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Diurnal Effects of Respiratory Resistance using an Airflow Perturbation Device

Nicholas Z. Rausch[1], Arthur T. Johnson[2]*, Jafar Vossoughi[3]

[1]Undergraduate Student, Bioengineering, University of Maryland, College Park, MD, USA.
[2]*Professor Emeritus, Bioengineering, University of Maryland, College Park, MD, USA.
[3]President, Engineering and Scientific Research Associates, Brookville, MD, USA.
artjohns@umd.edu

***Corresponding Author:** Arthur T. Johnson, Professor Emeritus, Bioengineering, University of Maryland, College Park, MD, USA.*

Abstract

***Background:** The purpose of this study was to demonstrate possible changes in respiratory resistance throughout a 24-hour period using an Airflow Perturbation Device. The working hypothesis was that there was a significant difference in the respiratory resistance that can be attributed to changes throughout the day*

***Methods:** The research tested 25 healthy subjects sitting upright while utilizing the Airflow Perturbation Device (APD) to measure respiratory resistances at different times during the 24-hour day. The Airflow Perturbation Device (APD) is a noninvasive medical instrument (still under development) designed to measure respiratory resistance. In addition, factors that could influence differences in respiratory resistance, such as gender, height, weight, and other medical information, were recorded to facilitate understanding of the results.*

***Results:** The data revealed that there was no significant change in respiratory resistance due to diurnal effects.*

***Conclusion:** There was no evidence in the data pointing towards a diurnal change in respiratory resistance. If significant diurnal changes had been noted during this research, then future pulmonary measurements taken in a hospital or clinic would have to be interpreted differently during different times of the day. These results suggested that those adjustments are not required.*

Keywords: *Respiratory resistance, diurnal changes, pulmonary function tests.*

Introduction

Many human physiological attributes vary with time throughout the 24-hour day. Creating an understanding of the possible diurnal patterns can be important for medical purposes. This is because many expectations about standard values and other physiological measurements signifying abnormalities may need to be adjusted according to a 24-hour cycle. For example, some human characteristics that are dependent upon diurnal effects are body temperatures [1], circulating hormones [2], and even neural activity [3] can be affected by the time of day. Respiratory resistance is another physiological factor that is already an important clinical measurement recorded in hospitals and clinics nationwide. In fact, resistance measurements are valuable in assessing the effects of different bronchoconstrictive and bronchodilatory drugs. This even includes airborne contaminants and natural particulates [4]. Many diseases or conditions such as asthma, bronchitis, pneumonia, and emphysema are also indicators of increased respiratory resistance, which demonstrates practicality in diagnosing patients through a measurement of respiratory resistance [4]. Therefore, understanding the possible diurnal effects on respiratory resistance can determine the way measurements are interpreted inside hospitals and clinics, and can even affect treatment results that could vary with the time of day. These effects could possibly lead to enhanced treatment and diagnosis of diseases and conditions within the medical field. If there is a repeatable pattern within the data, the results should be of interest to pulmonologists and emergency care physicians. A diurnal pattern to respiratory resistance could be interpreted to provide specific treatment at varying times of the day where medication would be well received by the patient.

The airflow perturbation device (APD) is a medical instrument designed for noninvasive measurement of respiratory resistance. Through these noninvasive measurements this device accounts for airways, lung tissue, and chest wall components of resistance [4] [5] [6]. The APD was created as a way to simply, efficiently, and easily measure respiratory resistance, and has advantages for recording both on small children [4] [5] [7] and unconscious (or obstinate) patients [5] , whether the testing is done at home or in a hospital [8][9]. This device strives to alleviate the need for special breathing maneuvers and breathing coaches in an attempt to leave patients with no stress. Subjects are simply asked to breathe naturally through the device while a wheel rotates in the flow pathway. This wheel modifies flow rates and mouth pressures within the device by perturbing airflow and mouth pressure, which depend on respiratory and device resistances. Once a test is conducted, the ratio of the mouth pressure perturbation magnitude to the flow perturbation magnitude is displayed as a number on the screen of the APD, with separate resistances during both inhalation and exhalation breathing phases shown. The device also provides an additional average calculated from the inhalation and exhalation values. The numbers displayed can be subsequently associated with lung volume and flow. Resistance values are typically recorded through the mouth while patients are sitting upright; a nose-clip is also placed onto the patients so that no air will enter or leave via the nasal cavity.

