Effect of Urbanization on Objectively Measured Physical Activity Levels, Sedentary Time, and Indices of Adiposity in Kenyan Adolescents

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Background: Urbanization affects lifestyles in the developing world but no studies have assessed the impact on objectively measured physical activity in children and adolescents from sub-Saharan Africa. Purpose: To compare objectively measured habitual physical activity, sedentary time, and indices of adiposity in adolescents from rural and urban areas of Kenya. Methods: Physical activity and sedentary time were assessed by accelerometry for 5 consecutive days in 97 (50 female and 47 male) rural and 103 (52 female and 51 male) urban adolescents (mean age 13 ± 1 years). Body Mass Index (BMI) and BMI z-scores were used to assess adiposity. Results: Rural males spent more time in moderate-to-vigorous intensity physical activity (MVPA) compared with urban males (68 ± 22 vs. 50 ± 17 min, respectively; \( P < .001 \)). Similarly, Rural females spent more time in MVPA compared with urban females (62 ± 20 vs. 37 ± 20 min, respectively; \( P < .001 \)). Furthermore, there were significant differences in daily sedentary time between rural and urban subjects. Residence (rural vs. urban) significantly (\( P < .001 \)) influenced BMI z-score (\( R^2 = .46 \)). Conclusion: Rural Kenyan adolescents are significantly more physically active (and less sedentary) and have lower indices of adiposity compared with urban adolescents and this is a likely reflection of the impact of urbanization on lifestyle in Kenya.

Keywords: accelerometry, lifestyle, school-aged children, rural, urban, Kenya

Urbanization is a global trend which may be altering habitual physical activity and sedentary time of children and adolescents unfavorably, but there is almost no objectively measured data on physical activity of urban and rural adolescents in sub-Saharan Africa. We are aware of only a single published study on objectively measured physical activity levels in 6- to 16-year-old school-age children and adolescents from the African nation of Mozambique in comparison with levels in similarly aged Portuguese children and adolescents which reported that Mozambican children and adolescents engaged in significantly higher levels of physical activity compared with their Portuguese counterparts.1 Furthermore, a recent systematic review2 found that there is a large body of consistent evidence which suggests that habitual physical activity, objectively assessed by accelerometers, is inversely associated with body fat content in adolescents. However, of the 48 studies included in the systematic review, only 2 studies were from children and adolescents from the developing world and so evidence from some populations of youth is extremely limited.

Sub-Saharan Africa is known to be undergoing the ‘epidemiological transition’ as demonstrated by a reduction in childhood mortality due to communicable diseases and under-nutrition.3 These changes may be explained by rapid urbanization and adoption of Westernized lifestyles.4 Urbanization is often associated with extreme changes in dietary habits and habitual physical activity5 that underlie the distinct socioeconomic and environmental differences between rural and urban areas such as; active commuting to schools, fetching firewood, cattle herding, and fetching water from distant streams, which are typical energy-intensive occupational physical activities in many rural environments.6,7 On the other hand, typical urban lifestyles are characterized by consumption of energy dense-foods and sedentary activities such as motorized transport to school, TV viewing, and mechanization/automation of chores6,7 which may partially explain the observed differences in prevalence of lifestyle disorders such as obesity, hypertension, and diabetes between rural and urban populations in Africa.8

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It is now well established that physical activity has a range of health-related benefits for children and adolescents, with recommendations that at least 60 min of moderate-to-vigorous intensity physical activity (MVPA) should be accumulated daily. Guidelines also exist which recommend that children and adolescents restrict the amount of time they spend in sedentary behavior, a separate construct from physical activity. Increased childhood sedentary behavior has been proposed as a likely explanation for the increased secular trend in childhood obesity in the West. Accordingly, current interventions are focused on enhancement of physical activity in children and youth to reduce the risk of obesity.

