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## The effect of urbanization on sleep, sleep/wake routine, and metabolic health of residents in the Amazon region of Brazil

Andressa J. Martins<sup>a</sup>, Cheryl M. Isherwood<sup>b</sup>, Suleima P. Vasconcelos<sup>c</sup>, Arne Lowden<sup>d</sup>, Debra J. Skene<sup>b</sup>, and Claudia R.C. Moreno<sup>a,d</sup>

<sup>a</sup>School of Public Health, University of São Paulo, São Paulo, Brazil; <sup>b</sup>Faculty of Health & Medical Sciences, University of Surrey, UK; <sup>c</sup>Center of Health and Sport Sciences, Federal University of Acre, Brazil; <sup>d</sup>Stress Research Institute, Department of Psychology, University of Stockholm, Stockholm, Stockholm, Sweden

### ABSTRACT

Studying communities with different levels of urbanization may further the understanding of risk factors underlying metabolic diseases. The present study is unique by comprising detailed assessment of sleep and activity, biological rhythms, and metabolic factors of men from the same geographical location and place of birth that reside in different, rural vs. town, stages of urbanization. Sleep patterns, activity, and metabolic indicators in two groups (rural,  $n = 22$  and town/urban,  $n = 20$ ) of men residing in an Amazonian community (Xapuri, Acre, Brazil) were compared. Sociodemographic, anthropometric, and metabolic variables – fasting glucose, insulin resistance, triglycerides, total HDL cholesterol, LDL cholesterol, and VLDL cholesterol – were assessed. Sleep patterns, light exposure, and physical activity levels were additionally assessed by actigraphy, plus daily activities were recorded in diaries for 10 days. Town/urban dwellers were found to have significantly higher body weight, fasting glucose, insulin levels, and insulin resistance than rural dwellers, whereas triglycerides levels were similar. Town/Urban dwellers had shorter sleep duration ( $p < .01$ ) and later sleep onset and offset times ( $p = .01$ ). Our findings show an association between stage of urbanization and presence of risk factors for metabolic disorders, such as overweight, insulin resistance, increased glucose levels, short sleep duration, and less natural light exposure during work times.

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### KEYWORDS

Urban; rural; metabolic diseases; metabolic parameters; sleep; natural light exposure; circadian routine

### Introduction

Non-communicable diseases are a significant concern in the context of global public health of both developed and developing countries (Ali et al. 2015). In this regard, urbanization is associated with a lifestyle of reduced physical activity, energy-dense nutrient-poor diets, sedentary work, extended exposure to artificial light, and reduced sleep duration (Caballero 2005). In turn, these lifestyle factors are associated with risk factors for diseases of civilization, e.g., dyslipidemias, obesity, hypertension, and insulin resistance (Popkin 2009). Sleep restriction, itself, has been linked with compromised metabolic health (Christou et al. 2019; Farr and Mantzoros 2018) in the form of disrupted glucose metabolism (Potter et al. 2016) and reduced insulin sensitivity (Roenneberg et al. 2012; Spiegel et al. 1999).

The proportion of the population residing in urban areas globally has increased from 13% in the early 20th century to almost 50% in 2005 (Kearney 2010), and according to the World Cities Report, published by the United Nations in 2016, 54% of the world's population

lives in urban areas. The report also notes this trend has remained steady for the past 20 y, especially in developing nations, such as Asian, Latin American, and African countries (United Nations Human Settlements Program 2016). Recent research studies comparing urban versus rural and hunter-gatherer communities highlight the relationship between the urbanization of small cities and sleep quality (Beale et al. 2017; De la Iglesia et al. 2015; Moreno et al. 2015). Moreno et al. (2015) reported Amazonian rubber tappers (rural dwellers) with access to electricity slept for less time than those without electricity. De la Iglesia et al. (2015) also reported shorter sleep duration in those with access to electricity among two indigenous communities of hunter-gatherers in Argentina. More recently, Beale et al. (2017) found later sleep start times in urban dwellers compared to rural dwellers in Mozambique. In addition, urban vs. rural residence has an effect on the diet-sleep association; for example, relative intake of protein was found to be inversely associated with sleep duration, but only in rural residents (Liu et al. 2018). The association between

sleep and diet may have an effect on metabolic indicators. A study conducted on a rural Brazilian population revealed poor sleep quality to be independently associated with a poorer lipid profile, suggesting poor sleep quality may be an epiphenomenon of other sleep disturbances (Geovanini et al. 2019).

