Physical activity and BMI inequalities throughout childhood: a Brazilian birth cohort study

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Summary

Background Utilising the 2015 Pelotas (Brazil) Birth Cohort, the current study investigated differences in physical activity (PA) and BMI-for-age between sex, race, and socioeconomic status (SES) at ages 1 (n = 4018), 2 (n = 4014), 4 (n = 4010), and 7 (n = 3867).

Methods Demographics collected via surveys included sex at birth, skin colour, a proxy for race, at 4 years, and an assets index collected at all ages to determine SES. Height and weight estimated BMI-for-age and PA via wrist-worn accelerometers. Means and 95% confidence intervals described PA and BMI-for-age, using t-tests, ANOVAs, and chi-squared tests to determine significant differences. Trajectory models compared longitudinal patterns from 1 to 7 years.

Findings Starting at age 2, Black and Brown children and poorer children engaged in more PA. Poorer children presented lower BMI-for-age at ages 4 and 7. Trajectory models revealed that boys, Black and Brown, and poorer children represented increasing and high PA groups. Boys and Black and Brown children were most prevalent in higher BMI-for-age trajectory groups.

Interpretation The current study revealed PA and BMI-for-age inequalities across multiple demographic variables during early life. These results may reveal when inequalities may arise and reveal time points to intervene for populations at risk of poor health-related quality of life.

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Keywords: Physical activity; Children; Disparities; Income; Race; Weight status

Introduction

According to the World Health Organization (WHO), nearly half of adults and approximately ¾ of children in the Americas do not meet physical activity recommendations.[1] This is alarming as physical activity has consistently been shown to reduce the risk of all-cause mortality, chronic disease, compromised mental health, and poor growth and development.[2,3] In adulthood, inequalities in physical activity patterns have been observed across many demographic characteristics such as age, sex, income, education, and race/ethnicity. For instance, the WHO reported that in the Region of the Americas, adult males tend to self-report more physical activity than adult females, and more girls (85%) at ages 11–17 years are considered inactive in comparison to boys (78%) at the same age. Additionally, increased levels of physical inactivity have been observed worldwide as individuals age.[1]

Beyond physical activity, health outcomes related to all-cause mortality, chronic disease, and childhood growth and development such as weight status have also been studied. Globally, obesity rates have tripled in adults since 1975 and increased from 4% to 18% in children.[4] Similar to physical activity, inequalities in

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Research in context

Evidence before this study

Pubmed and Google scholar were used to search for articles published up until January 2024, using terms such as, but not limited to, "children", "physical activity", "disparities or inequalities", and "weight status". The current evidence has illustrated disparities in health outcomes such as physical activity patterns, nutritional status, and weight status based on many demographic variables such as age, sex, race/ethnicity, income status, and social class. These disparities are observed in both high-income and middle-income countries. Brazil, a middle income country, was the focus of the present study considering the use of the Pelotas (2015) cohort. In Brazil, previous literature indicates that higher income and educated adults engage in more self-reported leisure time physical activity, although, accelerometer based studies indicate more physical activity amongst lower socioeconomic status individuals. Additionally, black or mixed and lower educated women exhibited increased body mass index over an 8 year prospective study. Other birth cohort studies in children have linked physical activity trajectories with weight status and also exhibited clear differences in these patterns based on sex and parent education. Thus, the present study attempted to add to the existing literature following large cohorts by addressing children beginning at infancy (1 year) and following their physical activity and weight status as they enter the school age developmental stage (6–7 years).

Added value of this study

Our study complements the work previously published using that Pelotas (2015) cohort that determined potential inequalities during early childhood (<4 years). The present work continues this assessment as children enter school age (7 years) and indicates continued inequalities based on sex, race/ethnicity, and socioeconomic status. Further, the present study conducted trajectory analyses that provided evidence of specific groups that may be at a greater risk of suffering from poorer health status later due to current trends such as, low physical activity rates in girls and higher BMI-for age in black children. Although, observations such as higher physical activity rates and lower BMI-for age trajectories amongst the poorest children, and higher physical activity rates in black and brown children also reveal patterns not typically observed in adults and require continued assessment and observation. These results may suggest that at younger ages, such health behaviours in these typically marginalized groups are stable, and it is not until later in life do inequalities begin to arise causing these groups fall behind.

Implications of all the available evidence

Existing work globally has revealed that in middle and higher income countries, disparities in physical activity and weight status are prevalent and negatively affect historically marginalized groups such as women and girls, low income/socioeconomic and black and brown individuals. Although considering much of the work has observed adults, adolescents and school aged children, the present study provides critical evidence for similar rates and trends during early childhood (1–7 years). Thus, indicating that such disparities observed during later life stages may be occurring as year as infancy and toddlerhood. Such critical data is necessary in understanding when and where health behaviour interventions may provide greater successes in alleviating disparities observed during later childhood or adulthood. The present study also provides nuance as atypical patterns observed amongst low socioeconomic status and black and brown children may also indicate that physical activity and weight status disparities are not always in the expected direction.

weight status based on many demographic characteristics are evident during adulthood. For instance, in the United States between 1960 and 2008, rates of obesity increased particularly in Black women as well as women with less education years.[5] However, it ought to be noted that these disparities are not observed solely in high-income countries, but also middle-income countries. Pertaining to specific countries in the Regions of the Americas, Brazil, an upper middle-income country, exhibits marked health inequalities based on sex, race, and socioeconomic status (SES) particularly due to the rise in chronic disease and needs for health goods and services.[6–8] Previous Brazil studies have reported that adults with more years of education, and higher income tend to self-report more total and leisure time physical activity.[9,10] Another study showed that higher overall physical activity was associated with lower SES individuals.[11] Further, weight disparities based on sex, race, and education also exist. An 8-year prospective study found that lower education and race amongst women, particularly those identifying as Black or mixed (Pardo), were associated with greater increases in body mass index (BMI) over time.[12]

