Objectively Measured Physical Activity Patterns in Children with Overweight and (Morbid) Obesity Across Different Weight Categories, Age Groups and Gender

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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 patterns (total PA, sedentary time (ST), light PA and moderate to vigorous intensity PA (MVPA)) were measured with the GT3X Actigraph accelerometer. Wear time validation was set on four days, 480 min/day, including one weekend day.

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 (STB) 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 MVPA than boys (B -11 min/day, p<.001) and for each year increase of age with increasing age, children performed less PA (B -46 cpm, p<.001) and STB increased (B 18 min/day, p<.001).

Conclusion: Weight category morbid obesity, younger age and male gender were positively associated with PA and negatively with SB. PA and ST is different in subgroups of children with overweight and (morbid) obesity, depending on gender, age and overweight severity. In particular in older girls in the weight category 'obesity', levels of PA and ST are worrisome. These findings highlight the need for tailored PA promotion.

Trial registration: The trial is registered with Clinicaltrials.gov NCT02091544

Background

Over the last few decades, childhood overweight and obesity rates have increased globally. In the Netherlands, the prevalence of overweight in primary school children (4–12 year-old) and adolescents (12–16 year-old) is 11.9% and 11.6% respectively, and of obesity 3.4% and 1.6% (1). The prevalence of Dutch children with morbid obesity was 0.59% in boys and 0.53% in girls in 2009 (2). Alarmingly, morbid obesity is the fastest growing subcategory of childhood obesity worldwide (2, 3). The shift towards more severe forms of childhood obesity is associated with an increased health risk for developing life-threatening chronic diseases, psychological disorders and premature death (2, 4, 5). A generally accepted premise is that treating obesity in its earliest stage is of great importance (6–8). As such, more knowledge is required for the development of tailored treatment options for children having overweight, obesity and morbid obesity, which might be different for each of these subgroups.

Low levels of physical activity (PA) play an important role in the development of childhood overweight and progression to more severe obesity (9). Guidelines have been developed to promote PA and to foster its health benefits (10). The World Health Organization, as well as the Dutch government, recommends that children and adolescents spend a minimum of 60 minutes of moderate to vigorous physical activity (MVPA) each day, preferably including more vigorous intensity activities and sedentary time (ST) should be minimalized (10, 11). Subjectively measured data indicates that 45% of Dutch children (4–11 year-old) and 69% of adolescents (aged 12–18 years) do not meet these public health guidelines (1). Even though these guidelines have been developed internationally, the evaluation of PA levels specifically among children with overweight and (morbid) obesity is lacking. Therefore, the prevalence of children that meet the recommendations in these subgroups and the room for improvement as a target for intervention remains unclear.

The study of Salawi et al. (2014) included children with morbid obesity and showed that these children self-reported to perform on average 18 min less MVPA compared to children with overweight or obesity (51 vs 69 min/day respectively) (12). However, subjective methods, such as the questionnaires used in the study of Salawi et al. (2014), tend to overestimate levels of PA. Objective measurements, such as accelerometry, are more accurate to determine the amount of PA, as well as the
intensity (13). A review of Elmesmari et al. (2018) included studies that used accelerometry to measure PA and reported that these studies in general showed that children and adolescents with obesity are slightly less physically active and more sedentary compared to children without obesity (14). Though, in all of these studies PA was not compared between children with different degrees of overweight and obesity. Furthermore, influencing factors such as age and gender should be considered when investigating PA between weight categories, since it has been shown that boys are generally more physically active than girls and PA declines with aging (15, 16). Only a few PA studies that used accelerometry included children with overweight and obesity and also investigated the effect of age and gender (17–19). For instance, the study of Jago et al. (2019) showed that in the age range 6–11 years PA decreases with increasing age in children with overweight and obesity (17). However, inclusion of narrow age ranges as in the study of Jago et al. (2019) and small samples sizes impair strong conclusions from these studies on PA in children in different weight categories, taking age and gender into consideration (17).

In summary, although it is generally accepted that promotion of PA is important in the treatment of children with overweight and (morbid) obesity, to date, no studies have evaluated the differences between objectively measured PA levels in children with different overweight categories and the influence of age and gender. Insight in PA patterns in different subgroups is needed to develop or improve tailored childhood obesity interventions. Therefore, the current study aimed to assess objectively measured PA patterns including light PA, MVPA and ST across different weight categories, age groups, and gender in Dutch children with overweight and (morbid) obesity. We hypothesized that PA decreases with increasing overweight severity, with a gender difference in favor for boys and a negative effect of an older age in all groups.