Several published studies have demonstrated a relationship between elevated body mass index (BMI) and short sleep duration and later sleep timing (Lucassen et al. 2013; Roenneberg et al. 2012). Both animal models and human studies have shown that exposure to light can modulate metabolism, especially the appetite regulating hormones, for example, leptin, and ghrelin as well as increase body weight and adiposity (Figueiro et al. 2012; Fonken et al. 2010).

Greater knowledge of the sleep patterns and nutrition among communities that undergo urbanization, in comparison with nearby rural communities, is fundamental to better understanding the impact of urbanization on human health, especially in the context of non-communicable diseases. Northern Brazil, particularly the Amazon region, is the ideal environment for this type of study. Its population residing in rural areas is without access to electricity and the nearby small towns are in the initial stages of industrialization with access to modern industrialized facilities. There has been very low migration in the area in comparison to the Southern regions of Brazil. Furthermore, this location is around latitude 10°, which means low variation in the daytime natural photoperiod duration during the year.

From the above scenario, the present study is unique by comprising detailed assessment of sleep and activity, biological rhythms, and metabolic factors, making it possible to compare two similar groups (same geographical location, place of birth) in different stages of urbanization (rural vs. town/urban dwellers).

## Methods

**Study sample and design.** We conducted a cross-sectional study of two similar groups (geographical location, place of birth) in different stages of urbanization (rural vs. town/urban dwellers). Sociodemographic data, lifestyle habits, anthropometry, nutritional status, and metabolic indicators were collected. The study was conducted on two occasions, between September and October 2015 and July and August 2016.

The total sample of the study ( $n = 42$ ) consisted of two groups: 1) rural dwellers ( $n = 22$ ), who were residents in the extractive reserve of Chico Mendes located in the municipality of Xapuri; 2) town dwellers ( $n = 20$ ), who lived nearby in the town of Xapuri (Latitude: 10° 39' 06" S; Longitude: 68° 30' 16" W), and were employed in

the education and services sectors. Both the rural and town groups were composed of males with mean age of 41.6 (SD = 10.9) and 38.8 y (SD = 8.2), respectively. Both groups had lived all their lives in the area, and no former rural workers comprised the urban sample.

The state of Acre, located in the northern region of Brazil, has 16,091 inhabitants in an area of 5,347,446 km<sup>2</sup>, of whom 5,761 (36%) reside in the rural area and 10,330 (64%) in the urban area (IBGE 2010).

Inclusion criteria for the town dwellers were: male, life, and work routine of daytime activity and nighttime sleep, and residing in urban (town) setting. The inclusion criteria for the rural dwellers were: male sex, residing and working in the extractive reserve (activities such as extraction of latex, nuts, subsistence agriculture, and raising small animals) with access to electricity in their homes. School teachers from the local public school were invited to participate as town dwellers, and rural dwellers were randomly invited. Females, shift-workers, and males with preexisting self-reported sleep disorders were excluded.

## Variables

### Socio-demographic and lifestyle questionnaire

Data on socio-demographic aspects were collected, such as age, sex, education, marital status, and number of persons per residence, number of children <18 y of age, and life habits (physical activity, smoking, and alcohol intake).

### Nutritional Status

Nutritional status was evaluated by measuring BMI, body fat percentage, and waist circumference. According to the recommendation of the World Health Organization (WHO 2000), BMI was categorized as follows: <18 kg/m<sup>2</sup> = low weight; ≥18.5 kg/m<sup>2</sup> to <25 kg/m<sup>2</sup> = eutrophy; ≥25 kg/m<sup>2</sup> to <30 kg/m<sup>2</sup> = overweight; ≥30 kg/m<sup>2</sup> = obese. Following the proposal by the Brazilian Society of Cardiology in 2013, we used a waist circumference ≥90 cm in men as constituting abdominal obesity indicative of risk for metabolic morbidities. Body fat index, visceral fat index, and metabolic age were calculated using the Tanita® (BC 543) digital scale.

