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Development of sleep/wake, activity and temperature rhythms in newborns maintained in a neonatal intensive care unit and the impact of feeding schedules

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ABSTRACT

Biological rhythms in infants are described as evolving from an ultradian to a circadian pattern along the first months of life. Recently, the use of actigraphy and thermistors with memory has contributed to the understanding of temporal relations of different variables along development. The aim of this study was to describe and compare the development of the rhythmic pattern of wrist temperature, activity/rest cycle, sleep/wake and feeding behavior in term and preterm newborns maintained in a neonatal intensive care unit (NICU).
Methods: Nineteen healthy preterm and seven fullterm newborns had the following variables monitored continuously while they were in the NICU: activity recorded by actigraphy, wrist temperature recorded with a thermistor and observed sleep and feeding behavior recorded by the NICU staff with diaries. Subjects were divided in 3 groups according to their gestational age at birth and rhythmic parameters were compared.
Results: A dominant daily rhythm was observed for wrist temperature since the first two weeks of life and no age relation was demonstrated. Otherwise, a daily pattern in activity/rest cycle was observed for most preterm newborns since 35 weeks of postconceptional age and was more robust in term babies. Feeding and sleep/wake data showed an almost exclusive 3 h rhythm, probably related to a masking effect of feeding schedules.
Conclusions: We found that wrist temperature develops a daily pattern as soon as previously reported for rectal temperature, and with acrophase profile similar to adults. Moreover, we were able to find a daily rhythm in activity/rest cycle earlier than previously reported in literature. We also suggest that sleep/wake rhythm and feeding behavior follow independent developmental courses, being more suitable to masking effects.

1. Introduction

The ontogenesis of biological rhythms in infants is described as a non-linear transition from an ultradian to a circadian pattern along the first months of life, particularly for sleep/wake behavior (Hellbrugge, 1960; Menna-Barreto, Benedito-Silva, Marques, Andrade, & Louzada, 1993; Shimada et al., 1999; Rivkees, 2004; Thomas, Burr, Spieker, Lee, & Chen, 2014). Mirmiran

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and Kok (1991) have also demonstrated a circadian rhythm in rectal temperature even for newborn infants, suggesting an earlier emergence of the circadian component for this variable in relation to the sleep/wake cycle.

Environmental conditions in which the endogenous timekeeping system develops in the beginning of life can play an important role in the final rhythmic expression, as suggested by some studies in rodents reared under constant light during lactation (Cambras, Canal, Torres, Vilaplana, & Díez-Noguera, 1997). The endogenously generated rhythm will be synchronized to environmental cycles, as light/dark cycle, but also other factors can influence human rhythmic expression (Rivkees, 2004; Thomas et al., 2014) and in free living conditions it is the expressed rhythm immersed in environment that will be studied.

Although circadian rhythms in newborns maintained in neonatal care units (NICU) are considered unstable (Tenreiro et al., 1991), different patterns in rhythmic development, behavior and weight gain are described in newborns maintained under constant light versus light/dark cycle (Brandon, Holditch-Davis, & Belyea, 2002; Guyer et al., 2015; McMillen, Kok, Adamson, Deayton, & Nowak, 1991; Vásquez-Ruiz et al., 2014). However, this relation to light conditions is not always demonstrated (Ardura, Andrés, Aldana, & Revilla, 1995; Mirmiran, Baldwin, & Ariagno, 2003), suggesting that other environmental factors could influence the development of biological rhythms. Ultradian periodicities in temperature and activity rhythms, related to feeding schedule (Glotzbach, Edgar, & Ariagno, 1995), have been identified in preterm newborns maintained in NICUs; otherwise, Korte, Wulff, Oppe, and Siegmund (2001) demonstrated a circadian pattern in rest/activity cycle, with the use of actigraphy, in fullterm newborns, whereas feeding behavior exhibited periodicities of 2–4 h.

Recently, actigraphy monitors, movement acceleration sensors with memory, allowed continuous data recording in longitudinal studies and have been employed in a number of researches of infants and children (Sadeh, Lavie, Scher, Tirosh, & Epstein, 1991; Sung, Adamson, & Horne, 2009; Thomas, Burr, & Spieker, 2015). Sung et al. (2009) demonstrated that it is a reliable method for determining sleep in preterm infants from 30 to 40 weeks of postconceptional age when compared to behavior observation, with agreement rates comparable to data of fullterm infants.

Temperature rhythm studies have also been improved with the use of a thermistor with a data logger – iButton Thermochron® – Maxim Dallas (Dallas, Texas, EUA), allowing continuous wrist temperature recording (Areas, Duarte, & Menna-Barreto, 2006; Van Marken Lichtenbelt et al., 2006). Wrist temperature curve is plotted as a mirror image of rectal temperature, with its acrophase occurring at night (Sarabia, Rol, Mendiola, & Madrid, 2008). Zornoza-Moreno et al. (2011) monitored ankle skin temperature with iButtons® in infants along the first six months of life, finding a dominant circadian rhythm only after 3 months of age, later than observed for rectal and skin temperature in previous studies (Mirmiran & Kok, 1991; Tenreiro et al., 1991). Core temperature circadian rhythm, especially the decreasing portion, is primarily determined by variations in heat loss of the skin of the extremities (Kräuchi & Wirz-Justice, 1994). Krauchi and Wriz-Justice (1994) suggested that the circadian cycle of heat loss is affected by vasomotion in distal regions leading to temperature increases in these regions, phase advanced in relation to changes in rectal temperature.

The evaluation of biological rhythms with the use of these recent techniques, simultaneously, in a longitudinal study, can bring new information about the ontogenesis of circadian rhythms and the temporal relations between different variables along aging. The aim of this study was to describe and compare the development of the rhythmic pattern of activity/rest cycle recorded with actigraphy, sleep/wake behavior recorded with diaries and wrist temperature rhythm, in term and preterm newborns maintained in a NICU, evaluating the impact of environmental cycles, particularly of feeding schedules, and the possible changes in the rhythmic pattern along early human development.

2. Material and methods

2.1. Subjects

Nineteen healthy preterm and seven term newborns were selected from the neonatal care unit of the University Hospital of the University of São Paulo. The project was approved by the ethical committees of both the University Hospital and of the Biomedical Sciences Institute, according to the Declaration of Helsinki. All parents received the appropriate information about the research and signed a written informed consent.

All infants should have Apgar scores $\geq$7, no evidence of perinatal asphyxia or neurological disease to be included in our study and were not been treated with sedative drugs. Gestational age, Apgar score, anthropometrical measurements and health conditions were assessed in all newborns. Fullterm and preterm babies with ages ranging from 28 weeks to 36 weeks of gestational age at birth were included. All babies had their data recording started until 10 days of postnatal age.

All infants remained in the NICU along data recording and the unit routine was not changed for our study. Lights remained on along the 24 h of the day, but there were also windows allowing for natural illumination, in such a way that light intensity is around 870 ± 616.9 lx from 8 am to 8 pm and 395 ± 345.1 lx from 8 pm to 8 am. Feeding was provided every to 2 or 3 h according to medical prescription and nursery care was also preferentially provided in these occasions.

2.2. Methods

All infants had their activity, temperature and observed sleep and feeding behavior recorded continuously while they were in the NICU. Sleep, activities and feeding diaries were filled every day by the nurse responsible for the newborn, according to a diagram divided in 10 min blocks in such a way that every 10 min babyís behavior was classified as sleep or