Despite the suggestion that energy expenditure in third world countries is in line with that of the developed world, previous studies provide considerable contradictory evidence, albeit mostly indirect evidence, of very high activity levels in children and adolescents with some studies reporting that Kenyan and Ethiopian children from rural areas run up to 20 km to school daily, and are also engaged in physically active leisure time activities and household chores. This high childhood habitual physical activity has been proposed as one of the explanations for the success of Kenyan and Ethiopian runners since most of the elite runners originate in small villages in rural areas where physical activity levels are considered to be higher than in towns. Rapid urbanization has occurred in Kenya in recent years but the extent to which urbanization has affected habitual physical activity, sedentary time, and indices of adiposity of Kenyan children/adolescents has only been assessed using subjective means. Thus, objective assessment of habitual physical activity levels and sedentary time in these populations remains to be determined. The primary purpose of the current study, therefore, was to determine habitual physical activity levels and sedentary time in Kenyan adolescents from rural and urban areas using objective measures (ie, accelerometry). A secondary aim was to test for relationships between objectively measured physical activity, sedentary time, and adiposity in Kenyan adolescents in light of recent recommendations that at least 60 min of MVPA should be accumulated daily.

Material and Methods

Subjects

A convenience sample of 247 apparently healthy adolescents aged 12 to 16 years attending primary schools in rural and urban areas of Kenya were recruited for this study. The rationale for selection of this convenient sample was based on practical reasons. Accelerometry is a novel technique (even more so in Africa). Older youths compared with very young children were therefore selected simply because of compliance issues and concerns over loss of devices. Compliance to study protocol becomes a major problem in studies of this nature where continuous monitoring for extensive periods is required, especially in very young children. All the schools used in the study were day schools; to examine the influence of active commuting to school on overall physical activity levels. Subjects suffering from injury or any condition likely to limit physical activity were excluded from the study. The study participants from rural areas were 97 (50 female and 47 male) and from urban areas 103 (52 female and 51 male; see Table 1 for physical characteristics). All female subjects reported that they were postmenarche. Ethical approval was granted by The Institutional Research Ethics Committee (IREC), Moi University, Eldoret, Kenya. Written informed consent was obtained from the parents/guardians of each subject and from the Principals of each participating school in Eldoret Town Council (urban group) and Wareng County Council (rural group). In addition, subjects were required to personally assent to participate in the study. Furthermore, subjects were free to withdraw from the study at any stage if they felt uncomfortable without the need to provide any explanation. However, none of the subjects withdrew.

Subjects were assigned to the urban group if they lived within the municipal boundaries of Eldoret town and were served at home with mains electricity and piped water. Eldoret is a town (2100–2700 m above sea level) in western Kenya and the administrative center of Uasin Gishu District of Rift Valley Province with a population of 193,830 in 1999 (census). In contrast, subjects were assigned to the rural group if the subjects lived in small and remote villages in the Nandi region of Kenya without access to mains electricity and piped water at home. Urbanization was therefore used as a proxy for socioeconomic and environmental differences existing between rural and urban areas and reflected in marked lifestyle differences between these 2 areas and thus a useful model to examine increasing sedentary lifestyles of modern urbanized areas in Kenya and beyond and not necessarily restricted to the study area or Kenyans.

Habitual physical activity levels were assessed by uniaxial accelerometry for 4 consecutive weekdays and 1 weekend day. The Actitrainer (ActiGraph LLC, Pensacola, FL, USA) is a novel triaxial accelerometer designed to measure and record time varying accelerations ranging in magnitude from approximately 0.05 to 2.0 G. The Actitrainer is surrounded in a metal shield and packaged into a plastic enclosure measuring 5 × 4 × 1.5 cm and weighs approximately 45 g including a 3V (2430) coin cell lithium battery. The Actitrainer has a sampling range of 0.25 to 2.5 Hz, a sampling frequency of 30 Hz and contains a cantilevered rectangular piezoelectric bimorph plate and seismic mass, a charge amplifier, analog band-pass filters, and a voltage regulator to measure acceleration in either uniaxial, biaxial or triaxial planes. The filtered acceleration signal is digitalized and the magnitude is summed over a user specific time (an epoch interval). At the end of each epoch the summed value is stored in memory and the numerical integrator reset. For the purpose of this study, sedentary time and physical activity levels were assessed using cut-points for sedentary and MVPA developed by Puyau et al. These cut-points have been validated in children and adolescents.
age 6 to 16 years as follows: sedentary time <800 counts per minute (CPM) and MVPA >3200 CPM. The time spent in bouts of MVPA was also determined. The definition of a bout was at least 5 min of consecutive MVPA, allowing for 20% of interruption within the bout (ie, if the bout was exactly 5 min, then 1 min interruption was permitted). A standard activity diary that would typically complement accelerometry assessment to collect supplementary data such as mode of exercise (walking/running), duration, wear time of accelerometer, etc was used to obtain data on mode of transport to school, time taken to get to school, daily hours awake and engagement in specific physical activities such as playing football, running, cattle herding; playing netball, swimming, fetching water from streams, and fetching firewood. However, this data should be treated with caution since it has limitations inherent in this form of subjective data.