### Metabolic Parameters

A fasting (morning) blood sample for the measurement of glucose, insulin, triglycerides, total cholesterol, HDL, LDL, and VLDL cholesterol was collected by a trained nurse and transported for analysis to an authorized

laboratory according to all transport protocols of biological material in the state capital of Acre, Rio Branco. Triglycerides, total cholesterol, and LDL-cholesterol ranges were established by the Brazilian Dyslipidemias Directive; high  $\geq 150$  mg/dL (triglycerides), 200 mg/dL (total cholesterol),  $\geq 100$  mg/dL (LDL-cholesterol); low  $< 40$  mg/dL (HDL-cholesterol) (Simão et al. 2013). The 2016 reference values of the Brazilian Diabetes Society were used to categorize fasting glycemia. Insulin resistance was calculated using the HOMA-IR (*Homeostasis Model Assessment*). Values  $> 2.71$  were considered high for the Brazilian population according to Geloneze et al. (2006).

### Activity and Sleep

A daily activities diary was completed by the study participants with the aid of the researcher when necessary. The diary consisted of a 24 h schedule divided into 15 min intervals, which presented the following activities: work, transportation, sleep, meal or snack, play, and other leisure activities. Participants wore a light-activity monitor on their non-dominant wrist for 10 consecutive days to investigate sleep patterns, light exposure, and physical activity level. The light-activity monitor contains an accelerometer to record activity levels and light per 60 s epochs (*ActTrust Condor Instruments*). Raw data were checked and corrected for inconsistencies according to the information contained in the activities diary and subsequently edited using Philips Actware 6.0.5 software (*Philips Respironics*). After editing all of the actograms, the variables related to sleep for work days and days off were estimated. The variables analyzed were: sleep onset time, wake up time, sleep length, and time of midsleep.

### Statistical Analysis

The Shapiro Wilk test was used to evaluate the distribution of the variables. The Fisher's exact test was used to verify associations between the following categorical variables: marital status, education, presence of children  $< 18$  y, alcohol intake, smoking, physical activity, BMI, waist circumference, fasting glucose, triglycerides, total cholesterol, LDL-cholesterol, HDL-cholesterol, and VLDL-cholesterol.

Student's t-tests (or a non-parametric test when data were not normally distributed) were performed for independent samples on normally distributed data to compare between rural and town dwellers the variables of age, BMI, waist circumference, body fat, visceral fat, muscle mass, metabolic age, fasting glucose, fasting

insulin, triglycerides, total cholesterol, LDL-cholesterol, HDL-cholesterol, and energy (Kcal).

Repeated measures ANOVA tested main effects and the interaction between day of week (work days and days off) and location (rural/town) on sleep onset, wake up time, midsleep time, and sleep duration, as well as the main effects between location and time-of-day (hour) of physical activity and light exposure on work days and days off. *Spearman's* correlation tests were performed between BMI and energy intake (Kcal) of rural and urban participants. The Stata14 software program (Stata Corporation, College Station, TX, USA) was used for all statistical analyses. A  $p$ -value  $< 0.05$  level of statistical significance was adopted for all tests.

### Ethical Aspects

The study was approved by the Research Ethics Committee of the Faculty of Public Health of the University of São Paulo (CAAE: 44860515.0.0000.5421) and was conducted in accordance with the ethical standards established by the National Health Council (Resolution 466 of December 12, 2012) (Portaluppi et al. 2010). Volunteers, after being informed about the research objectives, provided signed informed consent.

