PREDICTION OF PHYSIOLOGIC MEASURES OF SLEEP DISORDERED BREATHING USING CEPHALOMETRIC AND ANTHROPOMETRIC MEASUREMENTS

by

SEUNG-JIN BAEK

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Thesis Advisors:

Mark G. Hans, D.D.S., M.S.D.

Suchitra Nelson, Ph.D.

Kingman P. Strohl, M.D.

Department of Orthodontics

School of Dentistry

CASE WESTERN RESERVE UNIVERSITY

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GRADUATE STUDIES

We hereby approve the thesis of

Seung-Jin Baek

candidate for the degree Master of Science

in Dentistry.

Signed: _____ (Chairman)

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Date: 6-10th, 1996

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Abstract

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Craniofacial structures and some anthropometric risk factors have been reported to be associated with obstructive sleep apnea syndrome (OSAS). This study examined the correlation between three anthropometric and fourteen cephalometric variables and eight physiologic measures of sleep disordered breathing (lowest O_2 saturation, average O_2 saturation, O_2 difference 1 (O_2 difference between baseline and lowest O_2 saturation), O_2 difference 2 (O_2 difference between baseline and average O_2 saturation), longest apnea duration, average apnea duration, longest hypopnea duration and average hypopnea duration). One hundred and eighty six habitual snorers were recruited over a period of six years and all subjects underwent cephalometric and polysomnographic study. The mean age of the subjects was 46.04 ±10.44 years with 69% male, 17% African-American, and 58% nonapneic snorers (RDI≤20). Forced-all regression analysis demonstrated that the seventeen independent variables explained 46% of the variation in lowest O_2 saturation and 41% of the variation in oxygen saturation difference between baseline and lowest O_2 saturation. In contrast, this same set of variables explained only 17.6% and 8.6% of the variation in longest hypopnea duration

and average hypopnea duration respectively. Step-wise analysis indicated that body mass index (BMI) and hyoid to mandibular plane distance were the best predictors for O_2 desaturation whereas age and the length of the tongue or soft palate were the most important predictors for apnea/hypopnea duration. The results suggest that different physiologic variables likely measure different aspects of disease and that craniofacial anatomic factors probably account for some of the variability in the expression of OSAS.

TABLE OF CONTENTS

Page

ABSTRACT ii

TABLE OF CONTENTS iv

LIST OF FIGURES v

LIST OF TABLES vi

GLOSSARY viii

INTRODUCTION 1

REVIEW OF THE LITERATURE 6

STATEMENT OF THESIS 54

METHODS AND MATERIALS 55

RESULTS 64

DISCUSSION 77

SUMMARY AND CONCLUSIONS 86

APPENDICES

A. Correlation Matrix and Regression Analyses 88

B. Human Investigation Consent Form 135

C. Approval of the University Review Commitee on Human Studies 137

REFERENCES 139

LIST OF FIGURES

Figure Page

1. Schematic diagram of the apneic cycle 5

2. Conventional linear and angular measurements 60

3. The counterpart analysis (1) 61

4. The counterpart analysis (2) 62

5. Cephalometric measurements of the tongue area relative to the intermaxillary area 63

LIST OF TABLES

Table Page

1. The Demographic Profile of the Study Population 64

2. The Anthropometric and Cephalometric Characteristics of the Sample 65

3. The Physiologic Measurements of Sleep Study in the Entire Sample 65

4. The Differences of Physiologic Measurements between Apneic and Nonapneic Groups 66

5. Correlation of Craniofacial and Physiologic Variables with RDI 67

6. Forced-All Regression Model for Dependent Variable O_2 Difference 1 68

7. Step-Wise Regression Model for Dependent Variable O_2 Difference 1 68

8. Forced-All Regression Model for Dependent Variable O_2 Difference 2 69

9. Step-Wise Regression Model for Dependent Variable O_2 Difference 2 69

10. Forced-All Regression Model for Dependent Variable Lowest O_2 Saturation 70

11. Step-Wise Regression Model for Dependent Variable Lowest O_2 Saturation 70

12. Forced-All Regression Model for Dependent Variable Average O_2 Saturation 71

13. Step-Wise Regression Model for Dependent Variable Average O_2 Saturation 71

LIST OF TABLES
(continued)

Table

Page

14. Forced-All Regression Model for Dependent Variable Longest Apnea Duration 72

15. Step-Wise Regression Model for Dependent Variable Longest Apnea Duration 72

16. Forced-All Regression Model for Dependent Variable Average Apnea Duration 73

17. Step-Wise Regression Model for Dependent Variable Average Apnea Duration 73

18. Forced-All Regression Model for Dependent Variable Longest Hypopnea Duration 74

19. Step-Wise Regression Model for Dependent Variable Longest Hypopnea Duration 74

20. Forced-All Regression Model for Dependent Variable Average Hypopnea Duration 75

21. Step-Wise Regression Model for Dependent Variable Average Hypopnea Duration 75

22. Summary and Comparison of Regression Models 76

GLOSSARY

Definitions of Anatomic Landmarks

Point/Line	Definition
A	Subspinale: Point in the median sagittal plane where the lower front edge of the anterior nasal spine meets the front wall of the maxillary alveolar process (Downs Point A).
ANS	Anterior nasal spine: Sharp Median Process formed by the forward prolongnation of the two maxillae at the lower margin of the anterior aperture of the nose.
Ar	Articulare (Bjork): Intersection of the lateral radiographic image of the posterior border of the ramus with the base of the occipital bone.
ARa	Anterior Ramus Plane: a line from the intersection of the functional occlusion plane (FOP) and the anterior borde of the ramus drawn parallel to PRa up to the refrence line.
B	Supramental: Deepest midline point on the mandible between infrandentale and pogonion (Downs point B).
Ba	Basion point: The most postero-inferior point on the clivus.
C2	The most posterior-inferior point on the corpus of the second cervical vertebrae.
C2tg	The tangent point of which a line from C2 passes through the odontoid process.
C4	The most posterior-inferior point on the corpus of the fourth cervical vertebrae.

Eb	Base of Epiglottis: The most deepest point of the epiglottis.
Et	Tip of the Epiglottis: The most superior point of the epiglottis.
FOP	Functional Occlusion plane: A line from the most posterior occlusal contact point to the last fully erupted maxillary and mandibular molars to the most anterior maxillary-mandibular first premolar occlusal contact.
Go	Gonion: External angle of mandible, located on the lateral radiograph by bisecting the angle formed by tangents to posterior border of ramus and the mandibular plane.
H	Hyoidale: The most superior-anterior point on the body of hyoid bone.
H'	Hyoidale Projection: The projection from H to mandibular plane.
MCF	Middle Cranial Fossa: Represented by a line from Bjork's articulare (AR) to SE.
Me	Menton: The most inferior point on the symphysis of the mandible in the median plane. Seen in the lateral radiograph as the most inferior point on the symphysial outline when the head is oriented in Frankfort relation.
N	Nasion: Craniometric point where the mid sagittal plane intersects the most interior point of the naso-frontal structure.
O	Obitale: The lowest point on the inferior margin of the orbit.
P	Tip of the soft palate.
Phw	Posterior Pharyngeal wall at the level of posterior superior airway space.
PNS	Posterior nasal spine: Process formed by the united projecting medial ends of the posterior borders of the two palatine bones.

PM	Vertical PM: A line from SE through the averaged inferior-most points of the left and right pterygomaxillary fissure.
Po	Anatomic Porion: Point on the upper margin of the porus acusticus externus.
Psp	The most superior-posterior point of the soft palate.
PRa	Posterior Ramus: A line from Ar to the intersection of the posterior border of the ramus with FOP.
REF	Refrence line: A line parallel to FOP from Ar anteriorly.
Rgn	Retrognathion: The most inferior-posterior point of the symphysis.
S	Sella Turcica: The center of the hypophyseal fossa, lodging the pituitary body.
SE	Sphenoethmoidal junction: The point at which the floor of the anterior cranial fossa intersects the averaged image left and right of the great wings of the sphenoid bone.
Tb	The dorsum of the tongue on a line joining the gonian (Go) and the supramentale (B).
Tt	Tongue tip: The most anterior point of the tongue which touches the lingual surface of the mandibular incisor.

Lateral Cephalometric Measurements

Variables	Interpretation
Cranial Base	
<BaSn	Cranial Base Angulation in mid sagittal plane.
MCF	Middle cranial fossa and posterior maxillary relative alignment (MCF/PM). A neutral MCF/PM is an internal angle of 40.3 degree. When a subject's PM is forward the neutral PM, a clockwise (+) results. This forward (+) alignment of the MCF results in mandibular retrusive effect (fig 2). When a subject's PM is behind the neutral PM, a counter-clockwise (-) results. The backward (-) alignment of the MCF results in a mandibular protrusive effect. If the neutral MCF plane coincides with the individual's own MCF, a neutral effect (0) is present.
Maxilla	
<SNA	Anteroposterior position of the maxilla relative to the anterior cranial base.
<ArN-PM	Posterior wall of the maxilla relative to the constructed cranial base (Ar-N).
A-PNS	Effective antero-posterior dimension of the maxilla when project to a line which is perpendicular to PM and passes point SE.
PNS-Ba	Horizontal position of PNS to Basion.
Mandible	
<SNB	Anteroposterior position of the mandible relative to the anterior cranial base.

Ram/MCF	Ramus width relative to middle cranial fossa horizontal dimension. The measurement of ramus width is made at the level of REF by comparing to the horizontal dimension of the MCF along this line. The distance from Ar to ARa and Ar to subject's PM are measured along the refrence line. A (+) effect occurs when the ramus width is less than Ar to subject's PM, and (-) effect when greater (fig 3). When the measurements are the same, a neutral (0) effect results.
ArA-ArB	Relative comparison of cumulative maxillary length from Ar to A point with cumulative mandibular point from Ar to B point. The measurements are made along the Refrence line.
Head Position	
FH-Hor	Head position interpreted by an angle formed by the Frankfort Horizontal plane and the True Horizontal (recorded from a fluid level device).
Soft Tissues	
Soft palate and Oropharynx	
P-PNS	Soft Palate Length.
Phw-Psp	Superior Posterior Airway Space (Distance measured along a line parallel to B-Go).
Tongue	
Tl	Tongue length: Length of the tongue measured from Tt-Eb.
T area	Area of the tongue (Outline from Tt along retrognathion surface to menton, Eb and dorsum of the tongue).
Hyoid Bone	
H-H'	Vertical position of the Hyoid relative to the mandibular plane.
H-Ver	Vertical position of the Hyoid relative to a line which is perpendicular to PM and passes point SE.

Neck

<C2C4-SN	A craniocervical angle formed by a line from C2 to C4 and S-N plane.
<C2-SN	A craniocervical angle formed by a line from C2 to C2tg and S-N plane.

Intermaxillary Dimension

AntrMxHt.	Anterior intermaxillary space height: The length of a perpendicular from the maxillary plane to menton.
PostMxHt.	Posterior intermaxillary space height: The length of a perpendicular from the maxillary plane to the mandibular plane which passes through the point where the FOP intersects the Phw.
In Mx Lth.	Length of the Intermaxillary space: Linear distance measured along the FOP from the point where it intersects the Tt anteriorly, to where it intersects the Phw posteriorly.
In Mx Area	Intermaxillary area: calculated by the average of anterior and posterior intermaxillary space height multiply by intermaxillary length.

Skeleton and soft tissue relationship

T/In Mx area	Ratio between tongue area to intermaxillary area in mid-sagittal plane.

INTRODUCTION

Obstructive sleep apnea has received increased recognition in several medical fields because of the serious systemic effects of the disease. The pathophysiologic basis for obstructive sleep apnea syndrome is complex, involving the physical properties of the pharynx, the muscular forces that support airway patency, and the homeostatic control mechanisms of respiration. The anatomic basis for OSAS lies in the hard tissue structures of the head and neck as well as the soft tissue structures comprising and supporting the upper airway. Unfortunately, there is no uniform method of classifying OSAS patients into categories based on a multifactorial scale that includes weighted consideration of each of the known risk factors. Similarly, assessment of overall therapeutic benefit is still difficult to judge because there is no generally agreed upon standard for uniform coding and reporting of results for OSAS therapy. Although there have been numerous research reports on OSAS, the complexity and intricacy of its pathogenesis is still debated. Because of the multifactorial etiology of the disease, diagnosis and treatment of OSAS demands a multidisciplinary approach involves both medical and dental professionals.

Obstructive Sleep Apnea Syndrome (OSAS) is characterized by repetitive episodes of upper airway obstruction that occur during sleep, usually associated with a reduction in arterial oxygen saturation. Apnea, the cessation of breathing for more than ten seconds, has been identified during sleep in some young, otherwise healthy individuals, as well as a greater number of older adults. Other groups prone to apnea

include postmenopausal women and children with tonsillar and adenoid hypertrophy (Strohl et al., 1986). Clinically the designation of OSAS is usually applied to individuals who experience frequent apneas and hypopneas during sleep with pathophysiological consequences. In addition, OSAS patients often snore heavily, wake up tired, and complain of excessive daytime sleepiness leading to occupational disability.

A recent epidemiologic survey suggested that the prevalence of OSAS may be as high as 10% of the adult male population over 50 (Phillipson 1993). Sleep related apneas are classified as central, obstructive or mixed, depending on the presence or absence of abdominal thoracic respiratory efforts. Obstructive types of sleep apnea are thought to occur when there is inadequate motor drive to upper airway muscles in the presence of effective diaphragmatic contraction. In contrast, central-type apnea appears to have inadequate drive to both the upper airway muscles and to the diaphragm (Olson, Strohl 1986). Fiberoptic visualization in twenty five male subjects with OSAS showed that the most common site of obstruction was in the oropharynx (76%). Obstructions also were found in the hypopharynx (11%) and larynx (2%) (Wilms et al., 1982). More than two sites of obstruction were identified in 36% of the patients.

Snoring is a major social disruption. Sounds are produced by an obstructed airway at the level of nasopharynx or oropharynx. It has been reported that snoring is the most common reason for OSAS patients to contact an otolaryngologist. The most common person to identify loud snoring is the bed partner.

Although there have been a number of studies on the etiology and pathogenesis of OSAS, the exact mechanisms that lead to OSAS are not clearly defined. However, there

is some evidence to support the hypothesis that craniofacial structures are associated with the development of OSAS as well as neurogenic controls to preserve the patency of the upper airway during sleep. Both genetic and environmental factors appear to influence each of the recognized risk factors of the disorder. These risk factors include craniofacial features, obesity, alcohol use and ventilatory control (Strohl et al., 1978).

A number of studies have used cephalometrics to evaluate craniofacial morphology in patients with OSAS. Typical craniofacial characteristics related to OSAS include increased hyoid to mandiblular plane distance, increased length of the soft palate, and decreased size of the posterior pharyngeal space. It is interesting to note in OSAS patients that the sagittal dimensions of upper face and anterior cranial base were reduced. These changes correlated with reduced bony pharynx opening and the increased lower face height. These were in turn associated with a retruded position of the chin and tongue. All of these factors contribute to lower pharynx crowding with elongated soft palate (Bacon et al., 1989). In other words, the faces of OSAS patients are "compressed" toward the posterior pharyngeal wall but mandibular length remains the same.

Differences in craniofacial anatomic structures of apneic and nonapneic snorers in upright and supine position were studied by Pracharktam et al., (1994). They concluded that while the magnitude of some variables increased in the supine position, no additional posture related differences between the two groups were found. Since these craniofacial features are present in awake upright subjects, a complete evaluation of the entire upper airway can be made in the standard upright cephalometer before medical or surgical therapy is instituted. The use of cephalometric radiographs to

evaluate craniofacial anatomy in OSAS patients has increased during the last decade.Two studies have attempted to differentiate OSAS subjects from other habitual snorers based on specific craniofacial risk factors (Bacon et al., 1988; Hans et al., 1996). Two other studies used statistical regression to analyze the correlation of cephalometric and anthropometric variables and Respiratory Disturbance Index (RDI) scores (Partinen et al., 1988; Nelson, Hans 1996). Still another study used cephalometric and physiologic parameters to predict treatment response (i.e., reduction in RDI) to a dental device (Eveloff et al., 1994). It has often been emphasized that abnormal craniofacial characteristics may increase an individual's risk of developing OSAS. These anatomic features can be quantitated with the cephalometric technique. However, to date no systematic study has tried to determine the relationship between cephalometric measurements and physiologic measures of sleep disordered breathing. The working hypothesis of the present study is that Respiratory Disturbance Index (RDI) gives a global evaluation of OSAS whereas other physiologic measures may be more highly associated with a specific phase of the apneic cycle (Figure 1) and provide additional information of the severity or characterestics of the breathing disturbance.

As seen in the scheme, RDI shown in Figure 1 is considered a global and traditional index that combines both oxygen desaturation and apnea/hypopnea duration. Apnea duration is measured as the time during the apneic cycle from the "closed" to the "reopen" status of the airway. Hypopnea duration is measured as the time from the"open" to the "closing" status of the apneic cycle. Both apnea and hypopnea cycles are usually associated with oxygen desaturation which may in turn indicate the severity of OSAS. Anatomic, and neurologic risk factors as well as compliance of the upper

airway may contribute differently to apneic activity during each specific phase of the apneic cycle.

The present study addresses the following:

1. Can craniofacial factors predict specific physiologic measurements such as the lowest O_2 saturation or the longest duration of apnea?

2. Are the cephalometric and anthropometric variables that predict apnea length and the lowest O_2 saturation similar to those that predict RDI?

3. Do all the craniofacial risk factors have equal importance in predicting apnea length and the lowest O_2 saturation, or is there a subset of the craniofacial variables that are more important than the rest?

Apneic cycle	Anatomic factors	Neurologic control	Surface tension (compliance)
Hypopnea O2 sat duration *longest average* — open	+++	±	±
closing — RDI O2 sat *lowest average* *O2 diff 1* *O2 diff 2* duration	?	+	+
Apnea O2 sat duration *longest average* — closed	?	++	++
reopen	+	+++	+++

Figure 1. Schematic diagram of the apneic cycle (working hypothesis)

REVIEW OF THE LITERATURE

Historical Perspective and the Clinical Syndrome

Obstructive sleep apnea was well described as " Pickwickian syndrome" in Charles Dickens' classic work *The Pickwick Papers* in 1837. In 1889, William Hill also recognized this syndrome, as the following statement illustrates:

> "The stupid-looking lazy kid who frequently suffers from headaches at school, breathes through his mouth instead of his nose, snores and is restless at night, and wake up with a dry mouth in the morning, is well worthy of the solicitous attention of the school medical officer."

In 1918, Sir William Osler coined the term "Pickwickian," referring to obese, hypersomnolent patients. Pickwickian syndrome was characterized by symptoms associated with obesity, excessive sleepiness, cyanosis, pulmonary hypertension, and right sided heart failure (Westbrook 1990).

Sleep research was not actively pursued until the early 1950's, when workers at the University of Chicago studied eye movement during sleep. By 1957, they had published the classic description of the electroencephalogram (EEG) in rapid eye movement (REM) patterns of overnight sleep in humans. This group was the first to use the term "REM sleep" and described the cyclic nature of REM and non-REM sleep. In 1965, Gastaut and coworkers reported the first polysomnographic study and began to describe Pickwickian syndrome based on sleep behaviors. They also began to classify sleep-induced apnea syndrome based upon the respiratory patterns seen during sleep. In 1973, sleep apnea was first described as a syndrome by Guilleminault et al. This group also established a sleep clinic at Stanford University to study patients with

sleep complaints (Koopmann, Moran 1990a). Therapeutic trials, some of them very effective, were conducted long before a complete understanding of the underlying problems was at hand. Guilleminault (1985) in reviewing the literature found that weight loss has been recommended for obese patients for many years, although pulmonary physiologists, particularly A. R. Fishman and his colleagues, noted that it does not always resolve all problems. In some patients, hypoxic and hypercapnic response curves remain abnormally low. Kuhlo and his colleagues case report stressed the effectiveness of tracheostomy in treating obstructive sleep apnea. Kumashiro and colleagues reported on a patient whose sleep apnea improved markedly with administration of the tricyclic antidepressant clomapramine. However, this patient's clinical symptoms were not clearly described. Today, tracheostomy to bypass the sleep-related obstruction is still performed, and tricyclic antidepressants such as protriptyline and clomipramine, which is unavailable in United States, are among the drugs administered to patients with mild to moderate obstructive sleep apnea syndrome.