**Protocol and Indices of Weight Status**

The study was conducted for 4 consecutive school days and 1 weekend day between January 2008 and May 2009. Before testing of each subject, activity monitors were tested and fully charged. The accelerometer was placed in a small nylon pouch and firmly adjusted at the right hip of the subject by an elastic belt. Activity diaries were completed by each subject or their parent(s). In all subjects, height was measured to the nearest 0.1 cm using a portable stadiometer (Somatometre Model SE V91, Seca, Birmingham, UK) and body mass measured to the nearest 0.1 kg using portable weighing scales (Seca, Model 761, Vogel & Halke, Hamburg, Germany). BMI relative to International Obesity Task Force (IOTF) definitions was used to define subjects as overweight or obese, and BMI z-scores were calculated relative to World Health Organization (WHO) reference data.

**Accelerometer Data Reduction**

The epoch was set to 1 s and reintegrated to 60 s using the ActiTrainer software (ActiGraph LLC, Pensacola, FL, USA). This epoch has been validated against criterion methods in children and youth aged 6 to 16 years. Data were further edited automatically to delete periods of 20 min or longer of consecutive zero counts before further analysis as recommended by Treuth et al who previously found that a period of 20 min or more of consecutive zero counts was not consistent with the awake state. A minimum of 8 hours of monitoring per day for at least 4 days was considered acceptable for evaluation of habitual physical activity and sedentary time. The appropriateness of these inclusion criteria for the assessment of habitual physical activity in children and adolescents has previously been demonstrated. Compliance to current physical activity guidelines of daily accumulation of at least 60 min of MVPA per day was assessed using the Puyau cut-points. Subjects were considered compliant to the MVPA guidelines if their MVPA averaged over the valid days of monitoring was ≥ 60 min per day.

**Statistical Analysis**

Descriptive statistics included calculations of means, standard deviation, and test of group differences following Kolmogorov-Smirnov test for normality. Multiple stepwise regression analysis was conducted to assess the effect of residence (rural vs. urban) on main study outcomes (ie, % time sedentary, total physical activity in CPM, % time in MVPA, BMI z-score, and time in MVPA bouts) controlling for age, gender, and residence. Compliance to published public health guidelines for appropriate MVPA levels was also assessed using binary logistic regression analysis; with MVPA compliance (coded as 0: <60 min; 1: >60 min) as the dependent variable. The predictors were residence (rural vs. urban) and gender, and their interaction. Independent t tests were used to determine differences between all means. Statistical significance was declared at P < .05. All statistical analysis was completed using the software package SPSS, Version 17.0 (SPSS, inc., Chicago, IL).

**Results**

**Descriptive Data**

Descriptive characteristics including anthropometric and key physical activity variables are shown in Table 1. All subjects were monitored by uniaxial accelerometry for a daily average of 13 ± 2 hours with an average CPM of 753 ± 237 (Table 1). Daily mean sedentary time was 584 ± 113 min which is equivalent to approximately 72% of monitored time in sedentary activities (Table 1). Subjects spent 54 ± 23 min daily engaged in MVPA which was approximately 7% of the daily monitored time (Table 1). In addition, 43 ± 23 min daily was spent engaged in MVPA bouts (Table 1). Analysis of the physical activity diaries of rural adolescents revealed that all 97 subjects reported either walking (n = 39 or 40%) or running (n = 38 or 60%) to school, covering distances ranging from < 1 km to > 7 km. Forty-eight percent (n = 47) of rural subjects reported taking less than 30 min to get to school, 21% (n = 20) between 30 min to 1 hour to get to school, while the remaining 31% (n = 30) of these subjects reported taking more than 1 hour to get to school. On the other hand, 50% (n = 52) of the urban subjects reported that they traveled to school by car while 41% (n = 42) walked to school. Only about 9% (n = 9) of the urban subjects reported running to school. All the urban subjects who either walked or ran to school reported that it took them less than 30 min to get to school (Table 1). All 200 subjects reported that they were involved in household chores and leisure time was spent doing active physical activities such as running, jumping, skipping, playing football or netball, swimming, and sedentary activities such as study, watching television or listening to the radio. In addition, rural adolescents typically reported engaging in activities not reported often by the urban adolescents: gardening, fetching water from streams,
fetching firewood, and cattle herding. All the adolescents reported that they were awake for at least 16 hours in each day.

