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# Heart rate variability in habitual college-aged snorers

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Heart Rate Variability in Habitual College-aged Snorers

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A Project Presented to  
the Faculty of the Undergraduate  
College of Health and Behavioral Studies  
James Madison University

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in Partial Fulfillment of the Requirements  
for the Degree of Bachelor of Science

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by Erica Elizabeth Searfoss

May 2014

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Accepted by the faculty of the Department of Kinesiology, James Madison University, in partial fulfillment of the requirements for the Degree of Bachelor of Science.

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## Abstract

**Purpose** Snoring is the primary, most distinguishable symptom of Obstructive Sleep Apnea (OSA). Increased activation of the sympathetic tone is also consistently identified in adults with clinically diagnosed OSA. We compared heart rate variability (HRV) in snoring and non-snoring college-aged subjects to assess any HRV alterations between groups that could potentially signify an early marker for developing OSA.

**Methods** 23 male snorers and 7 male non-snorer subjects were studied. The HRV variables in the R-R heart intervals were compared between the groups via obtaining heart rate from the polar RS800CX monitor and performing an analysis using an independent sample *t*-test. All subjects were of similar age, body composition, and physical fitness.

**Results** HRV was not significantly reduced in snoring subjects compared to non-snoring subjects. Age was significantly correlated to pNN50 ( $r=-0.48$ ,  $p=0.01$ ), RMSSDLog ( $r=-0.45$ ,  $p=0.01$ ), HFLog ( $r=-0.49$ ,  $p=0.01$ ), Log LF/HF Ratio ( $r=0.53$ ,  $p=0.00$ ), LFnu ( $r=0.50$ ,  $p=0.01$ ), and HFnu ( $r=-0.50$ ,  $p=0.01$ ).

**Conclusion** HRV alterations of increased sympathetic tone to parasympathetic tone are not significantly associated with young snorers. Increased age is correlated to elevated imbalance in HRV, most likely due to sympathetic build up over time as a result of increased progression of the sleep disorder. The HRV measure may be a useful indicator of diagnosed OSA in middle-aged adults, but not a powerful indicator of onset OSA in younger individuals because they are at too early of a point in potential progression of the disorder to elicit any significant physiological changes.

**Keywords:** snoring, heart rate variability, sympathetic tone, obstructive sleep apnea

## **Chapter I**

### **Introduction**

Obstructive sleep apnea (OSA) is characterized by repetitive cessations or decreases in ventilation during an individual's sleep cycle due to intermittent bouts of partial or total collapse of the pharyngeal airway [1]. The after-effect of the pharyngeal airway blockages is hypoxia and an inadequate amount of oxygen in the blood flow delivery from the lungs to the cells of the body. An obstructive apneic episode results from a complete airway obstruction involving a 10 second or greater cessation in respiration. An obstructive hypopnea is defined as a partial blockage in the pharyngeal airway leading to a periodic decrease in ventilation, rather than a complete cessation. Bouts of obstructive hypopnea can be just as severe as obstructive apnea in that ventilation decreases are highly associated with dramatic decreases in oxygen saturation [32]. Both obstructive episodes occur even with continued ventilation effort of the lungs [1]. An individual is diagnosed with OSA if they experience an average of five or more episodes of obstructive apnea or obstructive hypopnea per hour of sleep, along with encountering strong symptoms of excessive daytime sleepiness (EDS) [32]. EDS is a primary OSA symptom because it signifies sleep deprivation caused by obstructive apnea disturbances [39].

OSA is the dominant sleep disordered condition in America, affecting an estimated 15 million adults [32]. Due to the high prevalence and the likelihood of the disorder to develop without being clinically diagnosed, OSA is a major public health concern and it is critical that substantial measures are taken to identify the disorder. Individuals with OSA suffer from the stress reaction developed from constant sleep deprivation and can face long term physiological damage as a consequence of the oxygen deprivation during the obstructive apneas and hypopneas. Along with the severity of the disorder itself, OSA is also associated with a number

of comorbidities, which produce a greater threat to individual health. OSA has been shown to significantly increase the risk of cardiovascular diseases, including coronary artery disease, congestive heart failure, stroke, and atrial fibrillation [12]. In addition, OSA is also related to metabolic syndrome, hypertension, and diabetes mellitus [2-15].

Snoring, habitual or disruptive, is the most common sign of OSA [18-20]. Habitual and disruptive snoring cause poor sleep quality as well as major disturbances in sleeping patterns, often to the extreme extent in which breathing pauses completely [33]. Snoring occurs as a response to a reduction in airflow to the nose or mouth during sleep due to anatomical factors, which include incompetent oral muscle tone, space occupying masses, excessive length of the soft palate and uvula, and an obstructed nasal airway [33]. A relaxed oral muscle tone results in diminished rigid support in the mouth, which consequently leads to the falling of the tongue and throat muscles back into the airway creating a blockage in airflow [33]. Space occupying masses, specifically bulky throat tissue, cause a significant reduction in airflow because a vast amount of space is compromised in the pharyngeal airway [33]. Due to the increased risk of snoring with excess bulky or fat tissue, snoring is more prevalent in overweight men than non-overweight men [33]. Exaggerated length of the soft palate and uvula narrows the opening of airflow between the nose and the throat, which results in negative pressure on the pharyngeal airway during inspiration [33].

Snoring, and the irregular breathing associated with OSA, has a tendency to worsen with age [34]. Age is an important risk factor in OSA, with the highest prevalence occurring in middle-aged adults [35]. Other risk factors of OSA include witnessed gasping, obesity, excess adiposity, enlarged neck size, male gender, crowded appearing pharyngeal airway, and increased

blood pressure. All of these risk factors put one at higher risk for OSA and subsequently a higher risk of the associated cardiovascular diseases and other morbidities [11, 16-17].

OSA has been shown to lead to autonomic dysfunction, a key factor linking OSA to other chronic diseases [25]. Autonomic function can be assessed by fluctuations in normal heart rate rhythm. Heart rate rhythm can be evaluated by measuring heart rate variability (HRV), which is the variation in the time interval between heartbeats. High sympathetic drives have been observed in individuals that experience ventilation decreases and complete breathing cessations during sleep [23-24]. Previous scientific literature has demonstrated an association between increased prevalence in obstructive apneas and signs of high sympathetic activity [23-24].

