Comparison of sleep parameters assessed by actigraphy of healthy young adults from a small town and a megalopolis in an emerging country

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***Abstract*—The analysis of sleep quality and its impact on diurnal sleepiness is a crucial aspect of human health. Modern life in large cities compels people to spend less hours sleeping than they need. A wearable actigraphy that records accelerometry, light and body temperature was used to register the sleep habits of 54 healthy subjects for 14 days. From them, 28 participants resided in a town that could be regarded as a rural environment while the other subjects lived in the largest metropole of South America. The subjects filled three questionnaires to assess sleep quality (Pittsburgh Sleep Quality Index - PSQI), sleepiness (Epworth Sleepiness Scale - ESS) and chronotype (Morningness-Eveningness Questionnaire – MEQ-HO). The subjects were divided in urban and rural groups and several parameters obtained from actigraphy were compared between groups. Overall, the metropolitan group had worse sleep parameters. The total sleep time in metropolitan group was lower than the rural population, as well as the sleep quality parameters such as sleep efficiency. A possible explanation for these differences could be the social and work characteristics imposed in the metropolitan environment, forcing subjects to stay awake longer and away of natural light exposure. Sleep disorders are associated with several health and brain function problems. Therefore, it is imperative to establish changes in daily routine to promote a better sleep quality and prevent sleep disorders.**

I. Introduction

Sleep is influenced by environmental and social factors. These could be understood and assessed using objective and/or subjective approaches.

Polysomnography is the golden standard to determine the sleep state of the subject, including the different sleep phases, sleep apnea and sleep quality with a high precision. However, it requires that the subject is heavily instrumented and sleeps in a different environment, thus limiting its ecological validity.

Actigraphy is based on monitoring continuously the acceleration with a device usually attached to the wrist along with other variables such as temperature and ambient light. With this information, it is possible to identify periods of activity, rest and sleep. It provides a non-invasive method to assess sleep–wake cycles over long periods, from days to months in the natural environment of the user [1]. Nonparametric circadian rhythm analysis was used as the method for extracting circadian characteristics from the rest–activity cycle. The use of actigraphy is usually complemented with other methods in order to obtain more complete information about sleep problems and sleep-related behaviors [2].

The modernization of the cities has increased the gap between urban and rural activities. The intense routine and/or the natural light exposure contamination in metropolitan centers causes degeneration of the circadian timing system that may compromise sleep patterns [3]. The purpose of this study was to compare the sleep parameters with actigraphy between subjects in rural and urban environments.

II. Actigraphy

A. Hardware

The actimeter used for the analysis is the ActTrust® (Condor Instruments Ltda, Brazil) (Fig. 1).

Figure 1. The ActTrust device

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The ActTrust® (Condor Instruments, Brazil) device is equipped with a 3-axis accelerometer, two precision temperature sensors, one in the skin and one for the environment and a light sensor with RGB spectrum detailing. The devices were configured to register the activity data and to process it with Proportional Integral Mode (PIM) algorithm with a 60 seconds epoch. This algorithm, presented in Fig. 2 filters and integrates the acceleration to obtain a measure of the user's activity. The PIM data with 60 seconds epoch was integrated within every hour of the days generating twenty-four epochs of 3600 seconds. The resulting data was used to calculate the nonparametric parameters.

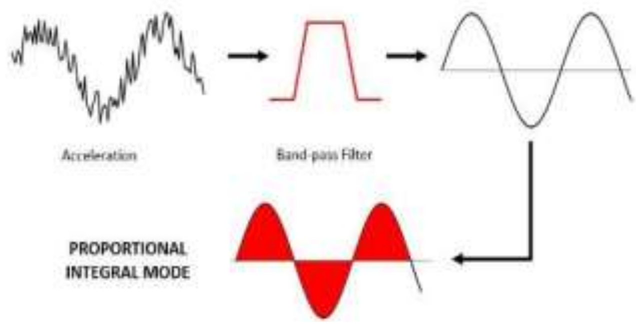

Figure 2. Proportional Integral Mode calculation block diagram

The data was downloaded using the software ActStudio® (Condor Instruments Ltda., SP, Brazil) (Fig. 3).