Comparison of Physical Activity Levels and Sedentary Time in Rural and Urban Kenyan Adolescents

Total habitual physical activity assessed as average CPM was significantly higher in rural male vs. urban male subjects (956 ± 143 vs. 626 ± 151 CPM, respectively; \( P < .001 \)) (Table 1). Similarly, average CPM was significantly higher in rural female vs. urban female subjects (915 ± 161 vs. 537 ± 150 CPM, respectively; \( P < .001 \)) (Table 1). With regard to patterns of activity and sedentary activities, urban males spent significantly more time sedentary than rural males (678 ± 95 vs. 555 ± 67 min, respectively; \( P < .001 \)) (Table 1). Similarly, rural males spent more time in MVPA compared with the urban males (68 ± 22 vs. 50 ± 17 min, respectively, \( P < .001 \)) (Table 1). Rural male adolescents also accumulated significantly more daily time in MVPA bouts compared with urban males (54 ± 24 vs. 38 ± 16 min, respectively, \( P < .001 \)) (Table 1). Similar patterns of physical and sedentary activities as those reported in males were found in females. As such, there were significant differences in the daily time spent in sedentary time between rural female vs. urban females (539 ± 91 vs. 694 ± 81 min, respectively; \( P < .001 \)) (Table 1), rural females spent more time in MVPA compared with urban females (62 ± 20 vs. 37 ± 20 min, respectively; \( P < .001 \)) (Table 1) and rural females accumulated significantly more daily time in MVPA bouts compared with urban females (52 ± 21 vs. 29 ± 19 min, respectively; \( P < .001 \)) (Table 1).

Multivariate Analysis of Physical Activity, Sedentary Time, and Adiposity Indices in Kenyan Adolescents

To identify the factors that may be associated with BMI z-score and objectively measured physical activity and sedentary time in the current study, total volume of physical activity (as evaluated by average CPM) and intensities of physical activity and sedentary time (% time sedentary, % time in MVPA and in MVPA bouts) were assessed by multivariate regression analysis (Table 2). The regression model included residence (urban vs. rural), gender and age. BMI z-score was significantly \( (P < .001) \) influenced by residence (adjusted \( R^2 = .46 \)) with a total model \( R^2 \) of 0.47 (Table 2). Similarly, total volume of physical activity was significantly \( (P < .001) \) influenced by residence (adjusted \( R^2 = .58 \)) with a total model \( R^2 \) of 0.59 (Table 2). In addition, % time sedentary was influenced significantly \( (P < .001) \) by residence (adjusted \( R^2 = .60 \)) with a total model \( R^2 \) of 0.61 (Table 2). Furthermore, % time in MVPA was significantly \( (P < .001) \) influenced by residence (adjusted \( R^2 = .30 \)) with a total model \( R^2 \) of 0.31 (Table 2).