During sleep, individuals with OSA undergo an over activation of the sympathetic nervous system, explained by the increased stimulation of peripheral and central chemoreflexes as the body undergoes obstructive apnea and hypopnea episodes [36]. An indirect relationship between oxygen and carbon dioxide occurs during bouts of obstructive apneas and hypopneas; as oxygen saturation decreases because of partial or complete pharyngeal airway blockage, carbon dioxide retention increases creating a disturbance in the balance of the gasses. An imbalance in gasses alerts brain receptors to stimulate the chemoreflexes to signal the sympathetic nervous system of the respiration acidosis [36]. Due to the cessations and decreases in ventilation, there are consequent decreases in venous blood return to the heart, disrupting normal blood pressure in the body and creating a disturbance in the heart's normal autonomic function [37-38]. Increased sympathetic activity acts to maintain normal blood pressure during the obstructive sleep apneas via vasoconstriction of the muscles [37-38]. Moreover, sympathetic nervous system dominance between the R-R heart intervals has also been evident in hypertensive individuals [25], as well as

individuals with coronary artery disease [21-22], demonstrating the autonomic dysfunction association between OSA, high blood pressure, and other cardiovascular problems [25].

OSA, as previously stated, is caused by airway obstruction and consequent hypoxia and is most commonly identified with habitual and disruptive snoring. Previous studies have been performed to evaluate the effects of airway obstruction and hypoxia on HRV, confirming the use of HRV as a key tool in measuring and identifying autonomic dysfunction in adults [26]. These studies consisted of measuring the HRV taken during undisturbed supine rest during a daytime awake period for 10 minutes [26]. Results verified the overstimulation of the sympathetic nervous system in OSA patients by revealing an increased ratio of low to high frequency in the R-R heart intervals [26].

### **Purpose**

HRV analysis had shown to be an effective screening tool in clinically diagnosed adult OSA patients [26], which inferred that the accuracy of the HRV measurements may have also been a powerful representative of indicating onset, not yet identified OSA in college aged snoring subjects. An objective of this study was to determine connections between heart rate imbalances and young snoring subjects to identify those at heightened risk for developing OSA by analyzing individual heart rate oscillation between beat to beat intervals and utilizing the knowledge that over stimulation of the sympathetic tone in HRV was seen in OSA patients. The goal of this study was to examine the differences in HRV between young subject snorers and non-snorers to determine the power of the HRV measure as an early marker of sleep disorders.

The hypothesis of this study was that heightened sympathetic activity in HRV measurements would be seen in the subjects that were constant snorers, as snoring has shown to be the predominant risk factor of OSA, when compared to the subjects that did not snore.

Establishing a significant relationship between sympathetic overdrives and snoring individuals would help to verify HRV analysis as an appropriate tool in assessing the risk of OSA in a young adult population. If HRV analysis proved to be accurate in predicting the onset of OSA in college age persons, further measures could be taken to prevent OSA in younger individuals before clinical diagnosis.

## CHAPTER II

### Methodology

#### *Subjects:*

The study aimed to obtain a sample of 40 college-aged (ages 18-26) sedentary males from the James Madison University and Harrisonburg community. Recruitment of subjects was done via flyers posted on local notice boards through campus mass emails, and also via a website which served as the research project's information base by including explanations of the design of the study and descriptions of the testing procedures in which subjects would participate. The website also held actual copies of the research project study documents. The documents did not contain any information that allowed for subject identification.

The aim of subject recruitment was to obtain a group of 20 snorers and a group of 20 non-snorers to participate in the project. Subjects were required to be sedentary individuals or not involved in regular exercises. Physical activity levels were assessed via questionnaire to control for potential effects of regular exercise on autonomic function. Regular exercise may have an attenuated effect of the sympathetic drive on resting heart rate, which could result in an increase in the R-R intervals at rest [27]. This adaptation needed to be accounted for, as it may have corresponded with alterations in sensitivity to the autonomic system, and therefore could have influenced HRV data [27].

Corresponding with a sedentary lifestyle, a body mass index (BMI) greater than  $25 \text{ kg/m}^2$  was also necessary to participate in the study. A BMI value is based on the ratio of an individual's body weight in kilograms to their body height squared in meters. The American College of Sports Medicine (ACSM) guidelines state that a BMI exceeding the value of  $25 \text{ kg/m}^2$  is overweight and a BMI above  $30 \text{ kg/m}^2$  is considered obese [28]. Excess body weight

influences an individual's risk of OSA; therefore it was crucial to have subjects of similar BMI values. For this study, all subjects were either overweight or obese according to ACSM guidelines. Other exclusionary criteria for the study included that subjects were not currently smoking, taking medication, or had any significant heart or lung disease.

*Pre-test:*

Subjects needed to read and sign an informed consent form. This form provided subjects with an overview of all aspects of the study including the study's intentions, the risks and benefits of participating, the consequences (if any) of withdrawing from the study, and the assurance of confidentiality to the subject involved. After subjects had granted consent, they were told to complete questionnaires on health and sleep habits.

The first questionnaire, the Health History Questionnaire (HHQ), asked about the subject's health history to ensure that the subject had no problematic health or medical conditions that would have made him ineligible for the study. This questionnaire took approximately five minutes. Following the HHQ, subjects needed to complete four additional questionnaires, all which took approximately one to two minutes each. The first and second questionnaires included the Berlin Questionnaire (BQ) and the STOP questionnaire, both of which served as tools for assessing subject's risk level for developing OSA by assessing their snoring habits and other potential risk factors related to OSA. The STOP questionnaire asked questions specifically related to snoring, tiredness during daytime, observed apnea, and high blood pressure [40]. The third questionnaire, the Epworth Sleepiness Scale (ESS), assisted in evaluating the subject's level of EDS. EDS, as stated previously before, is one of the strongest symptoms in identifying individuals with OSA. The last questionnaire, the International Physical

Activity Questionnaire (IPAQ), was used to obtain comparable estimates of the subjects' physical activity levels, which was statistically accounted for in the study.

*Testing Procedure - Body Assessment:*

After completing the necessary paperwork, subjects had their weight, height, waist and neck circumferences, and body composition assessed. Body weight was measured to the closest 0.1 kg via a physician's scale, and height was assessed to the closest 0.5 cm. Waist and neck circumferences were also measured to the nearest 0.5 cm. Following ACSM guidelines, waist and neck circumferences were measured using cloth tape with a spring loaded-handle in order to limit the pressure of the squeeze on the bare skin [28].