B. *Data analysis*

The actigraphy data was used to assess the sleep parameters. We obtained measures of Intraday Variability (IV), amplitude of rest (L5), Total Sleep Time (TST) and Sleep Efficiency (SE).

The intraday variability (IV) is calculated as the average of the differences between the posterior and previous hour normalized by the variance of one-hour activity data obtained with the PIM [4]. 'X' is the registered activity data or registry value; 'Xm' is the mean of all registry values; 'N' is the total number of records.

$$IV = \frac{\sum_{i=2}^{N}(X_i - X_{i-1})^2 N}{(N-1)\sum_{i=1}^{N}(X_i - X_m)^2} \quad (1)$$

This value is used to detect fragmentation of activity rhythms. A value of high IV is usually an indicative of daytime sleep and/or nighttime awakenings.

L5 is defined as the lowest sum of 5 consecutive hours of the activity log. Higher values of this variable are related to more movements in the sleep phase.

The total sleep time and sleep efficiency was obtained by activity analysis in the software ActStudio® (Condor Instruments Ltda., SP, Brazil), based on Cole-Kripke algorithm [5].

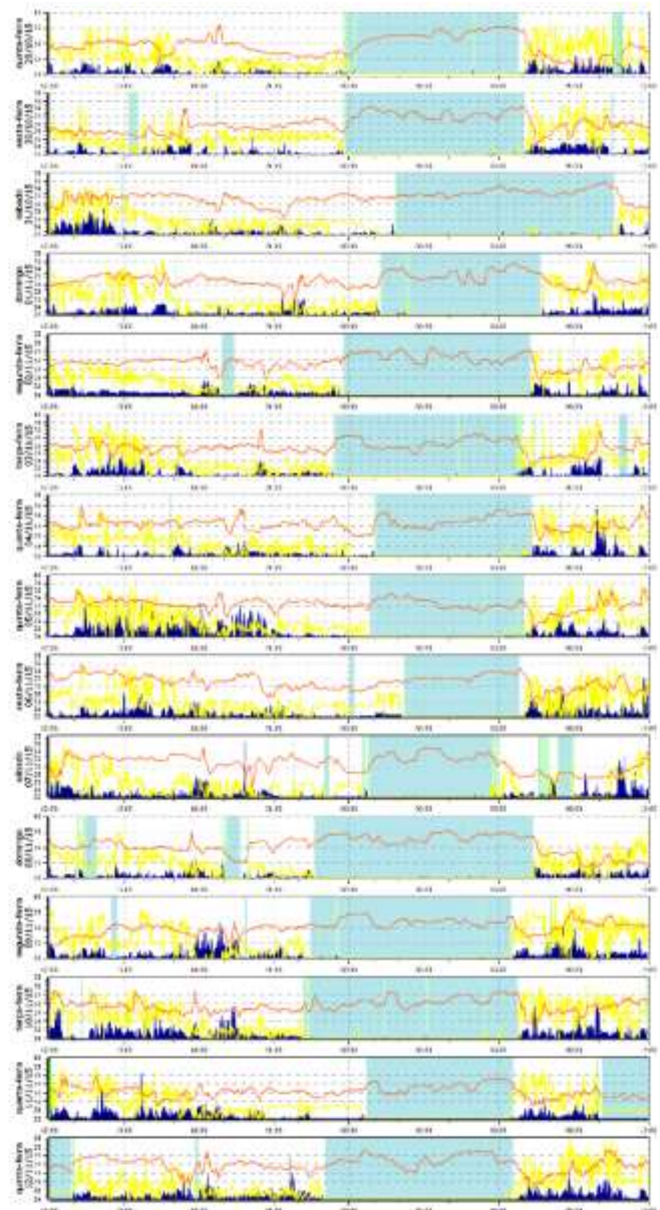

Figure 3. Actogram, raw actigraphy data along with the detection of the sleep intervals.