**Methods**

**Setting and participants**

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 youth healthcare division and general practitioners. Children and their families are referred to COACH for evaluation of their physical condition and lifestyle and for individual guidance with focus on lifestyle changes as published previously (18). The present study involves a cross-sectional analysis of PA data before intervention onset (baseline measurements). Data collection was performed from November 2013 until April 2019 with the exception of one year (October 2015 until December 2016) due to logistical reasons. The ActiGraph GT3X (Actigraph, Corp, USA) accelerometer was provided to 286 participants aged 4–18 years (89% of the total population) before the start of the lifestyle intervention. 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, both parents of all children gave written informed consent. Informed consent was also obtained from children aged ≥ 12 years. The study is registered at ClinicalTrial.gov (registration number: NCT02091544).

**Measurements**

**Accelerometry**

The Actigraph GT3X is a triaxial accelerometer. Accelerometry currently represents the most accurate, inexpensive, and reliable method for objectively measuring both the amount and intensity of PA, also in children and adolescents (19, 20). 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 intensive contact sports (e.g. judo). For other sports (i.e. running, ball sports etc.) participants were instructed to wear the accelerometer. 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 Evenson et al. (2008) were used; i.e. ST = 0–99 cpm, light intensity PA (LPA) = 100–2295 cpm, and MVPA ≥ 2296 cpm (21).
**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 analyzer (Growth Analyzer VE, Rotterdam, The Netherlands (22)), to adjust for age and gender. Children were categorized as overweight, obese or morbidly obese based on International Obesity Task Force (IOTF) criteria (23), corresponding to the 90th, 99th and 99.8th percentile respectively. (24) All anthropometric measurements were performed by trained health care personnel.

**Statistical analysis**

Differences between groups (weight categories: overweight, obesity, morbid obesity; gender: boys, girls; age: <12, ≥ 12 years) were assessed using ANOVA (with Fisher’s Least Significant Difference method for pair-wise comparisons if the overall test was significant) 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 the dependent variable, i.e. one of the different PA intensities (total PA (cpm), light PA, MVPA and ST min/day) and the independent variables, i.e. weight categories (2 dummy variables), gender (1 dummy variable), and age (numerical). 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 were repeated for weekend- and weekdays separately. No missing data were expected as the present study only involved baseline data and all measurements were performed on the same day, while an inclusion criterion was valid wear time, implying that PA patterns are not missing. 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 ST 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 PA patterns for the total sample as well as for the different weight categories, gender and age group

| Demographics | Total | OV | OB | MO | P | B | G | P | Secondary school age (< 12 y) | N = 202 | N = 58 | N = 93 | N = 51 | N = 90 | N = 112 | N = 98 | N = 104 | P |
|---------------|-------|----|----|----|---|---|---|---|-------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|---|
| Age, years    | 12 ± 3| 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 | 41/59 | .604| 47/53 | 42/58 | .530 |
| Anthropometry |       |     |     |     |   |   |   |   |                               |        |       |       |       |       |       |       |       |   |
| BMI z-score   | 3.15 ± .73 | 2.39 ± .33 | 3.16 ± .44 | 4.00 ± .53 | < .001 | 3.3 ± .8 | 3.0 ± .7 | .010 | 3.13 ± .73 | 3.17 ± .74 | .701 |
| PA            |       |     |     |     |   |   |   |   |                               |        |       |       |       |       |       |       |       |   |
| Total PA, CPM | 768 ± 298 | 780 ± 281 | 715 ± 263 | 851 ± 357 | .030 | 861 ± 330 | 698 ± 253 | < .001 | 910 ± 300 | 634 ± 227 | < .001 |
| ST, min/day   | 589 ± 142 | 601 ± 130 | 606 ± 138 | 547 ± 154 | .046 | 572 ± 151 | 602 ± 134 | .170 | 536 ± 133 | 640 ± 131 | < .001 |
| ST, %/day     | 69     | 69 | 70 | 66 | .033 | 67 | 70 | .010 | 64 | 73 | < .001 |
| LPA, min/day  | 221 ± 63 | 223 ± 63 | 214 ± 62 | 230 ± 65 | .300 | 230 ± 68 | 213 ± 59 | .073 | 248 ± 58 | 195 ± 57 | < .001 |
| LPA, %/day    | 26     | 26 | 25 | 29 | .048 | 28 | 36 | .056 | 30 | 23 | < .001 |
| MVPA, min/day | 41 ± 19 | 44 ± 18 | 38 ± 18 | 43 ± 20 | .106 | 47 ± 20 | 36 ± 16 | < .001 | 44 ± 19 | 38 ± 18 | .025 |
| MVPA, %/day  | 5      | 5 | 4 | 5 | .056 | 6 | 4 | < .001 | 5 | 4 | .008 |
| Wear-time min/day | 851 ± 132 | 868 ± 118 | 857 ± 137 | 820 ± 134 | .139 | 851 ± 135 | 851 ± 130 | .998 | 827 ± 126 | 873 ± 133 | .013 |