The evidence regarding inequalities in health behaviours and related outcomes amongst Brazilian adults calls into question when these disparities may begin to appear. However, this question remains unanswered, as there are few studies assessing inequalities in children, particularly during early life. A previous longitudinal study describing physical activity trajectories and their associations with sociodemographic variables among participants of the Pelotas (Brazil) Birth Cohorts at 12, 24, and 48 months revealed two trajectories, one moderate and one high, both showing a linear increase in physical activity in the early years but varying in volume. Girls, children from mothers with higher education, and children with high birth weight were less likely to belong to the high physical activity trajectory.[13] In another study, using the Pelotas Birth Cohorts, physical activity exhibited a bidirectional relationship with BMI-for-age, weight-for-age, and weight-for-length at 12, 24, and 48 months,[14] indicating that physical activity during early life is important for optimal growth and development. These past studies have begun to pave the way towards understanding disparities during early life, although it will be useful to continue to assess these trends as children enter school, lifestyles begin to change, and potential inequalities arise.

The 2015 Pelotas (Brazil) Birth Cohort provides a unique opportunity to investigate these variables and understand whether health disparities like those observed in adults can be identified during childhood. Identifying points in which inequalities begin to arise will provide useful information regarding the impact of demographics and SES on childhood development which in turn influences adult health behaviours and outcomes. Beyond identifying disparities during early life, it is important to understand if these inequalities may predict further inequalities later during childhood as this could indicate inequalities during adulthood as well. Additionally, assessing demographic and SES factors will provide researchers, public health officials, and policy makers with information surrounding groups to target when implementing interventions.

Considering the prevalence of low physical activity patterns and increases in BMI, and the evidence surrounding the influence of various demographic variables on inequalities in health behaviours and outcomes in Brazilian adults, the current study aims to further elucidate health inequalities across the lifespan. First, we investigated the difference in physical activity patterns, as well as BMI-for-age, between sex, race, and SES via assets index at ages 1, 2, 4, and 7 years. Further, we conducted a trajectory analysis to assess physical activity and BMI-for-age patterns between ages 1 and 7 years and explore differences in these patterns based on sex, race, and SES.

Methods

The current study utilized data from the 2015 Pelotas (Brazil) Birth Cohort, which consists of 99% of all hospital-delivered children between January and December of 2015 in the city of Pelotas, Brazil (N = 4275). Assessments were completed at birth, 3 months, 1, 2, 4, and 7 years with more than 92% of the children enrolled in the cohort's follow-ups. For the current study, children with completed physical activity and BMI data at ages 1, 2, 4, and 7 years were included (Supplementary Table S1). Written informed consent was provided by parents/guardians at all follow-up visits. The 2015 Pelotas (Brazil) Birth Cohort Study was approved by the School of Physical Education Ethics Committee from the Federal University of Pelotas (CAAE registration number: 26746414.5.0000.5313). More detailed information regarding recruitment and study logistics have been published previously.[15,16] Biological sex was collected at birth. Skin colour, collected at 4 years, was used as a proxy for race with answer options being 'White', 'Black', and 'Brown'- meaning mixed, which matched similar questions asked on the Brazilian census and an assets index was collected at birth, 1, 2, 4 and 7 years. The index was generated using a socioeconomic questionnaire standardized with questions about the family patrimony, the presence of a housemaid, and the educational level of the person considered the head of the household.[17] Questionnaires regarding transportation mode to and from school were also administered to the mothers when children were 7 years old. All questionnaires and instruments were applied by trained research team members.

At ages 1 and 2, weight was measured using a SECA 803 scale (SECA, Germany) with 100 g precision, and at age 4 and 7, a TANITA UM-080 scale with a maximum capacity of 150 kg and 100 g precision was used to measure weight. At 1 year, length was measured using a SANNY ES2000 portable anthropometer (SANNY, Brazil) with 5 mm precision. For age 2, a fixed anthropometer (Harpenden®) with a range from 30 to 110 cm and 0.1 cm precision, and by age 4 and 7 a fixed anthropometer (Harpenden®) with a maximum height of 206 m and 0.1 cm precision was used to measure height. Height and weight were both utilized to calculate BMI-for-age according to the WHO Growth Standards using the Anthro 2006 software.[18] According to the manual, we considered individuals with values higher or lower than five standard deviation units as outliers and excluded them from the analysis. The number of children excluded were 17, 10, 61 and 64, for 1, 2, 4 and 7 years respectively.

Triaxial wGT3X-BT accelerometers (Actigraph LLC., Pensacola, FL, USA; 3.3 × 4.6 × 1.5 cm; 19 g; dynamic range ± 8 *g*) were worn on the left wrist for 24 h/day with a minimum valid day set at 16 h.[19] At ages 1 and 2, participants had 2 days or data, based on previous protocols for infants.[19,20] At ages 4 and 7, participants had a week (7 days) of data. Due to a logistical problem in terms of the limited number of devices available at age 7, at the middle of the follow-up the protocol had to be changed, collecting data for 3 days. A sampling rate of 60 Hz was used, and the data were reduced at 5s epochs. The Actilife software (version 6.1, Actigraph Corp, Pensacola, FL) was used to download and extract raw data files, which were then analysed using the R package GGIR (http://cran.r-project.org). Raw acceleration was based on the Euclidian norm minus one (ENMO) measure, which summarized 3-dimensional raw data activity acceleration (from x, y, and z-axis) ($\text{ENMO} = \sum |\sqrt{x^2 + y^2 + z^2} - 1\ g|$). Data were expressed in milli-gravitational units (gravitational equivalent: 1000 mg = 1 $g = 9.81\ \text{m/s}^2$).[21] Non-wear time was estimated in 15-min blocks based on the characteristics of a 60-min window, where a block was considered non-wear time if the standard deviation of the 60-min window was <13.0 mg and the value range was <50 mg for at least 2 of 3 axes.