This study was intended to discover a possible relationship between time of day and respiratory resistance by utilizing the Airflow Perturbation Device. The hypothesis was that the there was a distinguishable difference in the respiratory resistance that can be attributed to changes throughout the day. These changes in bodily functions again are recognized as being possibly stimulated or repressed by the time of day. Respiratory resistance could then be another factor that could follow a trend throughout the 24-hour day.

Materials and Methods

Twenty five healthy subjects were recruited for the research study. These subjects were colleagues, acquaintances, and family members of the principal researcher. Ages of participants ranged from 18 to 53 years old, including both males and females who were willing to be tested at odd times during the day. The testing protocol was approved by the University of Maryland Institutional Review Board.

During the testing of each subject, medical history and consent forms were distributed to provide background information for each subject, as well as permission to be tested. The medical history forms recorded information regarding their gender, height, and weight to identify possible variables that can influence respiratory resistance. The subjects were seated and relaxed during testing. Each subject breathed normally into the APD through a personal sterile mouthpiece so that no viruses or microbes would be transmitted from one subject to another. The APD was held in one hand while the nose was pinched closed with the subjects' fingers or with a nose clip.

Subjects were tested at even intervals (once per hour) over the entire 24-hour day. Most of the data were collected between the hours of 1000 and 0100. There had to be a common basis to compare resistance measurements from many subjects tested at different times. Each subject was tested between the hours of 1000 and 1500, in order to form baseline values for all of the test subjects. Each subject was tested three times in a row each hour during a five-minute interval. The baseline value was formed by the average of resistance values during the time period of 1000 to 1500. The baseline value for each subject was used to normalize the resistance values for that subject throughout the diurnal period, and was assigned a normalized value of 1.0. All measurements taken at the times of the trial period for each subject were divided by the average value of measurements taken during the baseline interval.

The goal was to have an even number of subjects tested during dusk and early nighttime hours (1700-0100) and during the late night to early morning hours (0200 – 0900). However, not every test subject could be tested between the hours provided, due to conflicts in scheduling or with other activities. Instead, each subject was recorded during the times they provided. With these provided times, an attempt was made to test as many subjects as possible for each hour. At least eight subjects were tested for each hour. This was done in order to minimize effects of natural variations that have been documented in respiratory resistance data [4] [5] [10].

Results

Basic demographic data and the mean baseline respiratory resistance for each group are shown in Table 1. Out of the twenty-five subjects tested, sixteen were male and nine were female.

Table 1. *Subject Demographics*

	Male (16)	Female (9)
Age	20.4 ± 0.24 (19-22)	24.0 ± 3.63 (19-53)
Weight (kg) (Pounds)	74.0 ± 2.08 (56-84) 163.1875 ± 4.60 (125-186)	59.7 ± 3.75 (45-72) 131.67 ± 8.27 (100-160)
Height (cm) (Inches)	178.9 ± 1.43 (167-188) 70.4375 ± 0.5625 (66-74)	163.4 ± 1.85 (157 – 173) 64.3 ± .726 (62-68)
Hours of exercise per week	4.63 ± .591 (0-8)	9.67 ± 2.64 (3-25)
Hours of Sleep per night	7.19 ± .249 (6-9.5)	7.17 ± .333 (6-9)
Average Inhalation Resistance (Hours 1000-1500 cmH2O*sec/L	2.55 ± .117 (1.81-3.64)	3.19 ± .255 (1.92-4.58)
Average Exhalation Resistance (Hours 1000-1500) cmH2O*sec/L	2.57 ± .134 (1.71-4.00)	3.69 ± .441 (2.29-6.74)

Entries are the mean values ± standard deviations of the mean with range displayed in parenthesis.