### Results

Urban/town dwellers had higher levels of education than rural dwellers ( $p < .001$ ) and smoked less; 36.4% of rural dwellers were smokers vs. 5% of town dwellers;  $p < .05$ . No differences between the two groups were observed regarding marital status, having children at home, or alcohol consumption. However, there were differences regarding eating behavior, with higher carbohydrate consumption among rural dwellers in comparison to urban dwellers (details of eating behavior have been published elsewhere; Tiuganji et al. 2020). Moreover, urban/town dwellers had significantly higher ( $p < .05$ ) values of body fat, and consequently more indicators for overweight, obesity, and metabolic risks (Table 1 and Figure 1A-E).

Town dwellers had significantly higher ( $p < .05$ ) fasting glucose levels, fasting insulin, and HOMA-IR index compared to rural dwellers (Table 1 and Figure 2B-D). No statistically significant differences were observed between the levels of triglycerides, total cholesterol, HDL-cholesterol, LDL-cholesterol, and VLDL-cholesterol between the town and rural dwellers (Figure 2A). However, as depicted in Figure 1, there was a trend of higher values in these parameters among town dwellers, except for HDL-cholesterol,

**Table 1.** Age and metabolic parameters among rural ( $n = 22$ ) and town ( $n = 20$ ) dwellers.

Variables	Town ( $n = 20$ )	Rural ( $n = 22$ )	P-value (T- test)
	mean (SD)	mean (SD)	
Age (years)	43.50 (12.0)	42.00 (18.0)	0.332 <sup>a</sup>
BMI (kg/m <sup>2</sup> )	28.06 (4.2)	24.95 (3.3)	<b>0.011</b>
Waist (cm)	97.05 (10.9)	86.40 (9.4)	<b>0.002</b>
Fat (%)	25.07 (6.0)	19.23 (5.4)	<b>0.002</b>
Visceral fat (%)	10.05 (3.7)	7.72 (3.4)	<b>0.042</b>
Muscle (kg)	58.28 (7.1)	51.69 (5.6)	<b>0.002</b>
Metabolic age (years)	50.00 (20.0)	34.50 (20.0)	<b>0.006<sup>a</sup></b>
Triglycerides (mg/dL)	136.00 (113.0)	130.50 (32.0)	0.200 <sup>a</sup>
Insulin (uUI/mL)	10.99 (7.5)	4.42 (3.3)	<b>0.003<sup>a</sup></b>
Total cholesterol (mg/dL)	157.00 (38.0)	114.00 (28.0)	0.120 <sup>a</sup>
HDL-cholesterol (mg/dL)	40.21 (10.2)	43.54 (10.3)	0.305
LDL-cholesterol (mg/dL)	87.00 (43.0)	75.40 (33.0)	0.448 <sup>a</sup>
VLDL-cholesterol (mg/dL)	34.35 (11.6)	31.22 (11.3)	0.403
Fasting glucose (mg/dL)	88.52 (14.2)	79.36 (12.5)	<b>0.035</b>
HOMA-IR	2.11(1.0–3.4)	0.90 (0.5–1.3)	<b>0.001<sup>a</sup></b>

<sup>a</sup>Due to non-normal distribution, the median was calculated and Mann-Whitney tests conducted.

which was higher among rural dwellers, as a protective factor against cardiovascular diseases.

Town dwellers slept for shorter duration ( $F = 15.30$ ,  $p = .0004$ ) during work days, had later sleep onset ( $F = 28.30$ ,  $p < .0001$ ;  $F = 23.18$ ,  $p < .0001$ ), later wake up time ( $F = 5.11$ ,  $p = .0299$ ;  $F = 25.15$ ,  $p < .0001$ ), and later midsleep time ( $F = 25.89$ ,  $p < .0001$ ;  $F = 41.99$ ,  $p < .0001$ ) during work and days off (Figure 3).

Participants in rural areas were exposed to natural light since their work activities occurred in the field, with activities related to land cultivation management. Among the urban participants, there was less exposure to natural light, since their work activities took place indoors in enclosed spaces, such as schools and public offices (supplemental material). In both groups, as expected, there were higher levels of activity during the day; however, for the rural dwellers, higher activity levels were observed compared to the urban dwellers, with significant differences between the two groups during work days. No significant differences in light exposure were found between the two groups (rural and town dwellers) on days off (supplemental material). However, rural dwellers were significantly more active than town dwellers on their days off.