Body composition was evaluated via Dual-energy X-ray absorptiometry (DEXA). DEXA scan enables the researcher to assess body composition in three compartments: fat mass, lean mass, and calcified tissue mass, which provides for a more detailed and accurate overview of body composition than most other methods. Along with examining the total percent body fat, DEXA scan can also be used to quantify regional visceral adiposity percentages. As stated previously, excessive adiposity is a risk factor for developing OSA. Visceral adiposity has a significantly greater correlation to individuals with OSA versus individuals without OSA. Hence, a subject's visceral adiposity is important to determine via DEXA scan in order to evaluate if the individual does or does not have an increased risk of OSA [29].

*Testing Procedure - Heart Rate Variability Assessment*

Prior to assessing the subject's HRV, resting blood pressure (RBP) was measured according to ACSM procedures [28]. Blood pressure readings were taken at heart level, while the subject was in a comfortable supine position with his legs uncrossed. The blood pressure cuff bladder was large enough to cover 80% of the subject's upper arm circumference [28].

HRV is a relatively easy, inexpensive and non-invasive way of assessing individual autonomic function. Variation in beat to beat intervals was correctly measured using a polar RS800CX monitor via a simple heart rate monitor watch system [30]. Oscillation between heart beat intervals was detected when the subject was most relaxed in order to equally match the intervals occurring during a sleep cycle and produce the most accurate results. To enhance relaxation, a subject was guided to lay supine in a darkened room when being assessed.

HRV, along with heart rate, was obtained by the polar RS800CX monitor over a 15 minute time period. The heart rate measured by the monitor during the last minute was recorded as the subject's resting heart rate value because this was the minute in which the subject felt most relaxed during the assessment. A normal effortless adult respiration pattern consists of 12 breaths per minute, therefore an audible metronome was synchronized to sound at 12 beats per minute to try to best equalize this breathing pattern and control for any respiration effect on HRV variables.

#### *Testing Procedure: Actigraph Sleep Assessment*

After the HRV data had been recorded, each subject was given an Actigraph accelerometer (GT-3X plus). The subject was told to record the time that he went to bed and the time that he awoken. The subject wore the Actigraph accelerometer at night while he slept to measure his sleep patterns and store any movement during his sleep. The device was worn properly on the non-dominant wrist; due to the small size and light weight of the device, it did not cause any pain or discomfort to the wrist. An Actigraph accelerometer had shown to be very reliable in measuring the sleep variability of periodic sleeping periods or waking periods during an entire night's sleep cycle. Thus, the Actigraph accelerometer was used to provide practical,

obtainable information that no other sleep detective strategies could, such as individual recall [31].

*Statistical Analysis:*

Variables between groups were compared using an independent sample *t*-test, and a *p*-value less than 0.05 was considered statistically significant data. Variables that were not normally distributed were log transformed prior to statistical analysis. Normalized LF (LFnu) was calculated as  $LFnu = LF/(TP-VLF)*100$  and normalized HF (HFnu) was calculated as  $HFnu = HF/(TP-VLF)*100$ . Any significant differences found in terms of oscillation between R-R heart intervals with a dominant override of the sympathetic tone to the parasympathetic tone in snorers versus non snorers would be indicative of a correlation between snorers and heightened risk of onset OSA, considering the similar HRV patterns seen in OSA patients.

**Timeline:**

Recruitment of subjects began in September at the start of the 2013 fall semester. The recruitment continued throughout the fall semester and ended at the start of the following 2014 spring semester. If the goal of obtaining 40 sedentary male college student subjects was reached before that point, then the recruitment process would have ended earlier than proposed. In order to be pre-tested and tested, each subject reported to the Human Performance Laboratory in Godwin 209. The pre-test and test was administered on the same day and lasted no longer than one hour. The subject culminated his study participation when he returned the Actigraph accelerometer device to the Human Performance Laboratory the next consecutive day. The Actigraph accelerometer device was used for data download and analysis. The data collection was completed by January 2014, and the completion of the following statistical analysis of the

data was completed soon after. The completion research project due date was set for April 10<sup>th</sup>, 2014.

## Chapter III

### Manuscript

#### *Heart Rate Variability in Habitual College-aged Snorers*

##### **Abstract**

**Purpose** Snoring is the primary, most distinguishable symptom of Obstructive Sleep Apnea (OSA). Increased activation of the sympathetic tone is also consistently identified in adults with clinically diagnosed OSA. We compared heart rate variability (HRV) in snoring and non-snoring college-aged subjects to assess any HRV alterations between groups that could potentially signify an early marker for developing OSA.

**Methods** 23 male snorers and 7 male non-snorer subjects were studied. The HRV variables in the R-R heart intervals were compared between the groups via obtaining heart rate from the polar RS800CX monitor and performing an analysis using an independent sample *t*-test. All subjects were of similar age, body composition, and physical fitness.

**Results** HRV was not significantly reduced in snoring subjects compared to non-snoring subjects. Age was significantly correlated to pNN50 ( $r=-0.48$ ,  $p=0.01$ ), RMSSDLog ( $r=-0.45$ ,  $p=0.01$ ), HFLog ( $r=-0.49$ ,  $p=0.01$ ), Log LF/HF Ratio ( $r=0.53$ ,  $p=0.00$ ), LFnu ( $r=0.50$ ,  $p=0.01$ ), and HFnu ( $r=-0.50$ ,  $p=0.01$ ).

**Conclusion** HRV alterations of increased sympathetic tone to parasympathetic tone are not significantly associated with young snorers. Increased age is correlated to elevated imbalance in HRV, most likely due to sympathetic build up over time as a result of increased progression of the sleep disorder. The HRV measure may be a useful indicator of diagnosed OSA in middle-aged adults, but not a powerful indicator of onset OSA in younger individuals because they are at

too early of a point in potential progression of the disorder to elicit any significant physiological changes.