Table 1 Descriptive Characteristics of Kenyan Adolescents (Mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Rural</th>
<th>Male</th>
<th>Female</th>
<th>Urban</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>200</td>
<td>47</td>
<td>50</td>
<td>52</td>
<td>51</td>
<td></td>
<td></td>
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<tr>
<td>Age (years)</td>
<td>13.0 ± 1.0</td>
<td>13.3 ± 0.7</td>
<td>13.3 ± 0.6</td>
<td>13.0 ± 1.0</td>
<td>12.8 ± 0.7</td>
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<tr>
<td>Height (m)</td>
<td>1.60 ± 0.1</td>
<td>1.65 ± 0.1</td>
<td>1.61 ± 0.1</td>
<td>1.57 ± 0.1</td>
<td>1.58 ± 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>45.0 ± 9.0</td>
<td>41 ± 8.5</td>
<td>42 ± 7.3</td>
<td>48.1 ± 8.5</td>
<td>50.0 ± 6.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>18.0 ± 3.0</td>
<td>15.0 ± 2.0</td>
<td>16.2 ± 2.5</td>
<td>19.4 ± 2.8*</td>
<td>20.0 ± 2.0‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport to school (% car/walk/run)</td>
<td>26/41/34</td>
<td>0/19/81</td>
<td>0/40/60</td>
<td>50/39/12</td>
<td>51/43/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary (min)</td>
<td>584 ± 113</td>
<td>555 ± 67</td>
<td>539 ± 91</td>
<td>678 ± 95*</td>
<td>694 ± 81‡</td>
<td></td>
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<tr>
<td>MVPA (min)</td>
<td>54 ± 23</td>
<td>68 ± 22</td>
<td>62 ± 20</td>
<td>50 ± 17*</td>
<td>37 ± 20‡</td>
<td></td>
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<tr>
<td>CPM</td>
<td>753 ± 237</td>
<td>956 ± 143</td>
<td>915 ± 161</td>
<td>626 ± 151*</td>
<td>537 ± 150‡</td>
<td></td>
<td></td>
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<tr>
<td>% Sedentary</td>
<td>72</td>
<td>65</td>
<td>66</td>
<td>78</td>
<td>80</td>
<td></td>
<td></td>
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<td>% MVPA</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Compliance</td>
<td>35</td>
<td>60</td>
<td>50</td>
<td>21*</td>
<td>12‡</td>
<td></td>
<td></td>
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<tr>
<td>TIB</td>
<td>43 ± 23</td>
<td>54 ± 24</td>
<td>52 ± 21</td>
<td>38 ± 16*</td>
<td>29 ± 19‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI z-score</td>
<td>-0.7 ± 1.1</td>
<td>-1.7 ± 0.9</td>
<td>-1.2 ± 0.9</td>
<td>0.4 ± 1.3*</td>
<td>0.3 ± 0.7‡</td>
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</tbody>
</table>

‡ Significant difference between rural and urban females.
* Significant difference between rural males and urban males.

Abbreviations: BMI, Body Mass Index; MVPA, moderate-to-vigorous physical activity; CPM, average count per minute; TIB, time spent in MVPA bouts per day.

Note. % compliance to published guidelines for appropriate MVPA levels (ie, an accumulation of a minimum of 60 min MVPA daily).
Mean BMI z-score was significantly lower in rural male compared with urban male subjects (−1.7 ± 0.9 vs. 0.4 ± 1.3, respectively; *P < .001) (Table 1). Similarly, BMI z-scores were significantly lower in rural female compared with urban female subjects (−1.2 ± 0.9 vs. 0.3 ± 0.7, respectively; *P < .001) (Table 1). None of the rural adolescents in the current study were classified as either overweight or obese according to the International Obesity Task Force Definitions. On the other hand, 3 male and 6 female urban subjects were classified as overweight and 1 urban male was classified as obese. The prevalence of overweight/obesity in urban subjects was therefore estimated as 10% (ie, 10 out of 103).

Relationships Between Physical Activity, Sedentary Time, and BMI z-Scores in Kenyan Adolescents

BMI z-score was positively correlated with % sedentary time in Kenyan adolescents (r = .59, *P < .001) (Figure 1) and negatively correlated with % MVPA time (r = −.40, *P < .001) (Figure 1). Similarly, BMI z-score was negatively correlated with total volume of physical activity in Kenyan adolescents (r = −.50, *P < .001) (Figure 1).

Compliance With Recommended MVPA Levels in Kenyan Adolescents

In the current study, 35% (ie, 70 out of 200) of all Kenyan adolescent subjects met the current public health guidelines for MVPA, defined as an average of ≥60 min per day of MVPA over the days of monitoring. However, a greater percentage of rural males (60% or 28 out of 47) compared with urban males (21% or 11 out of 52) fulfilled this recommendation. Similarly, a greater percentage of rural females (50% or 25 out of 50) compared with urban females (12% or 6 out 51) fulfilled this recommendation. Residence was the only significant predictor of MVPA compliance (odds ratio = 7.5; 95% CI 2.9–22.5; *P < .001) (Table 1). On the contrary, gender was not a significant predictor, nor was there significant gender by residence interaction (*P > .05).

