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Research Article

Validation of Actiwatch for Assessment of Sleep-wake States in Preterm Infants

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S U M M A R Y

Purpose: The purpose of this study was to validate the Actiwatch with behaviorally determined sleep–wake state in preterm infants and to explore the influence of postmenstrual age on the accuracy of Actiwatch.
Methods: A prospective and comparative research design was used. Twenty-four preterm infants with postmenstrual age ranging from 28–38 weeks were studied. The infants were studied for 2 hours between two feedings. Infant's sleep and wake state was measured every 30 seconds using Actiwatch and the Anderson Behavioral State Scale simultaneously.
Results: Actiwatch demonstrated high agreement, sensitivity, and predictivity of sleep state, when validated with the Anderson Behavioral State Scale at the setting of high and automatic activity thresholds, and was not influenced by the infant's postmenstrual age. However, lower specificity and predictivity were found in the wake state, and influenced by postmenstrual age.
Conclusion: Results of this study suggest that high activity thresholds are the most accurate for determining sleep state in preterm infants, and health care professionals must take the limitations into consideration while using the Actiwatch to assess wake states.

Introduction

Sleep-wake patterns of preterm infants reflect the maturity of the central nervous system, and serve as an indicator of behavioral development (Gertner et al., 2002; Holditch- Davis, Belyea, & Edwards, 2005; Soubasi et al., 2009; Wikström et al., 2012). Clinicians also used sleep–wake patterns to detect if the infant is under stress. Many factors could interfere with sleep–wake states. Preterm infants had more active wake state and less quiet sleep when under stressful environment, such as noise and bright light (Bertelle, Sevestre, Laou-Hap, Nagahapitiye, & Sizun, 2007). Infants also would have heightened wake states after a painful procedure (Holsti, Grunau, Oberlander, & Whitfield, 2005). Therefore, to assess sleep-wake patterns can help caregivers better understand preterm infant's responses to the environmental stimulus and pain. Disrupted sleep patterns and frequent night awakenings of preterm infants produce psychological stress in 20–30% of parents (Feldman, 2006; Korja et al., 2008). It is necessary to promote optimum sleep–wake patterns of preterm infants. Therefore, an objective and precise instrument for measuring sleep pattern of preterm infants is required.

Sleep–wake patterns of preterm infants can be measured with observation of behaviors and physiological variables. Those variables include physical activities, breathing patterns and eye movements (Holditch-Davis, Brandon, & Schwartz, 2003). The Anderson Behavioral State Scale (ABSS), developed by Anderson in 1978, is appropriate for assessing preterm infant's sleep patterns (Medoff-Cooper, Bilker, & Kaplan, 2010). However, behavioral observations require direct and continuous observation, and it is liable to cause observer fatigue. Therefore, behavioral observations may only be appropriate for short term use.

Polysomnograph (PSG) and the Actiwatch are two physiological measurements commonly used to assess sleep patterns in adults and children (Hyde et al., 2007). PSG is the gold standard in sleep assessment (So, Buckley, Adamson, & Horne, 2005). However, PSG requires electrodes and monitoring equipment, which is expensive and impractical for long term monitoring, and not feasible for healthcare providers. The Actiwatch uses an accelerometer to

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detect and log wrist movements, known as actigraphy. The actigraphy continuously records the occurrence of limb movements and sums the number of movements for a given period. The small size of the Actiwatch, similar to a wrist watch, allows a noninvasive and continuous measure that can be used for prolonged periods of time in a variety of situations. Compared to PSG, the Actiwatch is more appropriate for long term monitoring of sleep-wake patterns (Hyde et al.; So et al., 2005). Previous studies showed agreement of 87–95% between behavioral observations and the Actiwatch for sleep measurement of term infants after the third month of life (Gnidovec, Neubauer, & Zidar, 2002). As the infant's age increases, agreement increases (Gertner et al., 2002; Gnidovec et al., 2002). Another study (So et al.) also indicated that the overall agreements between Actiwatch and PSG reached 89–94% in infants under 6 months of age.

The sleep–wake patterns of preterm infants are less mature and more poorly developed than those of term infants. In preterm infants, active sleep decreased with postmenstrual age (PMA) while quiet waking, active waking and quiet sleep increased (Holditch-Davis, Scher, Schwartz, & Hudson-Barr, 2004). Preterm infants demonstrate various sleep–wake patterns during the period from birth to term equivalent age. However, validation of the Actiwatch has not been established for preterm infants. Moreover, it is not clear whether the validity of Actiwatch varies by different PMA. Thus, this study aimed to investigate the agreement between Actiwatch and ABSS in assessing sleep–wake patterns of preterm infants. The specific objectives of this study were to investigate (a) the agreement rate between Actiwatch and ABSS in assessing sleep–wake patterns of preterm infants, (b) the sensitivity, the specificity and the predictability of Actiwatch in assessing sleep–wake patterns of preterm infants, and (c) the accuracy of Actiwatch on different PMA groups.