**Keywords:** snoring, heart rate variability, sympathetic tone, obstructive sleep apnea

## **Introduction**

Obstructive sleep apnea (OSA) is the dominant sleep disordered condition in America [32], characterized by repetitive cessations or decreases in ventilation during an individual's sleep cycle due to intermittent bouts of partial (hypopnea) or total collapse (apnea) of the pharyngeal airway [1]. Obstructive apneic and hypopnea episodes result in hypoxia and an inadequate amount of oxygen in the blood, which could lead to severe physiological damage. Diagnosis of OSA is established with five or more episodes of obstructive apnea or hypopnea per hour of sleep, along with encountering strong symptoms of excessive daytime sleepiness (EDS) [32] as a consequence of sleep deprivation caused by the obstructive disturbances [39]. A definitive diagnosis of OSA most often requires a nighttime polysomnography, or an overnight stay at a laboratory where numerous physiological variables related to sleep staging, respiration, and snoring are recorded throughout the night via an electroencephalogram, electromyogram, and an electrooculogram [32]. The physiological variables studied include breathing flow, breathing effort, oxygen saturation levels, and electrical activity of the brain, muscles, and eyes [32]. Having OSA is detrimental to one's health in such that a stress reaction is developed as a result of constant sleep restriction, and a number of comorbidities are associated with the disorder including cardiovascular diseases (coronary artery disease, congestive heart failure, stroke, atrial fibrillation) [12], metabolic syndrome, hypertension, and diabetes mellitus [2-15].

Autonomic dysfunction, specifically an overdrive of the sympathetic nervous system (SNS), is a principal consequence of OSA. Heightened sympathetic drive can be explained by

increased stimulation of peripheral and central chemoreflexes as carbon dioxide increases and oxygen saturation decreases repeatedly during the night as a result of apnea and hypopnea events [36]. Elevated SNS has been observed at rest in individuals with OSA [23-24]. Increased sympathetic activity via vasoconstriction of the muscles is also a response of the body to maintain normal blood pressure in circumstances of decreased venous blood return to the heart during obstructive sleep apneas [37-38]. Fluctuations in normal heart rate rhythm can be assessed by evaluating the variation in the time interval between heartbeats via heart rate variability (HRV) analysis. HRV analysis has been validated as a measure to evaluate autonomic function in adults and has verified that HRV is altered and most likely reduced in OSA patients, clinically meaning that there is less balance between the parasympathetic and sympathetic tone with an overstimulation of the SNS in OSA adults [26].

Snoring is a common risk factor of OSA [18-20] and occurs as a response to a reduction in airflow to the nose or mouth during sleep. The reduction in airflow in the pharyngeal airway is due to anatomical factors including relaxed oral muscle which permits the falling of tongue and throat muscles back into the airway [33], bulky throat tissue compromising space in the airway [33], and an exaggerated length of the soft palate and uvula which narrows the opening of airflow between the nose and the throat creating negative pressure in the airway [33]. Other common signs that raise the risk of OSA include older age, witnessed gasping, obesity, excess adiposity, enlarged neck size, male gender, crowded appearing pharyngeal airway, and increased blood pressure [11, 16-17].

Snoring is a serious risk factor for OSA, and a likely early sign of the development of OSA. Habitual and disruptive snoring can result in poor sleep quality as well as major disturbances in sleeping patterns, including the extreme breathing pauses and cessations

experienced in OSA patients [33]. Looking at younger snorers to see if there are any initial signs of altered autonomic function compared to younger non snorers will help establish if autonomic dysfunction is also an early risk factor for OSA.

HRV measurements are an effective screening tool in clinically diagnosed adult OSA patients [26], which led to the assumption that they may be just as effective in indicating early signs of potential OSA in young individuals. The goal of the study was to examine the differences in HRV variables between college age snorers and non-snorers to determine if autonomic function is altered and a potential early sign of the development of OSA. Establishing a strong relationship between heightened sympathetic activity and snoring would help to infer the HRV measure as an appropriate tool in assessing the risk for young persons in developing OSA.

## **Materials and Methods**

### *Subjects*

Thirty college-aged males from the James Madison University and Harrisonburg community participated in the study. The sample consisted of 23 snorers and 7 non-snorers. Subjects were not engaging in regular exercise in order to control for potential effects of attenuated sympathetic drive on resting heart rate that could result from exercise [27]. To account for similarities in excess body weight that could influence one's risk for developing OSA, subjects were required to be overweight, defined by the ACSM guidelines as having a body mass index (BMI) greater than 25 kg/m<sup>2</sup> [28]. Further inclusionary criteria for participation in the study included that subjects were not currently smoking, taking medication, or had any significant heart or lung disease.

### *Pre-test*

Subjects needed to read and sign an informed consent form regarding the study's intentions, risks and benefits of participating, the consequences of withdrawing, and the assurance of confidentiality to the subject involved. After consent was granted, the Health History Questionnaire (HHQ) was to be completed followed by the Berlin Questionnaire (BQ) and a questionnaire related to snoring, tiredness, observed apnea, and blood pressure (STOP). The HHQ assessed the subject's health and medical conditions, while the latter two evaluated the subject's extent of snoring and other OSA related risk factors. The third and fourth questionnaires to be completed were the Epworth Sleepiness Scale (ESS) and the International Physical Activity Questionnaire (IPAQ). The former assessment evaluated the subject's level of EDS and the latter was used to obtain comparable estimates of the subjects' physical activity levels that were statistically accounted for.

### *Evaluation of Body Composition*

After completing the necessary paperwork, subjects had their weight, height, waist and neck circumferences, resting blood pressure, and body composition (via the Dual-energy X-ray absorptiometry (DEXA)) assessed. All testing procedures strictly followed the ACSM guidelines [28].

### *Evaluation of Heart Rate Variability*

Heart rate variability measures consisted of time-domain parameters as well as frequency-domain parameters. A time-domain HRV parameter measure corresponding to parasympathetic function included RMSSD, which is the square root of the mean of the squares of differences between continuous RR intervals [42]. Time-domain HRV parameter measures corresponding to both sympathetic and parasympathetic function included SDNN, which is the

standard deviation of all normal RR intervals, and pNN50, or the percentage of differences between successive RR intervals greater than 50 milliseconds [42]. A frequency-domain HRV parameter measure that reflected both parasympathetic and sympathetic activity was total power (TP), or the energy in the heart period power spectrum of all RR intervals from 0 to 0.40 Hz [42]. Further frequency domain HRV parameter measures included very low frequency (VLF), low frequency (LF), and high frequency (HF) powers, which are the energy in the heart period power spectrum between 0.003 and 0.04 Hz, 0.04 and 0.15 Hz, and 0.15 and 0.40Hz, respectively [42]. The LF/HF ratio, or the ratio of low to high frequency power, was also a frequency-domain HRV parameter measure. HF corresponds to parasympathetic activity and VLF, LF, and the LF/HR ratio correspond to sympathetic activity [42].

