Mean ± SD 768 ± 298c 780 ± 281 715 ± 263e 851 ± 357e .030 861 ± 330f 698 ± 253f < .001 910 ± 300 634 ± 227 < .001

ST, min/day Mean ± SD 589 ± 142c 601 ± 130 606 ± 138e 547 ± 154e .046 572 ± 151 602 ± 134 .170 536 ± 133 640 ± 131 < .001

% per day 69c 69 70e 66e .033 67f 70f .010 64 73 < .001

LPA, min/day Mean ± SD 221 ± 63 223 ± 63 214 ± 62 230 ± 65 .300 230 ± 68 213 ± 59 .073 248 ± 58 195 ± 57 < .001

% per day 26c 26 25e 29e .048 28f 36f .056 30 23 < .001

MVPA, min/day Mean ± SD 41 ± 19 44 ± 18 38 ± 18 43 ± 20 .106 47 ± 20f 36 ± 16f < .001 44 ± 19 38 ± 18 .025

% per day 5 5 4 5 .056 6f 4f < .001 5 4 .008

Wear-time min/day Mean ± SD 851 ± 132 868 ± 118 857 ± 137 820 ± 134 .139 851 ± 135 851 ± 130 .998 827 ± 126 873 ± 133 .013

Abbreviations: M males, F females, BMI Body mass index, FM Fat mass, WC waist circumference, PA Physical activity, CPM Counts Per Minute, ST Sedentary time, LPA Light physical activity, MVPA Moderate-to-vigorous physical activity. Physical activity intensities are presented as mean minutes per day and as percentage of wear time. a FM was measured in a subgroup (group total N = 175, overweight N = 51, obese N = 82, morbidly obese N = 42) b WC was measured in a subgroup (group total N = 196, overweight N = 57, obese N = 90, morbidly obese = 49) c Significant difference between weight status categories, P < .05 d Statistically different between overweight and obese children, P < .0167 e Statistically different between obese and morbidly obese children, P < .0167 f Significant difference between gender, P < .05
Physical activity differences between weight categories, age and gender

Children with morbid obesity were significantly more physically active (851 ± 357 cpm vs 715 ± 263 cpm, p = .009) and less sedentary (547 ± 154 min/day vs 606 ± 138 min/day p = .018) compared to children with obesity (Table 1). Table 2 shows that after correcting for age and gender, children with morbid obesity performed more total PA (cpm) (corrected difference (B) = 188, p = .006) and less SB (B=-51 p = .024) compared to children with obesity. Boys were significantly more physically active (861 ± 330 cpm versus 698 ± 253 cpm, p < .001) and performed more MVPA (47 ± 20 versus 36 ± 16 min/day, p = .001) compared to girls. In addition, for each year increase of age, PA decreases on average with 46 cpm (p < .001) and SB increases with 18 min/day (p < .001). As additional analyses, we distinguished primary school children (4–12 y) and secondary school children (≥12 y). Primary school children were more physically active compared to secondary school children (910 ± 300 cpm versus 634 ± 227 cpm, p < .001).

### Table 2

| Overall p value between IOTF groups | OB vs OV | MO vs OV | MO vs OB | Gender (M vs F) | Age (per year) |
|-----------------------------------|---------|---------|---------|----------------|---------------|
| Total PA, CPM B (95% CI) P        | -53 (-134, 28) .195 | 65 (-28, 158) .170 | 118 (34, 202) .006 | 132 (63, 201) < .001 | -46 (-57, -35) < .001 |
| ST, min/day B (95% CI) P          | 2 (-40, 45) .917 | -49 (-98, 0) .050 | -51 (-95, -7) .024 | -20 (-56, 17) .287 | 18 (12, 23) < .001 |
| ST % per day B (95% CI) P         | 1 (-1, 4) .385 | -3 (-6, 0) .095 | -4 (-7, -1) .008 | -3 (-5, -1) .016 | 2 (1, 2) < .001 |
| LPA, min/day B (95% CI) P         | -9 (-27, 10) .353 | 4 (-17, 25) .702 | 13 (-6, 32) .190 | 11 (-5, 26) .164 | -10 (-12, -7) < .001 |
| LPA % per day B (95% CI) P        | -1 (-3, 2) .604 | 2 (0, 5) .074 | 3 (1, 5) .014 | 2 (0, 3) .104 | -1 (-2, -1) < .001 |
| MVPA, min/day B (95% CI) P        | -5 (-11, 1) .085 | -1 (-7, 7) .980 | 5 (-1, 11) .104 | 11 (6, 16) < .001 | -1 (-2, 0) .041 |
| MVPA % per day B (95% CI) P       | -1 (-1, 0) .125 | 0 (-1, 1) .489 | 1 (0, 2) .026 | 1 (1, 2) < .001 | 0 (-0.2, -0.04) .008 |
| Wear-time min/day B (95% CI) P    | -11 (-54, 31) .599 | -45 (-94, 4) .073 | -34 (-78, 11) .140 | 2 (-34, 39) .910 | 7 (1,13) .014 |