Trajectory models were built to identify patterns of physical activity and BMI-for-age in children from age 1–7 years. To identify those changes, a group-based trajectory model was applied.[22] This type of modelling can identify groups of individuals with similar trajectories, providing clusters of individual physical activity and BMI-for-age through time. The shape and number of groups were properly identified by the following criteria: a) best fit of the models based on log-likelihood, Bayesian criteria, Akaike criteria and entropy; b) number of participants in each group; c) visual observation of different trajectories; d) interpretability of the trajectory groups. The probability of individuals belonging to each group was higher than 70%[23] and the models did not use imputation. Final models for physical activity identified four groups, classified as: a) Stable Low; b) Moderate Increase; c) High Increase; d) Increasingly Stable. BMI-for-age model was modelled, and groups were identified and classified as: a) Low and Stable; b) Moderate and Stable; c) High Increase; d) High and Stable; e) Very High and Increasing.

All statistical procedures were conducted in STATA 17.0. The sample was described according to the inequality markers at birth, 1, 2, 4 and 7 years (Table 1). This same description was made for children with valid physical activity and BMI-for-age data from 1 to 7 years, and for the trajectory samples (Supplementary Table S1). Mean values and 95% confidence intervals of physical activity and BMI-for-age were used to describe possible inequalities according to sex, race, and SES. Trajectory groups were also described according to sex, race, and SES to obtain a longitudinal overview of possible inequalities. Finally, two sensitivity analyses were used to investigate possible inequalities for physical activity and BMI-for-age. First, we ran equiplots to graphically see differences across groups and over time. We also conducted chi square, t tests, and anovas to determine statistically significant differences across groups.

Ethics committee approval

The 2015 Pelotas (Brazil) Birth Cohort Study was approved by the School of Physical Education Ethics Committee from the Federal University of Pelotas (CAAE registration number: 26746414.5.0000.5313).

Role of funding source

The funding sources did not play any role in the study design, data collection or analysis, interpretation of data, writing of the report, or decision to submit for publication.

Results

Participant characteristics at all ages are described in Table 1. At baseline (birth) 4275 children were enrolled in the cohort. At 1, 2, 4 and 7 years, 4018 (95.4%), 4014 (95.4%), 4010 (95.4%) and 3867 (92.0%) children were followed up, respectively. In all follow-ups there was no difference in the sex distribution. Mean physical activity increased from 26.4 mg at 1 y to 53.2 mg at 7 y (Table 2). Higher values of physical activity were observed for boys as compared to girls at all ages. White children were less active than Black children from 2 years onwards. Children in the lowest quintiles of assets index (poorest) presented higher values of physical activity from 2 y onwards. See Fig. 1 for a depiction of these disparities via equiplots. Our sensitivity analyses showed that the poorest children presented a higher prevalence (76.1%)

	Baseline	1 year	2 years	4 years	7 years
	N = 4275	N = 4018	N = 4014	N = 4010	N = 3867
	N (%)	N (%)	N (%)	N (%)	N (%)
Sex					
Boys	2164 (50.6)	2044 (50.9)	2030 (50.6)	2028 (50.6)	1953 (50.5)
Girls	2111 (49.4)	1974 (49.1)	1984 (49.4)	1982 (49.4)	1914 (49.5)
Race[a]					
White	2829 (72.5)	2763 (72.7)	2764 (72.5)	2829 (72.5)	2679 (72.3)
Black	386 (9.9)	376 (9.9)	378 (9.9)	386 (9.9)	374 (10.1)
Brown	685 (17.6)	661 (17.4)	670 (17.6)	685 (17.6)	653 (17.6)
Assets index (quintiles)					
1 (low)	824 (20.0)	796 (20.0)	792 (20.0)	768 (20.0)	744 (20.0)
2	829 (20.1)	795 (20.0)	792 (20.0)	768 (20.0)	744 (20.0)
3	820 (19.9)	796 (20.0)	792 (20.0)	767 (20.0)	744 (20.0)
4	823 (19.9)	795 (20.0)	792 (20.0)	768 (20.0)	743 (20.0)
5 (high)	831 (20.1)	795 (20.0)	792 (20.0)	767 (20.0)	743 (20.0)

[a]Race was only collected at age 4.

Table 1: **Characteristics of children from the 2015 Pelotas (Brazil) birth cohort.**