Methods

Study design

A prospective, comparative research design was used. Sleep–wake patterns were assessed during the 2-hour interfeeding intervals using Actiwatch (Mini Mitter Company Inc., Sunriver, OR, USA) and the ABSS.

Setting and sample

A convenience sample of preterm infants was recruited from the neonatal intensive care unit and sick baby room of a medical center in Southern Taiwan. Inclusion criteria were (a) having no neurological problems and (b) being born between 23–37 gestational weeks. Exclusion criteria were (a) severe illness or congenital abnormality, (b) treated with sedatives or (c) restrained. Gertner et al. (2002) indicated a reduction in total sleep time over 32–36 weeks' gestational age. In accordance with this suggestion we grouped the included preterm infants into three groups: PMA less than 32 weeks, PMA between 32 and 36 weeks, and PMA more than 36 weeks. PMA is the corrected age of infants; it is equal to gestational age plus postnatal age. In this study, we used postmenstrual age to reflect the maturation of infants.

According to a previous study (So et al., 2005), the response within each subject group were normally distributed with a standard deviation of 1.3. The difference of means in agreement rate is 2.2. We set the statistical power at 0.8 and the type I error probability at .05. The Power and Sample Size Calculation Software, version 3.0 (Power and Sample Size com., Atlanta, GA , USA), was used to calculate the sample size. Result showed that seven participants for each group were required.

Ethical consideration

The study was approved by the Human Experiment and Ethics Committee. Parental written informed consent was obtained. The following information was verbally explained and also included as part of the consent form: (a) participation was voluntary, (b) the preterm baby would not be individually identified in any way, (c) participation could be discontinued at any time, (d) status of participating in this study would not affect the medical care they received, and (e) the original test data would be reviewed only by the researcher. Consent forms were obtained after the parents had decided participation in the research was in alignment with his or her values and goals.

Instruments

Actiwatch

The Actiwatch was used to record wrist motion of preterm infants during wake and sleep periods. The fundamental scientific principle of the Actiwatch is that a miniature piezo-electric transducer produces a voltage in response to a change in motion. The Actiwatch accelerometer sensitivity is 0.05 g-force; it weighs 16 g, and has a nonvolatile memory of 64 KB. Data from the Actiwatch were coded into sleep and wake in a 30-second epoch using commercially available software (Actiware version 5.0; Mini Mitter Company Inc., Sunriver, OR, USA). The voltage is amplified, digitized and then recorded on the device in nonvolatile memory. Later, the recorded data are transferred to a personal computer and can be subsequently analyzed to quantify activity during intervals characteristic of both wake and sleep. Actiwatch codes all epochs as wake is determined by comparing activity counts for 2 minutes surrounding the epoch. Actiwatch can distinguish sleep from wake using algorithms to quantify the reduced movement associated with sleep (So et al., 2005). If the counts exceed the threshold, the epoch is coded as wake. If it falls below, or is equal to the threshold, the epoch is coded as sleep. The Actiwatch software provided the wake threshold with low, medium, and high mode at activity counts of 20, 40, and 80 respectively. Another threshold of activity counts was the automatic setting mode, the formula was the mean activity counts in active period multiplied by 0.888 per epoch length. Actiwatch and PSG reached 89–94% agreement in infants under 6 months of age (So et al.).

Anderson Behavioral State Scale

The ABSS was adapted from the scale of Pamelee and Stern (as cited in Gill, Behnke, Conlon, McNeely, & Anderson, 1988); it was designed to measure the sleep-wake state of preterm infants using 12 detail behavioral sleep descriptors. Each state is judged by the criteria of body movement, regularity of respiration, openness of eyes, and muscle tension. The behavioral states were assessed as follows: 1 = regular quiet sleep, 2 = irregular quite sleep, 3 = active sleep, 4 = very active sleep, 5 = drowsy, 6 = alert inactivity, 7 = quiet awake, 8 = active, 9 = very active, 10 = fussing, 11 = crying, and 12 = hard crying. Interobserver reliability was reported among two observers (r = .95) for the instrument standardization (Medoff-Cooper, McGrath, & Bilker, 2000). In the current study, infant behavioral states were observed and coded at bedside immediately by one researcher every 30 seconds.

A 5-day program was devoted to train the researcher to assess preterm babies with ABSS. A didactic session was provided by a clinical nurse specialist, who had 10 years of preterm baby experience and had been trained with using ABSS. Assessment techniques and coding methods were demonstrated with videos. Case presentations and follow-up discussion were used to illustrate assessment techniques and correct coding responses. Assessment