Abbreviations: OB Obesity, OV Overweight, MO Morbid Obesity, B Boys, G Girls, BMI Body mass index, 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 percentage of wear time. a Statistical difference between overweight and obese children
b Statistical difference between obese and morbidly obese children c Statistical difference between overweight and morbidly obese children

Physical activity patterns across 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). Multiple linear regression (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 ST (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 decreased on average with 46 cpm (p = < .001) and ST increased with 18 min/day (p = < .001). As additional analyses, primary school children (4–12 y)
and secondary school children were distinguished (≥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
Results of the multiple linear regression analysis with PA patterns as the dependent variables and weight categories, age and gender as independent variables.

|                           | Overall p value between weight categories | OB vs OV B (95% CI) P       | MO vs OV B (95% CI) P       | MO vs OB B (95% CI) P | Gender (B vs G) B (95% CI) P | Age (per year) B (95% CI) P |
|---------------------------|------------------------------------------|-------------------------------|-------------------------------|------------------------|-------------------------------|-----------------------------|
| Total PA, CPM             | .022                                     | -53 (-134, 28) .195          | 65 (-28, 158) .170           | 118 (34, 202) .006     | 132 (63, 201) < .001         | -46 (-57, -35) < .001      |
| ST, min/day               | .057                                     | 2 (-40, 45) .917             | -49 (-98, 0) .050            | -51 (-95, -7) .024     | -20 (-56, 17) .287           | 18 (12, 23) < .001         |
| ST % per day              | .029                                     | 1 (-1, 4) .385               | -3 (-6, 0) .095              | -4 (-7, -1) .008       | -3 (-5, -1) .016             | 2 (1, 2) < .001            |
| LPA, min/day              | .376                                     | -9 (-27, 10) .353            | 4 (-17, 25) .702             | 13 (-6, 32) .190       | 11 (-5, 26) .164             | -10 (-12, -7) < .001       |
| LPA % per day             | .044                                     | -1 (-3, 2) .604              | 2 (0, 5) .074                | 3 (1, 5) .014          | 2 (0, 3) .104                 | -1 (2, -1) < .001          |
| MVPA, min/day             | .128                                     | -5 (-11, 1) .085             | -1 (-7, 7) .980              | 5 (1, 11) .104         | 11 (6, 16) < .001            | -1 (2, 0) .041             |
| MVPA % per day            | .062                                     | -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         | .175                                     | -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, B Boys, G Girls, 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.

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).
Table 3
Results of the multiple linear regression analysis with PA patterns during week- and weekend days as dependent variables and weight categories, age and gender as independent variables.

| Comparison                     | Overall p value between weight categories | OB vs OV B (95% CI) P | MO vs OV B (95% CI) P | MO vs OB B (95% CI) P | Gender (B vs G) B (95% CI) P | Age (per year) B (95% CI) P |
|--------------------------------|------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------------|-----------------------------|
| Total PA on weekday (CPM)     | .020                                     | -41 (-123, 40) .319  | 81 (-13, 175) .091   | 122 (37, 208) .005   | 150 (80, 219) <.001         | -45 (-56, -34) <.001        |
| Total PA on weekend day (CPM) | .094                                     | -46 (-159, 66) .419  | 84 (-46, 213) .203   | 130 (13, 247) .030   | 94 (-2, 190) .054           | -50 (-65, -35) <.001        |
| ST on weekday (min/day)       | .006                                     | 10 (-34, 53) .663    | -62 (-112, -13) .014 | -72 (-117, -27) .002 | -22 (-58, 15) .246          | 19 (13, 24) <.001           |
| ST on weekend day (min/day)   | .393                                     | 19 (-37, 75) .501    | -21 (-86, 44) .521   | -40 (-99, 18) .176   | 3 (-45, 51) .895            | 17 (10, 25) <.001           |
| LPA on weekday (min/day)      | .154                                     | -9 (-28, 10) .375    | 11 (-11, 33) .329    | 19 (-.378, 39) .054  | 13 (-3, 30) .102            | -10 (-13, -8) <.001         |
| LPA on weekend day (min/day)  | 0.982                                    | -1 (-25, 23) .919    | 1 (-26, 29) .936     | 2 (-23, 27) .853     | 8 (-13, 28) .456            | -9 (-12, -6) <.001          |
| MVPA on weekday (min/day)     | .331                                     | -4 (-10, 2) .205     | -1 (-7, 7) .981      | 4 (-3, 10) .294      | 11 (6, 16) <.001            | -1 (-2, -0.4) .063          |
| MVPA on weekend day (min/day) | .136                                     | -6 (-14, 2) .117     | 1 (-8, 10) .837      | -34 (-78, 11) .140   | 9 (3, 16) .006              | -1 (-2, 0.07) .068          |