ENMO (mg)	1 year Mean (95%CI)	2 years Mean (95%CI)	4 years Mean (95%CI)	7 years Mean (95%CI)
	N = 2974	N = 2645	N = 2955	N = 2877
Total	26.4 (26.1–26.6)	37.2 (36.9–37.6)	48.2 (47.8–48.7)	53.2 (52.6–53.7)
Sex				
Boys	**27.0 (26.6–27.3)**	**38.4 (37.9–38.9)**	**50.4 (49.7–51.0)**	**56.1 (55.2–57.0)**
Girls	**25.7 (25.4–26.1)**	**36.0 (35.5–36.4)**	**46.1 (45.5–46.6)**	**50.2 (49.6–50.9)**
Race				
White	26.3 (26.0–26.6)	**36.7 (36.3–37.1)**	**47.5 (47.0–48.0)**	**52.2 (51.5–52.8)**
Black	26.2 (25.5–26.9)	**37.9 (36.7–39.1)**	**49.7 (48.3–51.1)**	**56.4 (54.6–58.2)**
Brown	26.9 (26.3–27.5)	**38.9 (38.0–39.7)**	**50.3 (49.4–51.3)**	**55.7 (54.2–57.1)**
Assets index (quintiles)				
1 (low)	26.1 (25.6–26.6)	38.0 (37.1–38.8)	**50.0 (49.1–51.0)**	**56.0 (54.7–57.4)**
2	26.3 (25.8–26.8)	37.0 (36.2–37.9)	**49.0 (48.0–50.0)**	**54.2 (52.8–55.6)**
3	26.5 (26.0–27.0)	37.4 (36.6–38.2)	**47.6 (46.6–48.5)**	**52.2 (50.9–53.5)**
4	26.6 (26.1–27.1)	36.8 (36.0–37.7)	**46.9 (46.0–47.8)**	**51.1 (49.9–52.4)**
5 (high)	26.2 (25.7–26.7)	36.6 (35.8–37.5)	**47.5 (46.6–48.4)**	**51.8 (50.6–52.9)**
BMI Z-score	**N = 3931**	**N = 3708**	**N = 3585**	**N = 3531**
Total	0.68 (0.64–0.71)	0.54 (0.51–0.58)	0.69 (0.65–0.73)	0.84 (0.79–0.89)
Sex				
Boys	**0.74 (0.68–0.79)**	**0.58 (0.54–0.63)**	0.73 (0.67–0.78)	**0.97 (0.90–1.04)**
Girls	**0.61 (0.56–0.66)**	**0.50 (0.45–0.55)**	0.65 (0.60–0.71)	**0.71 (0.65–0.78)**
Race				
White	0.65 (0.60–0.69)	**0.52 (0.48–0.56)**	0.69 (0.64–0.74)	0.85 (0.79–0.90)
Black	0.77 (0.65–0.89)	**0.67 (0.56–0.78)**	0.70 (0.58–0.81)	0.83 (0.68–0.99)
Brown	0.72 (0.64–0.81)	**0.60 (0.51–0.68)**	0.68 (0.59–0.77)	0.83 (0.71–0.94)
Assets index (quintiles)				
1 (low)	0.64 (0.54–0.73)	0.49 (0.41–0.56)	**0.53 (0.45–0.62)**	**0.55 (0.45–0.65)**
2	0.77 (0.68–0.85)	0.57 (0.50–0.65)	**0.66 (0.57–0.75)**	**0.77 (0.66–0.88)**
3	0.69 (0.60–0.77)	0.56 (0.48–0.64)	**0.67 (0.58–0.76)**	**0.95 (0.83–1.06)**
4	0.67 (0.58–0.75)	0.54 (0.47–0.62)	**0.89 (0.79–0.98)**	**1.02 (0.91–1.14)**
5 (high)	0.63 (0.55–0.71)	0.55 (0.47–0.63)	**0.71 (0.62–0.80)**	**0.93 (0.82–1.04)**

Bold represents p-values < 0.05.

Table 2: **Physical activity and BMI z-score of children from the 2015 Pelotas (Brazil) Birth Cohort.**

of active commuting, and the values gradually lowering, reaching 18.8% in the richest group (Supplementary Table S2). BMI-for-age increased from 0.68 SD at 1 y to 0.84 SD at 7 y. In general, boys presented significantly higher values at all time-points, except at age 4. At age 1, 2, and 4 Black children presented higher BMI-for-age than White and Brown children, but this difference was only significative at age 2. There were significant differences in BMI-for-age according to assets index at ages 4 and 7 y, with higher categories presenting higher BMI-for-age. See Table 2 for results and Fig. 2 for a depiction of these disparities via equiplots.

Fig. 3 displays the trajectory groups found for Physical Activity and BMI-for-age. Children were placed in either high, moderate or low categories, insinuating that their physical activity and/or BMI-for-age started at age 1 in such categories in comparison to their peers. Beyond these three groups, they were further categorized into one of two options either stable or increase/increasing which insinuated that from ages 1–7 years their physical activity and/or BMI-for-age patterns either steadily increased or remained consistent. The final model for physical activity resulted in four trajectory groups (Stable Low, Moderate Increase, High Increase and Increasingly Stable), where the greatest proportion of children were in the Moderate Increase group, meanwhile for BMI-for-age five groups were observed (Low and Stable, Moderate and Stable, High Increase, High and Stable and Very High and Increasing), where the greatest proportion of children were in the Moderate and stable group.

Table 3 describes the trajectory groups for both physical activity and BMI-for-age according to sex, race, and assets index. In the case of sex differences in physical activity patterns, boys were consistently more prevalent in the increase or high categories, while girls were more prevalent in the Stable Low group. Considering race, the prevalence of White children decreases with the increment of physical activity over the years. Finally, regarding assets index and physical activity,

