Respiratory Physiology & Neurobiology 237 (2017) 35–41

Contents lists available at ScienceDirect

Respiratory Physiology & Neurobiology

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

Impact of arousal threshold and respiratory effort on the duration of breathing events across sleep stage and time of night

Soheeb A. Wains[a,b], Mohamad El-Chami[a,b], Ho-Sheng Lin[a,b,d], Jason H. Mateika[a,b,c,*]

[a] John D. Dingell Veterans Affairs Medical Center, Detroit, MI, 48201, United States
[b] Department of Physiology, Wayne State University School of Medicine, Detroit, MI, 48201, United States
[c] Department of Internal Medicine, Wayne State University School of Medicine, Detroit, MI, 48201, United States
[d] Department of Otolaryngology-Head & Neck Surgery, Wayne State University School of Medicine and Karmanos Cancer Institute, Detroit, MI 48201, United States

ARTICLE INFO

Article history:
Received 14 October 2016
Received in revised form
23 November 2016
Accepted 16 December 2016
Available online 28 December 2016

Keywords:
Non-rapid eye movement sleep
Chemoreflex sensitivity
Carbon dioxide reserve
Tidal volume
Partial pressure of end-tidal carbon dioxide

ABSTRACT

Purpose: The frequency and duration of breathing events are influenced by sleep stage and time of day. In the present study we examined if these modifications are linked to adaptations in the arousal threshold and/or the magnitude of respiratory effort during and immediately after breathing events.
Methods: Participants with sleep apnea slept for 3 h in the evening and morning. For breathing events detected during these sessions the rate of change of respiratory effort, maximum respiratory effort immediately prior to termination of an event, and the maximum tidal volume and the minimum partial pressure of end-tidal carbon dioxide ($P_{ET}CO_2$) immediately following an event were measured.
Results: The rate of change of respiratory effort was similar in N2 compared to N1 but the maximum respiratory effort immediately prior to event termination was greater (-10.7 ± 1.2 vs. -9.6 ± 1.0 cmH_2O/s, $P < 0.05$). Likewise, tidal volume was increased (1169 ± 105 vs. 1082 ± 100 ml, $P < 0.05$) and $P_{ET}CO_2$ was decreased (37.0 ± 0.8 vs. 37.7 ± 0.8 mmHg $P < 0.05$) following events in N2 compared to N1. A similar tidal volume and $P_{ET}CO_2$ response was evident following events in the morning compared to the evening independent of sleep stage.
Conclusions: We conclude that alterations in the arousal threshold, reflected by an increase in respiratory effort at event termination, coupled to increases in tidal volume and reductions in $P_{ET}CO_2$ contribute to modifications in event duration and frequency associated with variations in sleep state or time of night.
Published by Elsevier B.V.

1. Introduction

Recently we reported that the frequency and duration of apneic events is dependent on sleep stage (El-Chami et al., 1985a). More specifically, we showed that the duration and frequency of events was greater in N2 compared to N1 sleep, independent of the time of day (El-Chami et al., 1985a). The observed increase in event duration in N2 could be caused by an increase in the arousal threshold, along with an increase in the effective recruitment threshold for upper airway muscle activity (i.e. the point at which the upper airway muscles are recruited independent of the activating stimulus) (Cala et al., 1996; Eckert and Younes, 2014; Montserrat et al., 1996a). Alternatively, a blunted respiratory response to afferent inputs (e.g. chemoreflex and mechanoreceptor inputs), reflected by a decrease in the rate of change of respiratory effort during apneic events in N2 could be responsible for sleep stage related differences in apneic duration. The relationship between event duration and arousal threshold or respiratory response sensitivity should impact on respiratory effort immediately prior to termination of an event, and closely after establishment of airway patency.

Kimoff and colleagues reported that the rate of change of respiratory effort during breathing events in N2 is independent of event duration (Cala et al., 1996; Montserrat et al., 1996a). Thus, respiratory effort at the termination of an event might reflect increases in the arousal or effective recruitment threshold. If these findings are consistent across sleep states the rate of change of respiratory effort during events in N1 compared to N2 may be similar. However, the maximum response at the termination of an event and immediately upon re-establishment of upper airway patency may be increased if the arousal threshold or effective recruitment threshold is increased in N2 compared to N1. The present investigation was completed in part to test this hypothesis.

* Corresponding author at: John D. Dingell VA Medical Center, 4646 John R (11R), Room 4332, Detroit, MI, 48201, United States.
E-mail address: jmateika@med.wayne.edu (J.H. Mateika).

http://dx.doi.org/10.1016/j.resp.2016.12.009
1569-9048/Published by Elsevier B.V.

In addition to the variation in event duration and frequency in N2 compared to N1, we also recently reported that event duration was greater in the morning compared to the afternoon and evening within a given sleep stage (i.e. N2) (El-Chami et al., 1985a), consistent with previous published findings (Cala et al., 1996; Charbonneau et al., 1994; Fanfulla et al., 1997; Lavie et al., 1981; Montserrat et al., 1996b; Sforza et al., 1998). Likewise, event frequency was greater in the morning during N1 (El-Chami et al., 1985a). We provided evidence which suggested that the effect of time of day on the duration and frequency of breathing within a given stage of sleep might be mediated by a circadian variation in both chemoreflex sensitivity (El-Chami et al., 1985b), and upper airway collapsibility (El-Chami et al., 1985a). Explicitly, we found that an increase in chemoreflex sensitivity coupled to a decrease in the carbon dioxide reserve, and a more collapsible airway, was evident in the morning during N2 compared to the afternoon and evening (El-Chami et al., 1985b). These findings were evident despite the absence of hallmarks of sleep apnea (i.e. intermittent hypoxia) (El-Chami et al., 1985b).