The sleep apnea syndromes are a collection of clinical disorders characterized by recurrent episodes of apnea and/or hypoventilation during sleep and by relief of symptoms and signs of disease with relief of the sleep-induced respiratory disturbance (Strohl et al., 1984). Recurrent hypoxemia and hypercapnia during sleep lead to multiple arousals and sleep fragmentation. These factors have been identified as the most important in producing the symptoms and signs. The major clinical features of the adult sleep apnea syndromes have been defined in order of prevalence (Guilleminault et al., 1978). The major clinical symptoms are altered sleep behavior including snoring, enuresis, sleep walking, excessive daytime sleepiness, intellectual deterioration, sexual

dysfunction, personality changes, morning headaches, hypnagogic hallucinations and automatic behavior, pedal edema, exercise intolerance, dyspnea,and insomnia. The clinical features can also include reduced sleep latency, obesity, cardiac arrhythmias, sinus arrhythmia (30 bpm), bradycardia, asystole (greater or equal to three seconds), hypertension, pulmonary hypertension, and polycythemia.

Two distinct clinical syndromes of sleep apnea have been identified based on pathophysiological mechanisms: obstructive and central. Obstructive sleep apnea syndrome is characterized by episodes of either obstructive sleep apnea, during which respiratory effort continues despite pharyngeal obstruction to airflow, or of mixed apnea, during which respiratory efforts are absent at the start of the apnea but then start again before airflow resumes (Millman, Fishman 1988). By definition, central sleep apnea syndrome entails a cessation of both respiratory effort and airflow. This kind of "pure" central apnea is responsible for less than 5% of instances of sleep apnea. As a rule, the designation central sleep apnea syndrome is reserved for patients who have repetitive episodes of apnea that are solely central in type. An apnea is now defined as a cessation of airflow for ten seconds or longer. There is less consensus about the definition of hypopnea: some clinics define hypopnea as a 50 % reduction in airflow associated with a 4% fall in oxygen saturation. However, this definition is not entirely satisfying when applied to relatively healthy adults and children who fail to develop appreciable O_2 desaturation because of the shape of the oxyhemoglobin dissociation curve. Based on all-night polysomnographic evaluation of normal subjects, sleep apnea has been defined as greater than five apneas per hour or more than thirty apneas per night. Because of the unexpected finding that subjects older than sixty five years have a

high prevalence (35 to 40%) of recurrent apnea, some of the which are symptomatic and others asymptomatic, this definition of sleep apnea has been seriously challenged.

An apnea index (number of apneic episodes per hour of sleep) of five or greater was proposed as a more sensitive threshold for diagnosing sleep apnea syndrome. These criteria are widely used according to recent clinical and research publications (Guilleminault et al., 1980). However, the use of a threshold level of five apneic episodes per hour not reliably predict increased health risk or somnolence in aging subjects. Adjustment of the apnea index, based on studies of aging normal subjects and of aging patients with sleep apnea syndrome is necessary to insure reliable results in clinical and research applications (Berry et al., 1984).

Another phenomenon to be considered is partial apnea, called an hypopnea. Hypopnea is defined as a reduction in air exchange with decreased arterial oxygen saturation. The effects of episodes of hypopnea are similar to those seen in typical sleep apnea syndrome. To take into account this breathing abnormality Guilleminault have devised an Apnea-Hypopnea Index ((A+H)I), which is similar to the Respiratory Disturbance Index (RDI) that has been used in recent literature. The (A+H)I gives a good indication of the severity of the syndrome, but is not always sufficient to describe the entire problem. Several other indices have been combined with the (A+H)I to give more information on the patient, such as amount of time spent with oxygen saturation below a certain level (90%, 80%, 70%) or number of oxygen saturation drops below 90%, 80%, or 70%. A cardiac arrhythmia index that gives the number of cardiac arrhythmias per hour of sleep has also been devised (Guilleminault, Dement 1988).

However, any predetermined AHI cut-off value to define sleep apnea is somewhat

arbitrary and different criteria are often used (Hoffstein et al., 1991a). According to the International Classification of Sleep Disorders the diagnostic criteria for obstructive sleep apnea are (1990):

A. The patient has a complaint of excessive sleepiness or insomnia. Occasionally the patient may be unaware of clinical features that are observed by others.

B. The patient has frequent episodes of obstructed breathing during sleep.

C. Associated features include:

1. Loud snoring;

2. Morning headaches;

3. A dry mouth upon awakening;

4. Chest retraction during sleep in young children.

D. Polysomnographic monitoring demonstrates:

1. More than five obstructive apneas, greater than ten seconds in duration, per hour of sleep and one or more of the following:

2. Frequent arousals from sleep associated with the apneas;

3. Bradytachycardia;

4. Arterial oxygen desaturation in association with the apneic episodes; with or without

5. An MSLT that demonstrates a mean sleep latency of less than ten minutes.

E. Sleep apnea can be associated with other medical disorders, e.g., tonsillar enlargement.

F. Other sleep disorders can be present, e.g., periodic limb movement disorder or narcolepsy.

Severity Criteria:

Mild: Associated with moderated sleepiness or mild insomnia as defined above. The majority of habitual sleep period is free of respiratory disturbance. The apneic episodes are associated with mild oxygen desaturation or benign cardiac arrhythmias.

Moderate: Associated with moderate sleepiness or mild insomnia as defined above. Can be associated with moderate oxygen desaturation or mild cardiac arrhythmias.

Severe: Associated with severe sleepiness as defined above. The majority of the habitual sleep period is associated with respiratory disturbance, with severe oxygen desaturation or moderate to severe cardiac arrhythmias. There can be evidence of associated cardiac or pulmonary failure.

Duration Criteria:

Acute: Duration two weeks or less.

Subacute: Duration more than two weeks but less than six months.

Chronic: Duration six months or longer.

The first epidemiologic study for Israeli industry workers demonstrated that at least 0.89% of the sample had symptomatic sleep apnea (Lavie 1983). A more recent epidemiological survey suggested that the prevalence of this disease may be as high as ten percent of the adult male population over fifty (Philipson 1993). Another study suggested that the prevalence of OSAS is at least nine percent of the adult male and four percent of the adult female population (Young et al., 1993).

Prevalence rates for sleep apnea based on AI or AHI >5 are wide ranging: 1%-16% for adult males, and 1-5% for adult females; 28-67% for elderly males (older than sixty five years), and 20-54% elderly females. Approximately 16% of habitual snorers may have sleep apnea (defined as greater than thirty respiratory episodes per night). However, another study demonstrated that 28% of the subjects selected from the an

industrial population with subjectively reported excessive daytime sleepiness were found to have >five apneas per hour, as many as 66% of subjects with sleep apnea may not be hypersomnolent (Redline, Young 1993). Prevalence estimates thus are limited by discrepancies and disease definitions. The currently available data suggest that sleep apnea occurs commonly. Prevalence, however, varies markedly according to definitions utilized to characterize the disorder and population studied. Prevalence has been reported to range from 1% (in an industrial working Israeli population) to 42% (in an elderly nursing home population).

Two surveys of ten sleep disorders centers, conducted in 1978-1979 and 1980-1981, revealed that 46% of 8,000 excessive daytime sleepiness (EDS) patients had sleep apnea syndrome. Among sleep apnea patients, daytime sleepiness is a more common complaint than disturbed nocturnal sleep, and obstructive sleep apnea syndrome is more common than central sleep apnea. The prevalence appears to increase with age (Guilleminault, Dement 1988).

One thousand and one English men, aged 35-65 years, were identified from the age-sex register of one group general practice. Three subjects had clinically obvious and severe symptomatic obstructive sleep apnea, giving a prevalence of three per 1001 men (Stradling, Crosby 1991). The prevalence of snoring "Often"was much higher when the wife was present at the interview (23% v 10%) (17% overall; $p<0.0001$).

Respondents in a random digit dialing telephone survey included 685 people (356 women and 329 men, with a mean age of fifty years). Snoring was reported by 37%, gasping by 8%, excessive daytime somnolence by 36%, and hypertension by 28%; all symptoms were more prevalent in respondents older than fifty years. Snoring and

gasping were more common in men than women (Phillips et al., 1989).

Obstructive Sleep Apnea Syndrome is predominantly identified in middle aged men. However, postmenopausal women or children with tonsillar and adenoid hypertrophy are also potential groups particularly prone to sleep apnea (Block et al., 1980; Potsic, Wetmore 1990; Shprintzen 1982). Twenty postmenopausal women were monitored for disordered breathing (apnea and hypopnea) and oxygen desaturation during one night's sleep and compared with eighteen premenopausal women previously reported to have a low incidence of sleep-disordered breathing and nocturnal oxygen desaturation (Block et al., 1980). Postmenopausal women were found to resemble men with respect to disordered breathing during sleep and nocturnal oxygen desaturation. They speculated protection from these sleep events in premenopausal women might be afforded by the respiratory stimulant effects of circulating progesterone.

Obstructive sleep apnea of lesser degrees of severity in children are probably more common than is currently realized because of lack of a convenient mass screening device and agreement as to what constitutes significant obstruction. The vast majority of children with obstructed respiration during sleep and sleep apnea have a pharyngeal site as the sole cause. The most common cause of obstructive sleep disorders and obstructive apnea in children is adenotonsillar hyperplasia. It is suspected that the incidence of obstruction has increased with the decline in the number of tonsillectomies (Potsic, Wetmore 1990). Some children have a predisposition to airway obstruction because their pharynx has an abnormal shape or support. Patients with craniofacial anomalies with syndromes such as Crouzon, Apert, Down, Treacher Collins, Pierre Robin, cleft palate, achondroplasia, mucopolysaccharidoses, nasal congestion from

allergic rhinitis or infection, neuromuscular disorders, and tumors or space-occupying masses e.g., rhabdomyosarcoma and lymphoma, have a high association with sleep apnea (Shprintzen 1982).

Pathophysiology of Obstructive Sleep Apnea

It is possible that the cause of OSA is multifactorial in anyone individual or differs in different patients because to date no single pathophysiologic mechanism has been identified.

The following categories are proposed factors known to contribute to upper airway obstruction during sleep (Hudgel 1992)

1. Compliance or collapsibility of upper airway tissues
2. Pharyngeal inspiratory muscle function
3. Reflexes effecting upper airway caliber
4. Geometry of upper airway

Upper Airway Compliance or Collapsibility

Little is known about the intrinsic passive compliance of the pharyngeal tissues because of the difficulty in determining isolated pharyngeal volume and intraluminal pressure measurement during a totally relaxed state. Only one study showed that the oropharynx was often closed when the infant lay in a supine position. In contrast, a higher suction pressure was required to close the nasopharynx and substantially more pressure was needed to close the hypopharynx which indicates the oropharyngeal airway is inherently quite collapsible (Reed et al., 1985). Measurements of differential pressures across the palate and the hypopharynx revealed that the most common sites of upper airway collapse were above and below the uvula. This finding indicated the site

of obstruction is specific rather than involving the whole pharynx (Hudgel 1992). The acoustic reflection technique has been used to evaluate dynamic airway collapsibility, so called "effective compliance" which is defined as lung volume falls from functional residual capacity (FRC) to a residual volume (RV) (Bradley et al., 1986). These investigators found that patients with OSA displayed a greater decrease in their pharyngeal cross-sectional area than did controls. This finding demonstrated that OSAS subjects had excessive upper airway collapsibility. Another study showed OSA patients had a more collapsible upper airway than control subjects. This study eliminated the effect of active inspiration by applying a vacuum to the upper airway with the subjects relaxed at functional residual capacity (Suratt et al., 1983). The elastic modulus of the airway wall is affected by the elasticity of several structural elements. The mechanical linkage between the air-conducting airway and the surrounding, extraluminal structures is a potentially important interaction (Olson et al., 1988c). The effect of upper airway muscle activity (which would surely be expected to influence upper airway collapsibility) was not assessed in human studies. But in lightly anesthetized rabbits far less suction pressure was required to collapse the upper airway after hypoglossal nerve section than before nerve section (Brouillette, Thach 1979). Other studies also demonstrated that reduction of upper airway muscle activity such as genioglossus and geniohyoid was associated with airway obstruction during sleep (Remmers et al., 1978; Mathew, Remmers 1984). Their observations indicate that the mechanical activity of the muscles is instrumental in preventing upper airway collapse.

However, Strohl and Olson (1987) suggested that muscle activity alone does not predominantly affect upper airway stability. The intrinsic elastic properties of the

airway depend partly upon the contractile state of the muscle and partly upon its associated structures (connective tissue, blood vessels, etc.). In contrast to Broullette, administration of gallamine to halt skeletal muscle activity in the apneic, anesthetized rabbit produced little change in the airway closing pressure where as subsequent death resulted in the airway being significantly easier to close (Olson, Strohl 1988b). The action of the upper airway muscles cause changes in the airway size, not compliance of the upper airway wall. In addition, Parsi et al., (1989) identified a 7% increase in pharyngeal volume of normal human after local application of the vasoconstrictor. These data suggests that blood volume changes may affect upper airway size and collapsibility. Another nonmuscular factor, pharyngeal mucus, was identified to potentiate and contribute to persistence of the upper airway closure. Saline solution instillation into the upper airway did not produce this effect (Olson, Strohl 1988a).

Inspiratory Muscle Function

There have been several concepts proposed to address the role of the upper airway muscles in inspiration.

Balance of Forces Theory

The concept that inspiratory muscle imbalance may occur is based on the findings that upper and lower respiratory muscles respond quantitatively differently to the same ventilatory stimulus (Strohl et al, 1986; Block et al., 1984).Because of this differential activity, the upper airway may collapse when upper respiratory muscle activity decreases relative to the activity of the chest wall muscles. On the other hand, the upper airway opens when upper respiratory muscle activity increases relative to that of the chest wall muscles (Longobardo et al., 1982).

Critical Pressure Concept

It is hypothesized that the pharynx has the same properties as a "starling resistor" (Schwartz et al., 1989). In this model, upstream (nasal) and downstream (hypopharyngeal) segments have fixed diameter and defined resistances. The collapsible segment (mainly, the oropharynx) has no resistance but is subjected to surrounding pressures (critical pressure). Collapse occurs only when the surrounding pressures exceed intraluminal pressure by subatmospheric airway driving pressure generated by chest wall muscle contraction. In OSA patients, the collapsing pressure needed to close the upper airway is much lower than normal nonapneic subjects.

Periodic Breathing

It is hypothesized that the balance of electrical activity between the upper airway and chest wall inspiratory muscles affects upper airway caliber. A low levels of CNS neural efferent activity, an imbalance between the electrical activities of these two inspiratory muscle group exists and results in decreased upper airway caliber. This hypothesis was tested during periodic breathing induced by mild hypoxemia in NREM sleep in nine healthy male subjects (Hudgel et al., 1987). They concluded that the nonlinear activation of upper airway and chest wall inspiratory muscles contributed to fluctuations in upper airway resistance observed during periodic breathing. Another study also demonstrated that OSA patients have a suppression of the major respiratory muscles before an obstruction occurs. This suppression is in addition to involvement of the tongue and pharyngeal tissues. The obstruction process appears to be closely related to periodicities in arterial blood gases with consequent fluctuations in inspiratory motor input (Martin et al., 1980).

Inspiratory Timing

Another interesting variable that affects airway caliber is the timing of the inspiratory activities of upper airway and chest wall muscles (Hudgel, Harasick 1990). It has been demonstrated that inspiratory activity of the upper airway motor neurons begins before the activity of the phrenic nerve, diaphragm and thorax. But in obstructive sleep apnea patients the relative timing of inspiratory electrical activity of the upper and lower respiratory muscles was closely correlated with breath-to-breath as well as within breath changes in upper airway resistance. The exact mechanism of these timing differences is uncertain but might be related to pontomedullary ventilatory activity.

Reflexes and Upper Airway Caliber

Reflexes whose afferent limbs are located throughout the respiratory system may alter upper airway caliber through action on respiratory muscle function (Hudgel 1992). Those reflexes originate in the supralaryngeal airway, larynx or lungs and cardiovascular system. The selective occurrence of OSA during topical oropharyngeal anesthesia support the presence of an upper-airway-based reflex mechanism that contributes to the maintenance of upper airway patency (McNicholas et al., 1987). Other data indicate that topical anesthesia by 10% lidocaine spray and 0.25% bupivacaine gargle increases the frequency of apnea and hypopnea in snorers but not their duration (Chadwick et al., 1987, 1991). Lung (1987) demonstrated that an increase in lung volume decreased nasal resistance via a vagal reflex. However, Fouke and Strohl (1987) showed that changes in lung volume did not affect pharyngeal size in anesthetized animals. The extent of the impact of reflex activity on the pathophysiologic

manifestations of OSA has not yet been defined.

Upper Airway Anatomy

The upper airway includes the extrathoraic trachea, larynx, pharynx, mouth and nose. On clinical examination, the majority of patients with OSA do not have pathologic abnormalities of the upper airway. However, recent evidence indicates that OSAS patients do have anatomic traits that predispose them to airway closure during sleep. The functional result of this anatomic narrowing of the upper airway is an increase in upper airway resistance. With a narrowed airway, greater pressure is required to achieve the same airflow. Narrowing of the airway also leads to an increase in the velocity of air passing through the site of narrowing (Bernoulli effect). Subatmospheric intraluminal pressure during inspiration creates a positive transmural pressure which tends to draw the walls of the airway inward. This narrowing force is normally counteracted by the phasic inspiratory activation of the upper airway muscles resulting in an outward, dilating force. The net balance between these two forces is thought to determine the patency of the upper airway. Normal subjects and OSA patients do not develop upper airway closure during wakefulness because the net balance of the two counteracting forces is outward. Given the normal changes in neural stimuli that occur with sleep onset, a shift in the balance between these two forces results. During sleep, the net balance of forces in normal subjects is still outward. Even with the onset of REM sleep which further decreases upper airway muscle activity the net balance of forces is outward. In contrast, when patients with OSA fall asleep, the net balance of forces appears to be inward. Under these conditions, anything that acts locally reduce the size of the lumen of the oropharynx and hypopharynx tends to promote occlusion of

the pharyngeal airway. Three major anatomic and/or mechanical factors that act to narrow the pharynx are transluminal pressure of the pharynx, structural encroachment on the pharyngeal lumen, and mandibular alterations (Kuna, Rammers 1985). Each of these alone may not produce pharyngeal airway closure, but acting together or in concert with neural alterations, they may play a key role in airway occlusion. Multiple diagnostic modalities have been used to investigate the upper airway geometry of OSA subjects (Shepard et al., 1991). Different methodologies will be described with specific findings and their clinical usefulness.

Fiberoptic Visualization

The nose should be carefully examined for septal deviation, polyps, and narrowing with inspiratory collapse at the level of nasal valve. Direct visual inspection of the oropharynx is often difficult due to anatomic limitation. Fiberoptic pharyngoscopy solves this problem, permitting examination of the entire upper airway with the mouth closed and muscles relaxed. It was reported that the retropalatal segment of the upper airway was the dominant site of obstruction during sleep. The structures involved in airway occlusion are the muscles of the velopharyngeal sphincter and the tongue. The laryngeal airway was observed to be unobstructed throughout the cycle of respiration and during apnea (DeBerry-Borowiecki et al., 1978). Many specific pathologic conditions have been identified in individual patients as the primary cause of OSA at the level of the hypopharynx (Sher 1990). Airway examination of twenty five consecutive adult men with OSA demonstrated that the most common site of obstruction was the oropharynx(76%), followed by the hypopharynx (11%), and finally the larynx (2%). Thirty-six percent subjects demonstrated obstruction at more

than two sites (Wilms et al., 1982).

Fluoroscopy

Lateral fluoroscopy in six OSA subjects showed that the obstruction always began during inspiration when the soft palate touched the tongue and posterior pharyngeal wall (Suratt et al., 1983). Somnofluoroscopy in the preoperative evaluation of patients undergoing UPPP indicates that UPPP was more successful in OSA subjects in whom maximum collapse was confined to the region above the midpoint of the body of the second cervical vertebrae (C2)(67%) rather than below this level (9%) (Katsantonis, Walsh 1986). Video fluoroscopy is an excellent method for determining the dynamic changes that occur in the pharynx during ventilation in both the dorsal ventral and caudal rostral planes. It also permits analysis of movements of the mandible and hyoid bone, as these structures do not move laterally. But it exposes subjects to considerable radiation and requires a radiology technician.