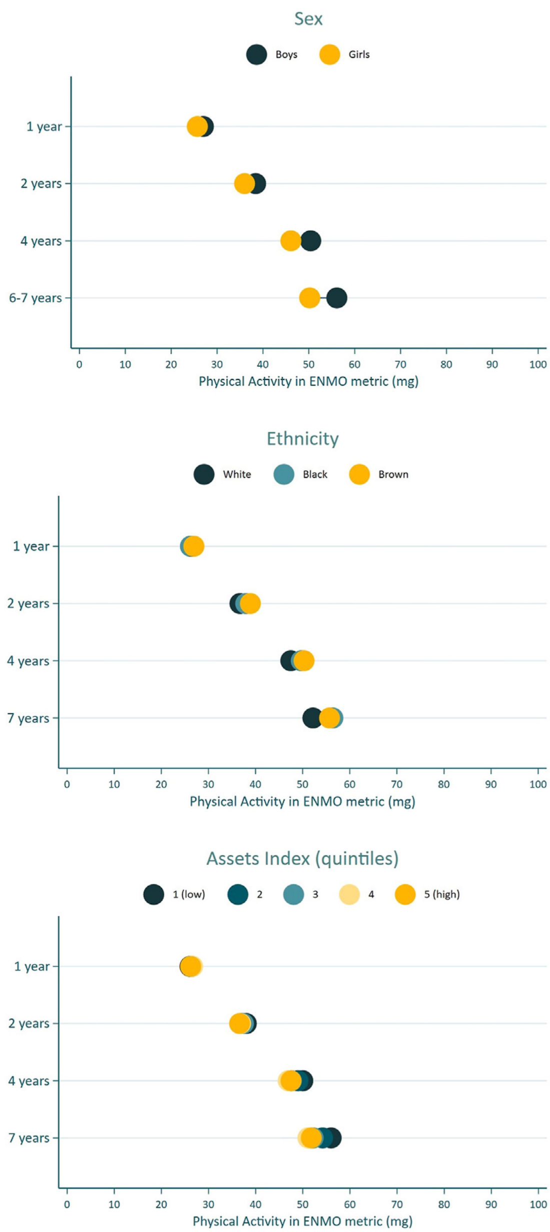

Fig. 1: Equiplots of physical activity according to sex, ethnicity, and assets index (1-poorest, 5-richest).

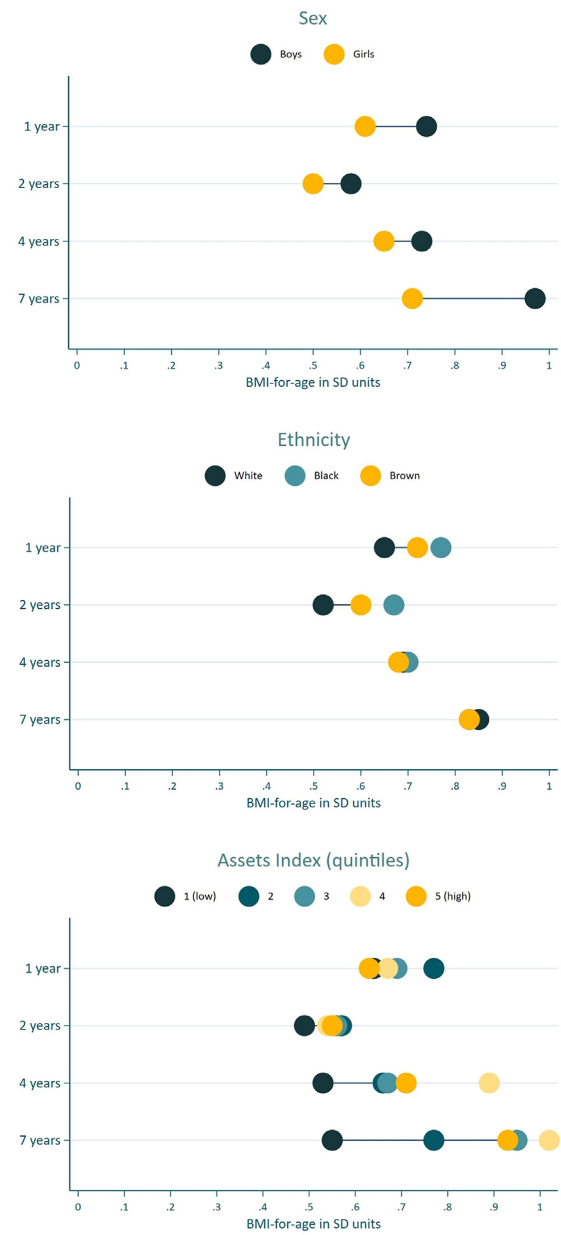

Fig. 2: Equiplots of BMI-for-age according to sex, ethnicity, and assets index.

children in the lowest quintile of assets index (poorest) were more prevalent on the higher active trajectory groups (High Increase-25.7%, Increasingly Stable-32.9%), whereas children in the highest quintile of assets index (richest) had no clear pattern in each trajectory group.

Pertaining to BMI-for-age, girls were more prevalent in the lower groups such as Low and Stable (51.4%) and Moderate and Stable (53.7%), while boys were more prevalent in the higher groups (High Increase- 55%, High and Stable- 52.6%, Very High and Increasing- 51.4%). Black (7.9%) and Brown (11.6%) children had the lowest prevalence in the Low and Stable group and had a higher prevalence in the moderate and high groups, while White children exhibited an opposite pattern with having the greatest prevalence in the Low and Stable group (80.5%). For assets index, we observed that the poorest children were more prevalent in the Low and Stable (25.5%) and Moderate and Stable (23.1%) groups and had the least prevalence amongst