Numbers of data points per hour are recorded in Table 2; this shows the number of participants tested at each hour of the day.

Table 2. *Data Points Per Hour of Day*

Time	Data Points Collected Per Hour of the Day
0100	5
0200	2
0300	1
0400	1
0500	1
0600	1
0700	1
0800	1
0900	1
1000	13
1100	14
1200	17
1300	20
1400	19
1500	21
1600	18
1700	19
1800	20
1900	15
2000	13
2100	13
2200	10
2300	6
2400	5
Average # of Data Points per Hour	9.9 ± 7.7 (1-21)

Entries are the number of participants tested at each hour of the day. The time is represented as the 24-hour cycle. The average number of data points per hour, as well as both standard deviation and range of data, is shown in the last row.

The graphed data in Figure 1 shows that there was no significant change in respiratory resistance due to diurnal effects. The average respiratory resistance for all participants throughout the baseline testing was 2.78 cmH2O*sec/L with a standard deviation of ±.655. There was no noticeable trend within the combined data on a 24-hour scale.

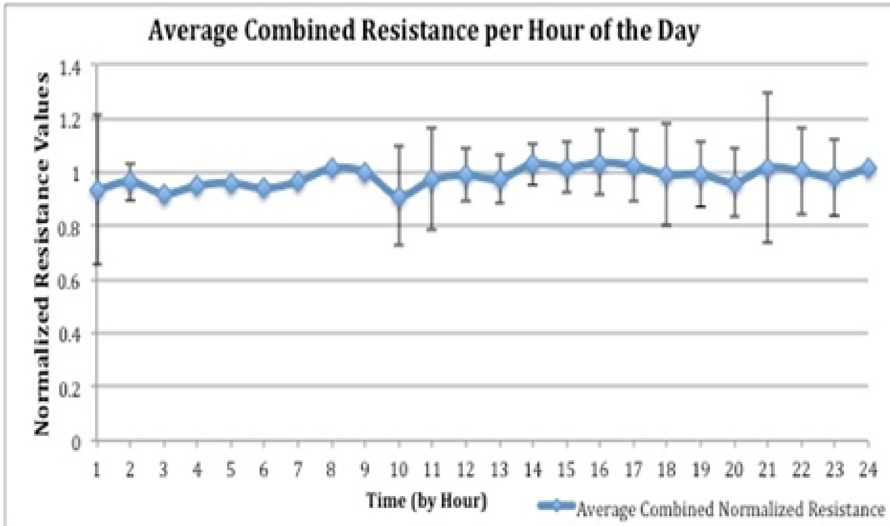

Fig 1. *Average combined inhalation and exhalation resistances of all the subjects . A summation was taken between the two with the standard deviation of the data calculated and applied. Error bars indicate the average standard deviation taken between both of the inhalation and exhalation.*

Both Figures 2 and 3 demonstrate steady resistance values for inhalation and exhalation breathing phases. The largest deviation from the normalized baseline value of 1.0 occurred between the hours of 1100-1200, where the resistance values in both inhalation and exhalation have a difference of around -.15 to -.2 cmH2O*sec/L. Between the hours of 2400 and 0200 on both Figures 2 and 3 there is a variance that is lower than that for the regular normalized trend (between .05 and .1 cmH2O*sec/L below 1.0).

