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Infant motor activity during sleep: Simultaneous use of two actigraphs comparing right and left legs

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ABSTRACT

Motor asymmetry during the first hours of sleep documented in adults found higher activity in the non-dominant limb. The stage of development at which such asymmetries first appear is unknown. Twenty healthy infants were followed from 7 to 12 months of age, at 3-week intervals, comparing motor activity of the right and left legs during sleep using twin actigraphs (AMI). Hour-by-hour analysis of the first seven hours of nocturnal sleep found no consistent difference in activity levels between the right and left legs. Using the standard algorithm for infants, which provides an overall estimate of sleep quality, revealed discrepancies in night waking episodes (Right versus Left) in 33% of the nights. Results pertaining to leg movement suggest that motor asymmetry is not yet present during the first year of life. However, given the large discrepancies in the detection of night waking, further investigation of the developmental course of circadian motor asymmetry is warranted.

1. Introduction

Adult and infant sleep differs markedly in terms of structure, duration, and distribution across 24-h, and its motor characteristics change (Ednick et al., 2009). The developmental changes that occur during sleep throughout infancy are dynamic and are largely attributed to the maturation processes of neural systems that control sleep (Emde & Walker, 1976; Hayes & Mitchell, 1998). For example, during early infancy a relatively high percentage of rapid-eye-movement sleep (REM) occurs, which is characterized by increased motor activity (sleep motility). This differs from the motor paralysis of skeletal muscles (atonia) that characterizes REM sleep in adults, with the exception of eye movements (e.g., Fagioli & Salzarulo, 1982; Kahn, Dan, Groswasser, Franco, & Sottiaux, 1996; Roffwarg, Muzio, & Dement, 1966; Tonetti et al., 2017).

Sleep motility includes large body movements, organized movements of specific muscle groups (e.g., fingers and toes, hand to mouth) and twitches, which are phasic muscle movements (e.g., grimaces and smiles) lasting less than 0.5 s (Blumberg, 2010; Fukumoto, Mochizuki, Takeishi, Nomura, & Segawa, 1981; Thoman, 1975, 1990). These sleep-related motor activities peak during the first three months of life, and decline continuously with increasing age (Fukumoto et al., 1981; Hayes & Mitchell, 1998). Phasic muscle activity is the first to decline (Fukumoto et al., 1981; Liefting, Bes, Fagioli, & Salzarulo, 1994), followed by a decrease in targeted/localized body movements. Periods without body movements systematically increase up to eight months of age and the

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frequency of large body movements during sleep remains relatively unchanged until the baseline level of motor activity stabilizes at around 9–13 months (Fukumoto et al., 1981). The extensive amount that infants move during active sleep is attributed to immaturity of the cerebral mechanisms that inhibit muscle tone and nerve signals to the spinal cord (Carney, Becker, & Bongiolatti, 2006; Kohyama, 2000).

1.1. Using sleep motility as a measure for sleep–wake patterns

Measuring motor activity as an indirect measure of sleep by means of actigraphy has been used to distinguish between sleep and wakefulness. An actigraph is a computerized activity monitor with a piezoelectric sensor sensitive to accelerations above 0.01 g per rad/s.

The actigraph continuously records and sums activity. The score represents the average number of limb movements in a given period. These data are subsequently scored to derive levels of activity, rhythm parameters (such as amplitude) and sleep/wake parameters using validated algorithms (Ancoli-Israel et al., 2003; Sadeh & Acebo, 2002; Sadeh, Lavie, Scher, Tirosh, & Epstein, 1991). Actigraphy has been shown to be a reliable and cost-effective technology for sleep research with adults (Morgenthaler et al., 2007), children (Meltzer, Montgomery-Downs, Insana, & Walsh, 2012) and infants (Sadeh, Acebo, Seifer, Aytur, & Carskadon, 1995; Sadeh et al., 1991; So, Buckley, Adamson, & Horne, 2005). This noninvasive and ecologically valid instrument (American Academy of Sleep Medicine, 2007) provides a valuable option for infant sleep research (Thoman & Acebo, 1995), including longitudinal studies in the natural sleep environment (Scher & Cohen, 2015; So et al., 2005).