Heart rate variation in beat to beat intervals was measured using a polar RS800CX monitor via a simple heart rate monitor watch system [30] over a 15 minute time period while the subject was lying supine in a dark room. Data used for analysis pertaining to oscillation between heart beat intervals was taken from the last five minutes of the assessment when the subject was most relaxed. An audible metronome was used to synchronize to sound at 12 beats per minute to equalize the normal adult breathing pattern and control for any respiration effect on HRV variables.

### *Statistical Analysis*

Heart rate variables between snoring and non-snoring groups were compared using an independent sample *t*-test, and a p-value less than 0.05 was considered statistically significant data. Variables that were not normally distributed were log transformed prior to statistical analysis. Normalized LF (LFnu) was calculated as  $LFnu = LF/(TP-VLF)*100$  and normalized HF (HFnu) was calculated as  $HFnu = HF/(TP-VLF)*100$ .

## Results

Baseline characteristics did not differ in age, body composition variables, and physical fitness between subjects (Table 1). There were 6 subjects who reported they snore only 1 day per week, 11 subjects who reported that they snore 2 to 4 days per week, and 6 subjects who reported that they snore 5 days or greater per week (Table 2).

The HRV analysis revealed no significant differences in HRV variables between snoring group and non-snoring group (Table 3). Although there were no significant differences between the non-snoring subjects and the snoring subjects, age was significantly correlated ( $p < 0.05$ ) with particular HRV variables (Table 4). The HRV variables include pNN50 ( $r=-0.48$ ,  $p=0.01$ ), RMSSDLog ( $r=-0.45$ ,  $p=0.01$ ), HFLog ( $r=-0.49$ ,  $p=0.01$ ), Log LF/HF Ratio ( $r=0.53$ ,  $p=0.00$ ), LFn<sub>u</sub> ( $r=0.50$ ,  $p=0.01$ ), and HFnu ( $r=-0.50$ ,  $p=0.01$ ).

## Discussion

Results from the current study show that no significant differences were found in patterns of HRV between snoring and non-snoring subjects. This indicates that in our group of well-matched subjects for age, body composition variables, and physical fitness levels, snoring did not appear to have an impact on HRV. Moreover, no further significant differences were identified when running the analysis excluding the 1 day per week snorers.

Although our findings do not reveal clear evidence of impact of snoring on HRV, snoring has previously shown to impact HRV in non-apneic middle-aged adults by simultaneously enhancing brain stem activity via inputs from mechanoreceptors [35], metabolic receptors [25, 21], and upper airway receptors [22,31]. These receptors stimulate the peripheral and central chemoreflexes to elevate SNS activity when the body experiences decreases in oxygen saturation

[36, 46]. Reductions in oxygen saturation can be due to the partial or complete pharyngeal airway blockages associated with snoring [36, 46].

Potential reasons that our results did not validate HRV alternation in snoring individuals compared to non-snoring individuals could be due to the tendency of snoring to worsen with age as well as the higher prevalence of snoring in a middle-aged population compared to a younger college-aged population [34]. Thus, college-aged snorers assessed in our current study may not have yet progressed to the level of snoring, in terms of intensity and duration, as their middle-aged counterparts. The greater amount of apneas and hypopnea episodes accumulated over time from young adulthood to middle-aged adult years, the more dominant the sympathetic tone becomes, leading eventually to a diminished HRV [40]. Young subjects from our current study may not have yet built up the necessary amount of enhanced brain stem activity and corresponding sympathetic activity resulting from long term snoring to elicit any substantial changes or reductions in HRV.

Moreover, previous literature found that HRV, with or without snoring symptoms, is reduced in middle-age adults [43]. This means that effects of HRV are age dependent, and as an individual develops from young adulthood to middle-aged years, the balances between the sympathetic tone and the parasympathetic tone become increasingly weakened. This theory offers further support to why HRV changes were not significantly evident in our younger sample population of our current study; simply because these chosen subjects were potentially too young in age to provoke any physiological deviations in heart rate that typically come in response to getting older.

Furthermore, when performing a Pearson correlation matrix in our current study, results revealed that age was significantly associated with HRV variables pNN50, RMSSDLog, HFLog,

Log of LF/HF Ratio, LFnu, and HFnu. This demonstrates more distinct HRV imbalances in our subjects as age increased, as clear correlations were found between increasing age and decreasing variation in the R-R heart intervals as well as increasing age and increasing activation of the SNS. Hence, college-aged subjects that had the primary risk factor of snoring who were sampled in our procedure may have been too young and likely way too early in their progression of possible OSA development to display any substantial physiological adaptations from the disorder. Based on our results, it appears possible that with increased age, the more susceptible one is to see heart rate relate to snoring in terms of noticeable signs of decreased HRV and elevated SNS.

Previous literature supports this analysis by finding that the non-balance in HRV found in individuals with OSA becomes more extreme over time [40]. One study compared the R-R heart interval patterns of moderate sleep apneic individuals to the R-R interval patterns of those who had developed further, more severe sleep apnea over time [40]. The sympathetic tone becomes more exaggerated and sleep apnea becomes more severe over time as a result of the continuous apneas and hypoxias that occur during sleep in individuals with OSA [40]. The results of this study showed that the LF/HF ratio was higher in the severe sleep apnea group compared to the moderate sleep apnea group, and a heightened LF/HF ratio corresponds to larger sympathetic activity [40]. This explains that with greater progression and worsening of the disorder, the greater was the dominance of the SNS [40]. Therefore, it is possible that even though the college-aged subjects assessed in our current study had a number of risk factors for OSA, this population may not yet be far enough advanced in the development of the potential disorder to display any signs of overriding sympathetic activity and corresponding HRV reduction.

Furthermore, another study found similar findings in that the more severe and far along the sleep disorder had become, the more increased the sympathetic burst frequency and the more decreased the balance in the R-R heart intervals [41]. This study assessed HRV of muscle sympathetic nerve activity and the R-R heart intervals in 15 patients with moderate-to-severe OSA, 18 patients with mild OSA, and 16 healthy control subjects [41]. When comparing the moderate-to-severe OSA group to the mild OSA group, the former had a higher LF-to-HF ratio, signifying a greater dominance of the SNS compared to the PNS [41]. The moderate-to-severe OSA group also showed to have a lower normalized HF variability, meaning a lower overall tone of the PNS when compared to the mild OSA group [41]. Patients with mild sleep apnea still had evident abnormalities in their HRV, but these abnormalities were much less pronounced than those of the moderate-to-severe OSA group [41]. This study offers support to our current study in providing evidence that if OSA has not yet developed to a mild, moderate, or a severe level (which it has not in our young population sample), then HRV alterations will not be very prominent or may not be noticed at all, which was the case for our study.