## Discussion

Modernization and urbanization are ongoing now in many distant regions and communities in Brazil, bringing with them changes in life habits that can impact health, including increasing risk for metabolic and cardiovascular diseases, plus reduction of quality of life. According to Malik and collaborators (2013), the negative consequences of an urbanized lifestyle are the result of

profound changes related to technological advances, intense mechanization, alteration of housing environment, broader availability of food options, increased sleep deprivation, and greater availability of social activities during the nighttime. According to the authors, all these aspects collectively impact quality of the diet, significantly reduce daily energy expenditure, and contribute to increased obesity.

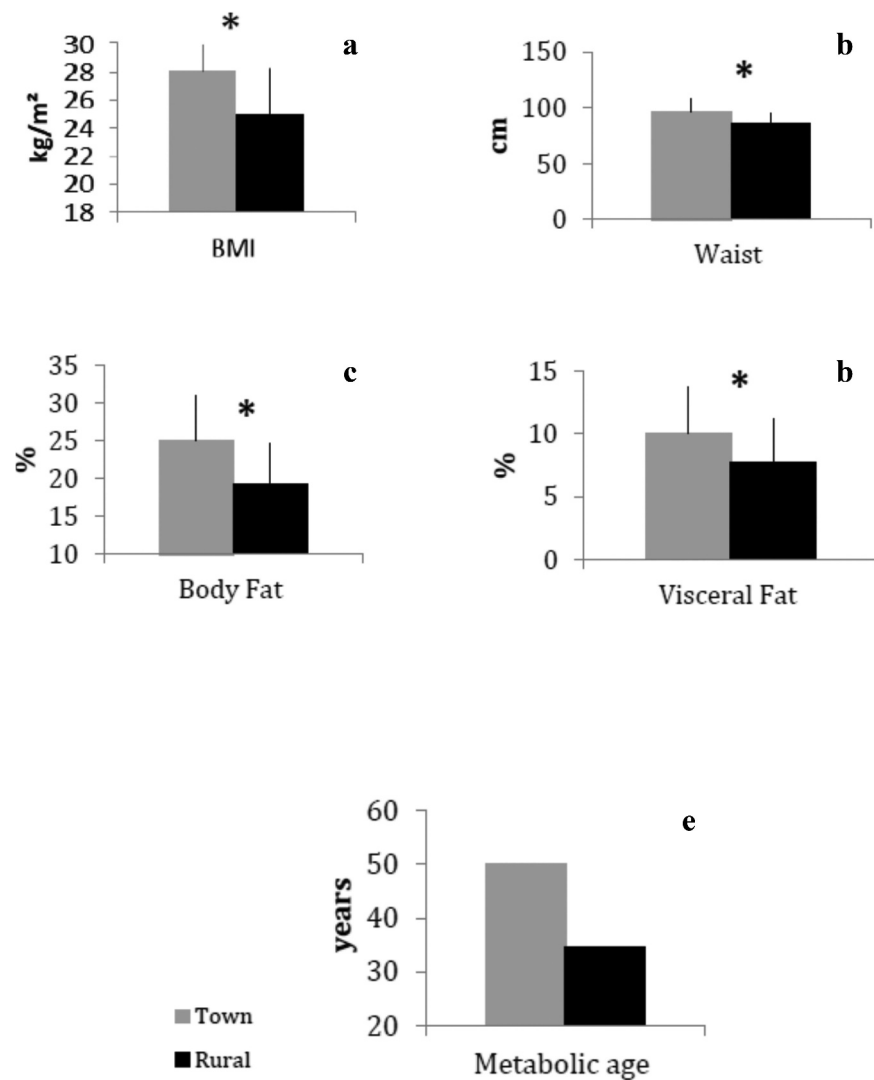
Here, we describe the differences between urban/town and rural cohorts in aspects related to nutritional status, as well as metabolic factors associated with the risk of non-communicable diseases and sleep quality. Our findings emphasize the prevalence of overweight and obesity among town residents, as well as high levels of biochemical markers – fasting glucose, fasting insulin, and insulin resistance by the HOMA-IR index – indicative of metabolic diseases. These findings can contribute to public policies that implement recommendations from the NOVA food classification system (Monteiro et al. 2018) regarding avoidance of ultra-processed foods, which are consumed in high amount by urban residents.