Acoustic Reflection Technique

As compared to fiberoptic pharyngoscopy , the acoustic technique is less invasive, and more easily quantitated. It is also inexpensive, quick, harmless and easily repeatable as compared to radiographic assessment. One of the major advantages of this technique is its ability to provide a dynamic picture of the airway as area measurements may be carried out as rapidly as five times per second. The disadvantages are that it is not widely available, requires some degree of cooperation from the subject and would be difficult to perform during sleep. This technique is based on an analysis of sound waves that are launched from a loud speaker and travel along the wave tube into the subjects airway, where they are reflected. From the difference in the two signals,

changes in airway area are inferred as a function of distance from the recording microphone. It was reported that patients with OSA appeared to have a smaller pharynx than nonapneic patients, even when the measurements were performed in awake seated subjects (Rivlin et al., 1984). Using this technique, it was concluded that snorers with and without sleep apnea have smaller pharyngeal cross- sectional areas than nonsnorers and that snorers with sleep apnea have a further decrease as lung volume falls. In other words, nonapneic snorers have a "stiffer" pharynx that protects them from developing complete pharyngeal occlusion during sleep (Bradley et al., 1986).

Computerized Tomography (CT)

The initial studies conducted using conventional CT documented that patient with OSA had smaller minimum upper airway cross-sectional areas than nonobese control subjects (Haponik et al., 1983). When weight matched, the smallest airway area in OSA patients has been found in one study to be smaller (Kuna et al., 1988) and in another not significantly different (Stauffer et al., 1987). Stauffer concluded that increased inspiratory resistance to air flow in the naso-oropharynx is present during wakefulness in overweight men with OSA. He further hypothesized that this increased resistance is associated with disordered breathing during sleep even though CT was unable to demonstrate that pharyngeal size at functional residual capacity (FRC) is significantly different between patients and control subjects.

Conventional CT has been used to study the effect of nasal CPAP on upper airway (UA) dimensions in patients with OSA, thin nonsnorers and obese weight-matched snorers. Although all groups showed increases in UA dimensions in response to nasal CPAP, the velopharyngeal segment was not as distensible in the OAS patients

as it was in the control subjects (Kuna et al., 1988). The careful evaluation of the variations in UA dimensions in twenty five OSA patients demonstrated that the lower velopharynx (level 3) was found to be the smallest and most variable segment (55% change) and the hard palate (level 4) was the most stable region (29%) (Shepard et al., 1990). Changes in cross-sectional areas of greater than fifty percent were frequently observed during quiet tidal breathing in these patients. In addition to providing excellent anatomical detail of the airway and its surrounding structures, CT is easily quantitated, noninvasive and requires no instrumentation or anesthesia of the UA that may alter its physiologic behavior. Fast-CT is superior to conventional CT scanning in that the 50-msec scan time permits dynamic imaging with reductions in radiation exposure. The major disadvantages of CT are that the image is static, the cost is relatively high and the radiation exposure entailed with this technology is also high.

Fast-CT combined with EMG was used to examine systematically the changes that occur in UA size, collapsibility, and distensibility over the age range from twenty two to seventy eight years in normal awake men (Burger et al., 1992). Unexpectedly, minimal cross-sectional area at FRC and atmospheric pressure was larger in older age group (73 ± 9 mm ^{2}) than in the younger group(49 ± 7 mm^2). And the older age group demonstrated greater EMG activity than did the younger age group in response to negative UA pressure loading. They interpreted this phenomenon as increased compensatory mechanism by anatomic enlargement and UA dilator muscle activity in response to negative pressures in the older subjects. Preoperative awake CT of the UA was performed on 60 consecutive patients with symptomatic sleep apnea to determine the predictability of the soft tissue volumes before UPPP (Ryan et al., 1991). Patients

who had a good response had a smaller oropharyngeal cross-sectional area, a smaller upper airway volume, a smaller upper airway to tongue volume ratio, and a smaller oropharynx to soft palate volume ratio. This finding appears to be consistent with another report (Katsantonis, Walsh 1986). which showed sixty seven percent of patients had a successful response to UPPP when initial airway occlusion occurred in the retropalatal, superior oropharynx.

Magnetic Resonance Imaging

MRI is the newest approach for investigating UA structure and mechanical properties. MRI provides high-resolution images of the upper airway and is useful for assessing conditions associated with increased tissue water content and fat accumulation in the surrounding pharyngeal wall. A three-dimensional MRI study reported that upper airway size is reduced in OSA and increases following chronic nasal CPAP therapy.This increase may be due to resolution of upper airway edema (Ryan et al., 1989). Preliminary studies utilizing advanced computer based image analysis techniques have shown increases in lateral pharyngeal wall thickness and decreased retropalatal cross-sectional area in patients with OSA compared with normal subjects (Hoffman et al., 1989; Hoffman, Gefter 1990). A transverse and midsagittal MRI study showed that there was no difference in cross-sectional area of normal subjects, snorers and OSA patients. However, on transverse sections the pharyngeal cross-sectional had an elliptic shape with the long axis oriented in the coronal plane in normal subjects, where as in apneic and snoring patients the pharynx was circular or elliptic in shape and had the long axis oriented in the sagittal plane. It is suggested that a change in the pharyngeal cross sectional shape, secondary to a reduction in pharyngeal

transverse diameter, may be related to the risk of developing sleep related disordered breathing (Rodenstein et al., 1990).

Another MRI study also indicated that the area between the mandibular rami at the level of soft palate is critically important in determining which subjects will develop OSA (Eller et al., 1991). One of the most useful capabilities of MRI is its ability to detect the presence of fat in the soft tissues. Exploiting this strength, excessive deposition of fat around the UA in OSA patients was demonstrated compared to weight-matched control subjects (Horner et al., 1989). Although only limited information on MRI scanning of the UA is presently available, this technique has significant advantages in that it is noninvasive, does not entail exposure to ionizing radiation and can offer exquisite soft tissue contrast with the ability to image directly in multiple planes. However, studies performed during sleep are, unfortunately, limited by artifacts caused by snoring and an inability to monitor the field. As with CT scanning, the high cost and long data acquisition time are additional factors that limit its clinical use.

Cephalometric Radiography

Traditional cephalometric is used extensively in clinical orthodontics to quantify skeletal and soft tissue dysplasia before and after treatment. Recently, cephalometric radiography has been primarily used to evaluate the skeletal and to a lesser extent, the soft tissue anatomy that defines the boundaries of the upper airway (UA) in patients with OSA. The use of cephalometrics in the assessment of the airway has been employed since 1954. Early studies examining the airway have focused on measurements evaluating adenoids and the nasopharynx. In spite of highly complex

pathophysiology to develop OSA, many investigators have concluded that the craniofacial profile has important diagnostic value in both pre- and post-treatment evaluation. It may also explain the familial link and prevalence of the syndrome by tracing aberrant anatomic features. Cephalometric radiographs are taken in a standardized position with the subject seated upright, teeth in occlusion, and eyes directed forward in a natural head position so that gaze is parallel to the floor. Conventional cephalometry orients the subjects soft tissue Frankfort Horizontal parallel to the floor. Roentgenographic exposures are usually made at the end of expiration. Specific cephalometric landmarks are used to measure linear distances or angular relationships between carefully defined planes. The major disadvantage of cephalometric radiography is that it produces a static two-dimensional image of a three dimensional structure. In spite of this inherent limitation, cephalometric radiography is still an accepted technique for quantitating craniofacial skeleton and morphology.

In a study to evaluate whether measurements obtained from lateral cephalometric head films are accurate predictors of three-dimensional CT structures, the volume of the tongue, nasopharynx, and soft palate were accurately predicted by their cross-sectional areas, but not the volumes of the oropharynx and hypopharynx (Lowe et al., 1992). So, CT or MRI techniques appears to be superior to cephalometrics for calculations of oropharyngeal and hypopharyngeal volume. Upright and supine cephalograms were obtained in twenty OSA patients and ten asymptomatic control subjects to investigate changes in upper airway size and GG muscle activity (Pae et al., 1994). Tongue cross-sectional area increased 4.3% and oropharyngeal area decreases 36.5% when the OSA patients changed their body position from upright to the supine. No changes were

observed in tongue area, but soft palate thickness increased when the control subjects changed from the upright to the supine position. Furthermore, oropharyngeal cross-sectional area decreased 28.8% despite a 34% increase in resting GG EMG activity. Posterior tongue pressure increased 17% with the change from upright to supine position. They addressed the substantial effect of posture when assessing upper airway size in the erect posture (conventional cephalography) and in the supine position (computed tomography). On the other hand, a recent study suggested that anatomic measurements made from awake supine position cephalometric radiographs revealed no additional differences between OSAS and snoring subjects when compared to measurements made on radiographs taken in the upright position (Pracharktam et al., 1994) The most commonly measured cephalometric variables and their potential impact on the risk of developing OSAS will be described.

Anterior cranial base

Some investigators have found that the anteroposterior dimension of the cranial base (S-N) was significantly reduced in OSA patients compared to controls (Bacon et al., 1988; Bacon et al., 1989; Andersson, Brattstrom 1991). They also reported a strong correlation between the size of the pharynx and OSA. However, these findings were not supported in other studies (Strelzow et al., 1988). Strelzow found no significant difference in S-N and the angle made between the skull base and the FH plane when comparing control and OSA groups. It was hypothesized that acute cranial base flexion with an acute nasion-sella-basion angle reduced the pharyngeal space occupied by soft tissues anchored on the skull in the OSA patients (Jamieson et al., 1986). Teleologically, one would expect prognathism to develop as a result of this to

maintain a good airway. On the other hand, there are conflicting reports regarding cranial base flexion angle. Some authors reported no difference of this angle between control and OSA subjects (Bacon et al., 1988, 1989; Lyberg et al., 1989a) but other studies reported rather greater cranial base angle in OSA patients compared to controls (Andersson, Brattstrom 1991; Strelzow et al., 1988).

Maxilla

Two studies have reported that patients with OSA exhibit a retroposition of the maxilla and an elongated hard palate (DeBerry-Borowieck et al., 1988; Strelzow et al., 1988). They suggested that a retropositioned maxilla with increased ANS-PNS dimension places the already enlarged soft palate closer to the posterior pharyngeal wall thereby significantly narrowing the passage between the nasopharynx and the oropharynx. However, other studies showed that OSA patients had smaller hard palates and normally positioned maxilla when compared to nonsnoring controls (Andersson, Brattstrom 1991).

Pharynx

The bony dimensions of the pharynx have been reported to be smaller in OSA subjects compared to control (Bacon et al., 1988, 1989; Lyberg et al., 1989a). It was concluded that there was a strong tendency for posterior facial compression with narrowing of the pharyngeal airway, vertical hyperdevelopment, and a shortening of the cranial base (Bacon et al., 1988, 1989).

Mandible

Numerous studies have been conducted with regard to mandibular size, shape and position. However, the anatomic importance of retrognathia is still debated. Mandibular

retrognathism was demonstrated in six out of twenty five patients (24%) (Lyberg et al., 1989a), six out of ten (60%)(Riley et al., 1983) and in six out of nine male patients (70%) (Rivlin et al., 1984). The overall posterior displacement of the mandibular symphysis, (which represents the skeletal support of the anterior pharyngeal wall and depends on both mandibular size and position) was found to be highly significant in a number of reports (Rivlin et al., 1984; Lowe et al., 1995; Andersson, Brattstrom 1991; Jamieson et al., 1986). Nevertheless, other studies showed normal size and position of the mandible (DeBerry-Borowiecki et al., 1988; Djupesland et al., 1987). Still others reported a retruded position of the chin wit identical anatomic length of the mandible (Bacon et al., 1988, 1989; Lyberg et al., 1989a).

Hyoid bone

Studies have consistently found an inferiorly positioned hyoid bone when patients with OSAS are compared to nonapneic snorers or nonsnoring controls (Strelzow et al., 1988; DeBerry-Borowiecki et al., 1988; Lyberg et al., 1989a; Riley et al., 1983; Gilleminault et al., 1984; Djupesland et al., 1987; Pae et al., 1994; Pracharktam et al., 1994; Ferguson et al., 1995). Partinen et al., (1988) suggested that long mandibular plane to hyoid bone (MP-H) distance and width of the posterior airway space (PAS) (space behind the base of the tongue) were statistically significant predictors of elevated RDI. The cephalometric variables were much less useful for predicting the frequency of drops in O_2 saturation below eighty percent. Because BMI is the variable most highly correlated with RDI, study populations can be subdivided based on this measure. For example, the patient population can be subdivided into patients with clear anatomic abnormalities and low BMI, patients with morbid obesity and few abnormal

cephalometric measurements, and the largest group patients who have variably increased BMI and abnormal cephalometric measurements. The results have given to the concept that individuals with favorable craniofacial structures may tolerate massive weight gain prior to the development of clinically significant UA obstruction. In contrast, patients with abnormal skeletal structure, i.e. severe retrognathia, can develop OSA even in the absence of obesity. The majority of patients usually have a combination of obesity and abnormal craniofacial structures, which together contribute to UA narrowing and the development of OSA.

A recent study supports the concept that OSA subjects with and without obesity are likely to have a different pathogenesis (Tsuchiya et al., 1992). A sample of eight four adult male patients with OSA were classified by a cluster analysis on the basis of AI and BMI. One group consisted of patients with high AI and low BMI ratio and the other group comprised patients with a low AI and high BMI ratio. A high AI was related to a large skeletal anteroposterior discrepancy, a steep mandibular plane, and an inferoanterior position of the hyoid bone. In the patients with a low AI and high BMI ration, a high AI was related to a large tongue and a small upper airway. In both groups, BMI was the major contributor to AI. According to their results, it was concluded that the skeletal mismatch group with the high AI/ low BMI could respond well to the procedures that advance the mandible forward whereas weight reduction and/or UPPP may better contribute to the improvement of OSA symptoms in patients with atypical soft tissue abnormalities i.e. the low AI/ high BMI group. Regarding skeletal morphology, the most outstanding feature was the more inferior position of the hyoid bone in OSA patients.

The hyoid bone was consistently located at the level of cervical vertebrae C4-C6, compared with C3-C4 level in the controls (Djupesland et al., 1987). As the hyoid bone serves as an anchorage for the tongue muscles, its position also partly determines the position of the tongue. This means that more of the tongue mass is located in the hypopharyngeal level in OSA patients and therefore the base of the tongue has a more upright position. One interesting study showed that BMI, MP-H, PNS-P, and palate-cervical vertebrae angulation failed to explain significantly more of the variation associated with a in four percent oxygen desaturation dip rate than did neck size alone. They suggested that this finding implied that these indices are secondary effects of increases in neck mass rather than independently important etiologic factors (Davies, Stradling 1990).

Soft palate size may also be an indirect marker of neck obesity. Sleep apnea patients have fat deposits in the uvula which are absent from weight matched controls. Furthermore, partial pharyngeal obstruction leads to snoring which leads to edema and elongation of the uvula. The increase in MP-H may also be explained in several ways. The increased hyoid to mandibular length and hard palate to cervical vertebrae angle may be the result of a postural response by OSA patients to reduce upper airway resistance by extending the head (Tallgren, Solow 1987). Another explanation holds that some of the increase in MP-H seen in OSA patients results from a compensatory response to airway narrowing. Dropping the hyoid bone draws the root of the tongue down and out of the overcrowded pharynx (Rivlin et al., 1984; Davies, Stradling 1990). A similar response was shown after surgical mandibular shortening when the airway is narrowed resulting in a repositioning of the tongue (Wickwire et al., 1972;

Sinclair, Proffit 1990).

Soft tissue structures

Knowledge of the site of airway obstruction is central to the understanding of the pathogenesis of OSA syndrome. Many studies have shown that the length, width and size of the soft palate in the sagittal dimension is increased in OSA patients (Bacon et al., 1988, 1989; Strelzow et al., 1988; DeBerry-Borowiecki et al., 1988; Lyberg et al., 1989a.b.; Riley et al., 1983; Gilleminault et al., 1984; Lowe et al., 1995). Lyberg et al., (1989b). studied the oropharyngeal soft tissue profiles by cephalometric analysis in twenty five OSA patients and ten controls. They found that due to increased length and thickness, the area of the soft palate was about 1.7 times larger in the OSA patients and occupied a larger portion of the pharyngeal area (39% vs 21%). Pharyngeal airway spaces were measured generally in four sites; upper pharyngeal wall at the level of hard palate, middle pharyngeal wall at the level of uvula tip, lower pharyngeal wall at the level of vallecula and PAS (the minimal distance between the base of the tongue and the posterior pharyngeal wall). In addition, some areas are measured to determine the potential obstruction in the midsagittal plane of nasopharynx, oropharynx and hypopharynx.

However, another study confirmed the narrower pharyngeal area in OSA patients but found no significant difference in soft palate length or area between apneic and non-apneic snorers (Pracharktam et al., 1994). Despite the obvious limitations of two-dimensional method, cephalometric techniques have been used to evaluate the size of the tongue and airway structures. Changes of the upper airway structures secondary to a body position change from upright to supine in OSA patients appear to be different

from that seen in symptom free controls (Pae et al., 1994). They found increases in the cross-sectional area of the tongue and also an increase in the tongue mass as it settles inferiorly in OSA patients in the supine position. They attributed these changes to the effect of gravity (Crumley et al., 1987). In control subjects the tongue fell back into a bunched-up position, and the actual tongue area was reduced. The superior posterior airway was lengthened to keep the airway open. It was speculated that decreased or poorly coordinated phasic activity, along with decreased tonic activity of the genioglossus and hyoid muscles could be a crucial factor in pharyngeal obstruction. Tonic activity of the upper airway muscles is directly related to the size of the airway, especially in OSA patients. Upper airway dimensions may also be affected to a greater degree by gravity because of GG muscle hypotonicity or heavier tongue (Pae et al., 1994; Lowe et al., 1995).

In contrast, Pracharktam et al., (1994) failed to find significant changes in tongue length or area when upright and supine cephalograms of OSAS and control subjects were compared. They concluded that previously reported differences in upper airway dimensions in the upright and supine position, may have related more to differences in head and neck angulation and/or cephalometric technique errors.

Loss of tone in postural muscle is a characteristic feature of sleep. REM sleep is associated with a further marked loss of muscle tone which is the result of active inhibition of alpha and gamma spinal motorneurons (Sullivan et al., 1984). Normal subjects have a reduction of tonic electro-myographic activity in the GG muscles during NREM sleep but phasic inspiratory linked activity continues. However, during REM sleep, all tonic activity disappears and phasic inspiratory activity occurs irregularly. If

dilator activity is essential for airway patency, why doesn't everyone occlude during REM sleep? It is postulated that in normal subjects enough motor units are active throughout REM to prevent occlusion. Alternatively, continued activity of oropharyngeal dilator muscles other than the GG muscle may prevent occlusion during REM sleep in non-apneic individuals. However, the loss of muscle tone is only one factor in the etiology of obstructive apnea.

Enlargement of the tongue has been reported in OSA patients (Bacon et al., 1989; Andersson, Brattstrom 1991; Tsuchiya et al., 1992; Pracharktam et al., 1994). In contrast, Lyberg et al., (1989b) failed to identify an increased tongue length or area in OSA patients but confirmed that a more inferiorly positioned hyoid bone apparently placed the tongue in a more upright position with more of the tongue tissue at the hypopharyngeal level than found in normals. Multiple diagnostic modalities have been used to increase the understanding of the physiological behavior of the upper airway. The information contributed by each method of assessment has been generally complementary and led to an increased understanding of the underlying pathophysiology for the individual OSA patient. With regard to the structural narrowing of the UA in OSA subjects, it is important to note that none of the structural aberrations observed by any of the diagnostic modalities supported a cause and effect relationship between craniofacial morphology and of OSAS. Anatomic aberrations contributing to the development of OSAS should be elevated carefully in conjunction with pathophysiologic factors on the individual basis. Sullivan et al., (1984) summarized current theories for pathophysiological mechanism of OSAS by a combination of craniofacial features and muscle tone.

1. A mechanically narrow airway requires increased suction pressure to maintain inspiratory airflow; the suction pressure causes closure only during inspiratory efforts during sleep when the upper airway muscle tone is reduced. Thus airway occlusion is not dependent on abnormal loss of muscle tone in sleep

2. A mechanically narrow airway which is totally dependent on continuing muscle contraction of the dilator muscle for patency. The normal reduction of muscle tone during sleep leads to occlusion. In contrast to theory 1, this model does not require increased suction pressures to produce airway occlusion.