Abbreviations: B unstandardized regression coefficient (corrected effect), OB Obesity, OV Overweight, MO Morbid Obesity, B Boys, G Girls, 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.

Discussion

To our knowledge, this is the first study that evaluated objectively measured PA patterns using accelerometry in children across the different weight categories overweight, obesity and morbid obesity, and also evaluated the modifying effect of age and gender. The present study shows that children with morbid obesity performed in total more PA (cpm) than children with obesity. In addition, children with obesity spent a lower percentage of time being sedentary and a higher percentage of time in LPA. The difference in total PA (cpm) between these two weight categories exists during both weekdays and weekend days. In addition, children with morbid obesity spent less ST during a week day compared to children with obesity. These results are in contrast with our hypothesis that PA decreases with increasing overweight severity.

Previous studies showed that children with obesity were less physically active compared to children with normal weight (25, 26). Extension of these results to the assumption that children with morbid obesity are less physically active than children with obesity was refuted by the results of the present study. Several explanations for this remarkable finding can be considered. First, children with morbid obesity might be more aware of a healthy and active lifestyle than children with less morbid obesity.
after being referred to the obesity centre for treatment and might be more motivated to improve PA already before the start of the intervention. In addition, 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 key role in obesity development and maintenance. For example, 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 (27). Based on these findings, it could be suggested that even though children with morbid obesity were more physically active, they may compensate higher PA with a higher calorie intake. One could also question whether the degree of obesity may somehow affect the accuracy of the accelerometer to assess PA. However, the Actigraph accelerometer, which was used in the present study, was shown before to measure activity counts equally accurate across different weight categories (28).

In agreement with previous studies, the present study shows that boys are more physically active compared to girls and PA levels increase with age, up to an age of 10–11 years old, and then decrease at > 11 years when children head into puberty (29, 30). 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 experiencing more pleasure from exercise compared to girls (31). Furthermore, previous studies found gender differences concerning different PA types (32, 33). The results of the study of Reimers et al. (2018) showed that boys were more likely to engage in sports and active games, while girls prefer walking and/running or to play in a playground (33). It is recommended to provide tailored PA types in order to stimulate and improve PA. 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 (34). A methodological strength of this study is the use of objectively measured PA using accelerometry to measure PA in children across different weight categories (overweight, obesity and morbid obesity). Previous studies used self-reported PA or used objectively measured PA but did not differentiate between weight categories. The present study also evaluated differences between PA patterns in boys and girls and in different age categories in children with overweight and (morbid) obesity. Limitations were the cross-sectional design of the study and the absence of a power-calculation. In addition, children were instructed to remove the accelerometer during water activities and some contact sports, which may have impacted the accelerometry data. This is common for accelerometer-derived data. However, the time spent on these activities is generally very small compared to the entire observation interval.

The results of the current study provide new insights for medical specialists, health professionals, sport coaches and physical educational teachers, who can stimulate and motivate children to perform PA. Extra attention is needed for children with obesity, female gender and children from > 12 years. Consequently, interventions which include the school environment and parents are needed to increase PA during school as well in the home environment during weekends and after school hours. More insight in the specific needs and possibilities to increase PA and decrease ST in this subgroup is warranted.

Follow-up data of children participating in the COACH program are continuously being collected to determine the effect of the lifestyle intervention on PA across overweight categories including age and gender. The evaluation of PA and ST over time during this intervention will demonstrate whether PA can be changed in the different subgroups.

**Conclusion**

In conclusion, this cross-sectional study showed that there are differences in PA patterns between children with overweight, obesity and morbid obesity and that age and gender are modifying factors. These findings highlight the need for tailored interventions that promote PA and reduce ST.

**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  
ST Sedentary time

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.

Funding

Not applicable.

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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