Biological Psychology 106 (2015) 79–85

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

High cardiac vagal control is related to better subjective and objective sleep quality

Gabriela G. Werner[a,*], Brett Q. Ford[d], Iris B. Mauss[d], Manuel Schabus[b,c], Jens Blechert[a,c], Frank H. Wilhelm[a]

[a] Clinical Stress and Emotion Lab, Division of Clinical Psychology, Psychotherapy, and Health Psychology, Department of Psychology, University of Salzburg (Study Institution), Salzburg, Austria
[b] Laboratory for Sleep, Cognition and Consciousness Research, Division of Biological Psychology, Department of Psychology, University of Salzburg, Salzburg, Austria
[c] Centre for Cognitive Neuroscience, University of Salzburg, Salzburg, Austria
[d] Emotion & Emotion Regulation Lab, Department of Psychology, University of California, Berkeley, CA, United States

ARTICLE INFO

Article history:
Received 31 May 2014
Accepted 13 February 2015
Available online 20 February 2015

Keywords:
Parasympathetic nervous system
Heart rate variability
Respiratory sinus arrhythmia
Sleep quality
Polysomnography

ABSTRACT

Cardiac vagal control (CVC) has been linked to both physical and mental health. One critical aspect of health, that has not received much attention, is sleep. We hypothesized that adults with higher CVC – operationalized by high-frequency heart rate variability (HF-HRV) – will exhibit better sleep quality assessed both subjectively (i.e., with Pittsburgh Sleep Quality Index) and objectively (i.e., with polysomnography). HF-HRV was measured in 29 healthy young women during an extended neutral film clip. Participants then underwent full polysomnography to obtain objective measures of sleep quality and HF-HRV during a night of sleep. As expected, higher resting HF-HRV was associated with higher subjective and objective sleep quality (i.e., shorter sleep latency and fewer arousals). HF-HRV during sleep (overall or separated by sleep phases) showed less consistent relationships with sleep quality. These findings indicate that high waking CVC may be a key predictor of healthy sleep.

1. Introduction

The parasympathetic nervous system is the branch of the autonomic nervous system responsible for key restorative processes like "resting and digesting" (e.g., Sherwood, 2010). Effective functioning of this system has been linked with stronger phasic activity of vagus nerve efferent activity to the sino-atrial node of the heart, often termed *cardiac vagal control* (CVC). CVC can be measured non-invasively by quantification of respiratory sinus arrhythmia, i.e., the rhythmic oscillation in heart rate linked to breathing frequency (Grossman & Taylor, 2007). Greater CVC during resting baseline assessments at wake (CVC_{wake}) has been associated with both better physical and mental health (Beauchaine, 2001; Porges, 2007; Thayer & Lane, 2007). One particularly critical aspect of physical and mental health is sleep (Buysse, 2014), raising the possibility that CVC_{wake} would be positively linked with sleep quality. Yet, the links between CVC_{wake} and sleep have not received much attention. Therefore, we tested in healthy adults whether individual differences in CVC_{wake} are linked to sleep quality, as assessed with subjective (i.e., self-report questionnaire) and objective measures (i.e., full polysomnography).

1.1. CVC and health

Higher CVC_{wake} has been reliably linked with a range of positive physical health outcomes, including better cardiovascular health (e.g., Giese-Davis et al., 2015; Thayer & Lane, 2007) as well as positive mental health outcomes, including greater subjective well-being (e.g., Beauchaine, 2001; Geisler, Vennewald, Kubiak, & Weber, 2010). While multiple theoretical models have been proposed to account for the positive link between CVC_{wake} and health, most agree that CVC is a marker of processes involved in the regulation of arousal. In this view, the parasympathetic system exerts an inhibitory influence via the vagus nerve, which promotes calm states by actively reducing autonomic arousal (e.g., Berntson et al., 1997; Grossman & Taylor, 2007; Porges, 2007; Thayer & Lane,