Abbreviations: B unstandardized regression coefficient (corrected effect), OB Obesity, OV Overweight, MO Morbid Obesity, M Male, F Female, PA Physical activity, CPM Counts Per Minute, ST Sedentary time, LPA Light physical activity, MVPA Moderate-to-vigorous physical activity. Physical activity intensities are presented as mean minutes per day ± standard deviation or as percentages. a Significant difference between weight status categories, P < .05 b Statistically different between gender

Physical activity behavior on week- and weekend day

Table 3 shows that after correcting for age and gender, children with morbid obesity perform more total PA (cpm) during weekdays (B = 122, p = .005) as well as during weekend days (B = 130, p = .030) compared to children with obesity. In addition, for each year increase in age PA decreases both on weekdays (B=-45, p = < .001) and weekend days (B=-50, p = < .001).
into puberty. Girls and PA levels have been shown to increase with age, up to an age of 10–11 years old, and then decrease at >11 years when children head into puberty. Categories are accurate.

Categories for the Actigraph accelerometer adiposity on the accuracy of PA measurements remains unclear. However, there were no significant differences in activity counts among weight categories, age groups, and gender, at the start of a lifestyle intervention program. On average, participants spent 589 min/day in SB and 41 min/day in MVPA. Sixteen percent of the children met the PA recommendation of minimum 60 min/day MVPA. Children with morbid obesity performed in total more PA (cpm) than children with obesity. In addition, children with morbid obesity showed less SB and more LPA. Also during weekend days, total PA was higher for children with morbid obesity compared to children with obesity. When PA intensities are expressed as percentages of wear-time, the observed differences remain.

Differences in objectively measured PA between weight categories, age groups, and gender in the current study can be explained in various ways. Firstly, the development of overweight or obesity is multifactorial and complex. Not only PA, but also nutrition, metabolic, environmental, psychosocial, and cultural factors are considered to play a central role in obesity development and maintenance. According to Nemet et al. (2014) did not show any association between SB and BMI in children with normal weight, overweight, and obesity. Previous studies that evaluated associations between PA and weight categories showed contradictory results. Page et al. (2005) and Cooper et al. (2000) showed that children with obesity were less physically active compared to children with normal weight.

Table 3

| Overall p value between IOTF groups | OB vs OV B (95% CI) P | MO vs OV B (95% CI) P | MO vs OB B (95% CI) P | Gender (M vs F) B (95% CI) P | Age (per year) B (95% CI) P |
|------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------------|-----------------------------|
| Total PA, CPM weekday              | .027 a                | -41 (-123, 40) .319   | 81 (-13, 175) .091    | 122 (37, 208) .005          | 150 (80,.219 <.001 b        |
| Total PA, CPM weekendday           | .019 a                | -46 (-159, 66) .419   | 84 (-46, 213) .203    | 130 (13, 247) .030          | 94 (-2, 190) .054           |
| ST min/day weekday                 | .042 a                | 10 (-34, 53) .663     | -62 (-112, -13) .014  | -72 (-117, -27) .002        | -22 (-58, 15) .246          |
| ST min/day weekendday              | .009 a                | 19 (-37, 75) .501     | -21 (-86, 44) .521    | -40 (-99, 18) .176          | 3 (45, 51) .895             |
| LPA min/day weekday                | .014 a                | -9 (-28, 10) .375     | 11 (-11, 33) .329     | 19 (-378, 39) .054          | 13 (-3, 30) .102            |
| LPA min/day weekendday             | <.001 a               | -1 (-25, 23) .919     | 1 (-26, 29) .936      | 2 (-23, 27) .853            | 8 (-13, 28) .456            |
| MVPA min/day weekday               | .010 a                | -4 (-10, 2) .205      | -1 (-7, 7) .981       | 4 (-3, 10) .234             | 11 (6, 16) <.001 b          |
| MVPA min/day weekendday            | .019 a                | -6 (-14, 2) .117      | 1 (-8, 10) .837       | 34 (-78, 11) .140           | 9 (3, 16) .006 b            |

Abbreviations: B unstandardized regression coefficient (corrected effect), OB Obesity, OV Overweight, MO Morbid Obesity, M Male, F Female, PA Physical activity, CPM Counts Per Minute, ST Sedentary time, LPA Light physical activity, MVPA Moderate-to-vigorous physical activity. Physical activity intensities are presented as mean minutes per day ± standard deviation or as percentages. " Significant difference between weight status categories, P < .05 Statistically different between gender.