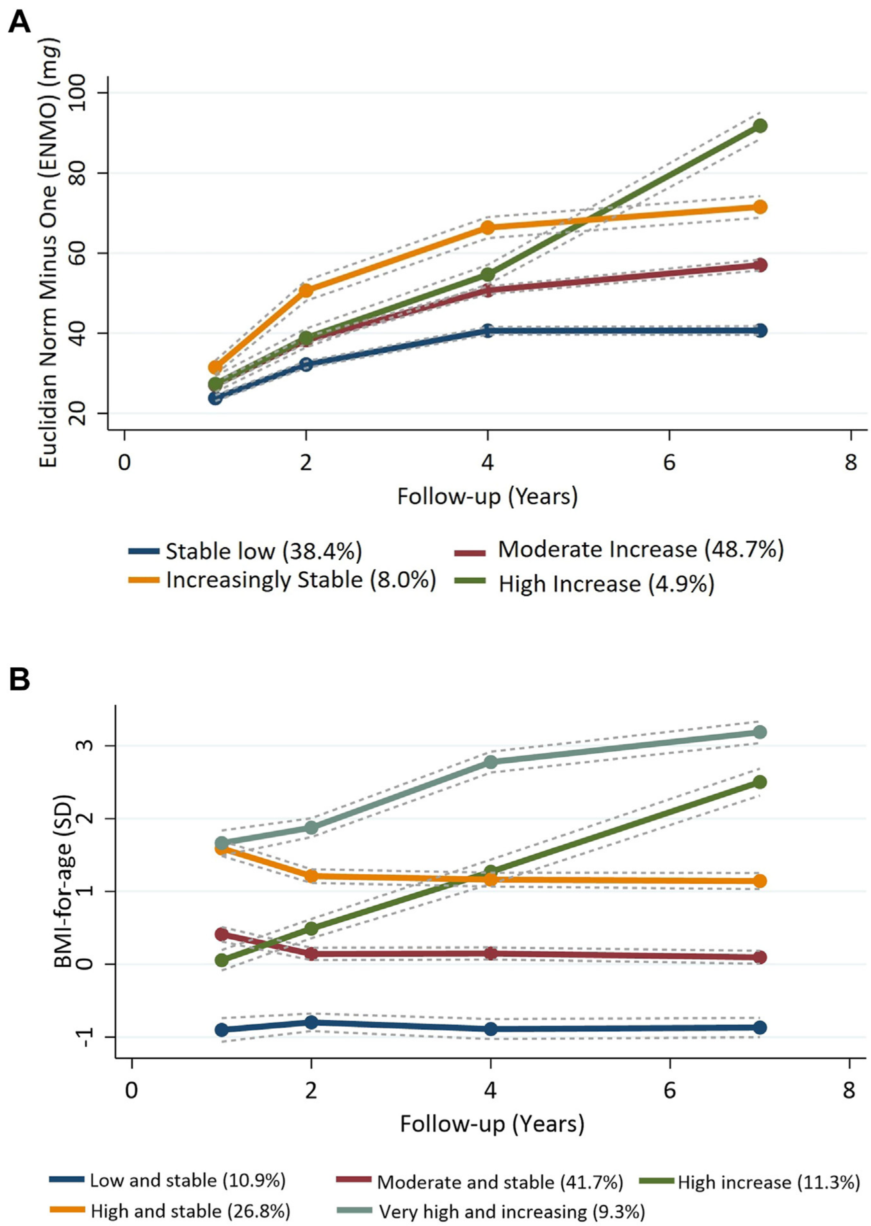

Fig. 3: Physical activity (A) and BMI-for-age (B) trajectories.

the groups with an increase in BMI-for-age (High Increase- 12.3%, Very High and Increasing- 14.8%).

Discussion

The current study was an observational analysis of the 2015 Pelotas Birth Cohort to investigate potential differences in physical activity patterns and BMI-for-age during early childhood (1–7 years) based on age, sex, race, and SES via assets index. The results indicated that overall physical activity increased between ages 1–7 years, boys were more active than girls at all ages, Black children, as well as children in the lowest quintile of the assets index (poorest), were more active at age 2 onward than their White and richer counterparts, respectively. Similar to physical activity, BMI-for-age also increased overall from ages 1–7 years and boys had consistently higher BMI-for-age than girls at all ages. Additionally, Black children had higher BMI-for-age than White and Brown children only at ages 1 and 2 and children of a lower asset index exhibited a lower BMI-for-age at ages 4 and 7 year. An additional aim comparing the trajectories of physical activity rates and BMI-for-age indicated that boys were more consistently prevalent in the higher

Physical activity	Trajectories groups			
ENMO (mg)	Stable low % (95% CI)	Moderate increase % (95% CI)	High increase % (95% CI)	Increasingly stable % (95% CI)
	N = 562	N = 742	N = 111	N = 71
Sex[a]				
Boys	39.9 (35.9–44.0)	54.7 (51.1–58.3)	67.6 (58.2–75.7)	80.3 (69.2–88.1)
Girls	60.1 (56.0–64.1)	45.3 (41.7–48.9)	32.4 (24.3–41.8)	19.7 (11.9–30.8)
Race[a]				
White	74.9 (71.2–78.4)	64.9 (61.4–68.3)	62.2 (52.7–70.8)	60.6 (48.6–71.4)
Black	11.3 (8.9–14.2)	13.0 (10.8–15.6)	16.2 (10.4–24.4)	15.5 (8.7–26.1)
Brown	13.8 (11.1–16.9)	22.1 (19.2–25.2)	21.6 (14.9–30.3)	23.9 (15.3–35.4)
Assets index 1 y (quintiles)[a]				
1 (low)	16.5 (13.6–19.8)	23.3 (20.4–26.5)	25.7 (18.3–34.8)	32.9 (22.7–44.8)
2	23.3 (20.0–27.0)	18.4 (15.7–21.4)	26.6 (19.1–35.8)	25.7 (16.7–37.4)
3	20.5 (17.3–24.0)	21.0 (18.2–24.1)	18.3 (12.1–26.8)	18.6 (11.0–29.6)
4	21.6 (18.3–25.2)	17.7 (15.1–20.6)	19.3 (12.8–27.9)	7.1 (2.9–16.2)
5 (high)	18.1 (15.1–21.6)	19.6 (16.9–22.6)	10.1 (5.6–17.4)	15.7 (8.8–26.4)