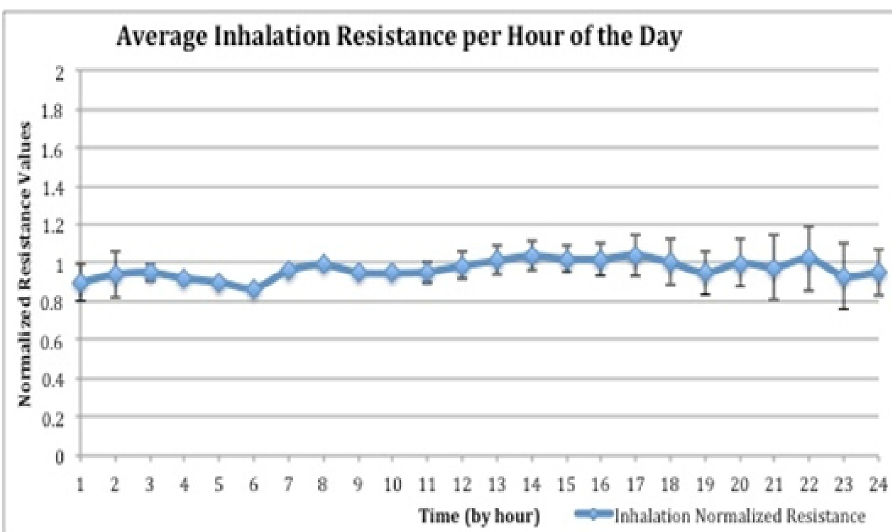

Fig 2. *Average inhalation resistances of all the subjects during the hours of the day. Error bars represent the standard deviation of the mean for the 24-hour cycle.*

There was no significant trend outside of minor variations within the data to indicate any change in respiratory resistance due to diurnal effects.

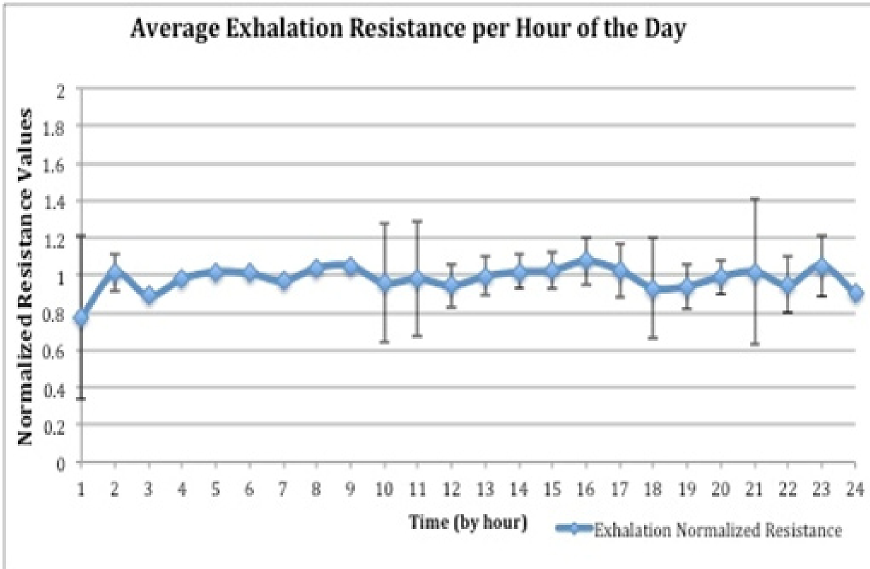

Fig 3. *Average exhalation resistances of all the subjects during the hours of the day. Error bars represent the standard deviation of the mean for resistance for the 24-hour cycle.*

Data for certain individuals indicated that there was some fluctuation in respiratory resistance throughout the day. In Figures 4, 5, and 6 are shown resistance values for one participant, designated "Subject 1".