Previous studies have shown a strong relationship between urbanization and the presence of non-communicable metabolic and cardiovascular diseases, in terms of their associated risk factors, such as overweight, high blood pressure, changes in serum lipids, and insulin resistance (Monda et al. 2007; Novak et al. 2012;). Such non-communicable diseases have huge impact on socioeconomic development, especially in developing countries, as they affect the economically active population, resulting in lost productivity (Alwan & Maclean 2009).

In contrast, our findings reveal the body weight and metabolic indicators of rural inhabitants are in the normal range. Rural dwellers, in comparison with town dwellers, were thus healthier despite having a higher proportion of smokers and doing less physical activity during leisure time. The literature reports that rural work, which in itself requires greater physical strength, may contribute significantly to a lower prevalence of cardio-metabolic risk factors among rural communities (Obirikorang et al. 2015). Nevertheless, the literature also shows a relationship between intense physical effort of rural work and quality of sleep. Martins et al. (2016) in a study of a similar rural population from the Amazon found an increased prevalence of musculoskeletal pain due to work effort that was associated with poorer sleep. Moreno et al. (2016) also showed rural work is an important predictor of sleep problems and musculoskeletal pain.

The sleep patterns of the urban dwellers in comparison to rural dwellers were characterized by delayed





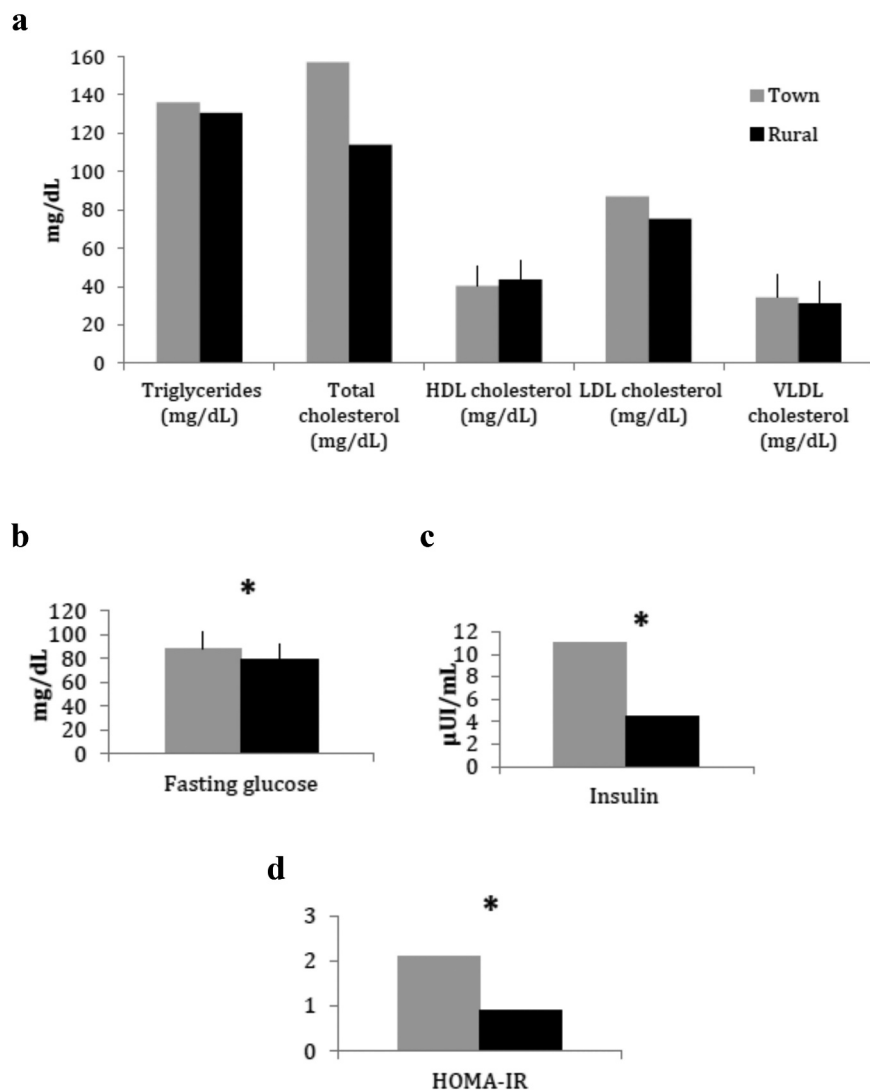
**Figure 1.** Mean ( $\pm$  SD) fasting lipid profile (A), glucose (B), insulin (C) and HOMA-IR (D) among town ( $n = 20$ ) and rural ( $n = 22$ ) dwellers. Student's  $t$  test or Mann-Whitney test. \* $p < .05$ .