3. Normal airway geometry with excessive loss of muscle tone during sleep, leading to airway narrowing, increasing inspiratory suction pressures leads to airway collapse.

4. Normal airway geometry, normal upper airway muscles and muscle tone, but abnormal instability of respiratory control causing oscillations and mismatching between diaphgram activity (and thus suction pressure) and upper airway dilator muscles.

5. Abnormal reflex/motor response causing active upper airway muscle constriction (e.g., triggering of a gaglike reflex).

Other Contributing Factors

Anthropometric Measurements

Obesity

Typical OSA patients are generally described to be overweight and to have a very short, thick neck. However, severe OSAS has also been reported in normal weight persons who have normal neck features (Cohn 1981). Moreover, sleep apnea can occur in normal, asymptomatic subjects but with a strong male predominance and increased severity in O2 desaturation for overweight men (Block et al., 1979). Browman et al., (1984) found only 40% of a large series of OSAS patients were obese. Although the mechanism for improvement in OSA with weight loss has not been delineated, it is possible that reductions in apnea severity are due to decreases in upper airway

collapsibility (Harman et al., 1982). Many investigations have found a strong correlation between obesity and the severity of OSA (Browman et al., 1984; Harman et al., 1982; Suratt et al., 1987; Schwartz et al., 1991). It was postulated that weight loss in apneic patients results in decreases in upper airway critical pressure (Pcrit) and that these decreases are associated with reduction in apnea severity (Schwartz et al., 1991). They suggested two possible explanations. One possibility is that the decrease of Pcrit is due to structural alteration i.e. simple widening of the pharyngeal aperture after weight loss (Suratt et al., 1987). Alternatively,the decreases in collapsibility with weight loss were due to improved neuromuscular control of the pharynx. The latter was also supported by the findings of enhanced preservation of pharyngeal cross-sectional area with changes in lung volume in the apneic patients who lost weight (Rubenstein et al., 1988).

Obesity and weight gain are associated with a variety of conditions detrimental to health, well-being, and longevity. The main problem is that measures of relative weight are unable to distinguish between adiposity , muscularity and edema. Skinfold measurements are usually used as the criterion for evaluating the utility of various body mass indices in estimating adiposity in adult and children. Revicki and Israel (1986) conducted a study to examine the relationship between four different indices of body mass, the weight-height ratio (w/h), Quetelet index (w/h^2), Khosla-Lowe index (w/h^3), and Benn index (w/h to the P power, P=1.8993), and skinfolds thickness and hydrostatic laboratory measures of body adiposity. Their results suggested that the Benn index and the Quetelet index are equally valid estimates of body fat and meet the criteria for a good body mass index (BMI) i.e., one that correlates minimally with

height and maximally with weight.

Neck circumference and BMI

Katz et al., (1990) revealed that AHI correlates with the external neck circumference , the body mass index, and the internal circumference of the distal pharynx. These three variables accounted for 39% of variability in AHI. They studied a group of 123 patients referred because of snoring and suspected OSA. The external neck circumference was measured at the level of the superior border of the cricothyroid cartilage and internal neck circumference were calculated from the measurements of pharyngeal, glottic and tracheal areas obtained by the acoustic reflection technique. Their data showed that neck circumference and the degree of obesity were important predictors of sleep apnea. They speculated that the static pharyngeal size modulated by the dynamic loading of the airway due to the weight of fatty tissue of the neck may contribute to the pathogenesis of OSA.

One study was conducted to determine the effects of a mass load on upper airway function in an animal model (Koenig, Thach 1988). The load was designed to simulate the effect of increased cervical adipose tissue. They reported that endoscopy revealed concentric narrowing of the pharynx during loading, upper airway resistance was increased, and loading caused decreased airway stability as reflected by closing pressure of the upper airway. Another report concluded that neck circumference corrected for height is more useful as a predictor of obstructive sleep apnea than general obesity (Davies et al., 1992). Davies also indicated that when neck circumferences corrected for height is used as a diagnostic test, it may be up to 77% sensitive and 82% specific for OSAS patients referred to a sleep clinic. However, this is not sufficiently

sensitive or specific to circumvent the need for sleep studies in the diagnosis of the disease. Another study was performed to test the hypothesis that for the same degree of generalized obesity, patients with sleep apnea have more fat over the neck than over the abdominal region (Hoffstein, Mateika 1992). Using apneic and nonapneic patients matched, on BMI and age , apneic patients had significantly higher BMI, neck, and abdominal circumferences when abdominal circumference were similar, the neck circumference was significantly higher in apneic patients. They indicated that there are fat deposits in the palatopharyngeal, glossopharyngeal and laryngopharyngeal airspace and concluded that obese patients with sleep apnea have fatter necks than equally obese nonapneic snorers.

Head form

Many of the anatomic changes described in people with OSA are even more pronounced in brachycephalic dogs. The typical clinical characteristics were collectively described as brachycephalic airway obstructive syndrome (Wykes 1991). The head shape of brachycephalic breeds such as English bulldog, Pekingese , Pug, and Boston terrier is caused by an inherited defect in the development of the bones at the base of the skull (Harvy 1989). Typical anatomic features include an increased facial index, an elongated soft palate (one hundred percent of affected brachycephalic dogs) stenotic nares (fifty percent of the affected dogs), and everted laryngeal ventricles and/or laryngeal collapse (thirty percent of affected dogs) and a shortened and distorted nasopharynx. The clinical signs are similar to those found in humans with OSA; respiratory distress, stridor, reduced exercise tolerance, noisy breathing and snoring, cyanosis and collapse. Especially, brachycephalic skulls have a facial index more than

twice that of mesocephalic skulls (e.g., German Shepherd Dog type) and three times that of dolichocephalic skulls (e.g., Collie type). The pattern of breathing was assessed in nineteen brachycephalic dogs, using tidal breathing flow- volume loop analysis (Amis & Kurpershoek 1986). They found that the shape of the dogs tidal breathing flow-volume loop (TBFVL) was not the same as that considered normal for healthy nonbrachycephalic dogs. They further noted that periodic breathing patterns occurred that were characterized by multiple episodes of alternating hypopnea and arousal. Interestingly, when brachycephalic dogs are anesthetized, they often develop severe obstructive apnea and require immediate endotracheal intubation.

Genetic Influence

Many of the risk factors for OSA, i.e., craniofacial structure, obesity, alcohol consumption, and ventilatory chemosensitivity may have a genetic basis.

The first well-documented case of familial obstructive sleep apnea was reported by Strohl and associates. Strohl et al. (1978) reported a family with multiple male relative with symptoms of hypersomnolence and nighttime restlessness in whom three brother had repetitive obstructive and mixed apnea during sleep. In this family diminished genioglossus electromyographic activity appeared to correlate with respiratory abnormalities during sleep. Two brothers showed loss of tonic activity in the tongue during non-REM sleep at times when upper airway occlusion developed. This finding is clearly abnormal, since in healthy supine subjects loss of genioglossus muscle activity only occurs during REM sleep. They concluded that changes in genioglossus muscle activity suggest a genetic abnormality of respiratory muscle control, a disorder known to cluster in families.

The distribution of symptoms, physiologic responses, and upper airway structure in ten members of one family spanning three generations of subjects with sleep apnea was reported (El Bayadi et al., 1990). All subjects had sleep apnea. Their data showed that all ten family members reported habitual snoring or nighttime gasping and ventilatory responses to hypoxia were markedly reduced in five of the subjects studied. Anatomically, no subjects demonstrated retrognathia but the posterior airway space was reduced in three subjects, the mandibular to hyoid distance was increased in four subjects and the two subjects with the longest soft palate with the most inferiorly displaced hyoid had the most severe sleep disorder. Finally, they suggested that the disorder may occur as a result of interaction between ventilatory control abnormalities and anatomic risk factors consistent with an autosomal dominant mode of inheritance.

The role of inheritance in obstructive sleep apnea was assessed by quantitating the degree of familial clustering of symptoms associated with sleep-related breathing disorders (Redline et al., 1992). In total, 272 subjects from twenty nine families identified through an index case with OSA and twenty one control families with no relative known to have sleep apnea were studied with questionnaires that ascertained health status and symptoms. Odds ratios of habitual or disruptive snoring, breathing pauses, and excessive daytime sleepiness increased progressively for subjects with increasing numbers of symptomatic relatives. Adjustment for body mass index, age and gender modestly reduced these odds ratios to 1.33 from 1.42. They concluded that risk appears to increase progressively with increasing numbers of affected relatives and is not explained by familial similarities in weight, tobacco consumption, or recognized nasal allergies. The significant clustering of symptoms within families further suggests

the need for studies to elucidate the biologic and physiologic correlates of these observations.

Sleep Position and Head Posture

In a sample of twenty normal healthy adults, the associations between cervical lordosis, craniocervical inclination, position of the hyoid bone, and cross-sectional dimensions of the pharyngeal airway were studied (Hellsing 1989). They reported that change from natural head posture to twenty degrees extension resulted in an increases in cervical lordosis and craniocervical inclination. Extending the head also significantly increased hyoid to mandible distance. In addition, they also noted that the horizontal cross-section of the free airway increased significantly at the level of second cervical vertebrae and highly significantly at the fourth cervical vertebrae while there was only a slight increases in the distance between the dorsal tongue surface and the posterior pharyngeal wall.

Tallgren and Solow (1987) investigated relationships between hyoid bone position , facial morphology and craniocervical posture in a dentate normal sample ranging from young children to adults. They indicated that mean vertical distances from hyoid to maxilla, the mandible and cervical column were significantly greater in the older age groups. A large hyoid to mandibular plane distance was associated with a larger mandibular inclination. The position of the hyoid in relation to the cervical column showed more stability than the hyoid relationship to the maxilla and the mandible. But the head position in relation to the cervical spine and the inclination of the cervical column showed no significant differences between the groups. They speculated that hyoid bone position is coordinated both with facial morphology and

cervical posture and that a stable hyocervical relationship reflects the functional demands for maintenance of airway patency. Compared to a reference group, the sample of patients with OSA showed markedly larger cranio-cervical angulation and a corresponding smaller cervical inclination to the horizontal plane (Solow et al., 1991). The experimental sample comprised twenty nine males patients aged twenty eight to seventy with polysomnographic diagnosis of OSA. Cephalometric radiographs were taken in natural head posture (mirror position). Their findings suggested that changes in the head posture change might be interpreted as a physiological adaptation to maintaining airway adequacy. At the same time, the visual axis was maintained in its original orientation in relation to the true vertical.

A relationship between head posture and facial development in growing subjects has been demonstrated in a series of studies. Evidence exists to support the following sequence of events:

1) Obstruction of the upper airway

2) Increase in the cranio-cervical angulation

3) The Soft tissue stretching

4) Vertical direction of facial development (Solow, Kreiborg 1977).

A cephalometric study of the effect of a posture change from the upright to supine showed that tongue length was reduced by approximately the same amount is OSAS and control subjects. However, the tongue cross-sectional area increased 4.3 % and the size of the oropharynx decreased 36.5% in OSA subjects whereas no changes were observed in tongue area and the oropharynx decreased only 28.8% in control subjects (Pae et al., 1994).

Yildirim et al., (1991) found somewhat different result without using the cephalostats. They reported uvular thickening, widening of the retro-glossal hypopharynx, anterior movement of hyoid bone, in both normal subjects and patients, and significant narrowing of the retropalatal airway in the OSA patients in the supine position. They also suggested that possible contributing factors included neck flexon, gravity, and alteration in upper airway reflexes.

Hoffstein and colleagues (1991b) reported an interesting result. They reported that AHI had to be greater than forty in apneic snorers before there was a significant difference in airway diameter at the tip of the palate and 1cm distal to it compared to the nonapneic snorers. They also indicated that the retropalatal distance and airway diameter in this area were significant predictors of snoring, but not apnea. They concluded that airway diameters account for some of the variability in snoring but they do not differentiate between apneic and nonapneic snorers.

Sleep position adjustment may be a viable treatment for some nonobese sleep apnea patients (Cartwright 1984). Sleep apnea severity was found to be twice as high during the time spent sleep on their backs as it was when they slept in the side position for twenty four males OSA patients of more than five AHI. In accordance with this report, it was suggested that a treatment based on changing sleep position might be effective selectively for poor sleepers with OSA who were close ideal body weight (Cartwright et al., 1985). The most commonly employed devices for sleep position training are a gravity-activated position monitor alarm on the chest, a pillow attached to the sleepers back by a belt around the waist or a tennis ball sewn into the pajama top at the mid back level. Many patients with severe sleep apnea of the OSA were reported to

adopt strange sleep positions such as upright in a chair or even kneeling beside the bed to avoid the back sleep posture (Yildirim et al., 1991).

Treatment Modalities for OSA

Obstructive sleep apnea remains a therapeutic challenge, despite growing knowledge of the pathophysiology of the disease and the development of new treatment modalities. The determinants of airway patency during sleep are multifactorial. Therefore, treatment modalities which address single factors such as anatomical anomalies are not uniformly beneficial. The current treatment modalities are categorized into conservative (or nonsurgical) and surgical approaches (Maniglia 1993; Strohl et al., 1986; Brooks 1993; Olson, Strohl 1986).

Westbrook (1990) summarized the medical management of OSAS as follows:

1) Things to Avoid

> All patients with OSA should avoid alcohol and other central nervous system depressants. Alcohol has been shown to be a powerful muscle relaxant and hypnotic that demonstrably makes sleep apnea worse. Narcotics for pain and anesthetics, reserpine which may cause nasal congestion propranolol, testosterone, environmental nasal irritants, smoking and high calorie intake should be avoided.

2) Positional Therapy

> In many patients with sleep apnea, the disordered breathing occurs only when they are on their backs and disappears in all other positions. In these patients, positional therapy can be helpful. But in individuals with severe hypersomnolence, clinicians need to be more aggressive in treatment, even when the apneas are just positional (Cartwright et al., 1991; Aubert 1992).

3) Pharmacological Treatment

> A variety of other drugs have been tried for sleep apnea with limited success (Strohl et al.,1986). The drugs that have been used fall into three general categories: those increasing upper airway patency (such as nasal sprays), those with respiratory-stimulating effects (such as acetazolamide, or

progesterone) and those with more neuroactive effects (such as antidepressants). Nasal decongestants and steroid sprays can be effective in a few cases, especially in those patients who develop OSA as part of a seasonal rhinitis. Protriptyline is probably the most widely used drug because of their pharmacologic action in suppressing REM sleep during which the longest and most severe desaturations are likely to occur. Of the twenty one patients who received medication for a period of three to fourteen months, four had a moderate improvement of sleep apnea while the remaining did not improve at all. In addition, the medication was discontinued because of poor compliance and anticholinergic side effects (Katsantonis et al.,1988). Progesterone, a potent respiratory stimulant, may be beneficial in certain patients with obesity/ hypoventilation syndrome. Nicotine seems to stimulate upper airway dilating muscles more than diaphragm muscle activity. Acetazoamide, which produces a metabolic acidosis, is most useful in central apneas of the periodic type. Strychnine did increase pharyngeal dilator muscle activity but is unlikely to be approved for clinical use. Supplemental oxygen usually just lengthens apneas, but it can ameliorate some of the severe desaturations especially during REM sleep. Compared with air administration, supplemental oxygen reduced the overall number of apneas, but there was a disproportionate decrease in central apneas while obstructive apneas increased (Strohl et al., 1986).

4) Nasal Continuous Positive Airway Pressure (Nasal CPAP)

Nasal CPAP was first introduced by Sullivan et al., in 1981. It provides for a "pneumatic splinting" of the upper airway thus preventing upper airway collapse during sleep. CPAP is the only treatment that challenges tracheostomy in effectiveness. It eliminates obstructive apneas in more than 99% of the patients who can tolerate the device (Westbrook 1990). The effectiveness of CPAP is dependent on the degree of positive pressure applied to the upper airway. CPAP is also known to be effective in the treatment of central sleep apnea, which strongly indicated that the same pathophysiologic processes may cause both disorders (Olson, Strohl 1986).

However, some patients cannot tolerate nasal CPAP.Reasons include claustrophobia, a feeling of suffocation, nasal drying or rhinitis, ear pain, and conjunctivitis. Short-term compliance was reported at approximately 90% (Westbrook 1990), 95% (Strohl et al., 1986) and 100 out of 138 patients (Katsantonis et al., 1988). But long-term compliance is much lower, 66% (Westbrook, 1990) or 53%(Katsantonis et al., 1988)and 65 to 70% (Stokes-Dickens A et al., 1989). However, CPAP is currently considered the treatment of choice for most patients with OSA syndrome because it has a very low risk, a relatively low cost, can be used diagnostically and oxygen can be easily added.

5) Dental Devices

It seems to be natural that dental devices are being promoted as a treatment alternative to surgical approaches or noncompliant CPAP subjects. The rationale for designing dental devices for treatment of OSA can be divided into three categories. The first type is designed to reposition the tongue slightly forward by means of negative pressure applied to the lingual compartment of the device (Cartwright et al., 1982, 1988). The second type is designed to lift the elongated soft palate or reposition the uvula (Adjustable soft palate lifter, Equalizer; Haze 1987). The rationale for this type is to reduce the vibration of the soft palate which causes the snoring sound. The third type is designed to position the mandible forward (Nocturnal airway-patency appliance; George PT 1987 Soll BA, George PT, 1985) (Snoreguard; Schmidt-Nowara WW et al.,1991) (Herbst; Pancherz, 1985; Rider EA 1988) mandibular repositioner (Jasper Jumper, Snoar; Knudson et al., 1992,1993; Bonham PE, 1988). The rationale for this movement is that the tongue is attached to the genial tubercles of the mandible and positioning the mandible forward moves the tongue forward. These mandibular repositioning appliances also change hyoid bone position and modify the lower airway space below the level of the base of the tongue.

Bonham and colleagues (1988) combined the use of cephalometrics and overnight polysomnographic monitoring to analyze the effects of a modified functional appliance on airway, sleep, and respiratory variables in patients with OSA. The mean vertical and horizontal changes in mandibular position while wearing the appliance were 8.49 mm and 2.28 mm respectively. The findings indicate that ten of twelve patients showed marked improvement in complete airway obstruction and it is attributed to the effect of the appliance on the oropharyngeal structure. Their data demonstrated that a mean increase of 2.76 mm was observed in the superior airway space when the appliance was worn. They also noted that the initial superior-anterior airway space was strongly correlated to a change in RDI score when the appliance was worn (r^2= 0.83).

A dental orthosis, designed to increase the size of the upper airway by advancing the mandible (edge to edge relationship horizontally, a 9mm opening vertically) was used in sixty eight OSA patients (Schmidt-Nowara WW et al., 1991). They reported a 75% acceptance rate with 42% of subjects showing on improvement in RDI score. Sleep disturbance improvement from 44% to 10% of non REM were reported. Interestingly, in fifty patients mandibular advancement sufficient to align the incisors produced on increase of posterior airway space (PAS) of 2.3 mm measured on the lateral cephalometric radiograph whereas eighteen patients did not demonstrate an increase in PAS on the cephalogram. They also noted side effects of the appliance such as increased salivation, discomfort of the teeth and gums, and one case of prolonged pain in the temporomandibular joint.

A plastic MAS(Mandibular Advancement Splint) was made for each subject from dental impressions to advance the mandible anteriorly up to 75% of full protrusion (O'Sullivan et al., 1993). Total sleep time, sleep efficiency, % REM sleep, and % sleep spent supine were similar with and

without MAS. MAS was associated with significant improvement in OSA and arterial oxygen saturation. They also reported there was symptomatic improvement in snoring in more than 80% of the patients. Clark et al., (1993) reported the prospective study results of using a two piece removable Herbst appliance in OSA patients. They found that 58% of the subjects improved their RDI score after three months and 52 % of the original subjects were still using the appliance successfully after three years. Another interesting project was conducted by the Sjoholm group (1994). They compared a modified Herbst appliance (mHA) to a muscle relaxation appliance (MR) on nocturnal breathing and body movement activity in OSA patients. The mHA was adjusted to anchor the mandible at 50 % of maximum protrusion and the MR covered an occlusal surfaces but did not protrude the mandible. The mHA showed significant improvement in oxygen desaturation and sleep body movement but not sufficient for acceptable control of sleep apnea. On the other hand, MR did not lead to a significant improvement in sleep quality but did partially reduce upper airway obstruction.