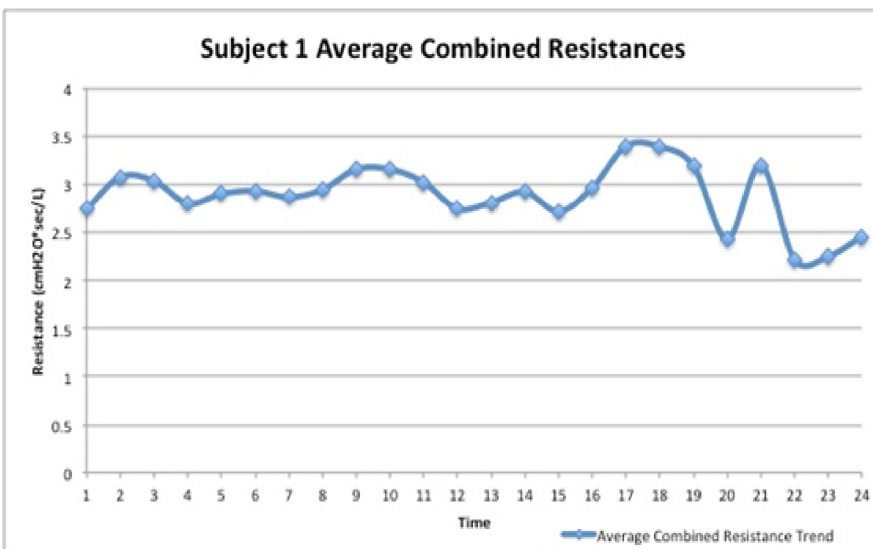

Fig 4. *Average combined resistance of a single subject during the 24-hour day. This is the raw data measured by the APD and displays the average of the triplicate data for each time point.*

During the hours of 1500 to 1800 there was a greater resistance (between 3.05 cmH2O*sec/L and 3.46 cmH2O*sec/L) than at any other times recorded. This then was followed by an eventual decline at hour 1900, which is lower than any other resistances recorded (2.41 cmH2O*sec/L at 1900, and staying below 3 cmH2O*sec/L from hours 0900-1200). Subject 1 did not report any current or prior medical conditions that would have influenced the resistance values.

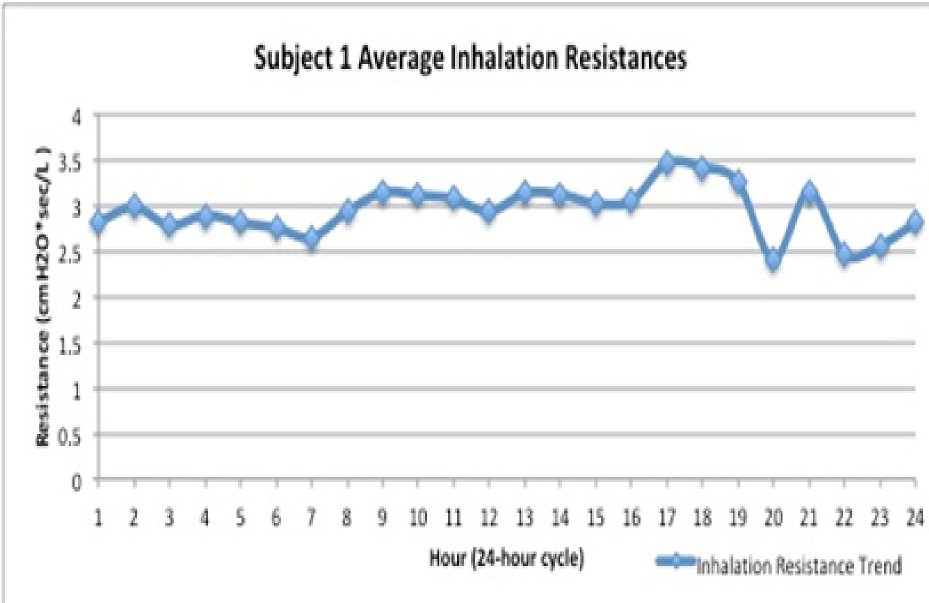

Fig 5. *Average inhalation resistance of a single subject during the 24-hour day. This is the raw data measured by the APD and displays the average of the triplicate data for each time point.*

At hour 1400 there begins a trend upward that peaks around the hours of 1600-1700 and then steadily trends back downwards to significantly lower resistance (3.36 cmH2O*sec/L at hour 1700 compared to 1.94 cmH2O*sec/L at hour 2200). This decrease in resistance eventually recovers throughout the night but eventually stabilizes at a value of approximately 3.00 cmH2O*sec/L.

at around a value of approximately 3.00 cmH2O*sec/L. demonstrate the previously see variations found within inhalation and exhalation graphs at hours 15:00 -18:00 and 19:00.

