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Reliable Method to Estimate Characteristics of Sleep and Physical Inactivity in Free-Living Conditions Using Accelerometry

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PURPOSE: The purpose of this study is to use a new method to assess the characteristics of sleep and diurnal physical inactivity in human beings by means of accelerometry, noninvasively and in free-living conditions.
METHODS: Forty girls and 40 boys aged 13 to 15 years, randomly selected from rural Senegal, wore an accelerometer for a 72-hour period during the dry season in 1998 and 2000. An algorithm already tested in another study was used to objectively calculate the characteristics of sleep and physical inactivity from movement registration provided by accelerometry.
RESULTS: Adolescent girls slept for a longer time and more quietly than adolescent boys (8 hours 45 minutes versus 8 hours 9 minutes). Girls were more inactive than boys (4 hours 23 minutes versus 2 hours 49 minutes). Reliability estimates of physical inactivity period measures were excellent (0.74 to 0.78), and those of sleep period and length measures were acceptable (0.45 to 0.61). Girls and boys had the same levels of reliability, except for sleep efficiency measures.
CONCLUSIONS: These findings could be explained by the nature and sex division of habitual tasks within the community. The accelerometer is a valid and useful epidemiologic tool for measuring characteristics of sleep and physical inactivity in free-living conditions. This innovative tool opens new prospects in epidemiology and public health, especially in the worldwide epidemic of chronic diseases associated with physical inactivity and sleep disorders.
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KEY WORDS: Activities of Daily Living, Adolescent Behavior, Chronic Diseases, Circadian Rhythm, Motor Activity, Reproducibility of Results, Rest, Sleep.

INTRODUCTION

Estimates of sleep and physical inactivity characteristics, in terms of quantity and quality, are at the core of new concerns in epidemiology and public health. Sleep disorders and low physical activity level characterized by repeated periods of physical inactivity are omnipresent in populations in industrialized countries and also are becoming increasingly frequent in populations in developing countries. In an endemic context of nutrition-related noncommunicable chronic diseases, measurement of physical inactivity characteristics is significant because there is a known association between physical inactivity, as a factor in energy imbalance, and overweight, obesity, coronary heart diseases, hypertension, and type 2 diabetes (1, 2). However, sleep disorders (sleep deprivation or short sleep duration, insomnia, sleep-walking, sleep apnea, and restless legs syndrome) have a negative impact on health and are associated with various diseases or social facts (3), such as: i) obesity (4–6) and increased risks for cardiovascular diseases, including hypertension, myocardial infarction, and stroke (7) in the case of sleep apnea and deprivation or short sleep duration; ii) alteration in appetite regulation in the case of short sleep duration (6, 8); iii) depression, cancer progression, and cancer incidence in the case of sleep disorders (9); and iv) heavy workload caused by economic and social pressure in the case of chronic sleep deficiency (10).

In developing countries, child labor is omnipresent and often is regarded as natural. Child labor increases the livelihood of households. These children have a heavy workload involving a high energy expenditure that could have an influence on their development and health. Moreover, they participate much more often and longer in moderate or vigorous activities and have periods of sleep and rest considered shorter compared with those of children in industrialized countries (11, 12).

It is essential to estimate the duration and quality of sleep of these children because it is the most favorable time to recover physically and psychologically from this heavy work.

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Selected Abbreviations and Acronyms

ICC = intraclass correlation coefficient
CI = confidence interval
IRD = Institut de recherche pour le développement

Therefore, their sleep needs can be increased. It also is significant to estimate characteristics and periods of rest or physical inactivity of these children during the daytime.

Therefore, it is necessary and useful to objectively know how to estimate, not only in laboratory conditions, but also in free-living conditions, main characteristics of physical inactivity and sleep in terms of quantity and quality. We show the method developed by our team of using accelerometry to objectively measure characteristics of sleep and physical inactivity periods by taking the case of working adolescents in developing countries. We also investigate the reliability of this method in free-living and field conditions to identify the number of days or nights of assessment required to obtain the usual characteristics of sleep and physical inactivity.

METHODS

Subjects and Surveys

Eighty Senegalese adolescents of the same age from a rural area (40 boys aged 14.2 years [SD, 0.6] and 40 girls aged 14.4 years [SD, 0.5]) were surveyed during the dry season in 1998 and 2000 within the framework of nutritional studies (13). Their physical activity was assessed quantitatively by means of accelerometry during 72 hours. The recording interval was set at 1 minute. The accelerometer CSA (model 7164; Computer Science and Applications Inc., Shalimar, FL) is an electronic apparatus that measures physical activity in a vertical plane. The accelerometer is small (5.1 × 3.8 × 1.5 cm), light (42 g), and easy to use. It was validated against other gold-standard techniques of physical activity measurement (14). Accelerometers were worn near the body center mass of adolescents, firmly fitted at the level of the left hip with a belt (by convention). All adolescents wore the accelerometer with total compliance.

Ethics

The aim of the study and methods used (accelerometry) were explained to each adolescent and their close relatives before oral consent was requested from them (most of the population is illiterate). The study protocol was approved by an annual agreement between the Senegalese Ministry for Research and the Institut de recherche pour le développement (IRD) center in Senegal and by a review board of the IRD in France. We followed the principles outlined in the Declaration of Helsinki.

Sleep Measurement

An algorithm was implemented by using Excel Visual Basics macro programming (Microsoft Corporation, Redmond, WA) to objectively calculate characteristics of sleep and diurnal physical inactivity from movement registration carried out by the accelerometer. In the case of sleep, this algorithm is based on reading graphs of movement counts between the hours of 20:00 and 12:00 (military time). This reading allows us to quantitatively visualize sleep periods (Fig. 1). From these graphs, the investigator noted a significant decrease (bedtime) or significant increase (waking up) in physical activity. Bedtime appeared as a continuous series of recordings of less than 25 counts/min (at least 5 consecutive minutes of <25 counts/min), and waking up was characterized by the more or less brutal shift from contiguous recordings of less than 25 counts/min to recordings of greater than 100 counts/min (at least 5 consecutive minutes of >100 counts/min).

Determination of bedtime and waking up was carried out manually for each night and each adolescent. Bedtime and wake-up hours were not necessarily equivalent to falling asleep and awakening hours, implying a light overestimate of the real sleep period. When the onset and end of sleep periods are determined, the algorithm allows us to calculate some characteristics of sleep: i) bedtime and waking up hours; ii) sleep period, defined as the difference between waking-up and bedtime hours; iii) sleep length, defined as number of minutes of less than 25 counts/min during the sleep period; and iv) an indicator of sleep quality (deep or fitful sleep), determined as sleep efficiency ([sleep length/sleep period] × 100). Diurnal physical inactivity periods are defined as number of minutes of less than 25 counts/min, apart from the sleep period previously determined.

Statistical Analysis

The reliability study of sleep and physical inactivity characteristics was performed according to sex on the basis of an intraclass correlation coefficient (ICC) (15) set at:

$$ICC_k = \frac{Msb - Msw}{Msb + ((d/k) - 1) \times Msw} \qquad \text{(equation 1)}$$

where Msb is mean square between subjects, Msw is mean square within subjects, d is number of effective repeated measurements (i.e., number of days of survey), and k is number of repeated measurements for which ICC was calculated. This coefficient k allowed to us extrapolate the ICC for a selected number of survey days: reliability of a given number of survey days is a function of this number of survey days (i.e., k). Ninety-five percent confidence intervals (CIs) of ICCs were calculated (16). An ICC of 0.7 or greater indicates good reliability of sleep and physical inactivity characteristics (17).