* Corresponding author at: Department of Psychology, University of Salzburg, Hellbrunnerstr. 34, 5020 Salzburg, Austria. Tel.: +43 662 8044 5164; fax: +43 662 8044 5126.
E-mail addresses: gabriela.werner@sbg.ac.at (G.G. Werner), brett.q.ford@berkeley.edu (B.Q. Ford), imauss@berkeley.edu (I.B. Mauss), manuel.schabus@sbg.ac.at (M. Schabus), jens.blechert@sbg.ac.at (J. Blechert), frank.wilhelm@sbg.ac.at (F.H. Wilhelm).

http://dx.doi.org/10.1016/j.biopsycho.2015.02.004

2009). One state characterized by lower arousal is sleep, as sleep can only occur when arousal is substantially reduced (Dahl, 1996). Given that CVC_{wake} is thought to be crucially involved in regulating arousal, further supported by links between reduced arousal and increases in CVC_{wake} (e.g., during mediation; Delgado et al., 2010), and given that sleep relies on low arousal, one might expect that sleep would also show a relationship with CVC_{wake}.

1.2. CVC and sleep

A variety of research has linked CVC and sleep. It has been shown that CVC increases in anticipation of sleep onset (e.g., Burgess, Trinder, Kim, & Luke, 1997) and remains enhanced during sleep (Stein & Pu, 2012; Trinder et al., 2001). Emerging evidence also supports a link between higher CVC_{wake} and better subjective sleep quality in specific populations like children or clinical samples (e.g., El-Sheikh, Erath, & Bagley, 2013; Fang, Huang, Yang, & Tsai, 2008; Hovland et al., 2013; Yang et al., 2011) as well as in healthy adults in the context of daily stressors (Jackowska, Dockray, Endrighi, Hendrickx, & Steptoe, 2012; Kageyama et al., 1998). Only one study measured objective sleep quality and found that higher levels of CVC_{wake} were associated with deeper sleep (i.e., delta power) in participants with alcohol-dependency (e.g., Irwin, Valladares, Motivala, Thayer, & Ehlers, 2006).

Research assessing links between CVC_{wake} and sleep, however, may not speak to the links between CVC during sleep (CVC_{sleep}) and sleep. Studies linking CVC_{sleep} (sometimes but not often separated for each sleep stage) and sleep quality showed, for example, reduced levels of CVC_{sleep} in patients with different sleep disorders, such as primary insomnia or in patients with chronic fatigue syndrome (e.g., Burton, Rahman, Kadota, Lloyd, & Vollmer-Conna, 2010; Stein & Pu, 2012; Tobaldini et al., 2013). A few studies also found a link between higher levels of CVC_{sleep} and better subjective sleep quality (e.g., Yang et al., 2011) in patient groups as well as in healthy individuals (Brosschot, Van Dijk, & Thayer, 2007; Patel et al., 2013).

While higher CVC_{wake} and higher CVC_{sleep} have both been linked with better sleep quality, additional research suggests that these links might be due to distinct processes. Some studies did not show a significant relationship between CVC_{wake} and CVC_{sleep} or found that CVC_{wake} – but not CVC_{sleep} – was associated with better sleep quality (Irwin et al., 2006; Jackowska et al., 2012). This might partly be due to variation in CVC_{sleep} across different sleep stages (Stein & Pu, 2012; Tobaldini et al., 2013) and across different periods of the same sleep stage across the night (Snyder, Hobson, Morrison, & Goldfrank, 1964), leading to heterogeneity of CVC_{sleep} during one night of sleep and relatively low reliability across nights. On the other hand, CVC_{wake} has shown good reliability as a stable trait marker (Bertsch, Hagemann, Naumann, Schachinger, & Schulz, 2012) and has been reliably linked to subjective sleep quality.

In summary, evidence suggests that CVC_{wake} and CVC_{sleep} are associated with different processes and are distinct predictors of sleep quality. During wakefulness, CVC corresponds to how people process and flexibly respond to their external environment, which implies the flexible regulation of physiological arousal (Dahl, 1996; Porges, 2007; Thayer & Sternberg, 2006). During sleep, however, CVC is not likely to correspond to online processing and responding to the environment. Rather, CVC_{sleep} may be related to maintaining a generally low arousal state to protect ongoing sleep. Importantly, existing evidence supports CVC_{wake} as the more reliable predictor of sleep quality in comparison to CVC_{sleep}.