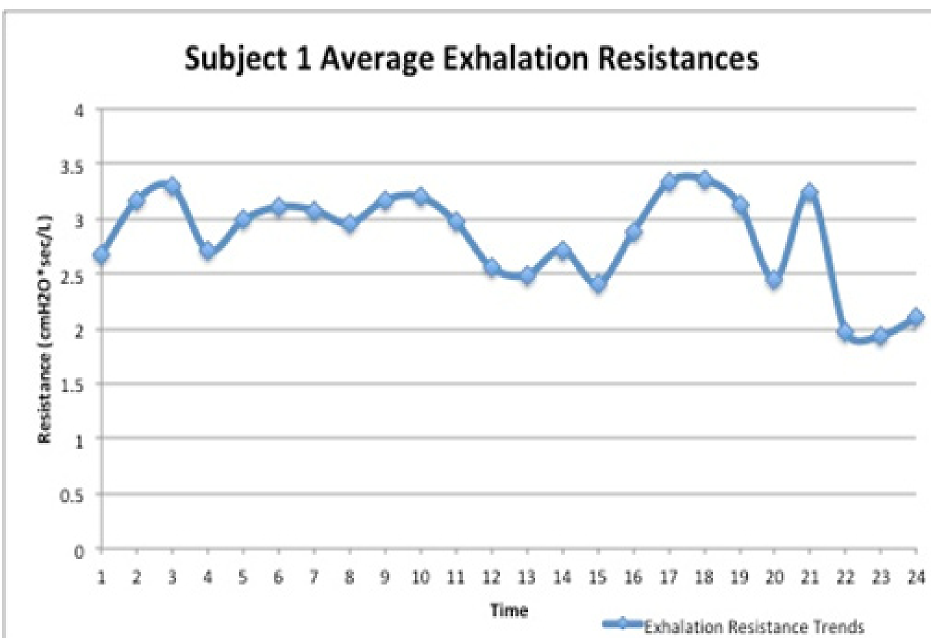

Fig 6. *This figure demonstrates the average exhalation rates of a single subject during the 24-hour day. This represents the raw data measured by the APD and displays the average of the triplicate data for each time point.*

Discussion

Whether or not respiratory resistance fluctuated throughout the day was the most important piece of information that was hypothesized from this data. While there were certainly small deviations from the baseline (see Figures 1, 2, 3 for average data for all subjects) the evidence does not seem to corroborate the hypothesis.

Looking back at Figures 4 through 6, one participant's resistance can vary at times throughout the day. We can draw the conclusion from this that respiratory resistance measurements for any particular individual can vary from one time to the next. A variation of about ten or twelve percent of the mean can be expected from time to time [10]. It is also understood that respiratory resistance values can vary significantly from subject to subject, with female resistance values usually greater than those of males of similar age [4][5][7][10].

At hour 1900 there was a standard deviation of almost 1 whole unit in Figures 1, 2, and 3. With over half of the participants tested (10) at hour 1900, this indicated that there were large variations among individual subjects. About 7-10 of the tested subjects smoked, used nicotine vaporizers, or had smoked recently, which is known to have an effect on increased heart rate and lung flow [11][12]. Additionally, 9 subjects indicated that they experienced (seasonal and year-round) allergies (congestion, coughing, increased mucus production, etc) due to increases in environmental particulates such as pollen during the months of March and April [13]. In addition, there is already a proven link between respiratory disease and function [14] with air particulate pollution, which could be another cause of variations within the data set [15].

The subjects tested were mainly students taking university courses (over 90 percent) and with that came difficulty in finding consistent times to conduct the research, and this limited the amount of data obtained for certain times of the day. During the hours of 0300-0900, there were very few data points that could be used to provide a meaningful average.

Another limitation to the study was the impact of allergies during the testing months of March through May. These afflictions can cause variations within the respiratory resistance of the test subjects and could skew any results. Additionally, smokers or subjects who used nicotine vaporizers could have potentially skewed data points if they had smoked prior to testing, as nicotine's effects on the body are far reaching. It may be necessary for follow up studies on the diurnal effects of respiratory resistance in order to determine the extent of these limitations.

Conclusion

The hypothesis that there were diurnal changes in respiratory resistance was not supported by the data. Further testing may have to be conducted in order to overcome the limitations of this study.

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