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Examination of wrist and hip actigraphy using a novel sleep estimation procedure ☆

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ARTICLE INFO

Article history:
Received 9 April 2014
Received in revised form
9 July 2014
Accepted 14 July 2014
Available online 16 September 2014

Keywords:
Actigraphy
Polysomnography
Penalized spline

ABSTRACT

Objective: Improving and validating sleep scoring algorithms for actigraphs enhances their usefulness in clinical and research applications. The MTI® device (ActiGraph, Pensacola, FL) had not been previously validated for sleep. The aims were to (1) compare the accuracy of sleep metrics obtained via wrist- and hip-mounted MTI® actigraphs with polysomnographic (PSG) recordings in a sample that included both normal sleepers and individuals with presumed sleep disorders; and (2) develop a novel sleep scoring algorithm using spline regression to improve the correspondence between the actigraphs and PSG.

Methods: Original actigraphy data were amplified and their pattern was estimated using a penalized spline. The magnitude of amplification and the spline were estimated by minimizing the difference in sleep efficiency between wrist- (hip-) actigraphs and PSG recordings. Sleep measures using both the original and spline-modified actigraphy data were compared to PSG using the following: mean sleep summary measures; Spearman rank-order correlations of summary measures; percent of minute-by-minute agreement; sensitivity and specificity; and Bland–Altman plots.

☆The work was supported by the U.S. Department of Veterans Affairs Health Services Research and Development grant PPO 09-246 [to JB Burch, PI], the U.S. Department of Defense through its U.S. Army Medical Research and Material Command Congressionally Directed Medical Research Programs, grant DAMD17-03-1-0139 [to JR Hébert, PI], and by National Institutes of Health grant HL095799 [to SD Youngstedt, PI]. Dr. Hébert was supported by an Established Investigator Award in Cancer Prevention and Control from the Cancer Training Branch of the U.S. National Cancer Institute (K05 CA136975).

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http://dx.doi.org/10.1016/j.slsci.2014.09.007

Results: The original wrist actigraphy data showed modest correspondence with PSG, and much less correspondence was found between hip actigraphy and PSG. The spline-modified wrist actigraphy produced better approximations of interclass correlations, sensitivity, and mean sleep summary measures relative to PSG than the original wrist actigraphy data. The spline-modified hip actigraphy provided improved correspondence, but sleep measures were still not representative of PSG.

Discussion: The results indicate that with some refinement, the spline regression method has the potential to improve sleep estimates obtained using wrist actigraphy.

1. Introduction

Physical activity and sleep are both recognized as important health determinants and represent critical targets for chronic disease prevention. A better understanding of the roles that these factors play in health and disease has been facilitated by the development and implementation of ambulatory, accelerometer-based monitoring devices [1–5]. Actigraphy has helped establish linkages between sleep disruption or reduced physical activity and various adverse health outcomes ranging from metabolic syndrome measures (e.g., obesity, hypertension), to increased rates of chronic disease and elevated mortality risk [6–13]. Refinements in actigraphy data processing and analysis may help to improve assessments of sleep and physical activity for use in disease prevention efforts.

Characterization of sleep via wrist actigraphy has gained popularity in clinical and research settings as an alternative to polysomnography (PSG). Though considered the "gold standard" for sleep assessment, PSG can be costly, labor-intensive, and invasive. Also, it typically involves sleeping in a novel environment and only can be reasonably implemented for 1–2 nights at a time [1–5]. Advantages of actigraphy include its low cost, convenience, and an ability to objectively estimate sleep in large populations for periods up to months at a time. However, some differences among actigraphs, including modality of quantifying movement, sampling frequency, and sensitivity of movement detection can influence their accuracy in estimating sleep. In addition, some sleep actigraphy devices lack documentation of their validity relative to PSG. With increasing interest in simultaneous ambulatory monitoring of sleep and physical activity, an unresolved question is whether data collected using hip-mounted actigraphs (typically used solely for physical activity monitoring) also can provide valid estimates of sleep [1–5,29]. If so, this would allow for reduction in cost and subject burden in studies involving both measures.

This investigation compared the accuracy of sleep metrics obtained via wrist- and hip-mounted MTI® actigraphs (Manufacturing Technology, Inc., ActiGraph, Pensacola, FL) with those derived from PSG recordings in a convenience sample of individuals attending a local clinic for sleep evaluation via PSG. The MTI® actigraph has been validated and used to characterize physical activity [14–16]. However, to our knowledge, this monitor had not been validated for sleep. A similar actigraph device has recently been used to assess physical activity and sleep in a nationally representative sample of the United States population [17].

Another study objective was to use spline regression as a novel sleep characterization methodology to improve both wrist- and hip-mounted actigraphic data relative to PSG-defined sleep. Spline regression is a useful mathematical technique for modeling complex nonlinear processes. It has been applied to accelerometer data to estimate energy expenditure and other physical activity measures, although it has not been used previously to characterize sleep [18,19].

2. Material and methods

The study sample consisted of patients attending a local sleep clinic for various sleep complaints (SleepMed, Columbia, SC) as well as presumed normal sleepers. Participants were given a physical examination and interview by a board-certified sleep physician [20]. All participants had been previously scheduled for an overnight PSG recording session. Clinical staff informed prospective participants of the present study and participants provided written informed consent per University of South Carolina Institutional Review Board (IRB) approval.

A standardized PSG protocol was implemented by clinic staff. Participants arrived at the clinic sixty minutes before their self-reported customary bedtime and were prepared for PSG recording ~30 minutes before initiating their sleep period. Participants completed a single night of PSG recording using Alice 4 PSG instrumentation operated by a certified PSG technician. Demographic and anthropometric information was obtained from clinical records (age, sex, body mass index [BMI = weight(kg)/height(m)^2]). Participants also completed the Epworth Sleepiness Scale (ESS) [22].

Each participant was equipped with two actigraphs (MTI® model 7164 accelerometer, ActiGraph, Pensacola, FL); one was worn on the non-dominant wrist, and the other was affixed to the hip. The actigraphs were initialized prior to recording using the same computer that was used for PSG recording so that the actigraphs were synchronized to the internal timing of the computer, thus allowing precise and accurate verification of the beginning and end of each recording period. Moreover, synchronization of the initiation of the PSG and actigraphic recordings also was performed each night with manually activated event markers on the computer and actigraph. At each participant's customary bedtime, which varied from 9 pm to 1 am, lights were turned out and participants were asked to attempt to sleep as desired, for up to a maximum of 8 h.

Recordings that included at least 6 h of complete PSG as well as wrist and hip actigraphy data were included in the