The variation in chemoreflex properties could result in an increased rate of change in respiratory effort during an event in a given stage based on the time of day. This postulation is supported by the findings of Sforza et al. (Sforza et al., 1998) but is in contrast to the findings of Kimoff and colleagues who reported that the rate of change of respiratory effort modified by pressure changes that activate upper airway mechanoreceptors, or increases in central respiratory drive, was not altered by the time of day (Cala et al., 1996; Montserrat et al., 1996a). Likewise, variations in chemoreflex properties, coupled to a more collapsible airway and an increased effective recruitment threshold, could result in an upsurge in respiratory effort immediately at the termination of an event and following re-establishment of airway patency (El-Chami et al., 1985a). The increase in effort following re-establishment of airway patency could lead to hypocapnia and the initiation of subsequent events upon re-establishing the sleep state (Dempsey et al., 2010; Mateika and Narwani, 2009; Mateika and Syed, 2013). This postulation is supported indirectly by Kimoff and colleagues (Cala et al., 1996; Montserrat et al., 1996a) who showed that the respiratory effort immediately prior to termination of the event was greater in the morning compared to the evening.

In the present investigation, respiratory effort during events, immediately prior to termination of events, and closely after establishing airway patency was measured to determine if sleep stage (i.e. N1 vs. N2 of non-rapid eye movement sleep) and time of day (i.e. evening vs. morning) modulate the arousal threshold and respiratory response sensitivity in individuals with obstructive sleep apnea.

2. Methods

2.1. Protocol

The Human Investigation Committees of Wayne State University School of Medicine and John D. Dingell Veterans Affairs Medical Center approved the experimental protocol. Thirteen male participants with untreated pure or predominantly obstructive sleep apnea but no other comorbidities (e.g., heart and lung disease, hypertension, and obesity) were enrolled in the study.

On their first visit to the laboratory, written informed consent was obtained. Furthermore, a physical examination, health and lifestyle questionnaires, blood pressure, lung volume measures, and a 12-lead ECG were completed. After ensuring that the inclusion criteria were satisfied, participants completed a baseline nocturnal polysomnogram on the second visit to the laboratory to confirm the presence of obstructive sleep apnea. Upon confirmation, participants were enlisted in the protocol and their sleep was monitored at home for two weeks, using an actigraph watch (Actiwatch Spectrum; Philips Respironics, Murraysville, PA), prior to obtaining the intended physiological measurements. During these two weeks, we requested that the participants adhere to a regular sleep-wake schedule with a sleep onset time of between 10 and 11 PM and a wake time between 7 and 8 AM. We also requested that the participants refrain from daytime napping. These criteria were implemented to establish a similar circadian rhythm in all the participants. Our published measures of core body temperature (El-Chami et al., 1985a) in conjunction with the actigraphy measures indicated that overall the participants adhered to our request. During the two week period the participants returned to the laboratory (i.e., visit 3) to determine the therapeutic continuous positive airway pressure required to maintain airway patency during data collection on visits 5 and 6. After the two week monitoring period, participants returned to the laboratory on three separate occasions (i.e., visits 4–6). A minimum of 7 days between visits was required. We requested that participants refrain from alcohol and caffeinated beverages at least 1 day before the visit. Participants were to arrive at the laboratory at 8:00 PM on the day. Once the participants arrived in our laboratory, they ingested a radiotelemetry pellet (CorTemp Sensor, Palmetto, FL), which was used to track their core body temperature in 10 s intervals during each visit. Using the data obtained from this device we were able to determine the nadir of core body temperature. Following instrumentation, the participants completed a constant routine protocol. The protocol consisted of 3 h sleep sessions in the evening, morning and afternoon (i.e., 10 p.m.–1 a.m., 6–9 a.m., and 2–5 p.m.). Participants slept in the supine position during all sleep studies. A detailed explanation of the protocol has been previously described (El-Chami et al., 1985a; El-Chami et al., 1985b).

Results from visits 5 and 6 have been published (El-Chami et al., 1985a; El-Chami et al., 1985b). Likewise, a portion of the data collected during Visit 4, which revealed circadian variations in breathing event frequency and duration, has been published (El-Chami et al., 1985a). Circadian deviations in these variables were greatest between the evening and morning sleep, while data collected during the evening and afternoon were similar. Consequently, because of this similarity measures of respiratory effort during and immediately following termination of breathing events were limited to the evening and morning sessions during visit 4 to test the hypothesis put forth in the present manuscript (see *Introduction*). Data was obtained from 11 of 13 participants. One participant did not complete Visit 4 due to time constraints, and technical issues (i.e. modulation of epiglottic pressure was not evident) prevented the measurement of respiratory effort in one other participant.

2.2. Instrumentation

During the sleep studies the monitoring montage included an electroencephalogram (C3/A2, C4/A1, O1/A2, and O2/A1), electrooculograms, submental electromyogram, and an electrocardiogram. Movements of the chest wall and abdomen were measured using inductive plethysmography (Respitrace; Ambulatory Monitoring, Ardsley, NY). Measurement of tidal volume was obtained using a pneumotachometer (model RSS100-HR; Hans Rudolph, Shawnee, KS) connected to a nasal mask. Oxygen saturation was measured using a pulse oximeter (Biox 3700; Ohmeda, Boulder, CO). Measures of end-tidal oxygen (model 17515; Vacumed, Ventura, CA) and end-tidal carbon dioxide (model 17518; Vacumed) were obtained from air expired into sampling tubes connected to nasal mask ports. Mask pressure was measured by a port on the nasal mask allowing the connection of a pressure transducer. Epiglottic pressure was measured using a

Download English Version:

https://daneshyari.com/en/article/5594215

Download Persian Version:

https://daneshyari.com/article/5594215

Daneshyari.com