Step-wise regression of baseline polysomnographic and cephalometric values allowed formation of an equation predicting AHI after appliance therapy (Eveloff et al., 1994). Comparison of pre-and posttreatment cephalometric values revealed no significant change in posterior airway space (PAS) despite a reduction in mean AHI In addition, the baseline MP-H was found to be significant shorter in the responders than in nonresponders and MP-H after mandibular advancement was likewise shorter in responders compared to nonresponders. The soft palate length (PNS-P) was significantly shorter in responders after treatment whereas baseline PNS-P was not different between the two groups.

A recent study conducted by Yoshida (1994) showed that subjects using the Esmarch sleep apnea appliance showed average decrease in AI of 58.2%. The diagnostic casts and cephalometric analyses revealed that the device was most effective for patients who exhibit a tendency toward micrognathia with a short soft palate. Another study indicated that subjects with large tongues tend to get tongue retaining devices and patients with obvious retrognathic mandibles tend to get mandibular advancement appliances (Lowe AA 1993).

Even though many case reports and case series have provided with their promising preliminary results, we cannot predict with a significant degree of accuracy the potential success of any one dental appliances.

6) Surgical Modalities

A number of surgical procedures have been proposed to eliminate sites of narrowing in the upper airway.

a) Tracheostomy Tracheostomy was first shown in the 1960s to eliminate most of the respiratory disturbances of sleep apnea by bypassing

the site of obstruction during sleep. However, because of short and long-term complications and the obvious adverse psychosocial influence, tracheostomy is reserved only for the most severe of the OSA patients. Granulation tissue growth, periodic episodes of upper respiratory infection with bronchitis, speech and exercise disturbances are the most common complaints (Koopman, Moran 1990b)

b) Adenoidectomy and/or tonsillectomy Adenotonsillectomy remains the oldest and most common means of treating OSA in children. It is effective in as many as 90% of patient without craniofacial or neurological abnormalities (Brooks LJ 1993). It has also been also shown that obstructive sleep apneas may persist after surgery but their frequency is greatly diminished. Simple tonsillectomy may not be uniformly effective.

c) UPPP Extensive surgical excision of soft tissue in the oropharynx, termed uvulopalatopharyngoplasty, is currently being performed for sleep apnea in many places. It was introduced by Fujita in 1981. Fujita's guidelines for selecting patients for UPPP without tracheostomy are

1) Apnea index less than fifty per hour of sleep
2) Lowest oxygen saturation above fifty percent
3) No significant abnormalities on electrocardiogram
4) No significant cardiopulmonary complications (Koopman, Moran, 1990).

A recent study of long-term success of UPPP after five years demonstrated that more than 80% of all cases had subjective symptomatic improvement but the actual RDI results were significantly worse (Lu et al., 1995). Potential complications of the procedure include speech and swallowing difficulties and regurgitation of food.

d) Maxillary, mandibular and hyoid advancement The combined Le Fort I osteotomy and sagittal split osteotomy is the standard surgical procedure for advancing the maxilla and mandible. The range of maxillary advancement was 4-8 mm and the range of a mandibular advancement was 12-24 mm with a mean of 16 mm (Riley et al., 1987, 1990). They recommended that the surgery would be successful for patients who have an obstruction at the base of tongue and meet one of the following criteria : 1) patients with normal skeletal development and severe OSAS (RDI> 50, oxygen desaturation < 70%): 2) morbidly obese patients: 3) patients with significant skeletal deficiencies (SNB< 74 degrees); and 4) patients who have failed other treatment.

An interesting study evaluated the effect of orthognathic surgery in treating OSA (Waite et al., 1989). Surgical success (respiratory disturbance index less than 10) with maxillomandibular advancement was reported to be 65% and the total desaturations below 90% greatly decreased. Moreover, the posterior airway space (PAS) consistently increased with these surgical procedures. Interestingly, the increases in PAS did not always correlate with

remissions in sleep apnea. Hyoid position after surgery was also variable and did not correlate with success (Waite et al., 1989).

e) Hyoid myotomy and suspension Many OSA patients are in their fifth and sixth decade of life and are not interested in orthodontics and orthognathic surgery. This has led to a development of a procedure that allows isolated advancement of the genial tubercle and genioglossus muscle. The sternohyoid, thyrohyoid and omohyoid muscles are sectioned. Strips of fascia harvested from thigh or temporalis area are then attached to the body of the hyoid (Riley et al., 1987, 1989, 1990). Fifth-five patients with OSA who had hyoid myotomy and suspension were evaluated (Riley et al., 1989). Successful treatment was defined as at least a fifty percent reduction in the number of respiratory events as well as a postoperative RDI less than twenty. Sixty seven percent had a good response and the mean SNB angle of the nonresponders and responders were 75.5 and 81.0 degree respectively. They concluded that the best candidates for hyoid myotomy are those with normal skeletal development, moderate OSAS (RDI less than fifty, oxygen desaturation not less than seventy percent) and who are less than ten percent over ideal body weight.

f) Base-of-tongue resection Verbal reports of excision of portions of the base of the tongue in the midline with either electrocautery or carbon dioxide laser have been encouraging. A wedge resection of the base of tongue approximately 2 to 3 cm long, 2 cm deep and 2 to 3 cm wide may be performed. The risks here include injury to the lingual arteries or the hypoglossal nerve (Koopmann, Moran, 1990). Adaptation occurring after an operative procedure might result in restoration of the airway to its original shape and size. Little is known of the coupling between muscle activity and airway size so that failure to maintain an adequate airway over time may be influenced by both static (elastic) and dynamic (muscular) factors.

Although there has been significant research on OSAS, there are only two studies that attempted to use the discriminant analysis to identify anthropometric and cephalometric variables which can distinguish OSAS subjects from nonapneic snorers. To our knowledge, the first study was conducted by Bacon and colleagues in 1989. This group reported that four variables entered the stepwise discriminant analysis. The variables in rank order of importance were soft palate length, upper face length, anterior cranial base length and lower face height. The jackknifed classification showed that ninety three percent of the population could be correctly classified using these four

variables. But, in this study, the two groups were not matched for weight and age and they used normal healthy dental students as the control group.

A recent study conducted by the Craniofacial Research Group, Department of Orthodontics, Case Western Reserve University, Cleveland, Ohio in 1996 (Hans et al., 1996) used two groups of sixty individuals with a history of loud snoring. One group had significant apneic activity and the other did not. These investigations show that a Craniofacial Risk Index (CRI) was able to correctly classify forty eight of the sixty nonapneic snoring subjects (80%) and forty nine of the sixty apneic subjects (82%) when fourteen variables were used in the discriminant model. Using four variables selected by stepwise regression (age, BMI, hyoid mandibular plane distance, and tongue length) forty six of the sixty nonapneic snorers (77%) and forty seven of the sixty apneic snorers (78%) were correctly classified. In addition, seven variables (cervical vertebrae-SN, BMI, hyoid to mandibular plane distance, tongue area, the ratio of tongue area to intermaxillary area, intermaxillary length, and tongue length) were found to be significantly different between apneic and nonapneic groups.

A qualitative and quantitative analysis of the literature was performed to examine the foundation for any relationship between craniofacial structure and OSAS (Miles et al., 1996). This literature search identified thirty two review articles, sixteen case reports, and ninety five sample studies from a total of 267 articles (254 published and thirteen unpublished). The most consistent and strongest effect sizes (i.e., those with the highest diagnostic accuracies) were found for mandibular plane to hyoid bone position, mandibular plane angle and mandibular body length. However, the authors concluded that evidence for a direct causal relationship between craniofacial structure

and OSAS is unsupported by the literature. These authors also recommended that research methods and data presentation be standardized. The authors also recommended that valid definitions of treatment success as well as for normal respiration, sleep disordered breathing (SDB), and overt OSAS need to be established.

Although there have been numerous studies on OSAS during the past decade, age specific diagnostic criteria have not been established. For example, are commonly used adult criteria for OSA, which are based on the number of complete obstructive apnea (OA) episodes per hour, useful to identify children with serious sleep-related upper airway obstruction? Rosen et al., (1992) examined eleven children who had clinical evidence for obstruction during sleep and physiologic evidence of impaired gas exchange. Only three of 111 severe desaturations were associated with complete obstructive apnea (OA) defined as absence of airflow with continued respiratory efforts for more than ten seconds. And only 55 of 1795 (3%) moderate desaturation episodes were associated with complete OA episodes. They suggested that criteria based on quantitative O_2 saturation data may be a better index of the presence and severity of upper airway obstruction in children.

In another study, Slutsky and Strohl (1980) suggested that because current analyses of episodic hypoxemia use methods that present only a segment of the O_2 profile overtime, comparison of oxygenation within and among subjects may be misleading. They quantified oxygen desaturation by using a special digitizer to convert analog data recorded on strip charts to the corresponding X and Y coordinates. They also suggested that this method may be useful to understand the effects of intermittent hypoxia by providing an accurate method of quantification.

All night polysomnography, the most reliable method for diagnosis, is time-consuming and costly and thus not suitable for large population based studies. Scharf et al., (1990) evaluated the use of self-administered questionnaires and short sleep studies to screen for sleep-disordered breathing (SDB) in forty hypertensive men ages 36-66 unselected for symptoms. The subjects eventually underwent overnight polysomnography to determine their apnea-hypopnea index (AHI) and the percentage of time during which arterial O_2 saturation was less than 90% (T90). They found that there were no features of the symptom questionnaire that strongly predicted AHI and only self-reported snoring and baseline arterial PO_2 significantly predicted T90. But they also found that AHI was not a major determinant of nocturnal desaturation and the AHI and T90 were not significantly correlated. Of the particular interest was the finding that seven patients exhibited a T90≥10% but had a normal AHI (<10). Others have also reported on patients with nocturnal hypoxemia unexplained by nocturnal apnea (Harman et al., 1981; Block et al., 1979; Findley et al., 1985). Other mechanisms, e.g., obesity or subclinical congestive failure, were considered to be responsible for hypoxemia in some of these patients. Because of the possible effects of REM sleep upon ventilation investigators have compared apnea length and arterial oxyhemoglobin saturation during REM and non-REM sleep. Findley et al., (1985) studied twelve patients with obstructive sleep apnea and measured four important variables of sleep-related breathing. The variables were: Mean Apnea Duration (MAD), total number of desaturation episodes per hour of sleep (oxygen saturation falls more than 4 %) or oxygen desaturation index (ODI), Mean Maximum Desaturations per episode or Mean Lowest Desaturation, and SaO_2-50 (the oxyhemoglobin saturation level below which a

patient spends fifty percent of the total sleep time). They concluded that sleep apneas are longer during REM sleep than non-REM sleep in patients with obstructive sleep apnea and hypoxemia is greater during REM sleep than non-REM sleep in subjects with, and without, sleep apnea syndrome.

An interesting study was conducted by Partinen and his colleagues (1988) to determine the respective impact of a well-defined set of cephalometric measurements and body mass index (BMI) on RDI and another index that measures oxygen saturation (SaO_2) drops below 80% that occur during nocturnal sleep (O_2-80-I). Their study indicated that BMI was highly correlated with both RDI and O_2-80-I. BMI always had a much larger coefficient than any of the cephalometric variables. Posterior airway space (PAS) was found to be correlated with RDI but not with oxygen desaturation. This study analyzed only obstructive sleep apnea patients whose average RDI score was 51.1 ± 28.6. In addition, they used on arbitrary level of desaturation (i.e., 80%) to estimate the physiologic impact of apneic events.

The goal of the present study is to correlate cephalometric findings to physiologic sleep measurements other than RDI. We plan to evaluate the relationship among fourteen cephalometric variables, three anthropometric measures, and BMI with respect to longest apnea, longest hypopnea, etc. The results of this study should expand our understanding of the role of anatomic factors in SDB.

STATEMENT OF THESIS

The purpose of the present study is to test a hypothesis that some craniofacial risk factors are associated with upper airway obstruction and apneic activity during sleep. Multiple regression analyses will be employed to develop a prediction model using fourteen cephalometric and three anthropometric measurements as independent variables and nine physiologic measurements as dependent variables.

Specific aims of the present study are to determine if:

1. craniofacial risk factors can predict specific physiologic measurements such as lowest O_2 saturation and longest duration of apnea.

2. a subset of the craniofacial variables is more important in predicting different physiologic variables of sleep disordered breathing.

The respective role of cephalometric risk factors in predicting physiologic variables of sleep may be useful in understanding the pathogenesis of OSAS and in deciding treatment strategy.

METHODS AND MATERIALS

Study Population

The study population consisted of 186 habitual snorers (mean age: 46.04 years, SD: 10.44, range: 25 to 65 years), recruited as part of an ongoing study to develop and test a craniofacial risk index. Subjects were identified through two local area hospital sleep centers (the Division of Pulmonary and Critical care, Department of Medicine, University Hospitals of Cleveland or the Department of neurology, University Hospitals of Cleveland and the Sleep Disorders Center of Veteran's Administration Hospital of Cleveland) and through advertisement.

Selection was limited to the subjects being healthy and free of medical problems such as major psychiatric disease, renal failure, heart failure, and pulmonary disease requiring continuous oxygen. Habitual snoring was identified through subjective report of the problem from the subject, spouse or the bed partner.

Collection of Data

Polysomnographic Data

One hundred seventy one of the subjects had one night recording of unattended home-monitoring sleep study (Edentrace 2, Edentec Corp, Eden Prairie, MN) to assess abnormalities in breathing and gas exchange. The variables monitored by this portable device were heart rate, chest wall impedance, oral and nasal airflow, oxygen saturation, sleep position and snoring. Home sleep monitoring has a correlation of 0.96 with standard laboratory polysomnographic procedures at the hospital (Redline et al., 1991).

An apnea was defined as complete cessation of airflow with some chest wall impedance accompanied by a 2.5% fall in oxygen saturation for at least 10 seconds or longer. An hypopnea was defined as a 50% reduction in airflow compared with baseline, associated with a 2.5% fall in oxygen saturation for at least 10 seconds or longer. The respiratory disturbance index (RDI) was calculated as the total number of apneas and hypopneas divided by the total sleep time in hours. At least six-hours of nocturnal sleep was required for calculating the RDI.

Standard overnight polysomnographic study was performed on fifteen subjects at University Hospitals. Studies included oronasal airflow measured with thermistor, respiratory effort assessed by surface chest wall and abdominal electromyography, arterial saturation assessed by finger pulse oximeter (Nellcor N-200 pulse Oximeter®, Nellcor Inc., CA), and sleep stages evaluated by electroencephalography (EEG), electrooculography (EOG), electrocardiography (ECG) and submental and tibial electromyography (EMG). Recordings were obtained with a polygraph (Grass Model 78 Research Polysomnograph, Grass Instrument Co. MA).

The physiologic measurements recorded by both the in-home and hospital based monitors included baseline oxygen sat, lowest oxygen saturation, average oxygen saturation, longest apnea duration, average apnea duration, longest hypopnea duration and average hypopnea duration.

Anthropometric Data

Body Mass Index (BMI) was calculated as the weight in kilograms divided by height in meters squared. The mean BMI for the entire sample was 30.98±7.58 with a range of 17.23 to 66.46 (kg/m^2).

The subject's head was measured using spreading calipers according to standard anthropometric methods. Classification of head form (Brachycephaly, Mesocephaly, or Dolichocephaly) was done by using the cranial index (ratio between cranial width and cranial length). Classification of facial type (Euryprosopic, Mesoprosopic, or Leptoprosopic) was obtained by calculating the ratio of bizygomatic width measured from the frontal radiograph to facial height measured from the lateral radiograph according to Montagu (1960). The ratio of cranial index to facial index was obtained by dividing the cranial index by the facial index (CI-FI).

Cephalometric Data

Lateral and frontal cephalograms were taken using natural head posture in an upright, seated position, at the end of expiration phase, with the teeth together in centric occlusion, and without swallowing. Natural Head Posture (NHP) was determined by having the subject look into his/her own eyes in a mirror located at the same level as his/her pupils (Moorrees, Kean 1958).

Natural head posture was recorded as an angle between the soft tissue Frankfort line and the true horizontal line obtained by a fluid level device with a metallic line (Showfety et al., 1983). The subject repeated the natural head posture several times and the most reproducible posture was recorded as NHP. Cephalograms were also taken at this position. To enhance the soft tissue outlines, each subject swallowed a tablespoon of contrast medium (Barium Sulfate Esophageal Cream, Rorer Pharmaceutical Corp.) that coated the dorsum of the tongue, the hard and soft palate and the pharyngeal wall.

All cephalograms were traced and digitized by an investigator blinded to the subject's apneic status. Tracings were done on 0.003 inch matte acetate paper (Masel,

Bristol, PA) with 0.3mm H lead pencil. All linear and angular measurements were computed using Dentofacial Planner® (Dentofacial software,Toronto, Canada) and area measurements were obtained by using a customized software program (Geo Calc®, Drs. John Blank, Robert Mensforth, Cleveland State University).

A total of fourteen conventional linear and angular measurements were selected based on the literature and on previous work done at CWRU (Figure 2-5, Glossary). These measurements were Basin to Sella Nasion (BaSN), Cervical Vertebrae to SN (C2C4SN), A-point to Posterior Nasal Spine (A-PNS), Hyoid to Mandibular Plane Distance (H-MP), Intermaxillary Length (Int.Mx.Lth), Soft palate Length (P-PNS), Posterior Nasal Spine to Basin (PNS-Ba), Superior Posterior Airway Space (Phw-Psp), angle between Frankfort and True Horizontal (FH-Hor), and tongue length (TL). Two measurements from the Counterpart Analysis of Enlow et al., (1971) were also used to analyze cranial base alignment (MCF) and ramus width relative to cranial base (RAM-MCF) (Figure 3, 4). The counterpart analysis is based on an individual's own anatomical features and compares different anatomic parts with each other to identify areas of compensation or imbalance.

The relative space occupied by the tongue within the skeletal framework was calculated by taking the ratio of the tongue area (T-area) to the intermaxillary space (Int.Mx. area) in the sagittal plane (Vig, Cohen 1974) (Figure 5).

Statistical Analysis

Descriptive Statistics

Means, standard deviations and ranges were calculated for all continuous independent variables. Distributions for age, race, sex and RDI were also described.

Comparison of Equality of the Means

The Student's t-tests were used for comparison of equality of the means between apneic and nonapneic groups. The t-tests were helpful to describe trends in the data.

Correlation Coefficients

Linear correlation was computed in order to determine the strength of the associations among independent and dependent variables.

Multiple Regression Analysis

All measures were treated as continuous variables. Nine dependent variables were used. These included baseline oxygen saturation, O_2 difference 1 (difference between baseline oxygen saturation and lowest oxygen saturation), O_2 difference 2 (difference between baseline oxygen saturation and average oxygen saturation), lowest oxygen saturation, average oxygen saturation, longest apnea duration, average apnea duration , longest hypopnea duration, average hypopnea duration. The independent variables included the 14 cephalometric and 3 anthropometric measurements.

A forced-all regression model was used to define the contribution of craniofacial risk factors in explaining individual physiologic variables during sleep (Kleinbaum et al., 1988). A step-wise regression model was used to find a subset of the given predictors which best accounts for variation of the individual physiologic measurement of sleep.

All computations were performed using the statistical package for the Social Sciences (SPSS for Windows®).