The limitations to our study included a small sample of control non-snorers to compare to the snorer group. With a larger sample, there would have been a greater chance in finding any statistical significant differences in the heart rate analysis data. Another limitation included that the amount a subject snores was self-reported by college age students. It is less likely that this age group has someone, for example a spouse, whom would be able to give them an accurate accounting of their snoring frequency.

To summarize, our hypothesis of the study, which stated that heightened sympathetic activity in HRV measurements would be seen in subjects who were snorers compared to those that did not snore, was not supported. Hence, although HRV has shown to be a key tool in

measuring and identifying autonomic dysfunction in adults with already clinically diagnosed OSA [26], the analysis may not be as powerful of an indicator in identifying not yet diagnosed OSA in college aged individuals. Solely using HRV as an early marker for the disorder may be a disadvantage in that physiological adaptations of increased SNS activity that evolves as a consequence of OSA over time may have not yet developed in younger persons who snore. In conclusion, although the college-aged snorers sampled had several risk factors for OSA including snoring, being overweight to obese, and having at risk neck circumference measures, this population may be at too early of a point in their possible development of OSA for snoring to elicit any valuable physiological changes in terms of HRV reduction.

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**Table 1-** Subject Characteristics

<b>Characteristic</b>	<b>Snorers (n=23)</b>	<b>Non Snorers (n=7)</b>
Age (yr)	20.3 ± 1.8	19.7 ± 2.0
BMI (kg/m <sup>2</sup> )	29.1 ± 2.6	28.8 ± 3.6
Waist (cm)	94.9 ± 10.3	89.8 ± 6.4
Neck (cm)	40.2 ± 2.0	39.6 ± 2.4
Total body fat (%)	23.4 ± 8.3	19.1 ± 5.9
MET·min·wk <sup>-1</sup>	2877.9 ± 2883.5	3460.4 ± 2279.4

BMI = body mass index; MET = metabolic equivalent

**Table 2-** Subjects' Self Reports of Snoring Frequency

<b>Snoring Frequency (days/week)</b>	<b># of subjects that reported relevant frequency (n=30)</b>
0	7
1	6
2-4	11
$\geq 5$	6

**Table 3-** Heart Rate Variability Analysis Data

<b>HRV Variable</b>	<b>Snorers (n=23)</b>	<b>Non Snorers (n=7)</b>
<b>SDNN (ms)</b>	81.4 ± 38.6	81.7 ± 27.1
<b>pNN50 (%)</b>	13.2 ± 9.7	18.7 ± 12.1
<b>RMSSDLog</b>	1.7 ± 0.3	1.8 ± 0.3
<b>TPLog</b>	3.8 ± 0.4	3.8 ± 0.4
<b>VLFLog</b>	3.4 ± 0.5	3.5 ± 0.5
<b>LFLog</b>	3.2 ± 0.4	3.2 ± 0.3
<b>HFLog</b>	3.0 ± 0.5	3.1 ± 0.5
<b>Log LF/HF Ratio</b>	2.2 ± 0.3	2.1 ± 0.5
<b>LFnu</b>	60.0 ± 16.6	54.1 ± 23.7
<b>HFnu</b>	40.0 ± 16.6	45.7 ± 23.7

HRV = heart rate variability; SDNN = standard deviation of all normal R-R heart intervals; pNN50 = the percentage of differences between successive R-R heart intervals greater than 50 ms; RMSSDLog = log transformed square root of the mean of the squares of differences between continuous R-R heart intervals; TPLog = log transformed total power; VLFLog = log transformed very low frequency; LFLog = log transformed low frequency, HFLog = log transformed high frequency; Log LF/HF Ratio = log transformed low frequency to high frequency ratio; LFnu = low frequency normalized units; HFnu = high frequency normalized units

**Table 4-** Pearson Correlation Matrix of Age and HRV Variables among all Subjects

<b>HRV Variable</b>	<b>Pearson Correlation (r) w/ Subject Age (n=30)</b>	<b>P-value (2-tailed)</b>
<b>SDNN (ms)</b>	-0.34	0.06
<b>pNN50 (%)</b>	-0.48*	0.01*
<b>RMSSDLog</b>	-0.45*	0.01*
<b>TPLog</b>	-0.35	0.01
<b>VLFLog</b>	-0.28	0.13
<b>LFLog</b>	-0.17	0.37
<b>HFLog</b>	-0.49*	0.01*
<b>Log LF/HF Ratio</b>	0.53*	0.00*
<b>LFnu</b>	0.50*	0.01*
<b>HFnu</b>	-0.50*	0.01*

\*Correlation is significant ( $p < 0.05$ )

HRV = heart rate variability; SDNN = standard deviation of all normal R-R heart intervals; pNN50 = the percentage of differences between successive R-R heart intervals greater than 50 ms; RMSSDLog = log transformed square root of the mean of the squares of differences between continuous R-R heart intervals; TPLog = log transformed total power; VLFLog = log transformed very low frequency; LFLog = log transformed low frequency, HFLog = log transformed high frequency; Log LF/HF Ratio = log transformed low frequency to high frequency ratio; LFnu = low frequency normalized units; HFnu = high frequency normalized units

## **Appendix A: Email Recruitment Statement**

Sleep Research at James Madison University

Researchers at James Madison University are recruiting young males to be subjects in a study on how sleep affects health. Good candidates are:

- 18 – 26 years old
- NOT regular exercisers (do not exercise 3 or more times per week)
- Not currently smoking
- Are without significant heart or lung disease
- Not currently taking medications
- Have a body mass index greater than 25 [BMI = weight in kg / (height in meters)<sup>2</sup>].

If you have been told that you snore, you may be a particularly good candidate. The study would require subjects to complete several questionnaires about your health and sleep habits, wear a small device for one night while sleeping, and a complete body composition assessment. Subjects will receive a report on their health status including percent body fat and sleep quality. If interested please contact us at 908-328-4244 or at [sleepstudy.jmu@gmail.com](mailto:sleepstudy.jmu@gmail.com).