Discussion

In the current study there were marked differences in habitual total volume of physical activity (CPM), MVPA, sedentary time, and weight status (reflected here as BMI and BMI z-score) between the 2 groups studied. Moreover, these differences were evident from the multiple regression analysis and were not explained by differences between the urban and rural groups in other variables such as age and gender. Previous studies of Kenyan adolescents from rural areas which used subjective measures of physical activity indicated a highly active lifestyle with subjects reporting that they walked on average for 3 hours per day and also spent an average of 40 min per day working in the field.17,18 The quantitative differences revealed by objective measurement in the current study between urban and rural groups may therefore reflect marked lifestyle differences which remain between rural and urban youth in Kenya and which is consistent with previous studies.6,7 All the rural adolescents in the current study engaged in active transport to school (ie, ran or walked to school) whereas half of the urban adolescents used motorized transport to get to school (Table 1). In addition, other than physically active play, rural adolescents consistently reported spending part of their ‘leisure time’ (defined here as time away from school), engaged in physically active household chores. For example, subjects reported activities such as fetching water from distant streams and fetching firewood, gardening, and running involved in cattle herding. In contrast, the urban sample studied either did not report such activities or reported these activities very infrequently. The urban subjects reported that they spent their leisure time pursuing largely sedentary activities such as studying, watching television, and listening to the radio. The differences in reported physical activity profiles between rural and urban adolescents are an indication of the

| Table 2: Multiple Regression Analysis of the Effect of Residence, Gender, and Age on BMI z-Score, CPM, % Time Sedentary, and % Time MVPA in Kenyan Adolescents |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Model**       | **BMI z-scores** | **Total volume physical activity (CPM)** | **% time sedentary** | **% time MVPA** |
| Residence       | β = 0.66, *P = .00* | β = 0.75, *P = .00* | β = 0.77, *P = .00* | β = −0.53, *P = .00* |
| Gender          | β = 0.07, *P = .21 | β = −0.14, *P = .03* | β = 0.1, *P = .03* | β = 0.15, *P = .01* |
| Age             | β = −0.07, *P = .22 | β = 0.02, *P = .61 | β = −0.03, *P = .59 | β = 0.04, *P = .48 |

Abbreviations: CPM, average count per minute.

* Significantly different *P < .05.

Note: Model Residence*Gender*Age = BMI z-score (adjusted R² = .46) F(3, 199) = 56.9, *P < .05. Model Residence*Gender*Age = Average CPM (adjusted R² = .58) F(3, 199) = 92.7, *P < .05. Model Residence*Gender*Age = % Sedentary (adjusted R² = .6) F(3, 199) = 100.3, *P < .05. Model Residence*Gender*Age = % MVPA (adjusted R² = .5) F(3, 199) = 29.5, *P < .05.
Figure 1 — Pearson correlation coefficient of % MVPA (top), % sedentary (middle), and average CPM (bottom) vs. BMI z-scores in Kenyan adolescents.
distinct socioeconomic and built environments between these 2 groups. Rural areas in Kenya do not have modern amenities such as mains electricity or piped water and schools are located remotely from villages which may help explain the more active lifestyle in the rural group in the current study. On the other hand, urban schools and households are served with modern necessities such as piped water and mains electricity with accessible roads and frequent motorized transportation. Consequently, urban adolescents might be expected to spend less of their leisure time engaged in such physically active chores. Previous studies which relied on subjective evaluation of physical activity in Kenyan adolescents also suggested that urban vs. rural differences might exist in Kenya. While the significant differences between urban and rural groups in the objectively measured physical activity in the current study might have been ‘expected’ based on the aforementioned studies and the lifestyle differences recorded in the diaries, differences in subjectively measured habitual physical activity and sedentary time are not always supported by objective measures. In the UK for example, studies which use subjective methods consistently find socioeconomic differences in child and adolescent physical activity and sedentary time which are consistently not found when physical activity is measured objectively.