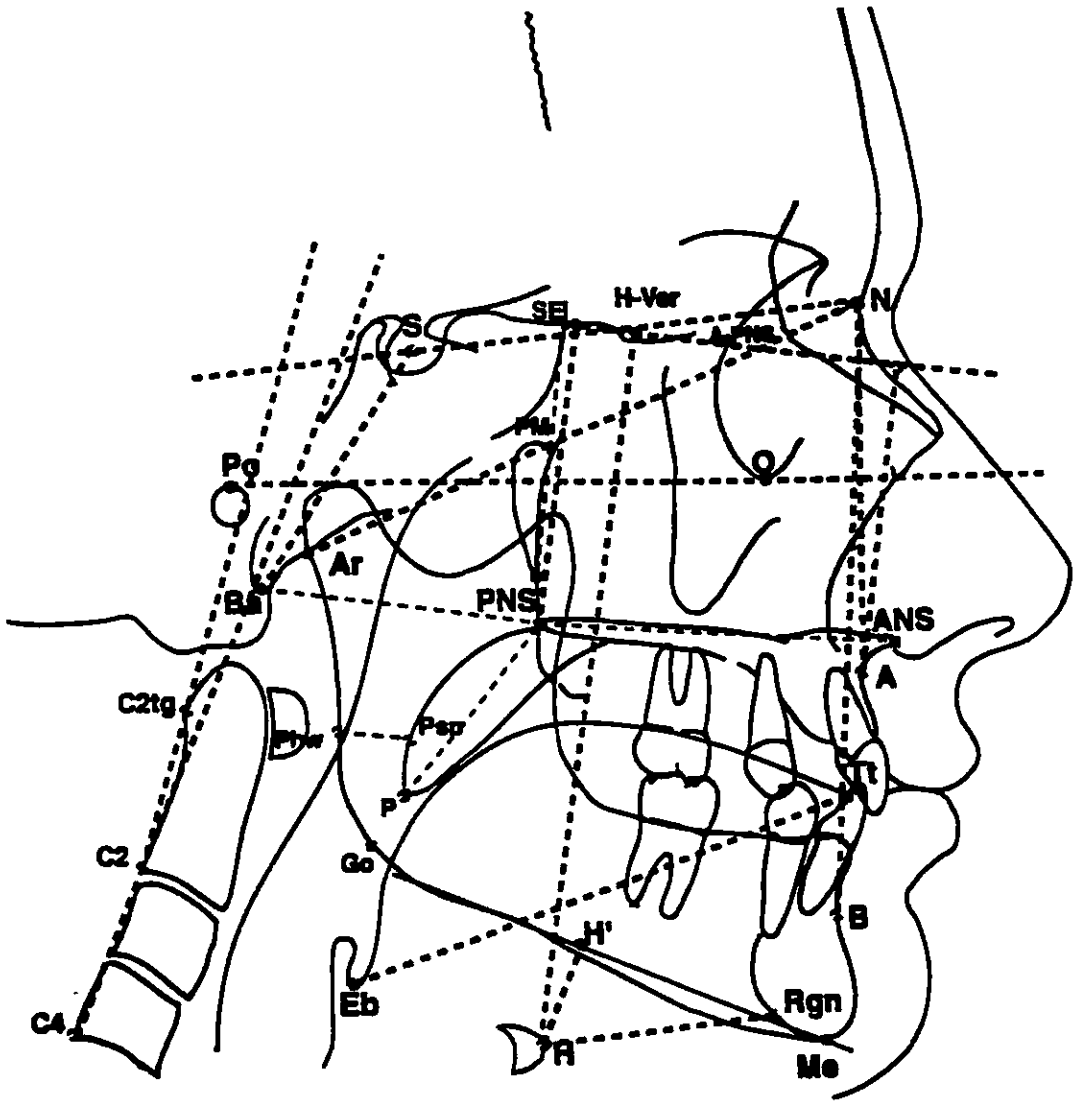


Figure 2. Conventional linear and angular measurements and additional soft tissue measurements.

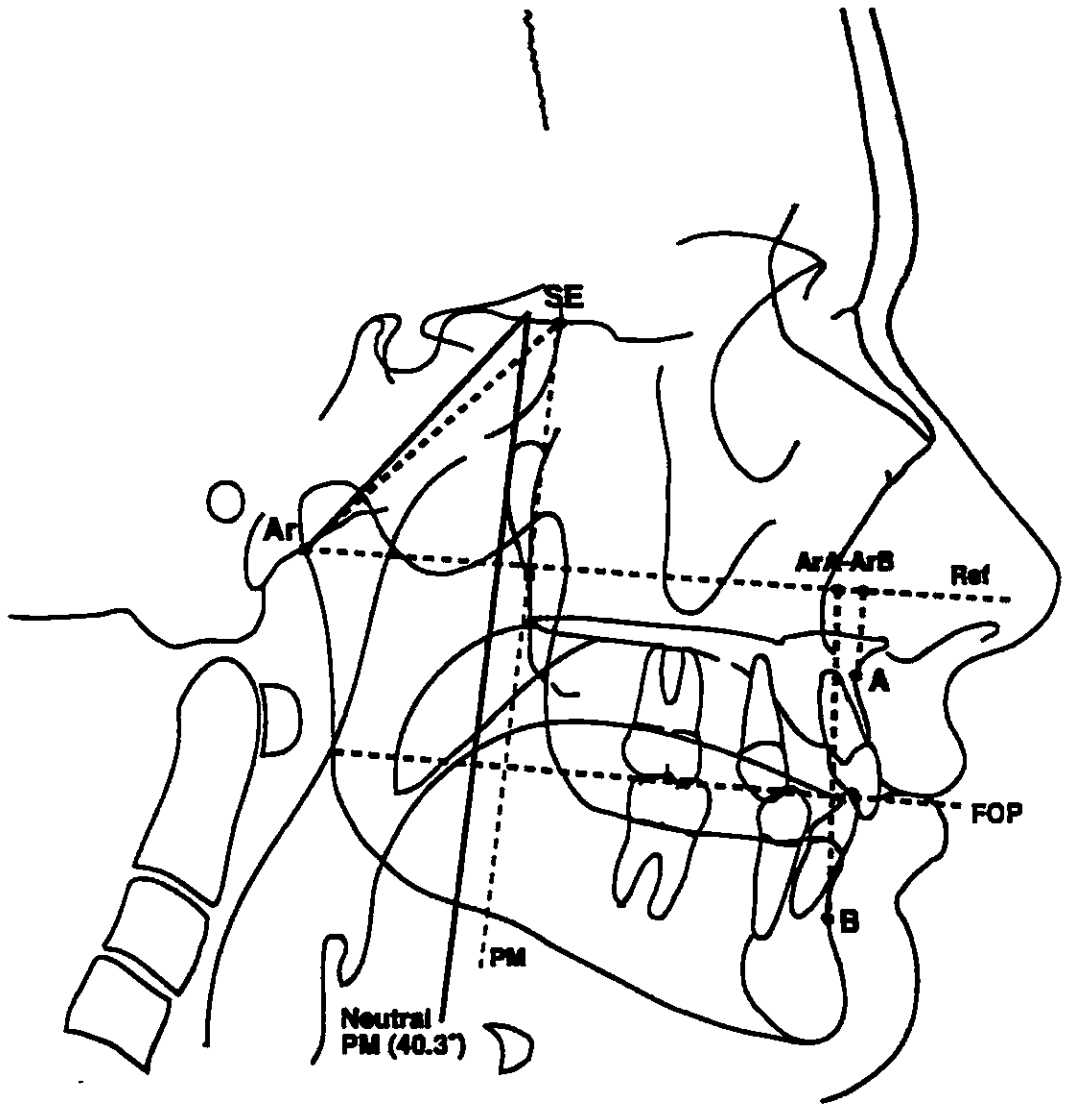


Figure 3. The Counterpart Analysis. This diagram demonstrates the effects of rotational alignment of the individual's own MCF compared to the neutral MCF on corresponding maxillary and mandibular placement. A clockwise (+) alignment is shown.; the relative comparison of cumulative maxillary length from Ar to A point with cumulative mandibular length from Ar to B point is demonstrated.

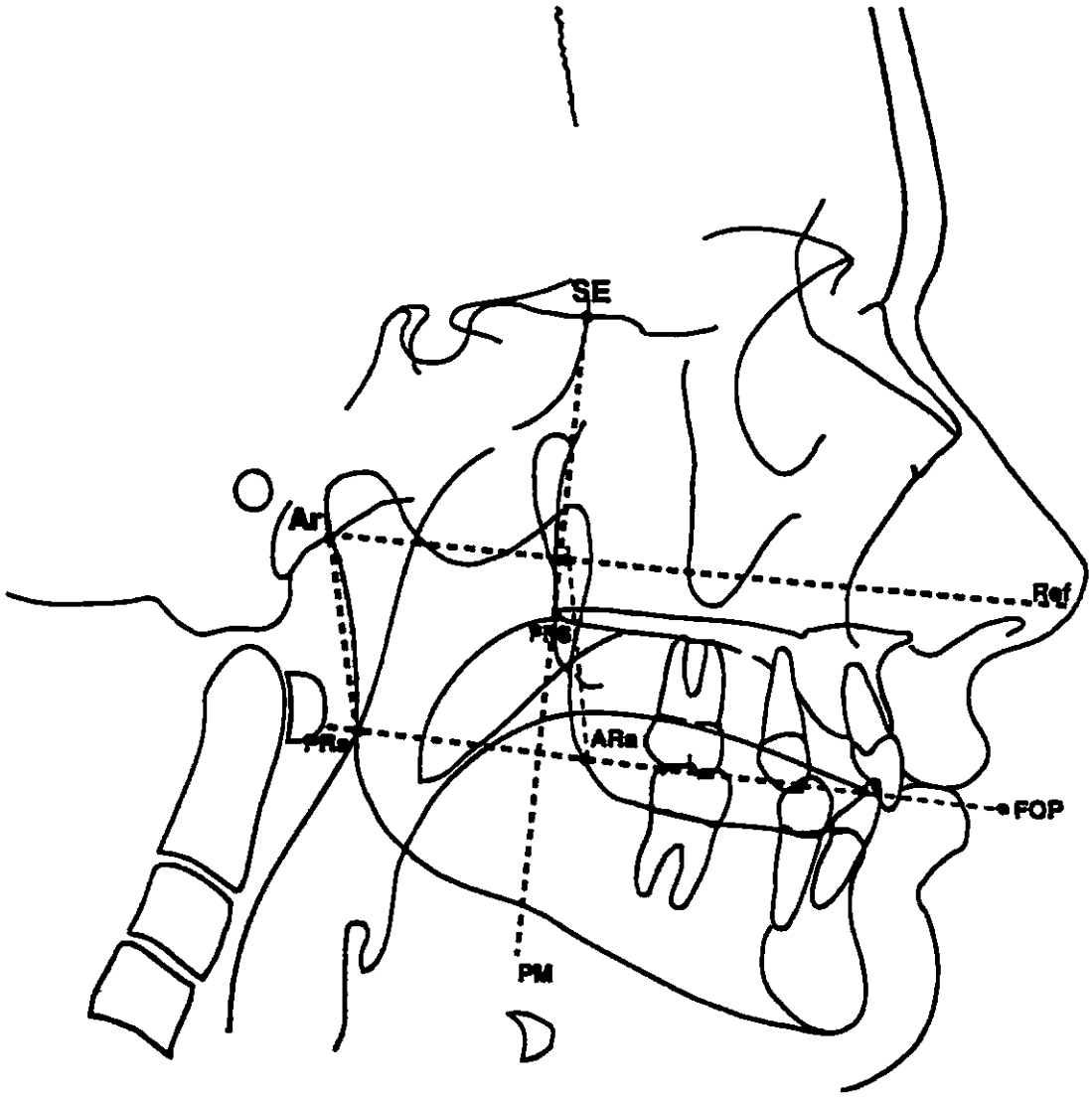


Figure 4. The Counterpart Analysis. This diagram demonstrates comparison of the horizontal dimension of the MCF with the width of the ramus. The diagram shows a protrusive (-) mandibular effect.

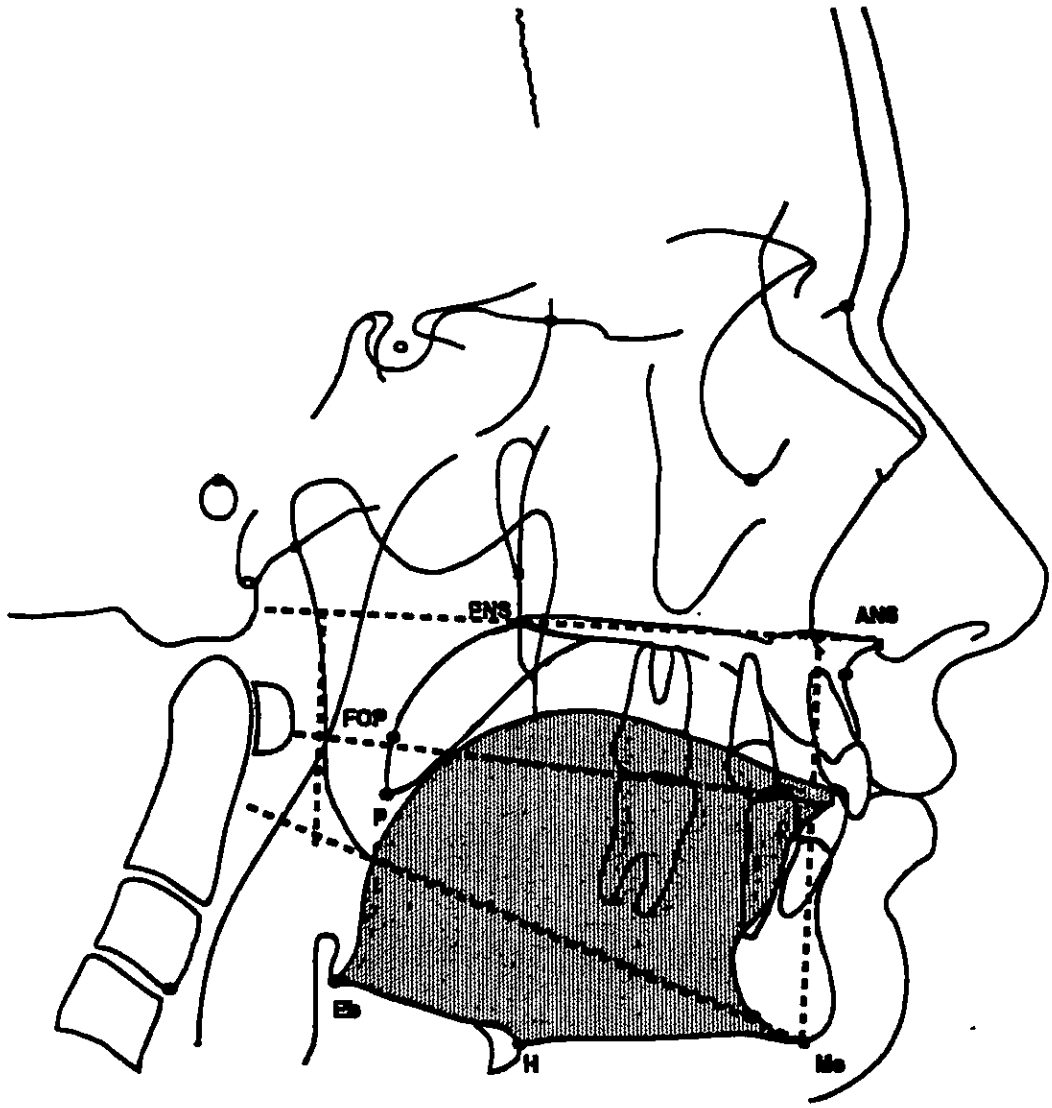


Figure 5. The ratio of tongue area to intermaxillary area. Anterior intermaxillary space height is the length of a perpendicular from the maxillary plane to the menton: Posterior maxillary space height is the length of a perpendicular from the maxillary plane to the mandibular plane which passes through the point where the FOP intersects the pharyngeal wall; Length of the intermaxillary space is a linear distance measured along the FOP from the point where it intersects the tongue tip to where it intersects the pharyngeal wall; Intermaxillary area is calculated by the average of anterior and posterior intermaxillary space height multiplied by intermaxillary length.

RESULTS

The study population consisted of 107 nonapneic (RDI<20) and 79 apneic (RDI>20) snorers (57.5% and 42.5% respectively). Percentage distribution of subjects and referral sources are demonstrated in Table 1. The age of the sample was 46.04±10.44 (years), Body Mass Index (BMI) was 30.98±7.58(kg/m^2),and Respiratory Disturbance Index(RDI) was 26.86±30.6.

TABLE 1.--The Demographic Profile of the Study Population

Variables	Percent
RDI(% apneic)	42.5
Sex (% male)	68.8
Race (% caucasian)	83.3
Sources (BB:VA:UH*)	50.5:41.4:8.1

* BB: Craniofacial Research Group in Bolton-Brush Growth Study Center
VA: Veterans Administration
UH: University Hospitals of Cleveland
RDI>20=apneic
RDI≤20=nonapneic

The means, standard deviations and ranges of all measures are summarized in Table 2. The data collected for the physiologic measurements of sleep showed 95.88±2.46% baseline oxygen saturation, 80.46±11.27 for lowest oxygen saturation(ranged 35% to 96%), 35.14±26.35(seconds) for longest apnea duration and 30.98±16.90 (seconds) for longest hypopnea duration (Table 3)

TABLE 2.--The Anthropometric and Cephalometric Characteristics of the Sample

Variables	Mean±SD	Range	
Age(year)	46.04 ± 10.44	25	65
RDI	26.86 ± 30.64	00	133.79
BMI(kg/m^2)	30.98 ± 7.58	17.23	66.46
CI/FI	0.84 ± 0.08	0.63	1.13
<BaSN	128.94 ± 5.26	114.8	141.2
<C_2C_4SN	112.48 ± 9.83	89.3	139.3
<FH-Hor	3.77 ± 5.57	- 9.6	20.6
A-PNS	51.01 ± 3.97	41.3	64.9
MCF	0.97 ± 3.16	- 10.9	8.3
RAM-MCF	2.33 ± 3.19	- 6.6	11.8
PNS-Ba	47.33 ± 3.95	34.8	58.4
P-PNS	45.99 ± 6.81	28.9	63.9
Phw-Psp	5.31 ± 3.18	0.0	13.4
INT.Mx.L	83.63 ± 7.28	65.0	112.7
T-area	4253.28 ±589.77	2928	6120
TL	86.19 ± 7.99	69.2	109.1
T-Int.M	0.91 ± 0.09	0.70	1.15
H-MP	20.77 ± 7.13	0.1	36.9

TABLE 3.--The Physiologic Measurements of Sleep Study in the Entire Sample

Variables	Mean±SD	Range	
Baseline O_2 Saturation(%)	95.88 ± 2.46	80	100
Lowest O_2 Saturation(%)	80.46 ± 11.27	35	96
Average O_2 Saturation(%)	91.10 ± 4.74	64	97
O_2 Difference 1*	15.21 ± 10.44	0	45
O_2 Difference 2**	4.97 ± 4.48	- 1	36
Longest Apnea (duration in sec.)	35.14 ± 26.35	8	267
Average Apnea (duration in sec.)	16.78 ± 5.90	5	35
Longest Hypopnea (duration in sec.)	30.98 ± 16.90	9	160
Average Hypopnea (duration in sec.)	16.05 ± 4.49	5	40

* O_2 difference between baseline and lowest O_2 saturation
** O_2 difference between baseline and average O_2 saturation

All physiological variables except average hypopnea was significantly different between apneic and nonapneic subjects with higher mean values for the apneic group (Table 4).

TABLE 4.--The Differences of Physiologic Measurements between Apneic (RDI>20) and Nonapneic Groups (RDI≤20)

Variable	Apneic Mean(SD)	Nonapneic Mean(SD)	P-value
Baseline O_2 Sat	94.9 (3.1)	96.6 (1.6)	0.000†
Lowest O_2 Sat	71.9(10.8)	86.7 (6.5)	0.000†
Average O_2 Sat	88.4 (6.0)	93.0 (2.1)	0.000†
O_2 difference 1*	22.9(10.3)	9.9 (6.5)	0.000†
O_2 difference 2**	7.0 (6.0)	3.6 (2.2)	0.000†
Longest apnea duration	48.1(33.7)	26.2(14.3)	0.000†
Average apnea duration	19.2 (6.1)	15.2 (5.2)	0.000†
Longest hypopnea duration	36.3(20.9)	27.3(12.3)	0.001†
Average hypopnea duration	16.4 (4.6)	15.8 (4.4)	0.401

†Using Bonferroni's correction significance assessed at $p \leq 0.005$
* O_2 difference between baseline and lowest O_2 saturation
** O_2 difference between baseline and average O_2 saturation

The correlation of RDI with independent variables (anthropometric and cephalometric values)(Table 5) indicated a higher linear relationship with BMI, H-MP, tongue length and tongue area. The correlation of RDI with physiologic variables of sleep study showed that lowest O_2 saturation, average O_2 saturation and baseline O_2 saturation were strongly correlated negatively with RDI whereas O_2 difference 1 and O_2 difference 2 were correlated positively with RDI (Table 5).