1.2. Motor asymmetry during sleep

The topic of motor asymmetry has long been investigated in adults using various methodologies, including actigraphy. Higher activity in the non-dominant hand during the first hours of sleep has been documented consistently (e.g., Lauerma, Kaartinen, Polo, Sallinen, & Lyytinen, 1994; Lauerma, Lehtinen, Lehtinen, & Korkeila, 1992; Lehnkering, Strauss, Wegner, & Siegmund, 2006; Natale, 2002; Natale, Lehnkering, & Siegmund, 2010; Natale, Martoni, Esposito, Fabbri, & Tonetti, 2007; Sadeh, Sharkey, & Carskadon, 1994; Van Hilten, Middelkoop, Kuiper, Kramer, & Roos, 1993; Violani, Casagrande, Cinelli, & Testa, 1992; Violani, Testa, & Casagrande, 1998). Jovanovic (1971) was among the first to show increased movement of the non-dominant hand over the dominant hand during sleep, through electromyographic recording, regardless of the phase of the REM/NREM cycle. This specific kind of motor asymmetry was also observed during the wake-sleep transition (Casagrande, Violani, De Gennaro, Braibanti, & Bertini, 1995) analyzed through polygraphic recording. Observing right-handed college students, Violani et al. (1998) found higher motor activity of the right hand during waking. During sleep, in the first part of the night, no motor asymmetry was observed, while in the second part of the night, the right hand moved more than the left hand did. The lack of motor asymmetry in the first part of the night, when slow wave sleep is more prevalent, was interpreted by Violani et al. (1998) to concur with the homeostatic deactivation of the dominant hemisphere, which decreases the superiority of the dominant hand over the non-dominant hand observed during waking and during the second part of the night.

Natale (2002), who observed more movements of the non-dominant hand during the four waking hours preceding sleep onset and the first four hours of sleep, interpreted these findings as suggestive of a circadian phase delay of the right hemisphere over the left hemisphere. To test the homeostatic hypothesis, Natale et al. (2007) examined motor asymmetries in sleep deprivation conditions (three consecutive wake-sleep cycles: baseline, sleep deprivation, and sleep recovery) and found higher motor activity of the non-dominant hand during baseline. They concluded that circadian motor asymmetries are not linked to the homeostatic process only. This conclusion was further supported in a subsequent study, in which Natale et al. (2010) assessed circadian motor asymmetries in right and left-handed university students. In the right-handed participants, increased motor activity in the late evening was recorded in the left hand in contrast, the opposite pattern was not documented in left-handed students (Natale et al., 2010).

In actigraphy studies in adults, the actigraph is placed on the non-dominant arm (de Souza et al., 2003). Simultaneous use of two actigraphs for comparing symmetry, or lack of (e.g., Natale, 2002; Natale et al., 2007; Rabuffetti, Meriggi, Pagliari, Bartolomeo, & Ferrarin, 2016) and for assessing placement effects (e.g., Zinkhan et al., 2014) has been reported. In infants, when side dominancy is not clearly established, the common practice is to place the actigraph on the left leg (Galland, Meredith-Jones, Terrill, & Taylor, 2014; Gnidovec, Neubauer, & Zidar, 2002; Jenni, Deboer, & Achermann, 2006; Kryger, Roth, & Dement, 2011; Landau et al., 2010; Sadeh et al., 1995; Scher, Epstein, & Tirosh, 2004; Shinohara & Kodama, 2012). This placement was found to be less disturbing to the infant (Sadeh et al., 1991) and prevents the infant from inserting the device into his/her mouth. However, several studies reported attaching the actigraph to the right ankle (e.g., Angulo-Kinzler, Peirano, Lin, Garrido, & Lozoff, 2002; So et al., 2005; Sung, Adamson, & Horne, 2009).

Systematic research comparing infants' sleep-related motility in the right versus the left leg is lacking. This might be related to outdated assumptions prevailing until the mid-1970s, concerning structural and functional symmetry of the infant brain. However, these have been refuted by studies that have found functional asymmetries even in newborn infants (Best, 1988). For example, Jovanovic (1971) highlighted the lack of functional dominance in infants up to age two years and argued that differences in sleep mobility during infancy are not expected. More recently, using fMRI, evidence of the beginning of lateralization in the somatic-sensory system has been documented in neonates during sleep segments that followed passive hand movements (Erberich et al., 2006). Still, as noted above, the question of right versus left limb movement during sleep has not been empirically examined in infants.