sleep onset and wake up time, as well as shorter sleep duration. Although both groups have electricity in their homes, the town is more illuminated and has more nighttime activities than the rural area. However, the quality of sleep of the rural residents was worse, as reported elsewhere (Martins et al. 2016). Bejamini et al. (2016) also found high prevalence (34.9%) of poor sleep quality in a Brazilian rural population. High prevalence of poor sleep quality thus appears to be a common finding in rural communities marked by strenuous work activities. Another study in a rural African community also found worse sleep quality among rural residents due to poor sleeping conditions and intense work activity (Beale et al. 2017). In addition, town residents with access to electricity also exhibited delays in sleep onset, similar to that found in the current study. Beale et al. (2017) also point out that some aspects of the urban environment may have beneficial effects on

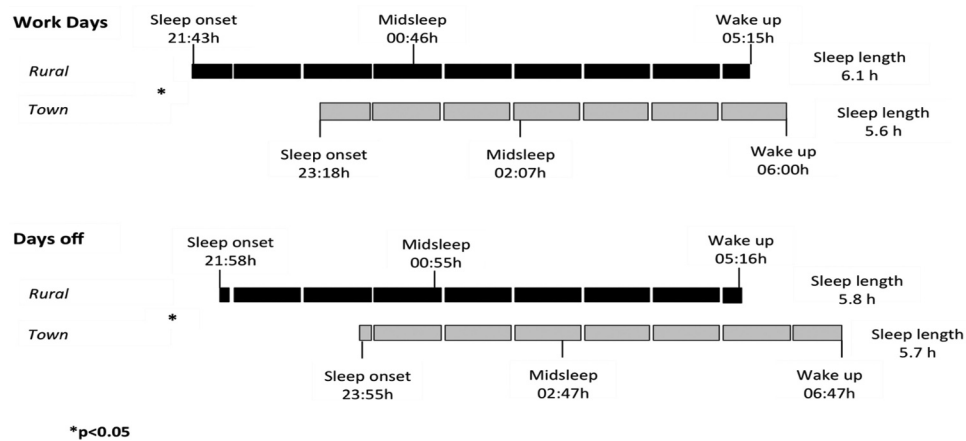
sleep, such as access to more comfortable sleeping places, safer homes, more comfortable room temperature, etc.

In our study, the jobs of town residents were less laborious and required less physical effort, thereby corroborating the above-discussed finding of recent publications. However, even in the face of these possible benefits generated by urbanization, our findings corroborate the growing literature showing shorter sleep duration, later sleep onset, later wake up time, and less light exposure during work days in town/city dwellers.

Patel and Hu (2008) in their systematic review showed shorter sleep duration increased the risk of obesity. It is well described in the literature that sleep deprivation/restriction reduces leptin levels and increases ghrelin levels, thus altering metabolism and satiety and contributing to increased obesity (Patel et al. 2006; Spiegel et al. 2004).