III. EXPERIMENTS

A. *Subjects*

A total of 58 non-shift workers undergraduate students without sleeping disorders from urban (N = 26) and rural (N = 28) environment volunteered to participate in the experiment. The Urban Group (UG) and the Rural Group (RG) had, approximately, the same age (Mdn = 22 and Mdn = 21, respectively, with U = 332 and p = .576), the same body mass index (Mdn = 23.6 and Mdn = 22.5, respectively, with U = 293 and p = .222), the same chronotype measured by the MEQ-HO (Mdn = 49.5 and Mdn = 48.5, respectively, with U = 340 and p = .684), the same sleep quality measured by the PSQI (Mdn = 6.0 and Mdn = 6.0, respectively, with U = 311 and p = .357) and the same subjective sleepiness measured by the ESS (Mdn = 10.0 and Mdn = 9.5, respectively, with U = 297 and p = .247).The study was approved by the two local Ethics Committees of the research sites, the Federal Institute of Education, Science and Technology of the Southeast of Minas Gerais, Barbacena, Brazil (register number 39125214.0.0000.5588) and the University Hospital of the University of Sao Paulo (register number 24020713.6.0000.0076).

B. *Actigraphy*

Participants were asked to wear an actimeter watch (ActTrust®, Condor Instruments, Brazil) all the time except while bathing. Sleep variables were analyzed with the proportional integration mode (PIM).

C. *Questionnaire parameters*

The Pittsburgh Sleep Quality Index Questionnaire (PSQI) [6] subjectively evaluates sleep disturbances as well as sleep quality. This questionnaire is composed of nineteen individual questions. The score of the answers is based on a 0 to 3 scale. A global sum of the components equal or greater than "5" indicates problems in sleep.

The Epworth Sleep Scale (ESS) [7] is a questionnaire that measures a person's general level of daytime sleepiness. The respondents should rate, on a 4-point scale (0 – 3), their usual chances of dozing off or falling asleep. Using a total cut-off score>10, it is possible to identify individuals with high possibility of excessive daytime sleepiness. Scores>16 indicate severe sleepiness.

The Morningness–Eveningness Questionnaire (MEQ-HO) was developed by Horne and Otsberg [8] to assess the chronotypes. This questionnaire is composed of nineteen multiple-choice with the score range of 16 to 86. Subjects with lower values were classified as larks and subjects with higher values were classified as owls.

D. *Data analysis*

Since the study variables were found to be heteroscedastic (assessed by Levene test) or followed a non-normal distribution (assessed by Shapiro-Wilk test), the Mann–Whitney U test was used to compare the groups. A statistical significant level of 0.05 was assumed. This statistical procedure was conducted in SigmaStat (version 3.5, Systat Software). To quantify the magnitude of the differences between the two groups Cliff's Delta (δ), a nonparametric effect size, was calculated as well as the corresponding 95% confidence intervals [9]. Therefore, this statistic was obtained using the following expression:

$$\delta = \frac{\#(\mathcal{X}_{UG} > \mathcal{X}_{RG}) - \#(\mathcal{X}_{UG} < \mathcal{X}_{RG})}{N_{UG} * N_{RG}} \qquad (2)$$

where the numerator represents a dominance matrix where the urban group individual values of a givens variable ($\mathcal{X}_{UG}$) are compared to the individual values of the rural group ($\mathcal{X}_{RG}$); and the denominator represents the product of UG sample size (N_{UG}) by the RG sample size (N_{RG}). This statistical procedure was conducted in Matlab (The MathWorks Inc.).

IV. RESULTS

For all analyzed variables, except for IV, a statistical significantly difference was found between the two experimental groups (Table 1).

TABLE I. SLEEP PARAMETERS DIFFERENCES

	Urban Group Median $_{[Q1-Q3]}$	**Rural Group** Median $_{[Q1-Q3]}$	U	p
L5	217.8 $_{[156.8-378.0]}$	116.1 $_{[90.9-190.9]}$	195	**.004**
TST (min)	370 $_{[350-420]}$	430 $_{[404-459]}$	213	**.009**
SE (%)	0.878 $_{[0.837-0.896]}$	0.905 $_{[0.878-0.940]}$	204	**.024**
IV (%)	0.720 $_{[0.631-0.863]}$	0.693 $_{[0.613-0.787]}$	325	.505

In figure 4 it is possible to identify the magnitude of the differences between groups in the analyzed variables.