Direct comparisons of urban vs. rural differences in objectively measured habitual physical activity and sedentary time in adolescents especially from sub-Saharan Africa are rare and therefore there are no directly comparable studies. Only 1 study appears to have measured habitual physical activity objectively in sub-Saharan children and adolescents and compared this with levels in Portuguese children and adolescents. It was found that Mozambican children and adolescents had higher levels of physical activity compared with their Portuguese counterparts. However, the Portuguese group engaged in significantly higher frequency and duration of MVPA bouts compared with the Mozambican group; these observed differences in physical activity parameters were attributed to environmental influences. On the other hand, Kelly and colleagues found increased sedentary time and gender differences in rural Irish children aged 4 to 5 years with boys significantly more active than girls (824 vs. 628 CPM). In addition, boys spent 74% of monitored time sedentary compared with 81% in girls. Similarly, boys spent 4% of monitored time in MVPA compared with 2% in girls. Kenyan adolescents from rural areas, on the other hand, had higher levels of physical activity and were less sedentary compared with the Irish children but showed similar gender differences with boys significantly more active than girls (956 vs. 915 CPM). Similarly, boys spent 65% of the monitored time sedentary compared with 66% in girls. Boys also spent 9% of monitored time in MVPA compared with 8% in girls. Therefore, it remains to be determined if the observed differences between sub-Saharan populations and Western populations can be replicated or are sample specific. The results of the current study are broadly consistent with recent systematic reviews on the association between physical activity, sedentary time, and adiposity in youth. This is further supported by a number of studies on the ‘nutrition transition’ which have suggested that subjectively measured physical activity or sedentary time, or ‘proxies’ for physical activity and sedentary time (such as reported TV viewing, mode of transport to school and physically intensive chores), tend to change unfavorably with development and urbanization in the developing world. Furthermore, the diets of the developing world are shifting rapidly, particularly with respect to fat, caloric sweeteners, and animal source foods. This nutritional transition is closely related to and may explain the current demographic and epidemiologic transitions seen in developing countries, with individuals increasingly consuming diets which are higher in energy but low in fiber. These changes are reflected in nutritional outcomes, such as changes in average stature, body composition, and morbidity. In the current study, 10% of urban adolescents were overweight/obese whereas none of the rural subjects were overweight/obese. In addition, an earlier study reported the prevalence of overweight/obesity in young children in urban areas in Kenya to be twice that found in rural areas (6.2% vs. 3.2%, respectively) suggesting that over-nutrition of young children could be an emerging phenomenon in urban Kenya. Similarly, prevalence of overweight and obesity was much higher in the urban adults (38% vs. only 18% in the rural adults).

Though current public health guidelines for physical activity in children and adolescents were not intended specifically for the developing world, it was of interest to assess compliance with the recommendation that adolescents accumulate at least 60 min of MVPA daily. In the current study, a higher percentage of rural adolescents 55% (53 out of 97) averaged 60 min of MVPA per day compared with only 17% (17 out of 103) of the urban sample (Table 1). This difference is consistent with the significant differences in objectively measured habitual physical activity between the groups noted above and supportive of the lifestyle differences (such as differences in active commuting to school) which were revealed by the activity diaries, anecdotal reports of rapid urbanization of rural Kenya and the increasing trend toward sedentary time in Kenyan adolescents especially from urban areas. This notwithstanding, the relatively low adherence rates to guidelines for appropriate physical activity levels observed even in rural Kenyan adolescents, raises some fundamental questions about the appropriateness of the physical activity cut-points used in the current study as well as the appropriateness of current physical activity recommendations. This point has been raised by previous authors who questioned the validity of physical activity cut-points and the current physical activity guidelines in view of the high compliance rates reported in some Western children in spite of the increasing prevalence of overweight and obesity in these populations.
Study Strengths and Weaknesses

The use of accelerometry permitted objective and precise measurement of habitual physical activity and sedentary time over long periods of time, and this has been rare in studies of youth in developing countries to date. Testing for associations between objectively measured physical activity and sedentary time and indices of adiposity in sub-Saharan Africa has been even less common. However, the cross-sectional study design makes it uncertain that lower levels of physical activity and/or higher levels of sedentary time in the urban group actually caused higher adiposity. On the other hand, a previous study suggested that differences in energy intake and not physical activity levels may primarily explain observed differences in adiposity but dietary intake was not measured in the current study. Secondly, it was impossible to account for possible seasonal variation in habitual physical activity levels and sedentary time in youth in the current study, yet seasonal variation might either increase or decrease habitual physical activity and sedentary time differences between urban and rural populations.

Conclusions

The current study found marked differences in daily physical activity volumes and intensities between rural and urban adolescents in Kenya, with much lower levels of physical activity and higher levels of sedentary time in the urban group. In addition, rural adolescents had much lower indices of adiposity compared with urban adolescents, and higher adiposity was associated with both lower levels of physical activity and higher levels of sedentary time. In addition, the validity of the current physical activity recommendations merits further inquiry in diverse populations-most of the evidence to date on this topic has been obtained from Western societies.

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