## Appendix B: Flyer Recruitment Statement

James Madison University Kinesiology Department

Subjects needed for a study on the impact of sleep on health



### Eligibility

- 18 – 26 years old men
- NOT regular exercisers (defined as 3 or more times per week)
- Not currently smoking
- Are without significant heart or lung disease
- Not currently taking medications
- Have a body mass index greater than 25 [BMI = weight in kg / (height in meters)<sup>2</sup>].
- SNORERS also wanted!

### Study Requirements

- Complete questionnaires on health and sleep habits
- Wear small device on your wrist for one night while you sleep
- Body composition measurement
- Ultrasound imaging of blood vessels in your neck and arm

### Subjects Receive

- Report on body composition (% fat)
- Report on sleep quality

### To Enroll in the Study

- Call (908) 328-4244
- Email [sleepstudy.jmu@gmail.com](mailto:sleepstudy.jmu@gmail.com)

## **Appendix C: Informed Consent**

James Madison University

Department of Kinesiology

Informed Consent

### **Purpose**

You are being asked to volunteer for a research project conducted by Dr. Trent Hargens and exercise kinesiology student Erica Searfoss from James Madison University studying the association of snoring with autonomic dysfunction in at-risk for sleep apnea young men.

The primary goals of this study is to examine whether the physiological alterations that are a result of habitual snoring in diagnosed obstructive sleep apnea (OSA) adults are evident in snoring at-risk not yet diagnosed younger individuals. The physiological alterations include reduced heart rate variability and increased sympathetic dominance.

### **Experimental Procedures**

You will be asked to visit the Human Performance Laboratory (Godwin 209) 2 times, 1 – 2 days apart. Your total time commitment for participation in this study will be approximately 1 hour. In addition, you will be asked to wear a device on your wrist for 1 night, while you sleep. This will be done in your own home. Detailed information on each visit is provided below:

#### Visit 1

Before any test is given, you will be asked to complete a prescreening and an informed consent form, to insure that you meet the study criteria and that you do not have any factors that would disqualify you from participation. Upon completion of the informed consent, you will be asked to complete a short health history questionnaire providing information about your characteristics and health. You will then be asked complete 4 standardized questionnaires about snoring and the quality of your sleep, daytime sleepiness, risk for OSA, and current physical activity levels.

You will then have your height, weight, waist circumference and neck circumference measured. After that, your body composition will be analyzed via a Dual-energy x-ray absorptiometer (DEXA). The DEXA scan will allow us to measure your percent body fat and the mineral content and density of your bones. The DEXA is much like an X-ray machine. The DEXA will scan your entire body very slowly; so, you will need to lie on a table without moving for almost 10 minutes, while the DEXA is passed over your entire body. You will feel no discomfort associated with this test.

Following the DEXA scan, we will ask that you wear a heart rate monitor while lying down in a darkened room for 15 minutes to get measures of your heart rate.

At the end of this first visit you will also be instructed on the proper use procedures for wearing an accelerometer to monitor your sleep for 1 night. An accelerometer is a small device that is to be worn on your wrist while in bed. You will also be asked to record the time you go to bed and the time you get up the following morning.

### Visit 2

One to two days after Visit 1, you will be asked to return to Godwin 209 to return the accelerometer.

### **Risks**

There are no risks associated with wearing an accelerometer. Also, there is no risk associated with heart rate, height, weight, and waist and neck circumference measures. A measurement with associated risks includes the DEXA scan.

The amount of radiation that you will receive in the DEXA exam is less than the amount permitted by the Food and Drug Administration (FDA) per year. The amount you will receive is equal to 1/20 of a chest x-ray or no greater than you normally receive each day from your surroundings over the course of a week.

### **Benefits**

There is no guarantee that you will get any benefit from taking part in this study. Benefits may include knowledge about your health status. You will receive information on your body composition, including percent body fat and bone mineral density, and an assessment of your sleep quality and risk for sleep apnea.

### **Inquiries**

If you have any questions or concerns or you would like to receive a copy of the final aggregate results of this study, please contact Dr. Trent Hargens at [hargenta@jmu.edu](mailto:hargenta@jmu.edu) or (540) 568-5844. In the case of any immediate concerns or adverse reactions during the study, contact Dr. Hargens on his cell phone (540) 810-1310.

### **Questions about Your Rights as a Research Subject**

Dr. David Cockley

Chair, Institutional Review Board

James Madison University

(540) 568-2834

[cocklede@jmu.edu](mailto:cocklede@jmu.edu)

**Confidentiality**

All data and results will be kept confidential. You will be assigned an identification code. At no time will your name be identified with your individual data. The researcher retains the right to use and publish non-identifiable data. All data will be kept secured in a locked cabinet. Final aggregate results will be made available to participants upon request.

**Freedom of Consent**

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind.

I have read this consent form and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

\_\_\_\_\_  
Name of Subject (Printed)

\_\_\_\_\_  
Name of Researcher (Printed)

\_\_\_\_\_  
Name of Subject (Signed)

\_\_\_\_\_  
Name of Researcher (Signed)

\_\_\_\_\_  
Date

\_\_\_\_\_  
Date

## **Appendix D: Subject Prescreening Information**

**Please complete the Following:**

Age (yrs):

Height (inches):

Weight (lbs):

### **Average Exercise Habits over the Past 2 Months:**

Avg. # days of exercise per week:

Avg. # of days of aerobic exercise per week:

Avg. # of days of resistance exercise per week:

**Do you currently use medications of any kind?**

**Have you previously been diagnosed with a heart or lung disease?**

**Do you have diabetes?**

## **Snoring**

Do you snore?

If yes, do you snore: (circle one)

1 Day per week

2-4 Days per week

5 or greater Days per week

**Appendix E: Health History Questionnaire**

HEALTH HISTORY QUESTIONNAIRE

TODAY'S DATE \_\_\_\_\_

NAME \_\_\_\_\_ AGE \_\_\_\_\_ DATE OF BIRTH \_\_\_\_\_

ADDRESS

\_\_\_\_\_

Street City State Zip

TELEPHONE: HOME/ CELL \_\_\_\_\_/ \_\_\_\_\_ E-MAIL ADDRESS \_\_\_\_\_

Person to contact in case of an emergency \_\_\_\_\_ Phone \_\_\_\_\_ (relationship) \_\_\_\_\_

Have you ever been diagnosed with cardiovascular disease? YES NO

Have you ever been diagnosed with musculoskeletal disease? YES NO

Have you ever had any heart problems? YES NO

Have you ever had Asthma? YES NO

Have you ever been told by a doctor you should not exercise? YES NO

Are you taking any Prescription (include birth control pills) or Non-Prescription medications?