TABLE 5.--Correlation of Craniofacial and Physiologic Variables with RDI

Craniofacial variables	Correlation coefficient	Physiologic variables	Correlation coefficient
Age	0.1443	Baseline O_2	- 0.4456
BMI	0.5194		
CI/FI	- 0.0396	Lowest O_2	- 0.7118
<BaSN	- 0.0113		
$<C_2C_4SN$	0.2745	Average O_2	- 0.6403
<FH-Hor	0.2115		
A-PNS	0.0794	O_2 Difference 1	0.6583
MCF	0.0225		
RAM-MCF	- 0.0282	O_2 Difference 2	0.5209
PNS-Ba	0.1982		
P-PNS	0.0990	Longest Apnea	0.3713
Phw-Psp	- 0.0347		
Int.Mx.L	0.1712	Average Apnea	0.3054
T-area	0.4662		
TL	0.4942	Longest Hypopnea	0.1160
T-Int.M	0.3810		
H-MP	0.5127	Average Hypopnea	- 0.0535

The regression model for dependent variable O_2 difference 1(Table 6) predicted that 40.8% of variation in the O_2 difference between baseline and lowest level oxygenation was explained by the 17 variables in the model. Step-wise results indicated that BMI, H-MP and age explained most of the variation in the dependent variable (Table 7). BMI was the largest predictor (partial r^2=0.259) followed by H-MP (partial r^2=0.089) and age (partial r^2=0.021). These three factors account for 36.9% variation in the model and are positively related with higher values leading to greater oxygen drop.

TABLE 6.--Forced-All Regression Model for Dependent Variable O_2 Difference 1*

Variables	B	Beta	P-value
<BaSN	- 1.1179	- 0.0593	0.4924
<C_2C_4SN	0.0834	0.0775	0.4570
<FH-Hor	0.0248	0.0132	0.8686
A-PNS	0.2797	0.1066	0.2070
Age	0.1666	0.1674	0.0238
BMI	0.6432	0.4637	0.0000
CI/FI	- 8.1226	- 0.0640	0.3792
H-MP	0.3894	0.2666	0.0162
Int.Mx.L	- 0.1003	- 0.0689	0.6061
MCF	0.1408	0.0429	0.6588
P-PNS	- 0.0953	- 0.0622	0.4785
Phw-Psp	- 0.4039	- 0.1218	0.1508
PNS-Ba	0.1936	0.0710	0.5091
RAM-MCF	0.3363	0.1009	0.1472
T area	- 4.5947	- 0.0261	0.8620
T-Int.M	- 8.6779	- 0.0788	0.5247
TL	0.0503	0.0383	0.7729
Constant	- 11.5812		0.6574

* O_2 difference between baseline and lowest O_2 saturation
† The R^2 for the forced-all model was 0.408

TABLE 7.--Step-Wise Regression Model for Dependent Variable O_2 Difference*

Variable	Coefficient(Beta)	R^2	P
1.BMI	0.449	0.259	0.0000
2.H-MP	0.262	0.089	0.0001
3.Age	0.154	0.021	0.0180

* O_2 difference between baseline and lowest O_2 saturation
† The R^2 for the model with 3 variables was 0.369

The regression model for dependent variable O_2 difference 2 (Table 8) demonstrated that only 19% of variation in oxygen drop from baseline to average O_2 Saturation was explained by the 17 variables in the model. Step-wise results indicated that BMI and H-MP explained most of this variation (17%) (Table 9). BMI was the

largest predictor (partial r^2=0.133) followed by H-MP (partial r^2=0.038).

TABLE 8.--Forced-All Regression Model for Dependent Variable O_2 Difference 2*

Variable	B	Beta	P-value
<BaSN	- 0.0091	- 0.0106	0.9160
<C_2C_4SN	0.0053	0.0116	0.9241
<FH-Hor	0.0318	0.0395	0.6743
A-PNS	0.0143	0.0127	0.8976
Age	- 0.0072	- 0.0171	0.8431
BMI	0.1889	0.3114	0.0003
CI/FI	- 3.1786	- 0.0584	0.4956
H-MP	0.1121	0.1789	0.1691
Int.Mx.L	0.0105	0.0166	0.9149
MCF	0.0748	0.0530	0.6432
P-PNS	- 0.0356	- 0.0542	0.6009
Phw-Psp	- 0.1357	- 0.0953	0.3373
PNS-Ba	- 0.0466	- 0.0396	0.7532
RAM-MCF	0.0905	0.0633	0.4374
T area	- 1.2757	- 0.0169	0.9236
T-Int.M	1.9201	0.0404	0.7796
TL	0.0157	0.0278	0.8582
Constant	0.4864		0.9704

* O_2 difference between baseline and average O_2 saturation
† The R^2 for the forced-all model was 0.190

TABLE 9.--Step-Wise Regression Model for Dependent Variable O_2 Difference 2*

Variable	Coefficient (Beta)	R^2	P
1.BMI	0.310	0.133	0.0000
2.H-MP	0.204	0.038	0.0061

* O_2 difference between baseline and average O_2 saturation
† The R^2 for the model with 2 variables was 0.171

The forced-all model for dependent variable lowest O_2 saturation (Table 10) indicated that 46.1% of variation in the lowest oxygen level was explained by 17

variables in the model. Step-wise results showed that BMI,H-MP and age explained most of the variation (41.7%) and their respective contributions were 30.2%, 9.5% and 2% respectively (Table 11). These factors were negatively correlated with higher values leading to lower oxygen saturation levels.

TABLE 10.--Forced-All Regression Model for Dependent Variable Lowest O_2 Saturation

Variable	B	Beta	P-value
<BaSN	0.0631	0.0292	0.7183
<C_2C_4SN	- 0.0612	- 0.0526	0.5914
<FH-Hor	- 0.0604	- 0.0298	0.6946
A-PNS	- 0.2379	- 0.0842	0.2917
Age	- 0.1776	- 0.1641	0.0190
BMI	- 0.7378	- 0.4888	0.0000
CI/FI	14.8104	0.1072	0.1188
H-MP	- 0.4723	- 0.2990	0.0043
Int.Mx.L	0.0669	0.0424	0.7375
MCF	- 0.1827	- 0.0513	0.5769
P-PNS	0.1487	0.0895	0.2828
Phw-Psp	0.4651	0.1296	0.1049
PNS-Ba	- 0.2796	- 0.0947	0.3529
RAM-MCF	- 0.3354	- 0.0930	0.1592
T area	5.7773	0.0304	0.8299
T-Int.M	7.4157	0.0620	0.5967
TL	- 0.0421	- 0.0295	0.8134
Constant	113.4611		0.0000

† The R^2 for the forced-all model was 0.461

TABLE 11.--Step-Wise Regression Model for Dependent Variable Lowest O_2 Saturation

Variable	Coefficient (Beta)	R^2	P
1.BMI	- 0.486	0.302	0.0000
2.H-MP	- 0.274	0.095	0.0000
3.Age	- 0.147	0.020	0.0178

† The R^2 for the model with 3 variables was 0.417

All the 17 variables could predict 33.8% of the variation in average O_2 saturation whereas the step-wise regression model predicted only 29.1% (Table 12 and Table 13). The two largest predictors were also BMI and H-MP.

TABLE 12.--Forced-All Regression Model for Dependent Variable Average O_2 Saturation

Variables	B	Beta	P-value
<BaSN	0.0029	0.0032	0.9709
$<C_2C_4SN$	- 0.0112	- 0.0228	0.8318
<FH-Hor	- 0.0531	- 0.0627	0.4532
A-PNS	0.0216	0.0182	0.8373
Age	- 0.0042	- 0.0092	0.9043
BMI	- 0.2315	- 0.3603	0.0000
CI/FI	5.8268	0.1000	0.1909
H-MP	- 0.1265	- 0.1900	0.1018
Int.Mx.L	0.0014	0.0022	0.9873
MCF	- 0.1403	- 0.0934	0.3629
P-PNS	0.0456	0.0659	0.4783
Phw-Psp	0.0529	0.0352	0.6925
PNS-Ba	0.0286	0.0228	0.8385
RAM-MCF	- 0.1238	- 0.0816	0.2662
T area	- 0.0012	- 0.1511	0.3373
T-Int.M	- 4.3435	- 0.0858	0.5080
TL	0.0109	0.0180	0.8963
Constant	100.7714		0.0000

† The R^2 for the forced-all model was 0.338

TABLE 13.--Step-Wise Regression Model for Dependent Variable Average O_2 Saturation

Variable	Coefficient (Beta)	R^2	P
1.BMI	- 0.394	0.216	0.0000
2.H-MP	- 0.283	0.075	0.0000

† The R^2 for the model with 3 variables was 0.291

The regression model for the dependent variable longest apnea duration showed

that only 26.3% of the variation was explained by the 17 variables in the model (Table 14). Step-wise variable selection included age (partial r^2= 0.103), T-Int.M (partial r^2=0.054), BMI (partial r^2= 0.033), and <BaSN (partial r^2= 0.022) as the 4 factors that explained 21.2% of the variation in longest apnea duration (Table 15).

TABLE 14.--Forced-All Regression Model for Dependent Variable Longest Apnea Duration

Variables	B	Beta	P-value
<BaSN	- 0.9562	- 0.1907	0.0499
<C_2C_4SN	0.1033	0.0378	0.7440
<FH-Hor	0.1721	0.0362	0.6855
A-PNS	0.2726	0.0412	0.6626
Age	0.7424	0.2961	0.0004
BMI	0.7983	0.2284	0.0057
CI/FI	10.7118	0.0334	0.6814
H-MP	- 0.1502	- 0.0406	0.7401
Int.Mx.L	- 1.0576	- 0.2880	0.0560
MCF	0.9258	0.1119	0.3071
P-PNS	0.5301	0.1370	0.1644
Phw-Psp	- 0.0397	- 0.0047	0.9599
PNS-Ba	0.4387	0.0639	0.5968
RAM-MCF	0.3087	0.0367	0.6361
T area	4.0120	0.0090	0.9571
T-Int.M	15.2119	0.0544	0.6930
TL	0.3139	0.0943	0.5245
Constant	67.2568		0.3617

† The R^2 for the forced-all model was 0.263

TABLE 15.--Step-Wise Regression Model for Dependent Variable Longest Apnea Duration

Variable	Coefficient (Beta)	R^2	P
1.Age	0.293	0.103	0.0001
2.T-Int.M	0.186	0.054	0.0104
3.BMI	0.204	0.033	0.0044
4.<Ba-SN	- 0.149	0.022	0.0349

† The R^2 for the model with 4 variables was 0.212

All 17 variables predicted 25.8% of the variation in the average apnea duration (Table 16). The step-wise regression model explained 22.8% (Table 17) of the variation using age, tongue length, and intermaxillary length.

TABLE 16.--Forced-All Regression Model for Dependent Variable Average Apnea Duration

Variables	B	Beta	P-value
<BaSN	- 0.0660	- 0.0588	0.5441
$<C_2C_4SN$	0.0169	0.0277	0.8113
<FH-Hor	- 0.0832	- 0.0782	0.3838
A-PNS	0.0871	0.0588	0.5346
Age	0.2090	0.3723	0.0000
BMI	0.0311	0.0398	0.6271
CI/FI	- 0.5881	- 0.0081	0.9200
H-MP	0.0654	0.0790	0.5200
Int.Mx.L	- 0.2860	- 0.3479	0.0217
MCF	0.1906	0.1029	0.3488
P-PNS	0.0563	0.0651	0.5091
Phw-Psp	- 0.0310	- 0.0166	0.8613
PNS-Ba	0.0106	0.0069	0.9543
RAM-MCF	0.0152	0.0080	0.9173
T area	- 0.0013	- 0.1317	0.4359
T-Int.M	- 6.7497	- 0.1078	0.4357
TL	0.2647	0.3553	0.0178
Constant	17.6030		0.2880

† The R^2 for the forced-all model was 0.258

TABLE 17.--Step-Wise Regression Model for Dependent Variable Average Apnea Duration

Variable	Coefficient (Beta)	R^2	P
1.Age	0.350	0.138	0.0000
2.TL	0.293	0.032	0.0002
3.Int.Mx.L	- 0.265	0.058	0.0006

† The R^2 for the model with 3 variables was 0.228

For the longest hypopnea duration, only 17.6% of variation was predicted by all the variables forced into the model (Table 18). The step-wise results indicated that age, BMI and P-PNS were the most important variables for predicting the longest hypopnea duration with their contribution 5.9%, 4.3% and 2.4% respectively (Table 19).

TABLE 18.--Forced-All Regression Model for Dependent Variable Longest Hypopnea Duration

Variables	B	Beta	P-value
<BaSN	0.3600	0.1115	0.2739
$<C_2C_4SN$	- 0.1921	- 0.1097	0.3697
<FH-Hor	- 0.1097	- 0.0360	0.7048
A-PNS	0.0011	2.6950	0.9978
Age	0.3791	0.2337	0.0086
BMI	0.5244	0.2290	0.0080
CI/FI	- 21.3225	- 0.1037	0.2305
H-MP	- 0.3006	- 0.1274	0.3303
Int.Mx.L	0.3254	0.1359	0.3901
MCF	- 0.1165	- 0.0217	0.8524
P-PNS	0.5794	0.2337	0.0269
Phw-Psp	0.2612	0.0484	0.6275
PNS-Ba	- 0.7677	- 0.1729	0.1742
RAM-MCF	0.2925	0.0544	0.5090
T area	- 0.0032	- 0.1159	0.5195
T-Int.M	42.0203	0.2336	0.1101
TL	0.0451	0.0212	0.8925
Constant	- 50.3577		0.3232

† The R^2 for the forced-all model was 0.176

TABLE 19.--Step-Wise Regression Model for Dependent Variable Longest Hypopnea Duration

Variable	Coefficient (Beta)	R^2	P
1.Age	0.211	0.059	0.0056
2.BMI	0.186	0.043	0.0120
3.P-PNS	0.161	0.024	0.0350

† The R^2 for the model with 3 variables was 0.126

All the 17 variables predicted only 8.6% of the variation in average hypopnea duration (Table 20). This along with the 3.2% predicted by the step-wise method (Table 21) was the poorest model. None of cephalometric variables were included in predicting the average hypopnea duration when the step-wise regression model was used.

TABLE 20.--Forced-All Regression Model for Dependent Variable Average Hypopnea Duration

Variables	B	Beta	P-value
<BaSN	- 0.0575	- 0.0670	0.5318
$<C_2C_4SN$	0.0135	0.0289	0.8218
<FH-Hor	- 0.0082	- 0.0101	0.9194
A-PNS	0.1064	0.0951	0.3655
Age	0.0667	0.1547	0.0967
BMI	6.1346	0.0010	0.9911
CI/FI	- 3.4328	- 0.0628	0.4902
H-MP	- 0.0247	- 0.0393	0.7749
Int.Mx.L	0.1095	0.1720	0.3020
MCF	- 0.0110	- 0.0077	0.9500
P-PNS	0.1204	0.1826	0.0994
Phw-Psp	0.0694	0.0483	0.6454
PNS-Ba	- 0.0327	0.0277	0.8355
RAM-MCF	0.0970	0.0679	0.4343
T area	- 0.0013	- 0.1804	0.3417
T-Int.M	12.1760	0.2544	0.0986
TL	- 0.1048	- 0.1854	0.2638
Constant	6.8837		0.6294

† The R^2 for the forced-all model was 0.086

TABLE 21.--Step-Wise Regression Model for Dependent Variable Average Hypopnea Duration

Variable	Coefficien (Beta)	R^2	P
1.Age	0.180	0.032	0.0189

† The R^2 for the model with 1variable was 0.032

Table 22 summarized and compared the regression models for eight dependent variables and the most important cephalometric and anthropometric predictors.

TABLE 22.--Summary and Comparison of Regression Models

PHYSIOLOGIC VARIABLES	Forced-all (%)	Step-wise (%)	PREDICTORS
O2 difference 1	40.8	36.9	BMI/H-MP/Age
O2 difference 2	19.0	17.0	BMI/H-MP
Lowest O2 sat	46.1	41.7	BMI/H-MP/Age
Average O2 sat	33.8	29.1	BMI/H-MP
Longest apnea duration	26.3	21.2	Age/T-IntM/BMI/BaSN
Average apnea duration	25.8	22.8	Age/TL/Int.Mx.L
Longest hypopnea duration	17.6	12.6	Age/BMI/P-PNS
Average hypopnea duration	8.6	3.2	Age

DISCUSSION

Although there is consensus on that a diagnosis of sleep-disordered breathing should be based on the number of apneas and hypopneas that occur during sleep, the appropriate number of apneas and hypopneas for diagnosing clinically significant obstructive sleep apnea varies among practitioners. While the cut-off value of five or more apneas (AI) per hour is historically considered abnormal, the origins of this number are vague and somewhat arbitrary. In addition, the longevity of individuals who have an AI>5 on polysomnography is not necessarily reduced (Bresnitz et al., 1994). In addition, various studies have used different definitions of sleep apnea syndrome, making comparisons difficult.

RDI is a traditional index and a summary measure. It is the most commonly used criteria to differentiate diseased subjects from normals. However, it has yet to be shown whether RDI can predict the progression of illness over time, predict the degree of sleepiness as measured by the multiple sleep latency test, or track the natural history of disease expression (Sforza et al., 1994).

Qualitative and quantitative measurements other than RDI have been proposed to delineate the entity of OSA more specifically. As a recommended by the American College of Chest Physicians and the Association of Sleep Disorders Centers (Martin et al., 1985) reports should contain sleep staging, type of respiratory patterns, oxygen saturation, cardiac rate and rhythm, and interpretation. Moreover, it was suggested that criteria based on quantitative O_2 saturation data may be a better index of the presence

and the severity of upper airway obstruction in children (Rosen et al., 1992). Another study indicated that RDI was not a major determinant of nocturnal desaturation and there was a lack of significant association between the percentage of sleep time during which the saturation was less than 90% (T90) and RDI (Scharf et al., 1990). The presence of illness as identified by the patient or the physician is the result of an integration of the number of apneas and hypopneas as well as subjective symptoms, levels of susceptibility, sleep fragmentation and hypoxemia. These later indicators are not captured by RDI. Because of this new push for more sleep data, many studies now include quantification of oxygen saturation (Slutsky, Strohl 1980), duration of apnea and hypopnea (Findley et al., 1985; Harman et al., 1981; Block et al., 1979) and ODI (the total number of SaO_2 drops≥3% by the determined total sleep time in hours) (Stoohs et al., 1995).

An index that counts the number of transient oxygen desaturations such as the Oxygen Desaturation Index (ODI) may eventually replace or augment indices that count the number of cessations in airflow. However, employment of SaO_2 monitoring alone carries with it a risk of finding both false-negative and false-positive results. For example, sleep time cannot be estimated at all and body movements often create artifacts in the SaO_2-recording that may be indistinguishable in shape from desaturations resulting from apneas. In addition, some cases of OSAS with predominantly short apneas have few significant decreases in SaO_2. However, the large number of arousals still leads to daytime somnolence (Svanborg et al., 1990). As long as one keeps in mind these limitations, one can evaluate the relationship between cephalometric variables and sleep-related physiologic variables such as oxygen saturation, duration of

apnea.

To our knowledge, there have been only two studies (Partinen et al., 1988; Nelson, Hans 1996) that have tried to predict RDI using craniofacial risk factors. The first study (Partinen et al., 1988) was conducted in 157 OSA patients (mean RDI=51.1, range 10-130) and used RDI and O_2-80-I (i.e., the number of SaO_2 drops below 80 percent per hour of sleep) as the dependent variables. The second study (Nelson, Hans 1996) also used RDI as the outcome variable.

In contrast to previous studies, the present study employed both apneic and nonapneic subjects (the mean RDI =26.86, range 0-133.79) to predict the variables that also describe the severity of sleep disordered breathing over RDI alone using craniofacial variables. There are several major findings from our data. First, anthropometric and craniofacial variables were good predictors for oxygen desaturation level or drops, but not for duration of apnea or hypopnea. Second, different subsets of craniofacial and anthropometric variables explained the variation in different physiologic measures of sleep. Third, craniofacial factors that predicted change in oxygen saturation and duration of apnea/hypopnea were similar to those that predicted RDI.

Consistent with previous reports (Hans et al., 1996), BMI was the most important predictor of changes in O_2 saturation. Hans et al., (1996) showed that the correlation with BMI was very strong, indicating that obesity alone may contribute to some individuals being in the "at risk" group. But this interpretation was based on use of discriminant analysis that treated apneic status as a dichotomous variable. On the other hand, step-wise regression models indicated that obesity accounted for only 12%

variation in RDI. Although a significant risk factor for OSAS, obesity may not always predispose an individual to disease (Nelson, Hans 1996). In comparison to Nelson's data, our data shows that BMI explained more of the variation in O_2 difference 1 (25.9%), lowest oxygen saturation (30%) and average O_2 saturation (21.6%) than the variation in RDI (12%) although overall prediction was lower in predicting the same variables (40.8%/ 46.1%/ 33.8% respectively) than in predicting RDI (66%). The present data is also consistent with the report by Partinen et al., (1988) who showed that BMI explains a large proportion of the variation in RDI and O_2-80-I.