Discussion

The current study evaluated objectively measured PA patterns of children with overweight, obesity and morbid obesity across different weight categories, age groups and gender, at the start of a lifestyle intervention program. On average, participants spent 589 min/day in SB and 41 min/day in MVPA. Sixteen percent of the children met the PA recommendation of minimum 60 min/day MVPA. Children with morbid obesity performed in total more PA (cpm) than children with obesity. In addition, children with morbid obesity showed less SB and more LPA. Also during weekend days, total PA was higher for children with morbid obesity compared to children with obesity. When PA intensities are expressed as percentages of wear-time, the observed differences remain.

Previous studies that evaluated associations between PA and weight categories showed contradictory results. Page et al. (2005) and Cooper et al. (2000) showed that children with obesity were less physically active compared to children with normal weight. Though Gomes et al. (2014) did not show any association between SB and BMI in children with normal weight, overweight, and obesity. It should be noted that these studies used subjective measures of PA.

Differences in objectively measured PA between weight categories, age groups, and gender in the current study can be explained in various ways. Firstly, the development of overweight or obesity is multifactorial and complex. Not only PA, but also nutrition, metabolic, environmental, psychosocial, and cultural factors are considered to play a central role in obesity development and maintenance. According to Nemet et al. (2010) food consumption increased after moderate intensity PA in children with overweight. However, food intake decreased after moderate intensity PA in children with normal weight. Based on these findings, it could be suggested that children with morbid obesity may compensate PA with more calorie intake compared to children with obesity. Another possible explanation may be selection bias and motivational factors as children in this study were referred by the youth and healthcare division. Participants, especially those with morbid obesity, could be more aware of the relevance of PA or showed socially desirable behaviour, which may result in higher motivation to be physically active at the moment of study enrollment. Furthermore, despite the fact that accelerometers are frequently used to measure objective PA behaviour, the effect of adiposity on the accuracy of PA measurements remains unclear. However, there were no significant differences in activity counts among weight categories for the Actigraph accelerometer. Therefore, it is expected that the results of the present study between the different weight categories are accurate.

In agreement with the findings of the present study, previous studies also suggest that in general, boys are more physically active compared to girls and PA levels have been shown to increase with age, up to an age of 10–11 years old, and then decrease at >11 years when children head into puberty. According to the findings of the present study, boys were more physically active compared to girls and activity counts...
decreased with age. Specifically, primary school-aged children (< 12 years) showed higher total PA compared to secondary school-aged children (≥ 12 years). The higher level of total PA in boys could be explained by a higher intrinsic motivation and more experience of enjoyment during PA compared to girls. This knowledge needs to be taken into account in order to stimulate and improve PA, especially amongst girls. Additionally, the negative association between PA and age highlights the importance of early PA promotion since the presence of comorbidities is already evident in primary school children with obesity.

Limitations were the cross-sectional design of the study and the absence of a power-calculation. The results of the current study highlights the importance of the development of tailored intervention strategies based on these findings. In addition, the results of the current study provide new insights for medical specialists, health professionals but also sport coaches/ physical educational teachers, who can stimulate and motivate children to perform PA.

Conclusion

In conclusion, this cross-sectional study showed that children with overweight and (morbid) obesity spent on average 41 min in MVPA per day and 16% of the children reached the PA guidelines of 60 minutes MVPA per day. Weight category, age and gender are associated with PA since children with morbid obesity performed more total PA and less SB compared to children with obesity, PA levels were higher for boys compared to girls and PA levels decreased with ageing. These findings highlight the need for tailored PA promotion and reducing SB. Follow up data of children participating in the COACH program need to examine the effect of the lifestyle intervention on PA across overweight categories including age and gender.

List Of Abbreviations

COACH Centre for Overweight Adolescent and Children's Health Care

cpm Counts Per Minute

FM Fat mass

FFM Fat free mass

LPA Light physical activity

MVPA Moderate to vigorous physical activity

PA Physical activity

SB Sedentary behaviour

Declarations

Ethics approval and consent to participate

The current study was conducted according to the Declaration of Helsinki and approved by the medical ethical committee of the azM and Maastricht University (METC azM/UM). Subsequently written informed consent was obtained from children aged > 12 years and their parents.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Not applicable.

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**Author contributions**

AV designed the study. GTV and ED carried out the measurements. GTV and BW performed statistical analyses. GTV, GP and AV wrote the paper. All authors were involved in revision and final approval of the submitted version.

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**Figures**

**Figure 1**

Flowchart of study enrolment. Abbreviations: OV overweight; OB obese; MO morbid obese

**Supplementary Files**

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