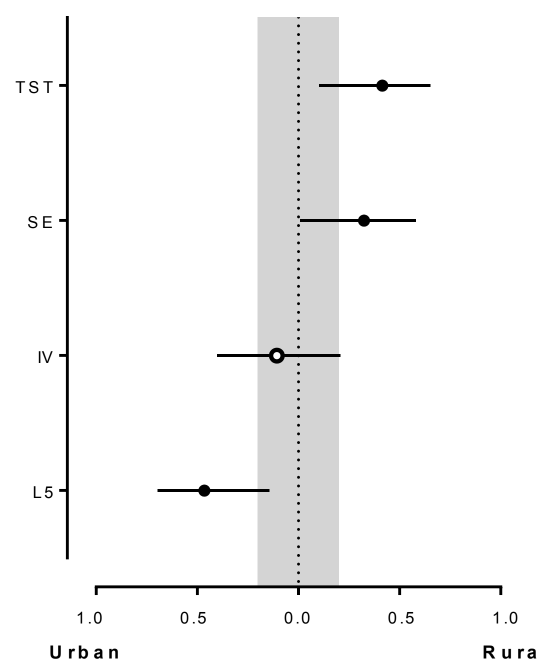

Figure 4. Cliff's Delta effect size with 95% confidence interval between urban and rural groups. A solid mark denotes a significant difference (p < .05) between groups and a blank mark the absence of significant differences. The shaded area specifies the interval in which the effect size of the difference between groups is trivial (-0.2 < δ < 0.2).

V. Discussion and Conclusions

Sleep disturbances are very common in modern time. The demands of society in big metropolitan areas forces people to adapt their sleep patterns to their daily activities. The delay in the initiation of the bedtime due to artificial lighting and early waking up due to social obligations results in a significant reduction in the quality of life [10].

A significant difference between metropolitan and rural populations was identified. Subjects that lives in rural area sleep more than subjects in the metropolitan area. In other words, it seems that urban people suffer from more sleep restriction than rural participants. This could be related to the need to fulfill working or social obligations, such as the long commuting hours needed in a metropole. It must be noted that this social sleep restriction, common in urban areas, is associated with the high incidence of various diseases such as depression, substance dependence such as smoking and metabolic disorders such as obesity [11-13].

Regarding the sleep restriction and sleep quality assessment by actigraphy, higher values of L5 means that the subject has more awakenings or movements during the sleep phase, which may compromise the quality of rest, resulting in more diseases and disturbances related to sleep deprivation. Higher values of L5 are also observed in patients with neurological diseases such as Alzheimer and Parkinson [14], populations in which the quality of sleep and circadian rhythms is known to be deteriorated. In the present study, although PSQI and ESS values were similar in both groups, metropolitan subjects showed higher values of L5 when compared to the rural sample, which means the lack of sleep quality. The intraday variability can also assess possible sleep disturbances, but the differences between groups were not significant. However, the sleep efficiency obtained from the actigraphy data supports the idea that the metropolitan population are worse sleepers, not only sleep less time but also, they showed a worse quality sleep.

Similar results about sleep efficiency were observed between rural and urban populations when was compared sleep parameters assessed by subjective questionnaires [3]. The authors concluded that the social and work obligations were one of the most important factors for the differences found. Our findings using objective analysis of sleep parameters strengthen this theory.

Lower total sleep times plus worse sleep quality parameters found in the urban group probably generates more consequences regarding sleep deprivation than expected in the rural group. Chronic sleep deprivation is associated with several health and brain function problems, which causes loss of performance in daily tasks and in the learning process, including motor control tasks, such as posture control [15, 16]. In addition, cognitive parameters like voluntary attention, perception, working memory and other functions with high cognitive demand depends on prefrontal cortex activation and this area is very vulnerable of sleep deprivation [17]. In this way, it is possible to assert that urban life subjects have sleep problems because they live in a large metropolis. These disturbances must not be ignored because they can generate serious consequences in health and cognition.

To prevent the problems related to sleep disturbances, health care institutions could assess sleep of risk patients with actimetry as an inexpensive and portable alternative to polysomnography in the point-of-care of the patients.

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