BMI-for-age	Low and stable % (95% CI)	Moderate and stable % (95% CI)	High increase % (95% CI)	High and stable % (95% CI)	Very high and increasing % (95% CI)
Standard deviation	N = 292	N = 1237	N = 320	N = 776	N = 259
Sex[a]					
Boys	48.6 (42.9–54.4)	46.3 (43.5–49.1)	55.0 (49.5–60.4)	52.6 (49.0–56.1)	51.4 (45.2–57.4)
Girls	51.4 (45.6–57.1)	53.7 (50.1–56.4)	45.0 (39.6–50.5)	47.4 (43.9–50.9)	48.6 (42.6–54.7)
Race					
White	80.5 (75.5–84.6)	70.3 (67.6–72.7)	75.0 (69.9–79.4)	70.2 (66.9–73.3)	73.4 (67.6–78.4)
Black	7.9 (5.3–11.6)	11.0 (9.4–12.9)	9.1 (6.4–12.7)	11.1 (9.1–13.6)	9.6 (6.6–13.9)
Brown	11.6 (8.4–15.9)	18.7 (16.6–21.0)	15.9 (12.3–20.4)	18.6 (16.0–21.6)	17.0 (12.9–22.1)
Assets index (quintiles)[a]					
1 (low)	25.5 (20.7–30.8)	23.1 (20.8–25.5)	12.3 (9.1–16.5)	19.7 (17.1–22.7)	14.8 (10.9–20.0)
2	17.4 (13.4–22.3)	20.4 (18.2–22.8)	21.2 (17.0–26.1)	23.0 (20.1–26.1)	16.0 (11.9–21.0)
3	24.4 (19.7–29.7)	19.8 (17.7–22.2)	20.9 (16.7–25.7)	19.7 (17.1–22.7)	23.7 (18.9–29.3)
4	16.0 (12.2–20.7)	17.1 (15.0–19.3)	27.2 (22.6–32.4)	19.9 (17.2–22.8)	26.8 (21.8–32.6)
5 (high)	16.7 (12.8–21.5)	19.6 (17.5–21.9)	18.4 (14.4–23.0)	17.7 (15.1–20.5)	18.7 (14.3–23.9)

[a]p-values < 0.05.

Table 3: **Trajectory groups for PA and BMI-for-age based on sex, race, and assets index.**

categories for both physical activity rates and BMI-for-age, Whites were more prevalent in the lower categories for physical activity rates and BMI-for-age, and finally, poorer children were more prevalent in the higher categories for physical activity and low and moderate categories for BMI-for-age.

Physical activity

When assessing the physical activity patterns, it was found that across all age groups, boys were more active than girls and the gap widened as the children increased in age. These were further confirmed by the trajectory analyses in which boys had a significantly greater prevalence in the Moderate Increase, High Increase, and Increasingly Stable groups. These results are consistent with literature reporting that boys tend to engage in more physical activity than girls.[1,24] Pertaining to the 2015 Pelotas cohort specifically, this pattern was also previously observed during early childhood.[13] This compliments the present study and reveals that the disparity in physical activity among sex may start as early as infancy (1 y) and continue to grow throughout early childhood into the school age period (7 y). With these results we can observe a clear opportunity for physical activity intervention implementation specific to girls that could begin as early as infancy and toddlerhood.

Analyses assessing race indicated that differences in physical activity disparities were evident at age 2 and continued onwards, where White children engaged in significantly less physical activity than Black and Brown children. Further, the trajectory analyses revealed that the prevalence of White children was greatest in the Stable Low physical activity group and Black and Brown children were more likely to be in the groups representing an increasing pattern, meaning they were more likely to increase their physical activity between ages 1 and 7 years. This was a particularly unexpected result.

Considering the Brazilian context as a national study on adults found that White participants had a higher prevalence of sport practice in 14 of the 16 activities measured.[25] However, previous work that has assessed objectively measured physical activity in countries such as the United States and the United Kingdom has revealed opposing findings that suggest that Black children are more active than other ethnic groups such as White, Asian, and Hispanic.[26] Therefore, our results are seemingly in opposition to adult populations in Brazil, yet more aligned with disparities measured in higher income countries. Considering the present study focus is descriptive, it is unclear why this may be occurring, as other factors are likely contributing. One may consider the types of activities children at this age are engageda in such as travel, unstructured and/or structured play, and household activities, as this could point to specific reasons why there appears to be a physical activity disparity during early childhood. For instance, in Brazilian adolescents aged 14–15 years, White students were more likely to have physical education at school, however children of Brown and 'yellow' race were more likely to engage in active commuting.[27] Considering the literature out of Brazil, it is possible that later in life during adolescence or adulthood, this disparity may change to match the adults' findings, however, continued observation of this 2015 Pelots cohort would be necessary to confirm this.

Beyond race, another observation made during toddlerhood was a potential disparity based on SES, as physical activity was significantly higher amongst children of the lowest quintiles of the assets index. This indicated that poorer children engaged in more physical activity starting at age two and continuing through seven years. Additionally, the trajectory analysis placed children in the lowest asset index quintile in the high active groups such as High Increase and Increasingly Stable. While seemingly unexpected considering the social position of poorer individuals, these findings match other work particularly from Pelotas, Brazil, indicating that during early life, poorer children are more likely to engage in physical activity.[28] Considering the young age of this cohort, it is likely the participants' physical activity is heavily influenced by their surroundings, such as their parents and/or siblings. However, future work is necessary to determine and confirm what factors could be driving such relationships. Exploration of parental roles, household activities and hobbies, play preferences, and other family and lifestyle factors related to SES will be critical in providing more context and cause to such findings. For instance, Brand et al., 2020 observed that a parent's commute to work, influenced their children's commute to school.[29] Therefore, it is possible that some of the children in the cohort, are actively commuting, such as walking or biking, to school. This hypothesis could be supported by the 'necessity-versus choice-based physical activity models' framework observed in many low-to middle-income countries proposed by Salvo et al., 2022, however, more information about the participants' lifestyle and choices is necessary to confirm if a similar pattern is being observed.[30]

BMI-for-age

Pertaining to the BMI-for-age rates, boys had higher BMI-for-age values than girls at all ages, which is an expected observation. The trajectory analyses revealed that boys were more likely to be placed in the High Increase, High and Stable, and Very High and Increasing groups. This may highlight a need to focus on the weight status of boys beginning at an earlier age, as these results may allude to a potential path of continued weight gain as they enter childhood and adolescence, which does appear to occur globally.[31] In a previous birth cohort study on childhood and adolescent overweight and obesity trends, Montiero et al., 2003 reported that there were relationships between overweight and obesity during adolescence and greater weight and height gain during childhood, particularly for boys.[32] Thus, our study may be exhibiting a similar trend as more boys were categorized into the "high" and "increasing" categories. This may give reason for early life interventions aimed towards boys to truly determine the cause and effect of this observation and potential decrease the risk of overweight and obesity later in childhood and adolescence.