**Figure 2.** Anthropometric variables (mean  $\pm$  SD) among town dwellers ( $n = 20$ ) and rural ( $n = 22$ ) dwellers. Student's  $t$  test: BMI (A), waist (B), body fat (C) and visceral fat (D). Mann-Whitney test: metabolic age (E); \* $p < .05$ .



**Figure 3.** Sleep patterns (sleep onset, midsleep, wake up time and sleep duration) on work days and days off among rural ( $n = 22$ ) and town ( $n = 20$ ) dwellers. Black: rural dwellers; Grey: town dwellers. \* $p < .05$  in all sleep parameters shown.

In addition to sleep, exposure to light has been a recurring research topic associated with obesity. According to Reid and collaborators (2014), exposure to moderate light levels at biologically appropriate times may influence body weight regardless of sleep duration and time of sleep onset. Obayashi et al. (2016), in a cohort study, demonstrated that exposure to light during the night and reduction of light exposure throughout the day were associated with an increase in obesity indicators in an elderly population, regardless of sleep duration, sleep onset, and sleep disorders. The 10 y follow-up assessment detected an estimated 10% increase in BMI and 10.2% increase in waist:hip ratio. Increased nocturnal light and reduced natural daylight exposure are common features of modern society (Lunn et al. 2017), and in combination may be an important risk factor for obesity.

One of the possible mechanisms that may explain the direct relationship between light exposure and body weight, independent of caloric intake, may be the direct influence of light on hormone synthesis, such as melatonin. Exposure to daylight may alter nocturnal levels of melatonin and the sensitivity of the circadian oscillator to light (Chang et al. 2011; Obayashi et al. 2012; Smith et al. 2004). These factors may influence energy metabolism. Changes in melatonin concentrations may also affect insulin sensitivity (McMullan et al. 2013; Peschke et al. 2013; Zanuto et al. 2013). These findings also corroborate the results of our research, since hyperglycemia and higher insulin resistance were observed among the town residents.

Another important aspect to be discussed in the genesis of weight gain is the timing of food intake (McHill et al. 2017). Although timing of food intake is not discussed here, several studies, both in humans and in animal models, state that eating foods at inappropriate times when they should be reserved for sleep can lead to overweight and metabolic diseases (Arble et al. 2009; Baron et al. 2013; Colles et al. 2007; Salgado-Delgado et al. 2010).

Some lifestyle characteristics found in town/urban settings may contribute to the excess weight observed in the town dwellers. In contrast, some aspects of urbanization, such as greater access to health and education, could contribute positively to the improvement of the issues discussed above. However, in developing countries such as Brazil, the growth of urban areas occurs rapidly, often without detailed planning and without basic infrastructures, so that the problems of urbanization impact especially the poorest populations of these regions (Malik et al. 2013; Popkin 2009). Xu et al. (2014) pointed out this aspect of rapid growth in a study of rural and urban populations in Shaanxi Province, China that is undergoing accelerated urbanization. The study found increased risk for metabolic syndrome among rural residents as a result of the recent sociodemographic and

lifestyle changes. The authors discussed the fact that rural communities in the process of urbanization share the same problems as cities, such as soil, water, and air contamination, but do not have access to the same facilities, such as hospitals, health care, adequate housing, education, and places for recreation and leisure activities.

In conclusion, our findings show an association between town/urban residence and the presence of risk factors for metabolic disorders, such as overweight, insulin resistance, increased glucose levels, short sleep duration, and reduced natural light exposure during work times. However, in a developing country like Brazil, rural populations seem to exhibit poorer sleep quality and adoption of some unhealthy lifestyle practices, like smoking (Geovanini et al. 2019; Martins et al. 2016).

This overview provides a dimension of the new challenges to individual and public health with advancement of the contemporary urbanized lifestyle within Brazil and its potential health risks over and above the existing health problems of rural areas, which arise from poor access to basic health care, low educational level, low income, and inadequate working conditions.

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## Conflicts of interest statement

We declare no conflicts of interest.

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## ORCID

Debra J. Skene  <http://orcid.org/0000-0001-8202-6180>  
 Claudia R.C. Moreno  <http://orcid.org/0000-0003-1839-9673>

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