Yes No

For each of your current medications, provide the following information:

MEDICATION Dosage- times/ day Time taken Years on medication Reason for Taking

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

ACTIVITY LEVEL EVALUATION

What is your occupational activity level?   Sedentary   Light   Moderate   Heavy

Do you currently engage in vigorous physical activity on a regular basis?   Yes   No

If so, what type(s)? \_\_\_\_\_ How many days per week? \_\_\_\_\_

How much time per day?   <15 min   15-30 min   30-45 min   >60 min

Do you engage in any recreational or leisure-time physical activities on a regular basis?

Yes   No

If so, what activities?

\_\_\_\_\_

On average: How often? \_\_\_\_\_ times/week;   for how long? \_\_\_\_\_ time/session

Do you ever have an uncomfortable shortness of breath during exercise or when doing activities?

Yes   No

Do you ever have chest discomfort during exercise?   Yes   No

## Appendix F: Epworth Sleepiness Scale

Subject ID \_\_\_\_\_ Name \_\_\_\_\_ Date Completed \_\_\_\_/\_\_\_\_/\_\_\_\_

This questionnaire asks you to indicate the chances of you becoming drowsy during hours of the day that you are not in bed sleeping. “How likely are you to doze off or fall asleep in the following situations?”

Use the following scale and indicate the most appropriate number for each situation.

0 = would never doze

1 = slight chance of dozing

2 = moderate chance of dozing

3 = high chance of dozing

<u>Situation</u>	<u>Chance of Dozing</u>
1. Sitting and reading	_____
2. Watching T.V.	_____
3. Sitting, inactive in a public place (ex. Theatre or meeting)	_____
4. As a passenger in a car for an hour without a break	_____

- 5. Lying down to rest in the afternoon  
when circumstances permit \_\_\_\_\_
  
- 6. Sitting and talking with someone \_\_\_\_\_
  
- 7. Sitting quietly after a lunch without alcohol \_\_\_\_\_
  
- 8. In a car, while stopped for a few minutes  
in the traffic \_\_\_\_\_

**Sum of Scores, items 1-8 (staff use only) \_\_\_\_\_/24**

## Appendix G: Berlin Questionnaire

### Berlin Questionnaire

Subject ID \_\_\_\_\_ Name \_\_\_\_\_ Date Completed \_\_\_\_/\_\_\_\_/\_\_\_\_

Height (cm) \_\_\_\_\_ Weight (kg) \_\_\_\_\_ Age \_\_\_\_\_

Please choose the correct response to each question:

#### **Category 1**

**1. Do You Snore?**

- a. Yes
- b. No
- c. Don't know

*If you snore:*

**2. Your snoring is:**

- a. Slightly louder than breathing
- b. As loud as talking
- c. Louder than talking
- d. Very loud – can be heard in  
adjacent rooms

**3. How often do you snore?**

- a. Nearly every day
- b. 3-4 times a week
- c. 1-2 times a week
- d. 1-2 times a month
- e. Never or nearly never

**4. Has your snoring every bothered other people?**

- a. Yes
- b. No
- c. Don't Know

**5. Has anyone noticed that you quit Breathing during your sleep?**

- a. Nearly every day
- b. 3-4 times a week
- c. 1-2 times a week
- d. 1-2 times a month
- e. Never or nearly never

**Category 2**

**6. How often do you feel tired or fatigued after you sleep?**

- a. Nearly every day
- b. 3-4 times a week
- c. 1-2 times a week
- d. 1-2 times a month
- e. Never or nearly never

**7. During your waking time, do you feel tired, fatigued or not up to par?**

- a. Nearly every day
- b. 3-4 times a week
- c. 1-2 times a week
- d. 1-2 times a month
- e. Never or nearly never

**8. Have you ever nodded off or fallen asleep while driving a vehicle?**

- a. Yes
- b. No

*If yes:*

**9. How often does this occur?**

- a. Nearly every day
- b. 3-4 times a week
- c. 1-2 times a week
- d. 1-2 times a month
- e. Never or nearly never

### **Category 3**

**10. Do you have high blood pressure?**

- a. Yes
- b. No
- c. Don't Know

## Appendix H: STOP Questionnaire

### Stop Questionnaire

Subject ID \_\_\_\_\_ Name \_\_\_\_\_ Date Completed \_\_\_\_/\_\_\_\_/\_\_\_\_

Height (Inches) \_\_\_\_\_ Weight (lbs) \_\_\_\_\_ Age \_\_\_\_\_

Neck Circumference (cm) \_\_\_\_\_

The **STOP** Test consists of four questions:

**1. Snoring**

Do you *snore* loudly (louder than talking or loud enough to be heard through closed door)?

**Yes No**

**2. Tired**

Do you often feel *tired*, fatigued or sleepy during the day?

**Yes No**

**3. Observed**

Has anyone *observed* you stop breathing during your sleep?

**Yes No**

**4. Blood Pressure**

Do you have or are you being treated for high blood *pressure*?

**Yes No**

High risk of OSA: answering yes to *two or more* questions

Low risk of OSA: answering yes to *less than two* questions

## Appendix I: International Physical Activity Questionnaire

# INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (August 2002)

## SHORT LAST 7 DAYS SELF-ADMINISTERED FORMAT

### FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health-related physical activity.

#### ***Background on IPAQ***

The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

#### ***Using IPAQ***

Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

#### ***Translation from English and Cultural Adaptation***

Translation from English is supported to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at [www.ipaq.ki.se](http://www.ipaq.ki.se). If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

#### ***Further Developments of IPAQ***

International collaboration on IPAQ is on-going and an *International Physical Activity Prevalence Study* is in progress. For further information see the IPAQ website.

#### ***More Information***

More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at [www.ipaq.ki.se](http://www.ipaq.ki.se) and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective*. *Research Quarterly for Exercise and Sport*, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

## INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

\_\_\_\_\_ **days per week**

No vigorous physical activities → **Skip to question 3**

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

\_\_\_\_\_ **days per week**

No moderate physical activities → **Skip to question 5**

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

\_\_\_\_\_ **days per week**

No walking → *Skip to question 7*

6. How much time did you usually spend **walking** on one of those days?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

**This is the end of the questionnaire, thank you for participating.**

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