Black children exhibited greater BMI-for-age than White and Brown children up until ages 4 and 7 where there was no difference between any racial groups. The trajectory analyses revealed that Black and Brown children were more likely to fall into the moderate and high BMI-for-age groups and White children were most prevalent in the Low and Stable group. This trajectory is a unique finding as previous work has indicated that later in life, during adolescence and adulthood Black and Brown individuals have exhibited higher rates of overweight and obesity.[33–35] Therefore, it is important to continue following this pattern through childhood to determine if there are later timepoints where disparities may appear. Considering the trajectory analyses of physical activity patterns indicating that Black and Brown children were more likely to fall into the "increasing" activity patterns, continued observation will also be critical in determining if these children remain in the higher weight status groups as well as increase their physical activity. If so, other factors such as diet, life stressors, and environment ought to be considered as determinants and causes of weight status during childhood development.

Regarding SES, there was no clear difference in BMI-for-age across age groups based on the asset index until the later ages, 4 and 7 years, where a statistically significant split indicating lower BMI-for-age amongst poorer children was beginning to arise. This early trend may be like previous observations of large cohorts of children from Brazil indicating no clear difference in weight status across SES factors,[36] however, the result at the later ages showcasing significantly higher BMI-for-age amongst children in a higher SES group is unexpected. Further, the trajectory analyses assessing SES patterns revealed that children of the lowest quintile (poorest) were more likely to be found in the Low and Stable and Moderate and Stable groups. When considering the physical activity trends, it is possible that the increased rates of physical activity in the lower SES groups are contributing to the alleviation of a potential increased weight status in these groups. However, this assumption cannot be confirmed because other factors such as diet and sedentary behaviour were not included in analyses. Regardless, these results do not necessarily align with what is observed in adult literature, thus there may be another time point during development when SES weight disparities switch to showcase lower BMI-for-age amongst higher SES groups. Continued longitudinal observations are necessary to further understand if such disparities may arise later in childhood or during a transition into adolescence and adulthood.

Strengths and limitations

While the present study has presented novel results, there are a few study limitations that ought to be considered. Firstly, when parents were surveyed on skin colour, other options beyond Black, White, and Brown were not included, therefore, other groups that make up a fairly small part of the Brazilian population (∼1) such as 'Yellow' or Indigenous, could be missing from the cohort. Further, certain variables that contribute to BMI-for-age were not included in the models such as food and dietary patterns, sedentary behaviour, family history, and sleep patterns. Hence, the ability to make any causal inferences based on the present work is limited due to missing the aforementioned variables related to BMI-for-age and considering the work was purely observational. Future studies assessing such disparities may consider the inclusion of such variables to strengthen these results and provide more context to the patterns observed in the present work. Finally, various forms of physical activity such as leisure time, work/school related, and commuting/travel were not included in the analyses. Analysing types of physical activity across sex, race/ethnicity, and SES is crucial in understanding where these disparities are taking place, where necessary interventions can be implemented, and could provide reasons for why some children may be more active than others. While these limitations are worth consideration, the study's strengths are also critical and should be highlighted. Firstly, having a large sample size strengthens the results as more complex analyses were able to be conducted, and with strong representation across all groups, the final conclusions are likely properly representative of the Pelotas, Brazil population. Additionally, the longitudinal model allowed for the analysis of the same children at each timepoint which removed any potential risk of confounding variables related to lifestyle that can arise when comparing different children. Finally, the trajectory analyses provide insight into the current course that the participants are on regarding their physical activity and weight status, which provides information regarding specific groups that may benefit more so from intervention than others.

Conclusion

Overall, the current study provides evidence of both physical activity and BMI-for-age disparities across multiple demographic variables during early childhood. Throughout the present study, differences were observed between boys and girls, economic groups, and races. Such disparities suggest the presence of inequalities, while the persistence of these differences as children age may indicate possible health inequities, associated with the dimensions studied. For clarity, health inequality refers to observable differences among subgroups within a population, such as SES, sex, and race/ethnicity,[37] while inequity refers to unjust and systematic differences, deemed to be avoidable and unnecessary, among people from different social groups, often related to poverty, discrimination, and lack of access.[38] Thus, these results are useful in determining when such inequities may begin to arise and aid in developing interventions to improve health behaviours as they point to specific populations that may be at a higher risk of poorer health-related quality of life both during childhood and potentially later in life.

Contributors

SAK: writing-original draft, writing-review & editing, decision to submit for publication; PCH: Conceptualization, supervision, funding acquisition, writing-review & editing, accessed & verified data, access to raw data; ICS: Accessed & verified data, access to raw data, writing-review & editing; MRD: Writing-review & editing, access to raw data; GSL: Writing-review & editing; OAL: Supervision, accessed & verified data, formal analysis, access to raw data, supervision, writing-review & editing.

Data sharing statement

The data used for this study are available with the corresponding author upon reasonable request.

Declaration of interests

We declare no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lana.2025.101111.

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