1.3. The present study

The primary aim of the present study was to extend previous research on links between CVC and health by examining the relationship between CVC_{wake} and sleep quality. The present research fills three important gaps. First, prior research has relied predominantly on clinical samples. To advance understanding of the basic relationship between CVC_{wake} and sleep quality, we investigated this question in *healthy adults*. Second, research to date has assessed sleep quality almost exclusively with subjective measures. To thoroughly and validly measure sleep quality, we obtained both *subjective and objective sleep measures*. More specifically, subjective sleep quality was indexed by the Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) and objective sleep quality by polysomnography (the gold standard for sleep assessments). Third, prior studies assessed CVC_{wake} typically only during relatively short periods (e.g., Fang, Huang, Yang, & Tsai, 2008; Hovland et al., 2013; Kageyama et al., 1998) or waking periods directly before sleep while resting in bed, which can produce confounds with circadian influences (e.g., Irwin et al., 2006; Trinder et al., 2001). In addition, resting baseline assessment without anything to do or focus on may lead to uncontrolled differences in mental activity (Wilson et al., 2014) and reduced reliability. To avoid these limitations, we employed a *minimally-demanding, standardized, and extended baseline* (Jennings, Kamarck, Stewart, Eddy, & Johnson, 1992) in the form of a full-length, emotionally neutral film to assess trait-level CVC_{wake}. This baseline assessment approach extends the window for CVC_{wake} assessment to improve its trait-like quality, while concurrently minimizing individual differences in mental activity.

We hypothesized that participants with higher (vs. lower) CVC_{wake}, operationalized by heart rate variability in the high-frequency spectral band (0.15–0.40 Hz, HF-HRV, Berntson et al., 1997) would exhibit higher subjective sleep quality (i.e., lower scores on the PSQI) and higher objective sleep quality (assessed by polysomnography). We also assessed $HF\text{-}HRV_{sleep}$ across the time spent sleeping and separately for each sleep stage. However, we included these indices primarily for exploratory purposes and, based on the extant literature, we did not expect strong and consistent relationships between $HF\text{-}HRV_{sleep}$ and either subjective or objective sleep quality. Finally, we aimed to assess whether associations between $HF\text{-}HRV_{wake}$ and sleep quality are specific to sleep quality per se, rather than sleep parameters more broadly construed (e.g., the duration of different sleep stages), which were included in complementary analyses.

2. Method

2.1. Participants

Participants were 29 healthy female undergraduates (University of Salzburg, all Caucasian) between 19 and 31 years of age ($M = 23.6$ years, $SD = 3.3$) with a body mass index (BMI) between 17.4 and 31.7 ($M = 21.8$, $SD = 3.5$). All participants were non- or only occasional smokers with no history of mental, neurological, or sleep disorders. We only accepted participants who were considered in the normal range of subjective sleep quality, as defined by values in the PSQI up to 7 (higher scores indicate poorer sleep) for the past month. The cut-off value for good subjective sleep quality in the PSQI is 5 (Buysse et al., 1989), but values up to 7 are acceptable because this still can be considered within a normal range of sleep quality in female student populations (Pranada, 2005) and we did not want to artificially reduce variance in this variable. The average reported sleep duration on the 3 days before the first night in the laboratory was 8.2 h ($SD = 1.1$ h).

2.2. Procedure

The investigation took place as part of a larger study in the *Clinical Stress and Emotion Lab* of the University of Salzburg. The whole study spanned 11 days. Participants completed daily sleep diaries to assure regular sleep cycles during the whole study. The study included four visits to the lab: the entrance examination, which took place at least 3 days prior to the first night and the 3 nights in the lab each separated by one night, as well as a final 3 days of sleep assessment by sleep diaries. The first night in the lab was used for adaptation and screening purposes (sleep disturbances like sleep apnea, insomnia, periodic leg movements, which did not occur in any of the participants) and was performed two nights prior to the experimental nights. Participants came to the lab around 9 pm and completed