In the present study, in contrast to BMI age was a predictor for duration of apnea and hypopnea. In addition, soft tissue structures such as tongue length and soft palate length are the only craniofacial factors involved. Even the contributions of tongue length and soft palate were minimal. We speculate that increased BMI, especially central obesity, might be associated with impairment of diaphragm function, decreased functional residual capacity (FRC), and through coupling of FRC to pharyngeal size, reduction in pharyngeal cross-sectional area. Another possible explanation would be relatively increased oxygen consumption that occur in the presence of both obesity i.e., abdominal loading and upper airway obstruction or increased instability of oxygen stores. Several reports have emphasized that a thick neck predisposes individuals to disease. However, it is not clear whether neck size is an indicator with an effect independent of BMI.

The present data supports the relationship between OSAS and age associated with obesity. In this model, although age was the most consistent factor to predict duration of apnea/hypopnea, it was not as strong as BMI. This may be because the study

population had about 17% African Americans. Redline (unpublished observation 1995) have reported that while age is a risk factor in the Caucasian population it is not a strong risk factor for African Americans. Therefore, it is not clear at this time if this observed ethnic variation is due to true differences in disease susceptibility or the result of the survival bias in the African American group. In addition, data from the Cleveland Family Study clearly demonstrated the increasing prevalence of OSA and snoring with age.

Why does age influence the duration of apnea and hypopnea rather than oxygen desaturation? One explanation is that age might be associated with compromised surface tension or compromised airway compliance. For example, habitual snoring is mainly caused by tissue redundancy in the area of the soft palate and posterior pharyngeal wall. Since snoring increases with increasing age, the same mechanisms may relate to apnea/hypopnea duration. Another explanation is that age might be associated with delayed or blunted response of upper airway to neurologic inputs. Still a third possibility would be that changes in the architecture or composition of sleep stages that occur with age contribute to apnea /hypopnea duration (i.e., relative increases in REM sleep compared to NREM sleep). Support for this theory can be found in Findley et al., (1985) who found that apnea duration was longer during REM than non-REM sleep in all patients with OSAS.

Our step-wise results found hyoid to mandibular plane distance to be the second most important variable explaining O_2 saturation and O_2 difference. But H-MP did not correlate with the duration of apnea or hypopnea. Anteroinferior position of the hyoid bone has been observed in many previous studies of OSAS patients (Strelzow et al.,

1988; DeBerry-Borowiecki et al., 1988; Partinen et al., 1988; Tsuchiya et al., 1992). There has been speculation that the inferior position of the hyoid bone, along with an elongated soft palate and upward head extension are all secondary phenomena related to variations in neck size (Davies, Stradling 1990). Davies and Stradling proposed that OSAS patients extend their head in upward position due to mass loading of the neck area. This extension results in inferior positioning of the hyoid bone. This is also a relationship between hyoid bone location and age. In the average three year old the hyoid bone is at a level between the third and fourth cervical vertebrae. From here it gradually descends to the level of the fourth vertebrae by adulthood (Bench 1963). Bench also found that the behavior of the hyoid bone was more consistent with growth of the vertebrae than with the chin. Descent of the hyoid bone seemed also to be consistent with a lowering of the tongue. The correlation between hyoid bone position and tongue-related measurements was high in the present study ($r=0.5$ between H-MP and tongue length, $r=0.71$ between H-MP and T/In Mx area).

Another study by Cohen and Vig (1976) showed that tongue mass increases until maturity and then with age becomes relatively larger in relation to the bony intermaxillary space. Therefore, the hyoid bone and thus the tongue would drop considerably over time to compensate for increases in bulk and to maintain airway and tongue function during growth. Previous reports on the growth of the pharynx and its physiologic adaptation also support the findings of the present study (Tourne 1991). Tourne found that adult nasopharyngeal depth is established early, and the pharyngeal capacity increases mainly by vertical growth at the lower level. It was postulated by Tourne that lowering of the hyoid bone represented an adaptation to maintain a

relatively constant anteroposterior diameter of the airway. Hans et al., (1996) also found that H-MP was the first variable selected using the step-wise discriminant method, and had the third highest standardized coefficient in the forced-all linear model. They suggested three possible reasons for the strong association between hyoid bone position and apneic activity. One possible explanation was that, since the hyoid bone is suspended in the pharynx, there may be a "hyoid response" to apnea that reduces the tonal activity of the suprahyoid musculature or increases activity in the infrahyoid muscles. Another possible explanation was that hyoid bone position drops in response to increases in soft tissue mass in the neck. The third possibility was that lowering of the hyoid bone was related to an elevation in head position. However there was poor correlation between H-MP and FH-horizontal in the Hans' study (r=0.1261). It is not clear at the present time why H-MP explains changes in oxygenation very well but it does not explain duration of apnea and hypopnea.

One of the interesting findings from the present study was that soft tissue morphology was a relatively good predictor for duration of apnea and hypopnea. Step-wise variable selection in the regression model chose tongue length, the ratio of tongue area to intermaxillary area and soft palate length (P-PNS) as predictors of apnea/hypopnea duration. Similarly Nelson and Hans (1996) demonstrated that tongue length was the most important variable in predicting RDI and explained 40% of variation of RDI in the step-wise model. Soft tissue morphology of OSA patients was compared to that of the control group by Lyberg et al., (1989b). They reported that the most characteristic finding was increased length and thickness of the soft palate in OSA patients. The soft palate had overall increased dimension and occupied significantly

more of the upper pharyngeal airway space. The tongue assumed a more upright position with more mass in the hypopharyngeal region to the depression of the hyoid. However, this study used a small sample (twenty five OSA and ten control) and the base of the epiglottis was more inferiorly positioned in OSAS subjects, but tongue length was not significantly different between two groups.

Nelson and Hans (1996) suggested three possible ways increasing in tongue length could lead to increased apneic activity. First, the tongue is a muscular organ and in the supine position, the tongue falls back posteriorly and obstructs the hypopharyngeal space. Thus, the longer the tongue is, the more likely that obstruction of the airway will occur. Second, increased tongue length could have been influenced by an inferior position of the epiglottic base. Third, tongue length could have been a surrogate measure for some other independent variable in step-wise regression model.

Surprisingly, it seems that there is no strong correlation between duration of apnea/hypopnea and O_2 desaturation. For example, the highest correlations were r=0.3196 between average duration of apnea and O_2 difference 1, and r=0.3157 between longest duration of apnea and O_2 difference 1. The lowest correlation was r=-0.0292 between average duration of hypopnea and average O_2 saturation. So, it may explain the reason why there are two different subsets of variables to predict two different apneic activities i.e., O_2 desaturataion and duration of apnea/hypopnea. It is also possible to clinically observe hypoxemia without apnea (Scharf et al., 1990) and some cases of OSAS with predominantly short apneas which may have few significant O_2 desaturation but still a large number of arousals causing daytime sleepiness (Svanborg et al., 1990).

There is certainly a need to address the need for standards in the assessment of disease and the uncertainty that exists concerning the pathogenesis of the OSAS. However, based on our findings it appears that treatment strategies and guidelines should be individualized and based on a more precise diagnosis and comprehensive understanding of the pathophysiology of OSAS.

Potential Limitations of the Study

There have been several methodological limitations to the present study. Some of the study population consisted of the subjects who were care-seeking volunteers while others were from an epidemiologic study thus introducing a potential selection bias. There was no objective method for quantifying habitual snoring. Snoring was primarily assessed by self- and bed partner reports. Sample distribution of RDI including all nine independent variables such as O_2 difference 1, lowest oxygen desaturation and so on may not be an ideal, normal distribution.

Stratification of subjects based on RDI, BMI and ethnic background could result in different prediction rate or different subsets of variables from the present findings.

Cephalometric radiography which is taken in awake state, upright position and provides a static, two-dimensional image could not entirely measure a dynamic, three-dimensional upper airway. One final limitation is the fact that the present data cannot describe "clinical severity index" unless we really combine RDI, O_2 desaturation, Epworth Sleepiness Scale (ESS), quantification of oxygenation (e.g., T50) and Multiple Sleep Latency Test (MSLT).

SUMMARY AND CONCLUSIONS

The present study attempted to test the hypothesis that some specific craniofacial risk factors are associated with upper airway obstruction during sleep. The study population consisted of 186 habitual snorers who were recruited from three major referral sources in Greater Cleveland area over a period of six years. The sample's mean age was 46.04 years ranging between 25 and 65, and RDI ranged 0 to 133.79 (107 nonapneic snorers and 79 apneic snorers). All the seventeen variables (fourteen cephalometric and three anthropometric) were used to develop the regression model for eight independent variables of physiologic measurements during sleep.

This study specifically focused on answering the following questions:

1. Are craniofacial structures able to predict specific physiologic measurements during sleep?

2. Do all of the craniofacial risk factors have equal importance in predicting the physiologic variables during sleep or are there a subset of the craniofacial variables that are more important than the rest?

Analyses of the data yielded the following results:

1. There was a statically significant difference ($p \leq 0.005$) between apneic and nonapneic snorers in all physiologic measurements of sleep except average duration of hypopnea.

2. RDI was highly correlated with BMI, H-MP, tongue length and tongue area ($r = 0.5194, 0.5127, 0.4942, 0.4662$ respectively).

3. RDI was highly correlated with lowest O_2 saturation, O_2 difference 1, average O_2 saturation and O_2 difference 2 ($r = -0.7118, 0.6583, -0.6403, 0.5209$ respectively).

4. There was no strong, linear association between duration of apnea/ hypopnea and oxygen desaturation such as O_2 difference 1 or 2, average O_2

saturation level and lowest O_2 saturation.

5. The best explained physiologic variable by the anthropometric and cephalometric risk factors was lowest O_2 saturation (Forced-all 46.1%, Step-wise 41.7%) followed by O_2 difference 1 (Forced-all 40.8%, Step-wise 36.9%).

6. The anthropometric and cephalometric variables explained very poorly the variation in longest duration of hypopnea and average duration of hypopnea (17.6% and 8.6% respectively by forced-all).

7. In general, the anthropometric and cephalometric risk factors were good predictors for oxygen saturation but not for duration of apnea and/ or hypopnea.

8. The anthropometric and cephalometric variables predicted better duration of apnea than that of hypoppea, lowest O_2 saturation than average O_2 saturation, and O_2 difference 1 than O_2 difference 2.

9. The most important predictors for oxygen desaturation were BMI and H-MP.

10. The most important predictors for duration of apnea/ hypopnea were age and soft tissues such as tongue length or soft palate length.

In conclusion. findings from the present study suggested that cephalometric and anthropometric variables may be associated with upper airway obstruction during sleep and may be helpful to explain variation in some physiologic variables of sleep-related breathing to a certain extent. In addition, this study indicated that obstructive sleep apnea is a multifactorial syndrome having, genetic, behavioral, functional and neuromuscular problems as well as morphological factors.

It is hoped that the craniofacial risk factors identified from the present study will be validated by further investigation, and ultimately will be utilized as a basis for treatment strategy as well as a practical diagnostic and research tool for obstructive sleep apnea syndrome.

APPENDIX A

Correlation Matrix and Regression Analyses

01 May 96 SPSS for MS WINDOWS Release 6.0 Page 1

This software is functional through August 31, 1996.

- - Correlation Coefficients - -

	0_BASN	0_C2C4SN	0FH_HOR	A_PNS	AGE	AVR_APNE
0_BASN	1.0000	.1002	-.0143	.0629	-.0432	-.1178
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .	P= .174	P= .847	P= .394	P= .559	P= .124
0_C2C4SN	.1002	1.0000	.5587	-.2343	-.0018	.1129
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .174	P= .	P= .000	P= .001	P= .981	P= .140
0FH_HOR	-.0143	.5587	1.0000	-.1593	.1294	.0597
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .847	P= .000	P= .	P= .030	P= .078	P= .437
A_PNS	.0629	-.2343	-.1593	1.0000	-.0331	.0311
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .394	P= .001	P= .030	P= .	P= .654	P= .686
AGE	-.0432	-.0018	.1294	-.0331	1.0000	.3655
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .559	P= .981	P= .078	P= .654	P= .	P= .000
AVR_APNE	-.1178	.1129	.0597	.0311	.3655	1.0000
	(172)	(172)	(172)	(172)	(172)	(172)
	P= .124	P= .140	P= .437	P= .686	P= .000	P= .
AVR_HYP	-.0273	-.0675	-.0313	.0426	.1776	.1787
	(171)	(171)	(171)	(171)	(171)	(170)
	P= .723	P= .381	P= .684	P= .580	P= .020	P= .020
AVR_O2	-.0169	-.2043	-.1728	-.0390	-.0487	-.2397
	(175)	(175)	(175)	(175)	(175)	(171)
	P= .824	P= .007	P= .022	P= .608	P= .522	P= .002
BASELINE	-.1478	-.0904	-.0955	-.0489	-.0150	.0610
	(173)	(173)	(173)	(173)	(173)	(172)
	P= .052	P= .237	P= .212	P= .523	P= .844	P= .427
BMI	.1210	.2332	.1261	-.0062	-.0609	.0112
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .100	P= .001	P= .086	P= .933	P= .409	P= .884
CI_FI	.0193	-.0127	.0967	-.1364	.2021	.0463
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .794	P= .864	P= .189	P= .063	P= .006	P= .546

(Coefficient / (Cases) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

- - Correlation Coefficients - -

	0_BASN	0_C2C4SN	0FH_HOR	A_PNS	AGE	AVR_APNE
H_MP	-.1806	.3137	.3050	.0250	.2727	.2647
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .014	P= .000	P= .000	P= .735	P= .000	P= .000
INT.MX.L	.2435	-.1142	-.0776	.4369	.0303	-.1287
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .001	P= .121	P= .292	P= .000	P= .682	P= .092
LONGEST1	.0602	-.0469	-.0456	.0627	.2379	.1821
	(171)	(171)	(171)	(171)	(171)	(170)

	P= .434	P= .543	P= .554	P= 416	P= .002	P= .017
LONGEST_	-.1677	.1161	.1348	.0067	.3173	.6552
	(172)	(172)	(172)	(172)	(172)	(172)
	P= .028	P= .129	P= .078	P= .931	P= .000	P= .000
LOWEST_O	-.0350	-.2082	-.1942	-.0917	-.1885	-.2844
	(176)	(176)	(176)	(176)	(176)	(172)
	P= .644	P= .006	P= .010	P= .226	P= .012	P= .000
MCF	.5176	-.1560	-.2047	.1606	-.1601	-.1133
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .000	P= .033	P= .005	P= .029	P= .029	P= .139
O2DIFF	-.0100	.2125	.1880	.0989	.1946	.3196
	(173)	(173)	(173)	(173)	(173)	(172)
	P= .896	P= .005	P= .013	P= .195	P= .010	P= .000
O2DIFF2	-.0173	.1711	.1413	.0115	.0197	.2776
	(171)	(171)	(171)	(171)	(171)	(171)
	P= .822	P= .025	P= .065	P= .881	P= .798	P= .000
P_PNS	-.0710	.0336	-.0039	.3158	.2631	.2106
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .336	P= .649	P= .958	P= .000	P= .000	P= .006
PHW_PSP	.2134	-.1527	-.0783	-.0063	-.2070	-.1959
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .003	P= .037	P= .288	P= .932	P= .005	P= .010
PNS_BA	.4779	-.1990	-.1001	.3906	.0226	-.0362
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .000	P= .006	P= .174	P= .000	P= .759	P= .637

(Coefficient / (Cases) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

- - Correlation Coefficients - -

	S_BASN	S_C2C4SN	SPN_HOR	A_PNS	AGE	AVR_APNE
RAM_MCF	.2231	-.1614	-.0313	.0188	.0704	.0198
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .002	P= .028	P= .672	P= .799	P= .340	P= .797
RDI	-.0113	.2745	.2115	.0794	.1443	.3054
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .878	P= .000	P= .004	P= .281	P= .049	P= .000
T__AREA	-.0677	.1168	.1010	.5000	.1332	.0986
	(185)	(185)	(185)	(185)	(185)	(171)
	P= .360	P= .113	P= .171	P= .000	P= .071	P= .200
T__INT.M	-.1166	.2730	.2150	-.0032	.1668	.2050
	(184)	(184)	(184)	(184)	(184)	(170)
	P= .115	P= .000	P= .003	P= .965	P= .024	P= .007
TL	-.0198	.3834	.2234	.4062	.1143	.2061
	(186)	(186)	(186)	(186)	(186)	(172)
	P= .788	P= .000	P= .002	P= .000	P= .120	P= .007

(Coefficient / (Cases) / 2-tailed Significance)

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- - Correlation Coefficients - -

	AVR_HYP	AVR_O2	BASELINE	BMI	CI_FI	M_MP
S_BASN	-.0273	-.0169	-.1478	.1210	.0193	-.1806

	(171)	(175)	(173)	(186)	(186)	(186)
	P= .723	P= .824	P= .052	P= .100	P= .794	P= .014
@_C2C4SN	-.0675	-.2043	-.0904	.2332	-.0127	.3137
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .381	P= .007	P= .237	P= .001	P= .864	P= .000
@FH_HOR	-.0313	-.1728	-.0955	.1261	.0967	.3050
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .684	P= .022	P= .212	P= .086	P= .189	P= .000
A_PNS	.0426	-.0390	-.0489	-.0062	-.1364	.0250
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .580	P= .608	P= .523	P= .933	P= .063	P= .735
AGE	.1776	-.0487	-.0150	-.0609	.2021	.2727
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .020	P= .522	P= .844	P= .409	P= .006	P= .000
AVR_APNE	.1787	-.2397	.0610	.0112	.0463	.2647
	(170)	(171)	(172)	(172)	(172)	(172)
	P= .020	P= .002	P= .427	P= .884	P= .546	P= .000
AVR_HYP	1.0000	-.0292	.0111	-.0401	-.0006	.0330
	(171)	(171)	(170)	(171)	(171)	(171)
	P= .	P= .705	P= .885	P= .602	P= .994	P= .668
AVR_O2	-.0292	1.0000	.3455	-.4661	.0677	-.3744
	(171)	(175)	(171)	(175)	(175)	(175)
	P= .705	P= .	P= .000	P= .000	P= .374	P= .000
BASELINE	.0111	.3455	1.0000	-.3832	.1332	-.2449
	(170)	(171)	(173)	(173)	(173)	(173)
	P= .885	P= .000	P= .	P= .000	P= .081	P= .001
BMI	-.0401	-.4661	-.3832	1.0000	.0453	.2431
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .602	P= .000	P= .000	P= .	P= .539	P= .001
CI_FI	-.0006	.0677	.1332	.0453	1.0000	.0805
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .994	P= .374	P= .081	P= .539	P= .	P= .275

(Coefficient / (Cases) / 2-tailed Significance)

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- - Correlation Coefficients - -

	AVR_HYP	AVR_O2	BASELINE	BMI	CI_FI	H_MP
H_MP	.0330	-.3744	-.2449	.2431	.0805	1.0000
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .668	P= .000	P= .001	P= .001	P= .275	P= .
INT.MX.L	-.0013	-.1047	-.2406	.2763	-.1428	-.1365
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .987	P= .168	P= .001	P= .000	P= .052	P= .063
LONGEST1	.5946	-.0857	-.1067	.1977	-.0495	.0714
	(171)	(171)	(170)	(171)	(171)	(171)
	P= .000	P= .265	P= .166	P= .010	P= .520	P= .353
LONGEST_	.1519	-.1935	-.0096	.1962	.0867	.2925
	(170)	(171)	(172)	(172)	(172)	(172)
	P= .048	P= .011	P= .901	P= .010	P= .258	P= .000
LOWEST_O	-.0523	.6946	.4088	-.5506	.0429	-.4346
	(171)	(174)	(173)	(176)	(176)	(176)
	P= .497	P= .000	P= .000	P= .000	P= .572	P= .000
MCF	-.0146	-.0604	-.1790	.1711	-.1012	-.2461

	(171)	(175)	(173)	(186)	(186)	(186)
	P= .850	P= .427	P= .018	P= .020	P= .169	P= .001
O2DIFF	.0565	-.6949	-.2033	.5098	-.0111	.4143
	(170)	(171)	(173)	(173)	(173)	(173)
	P= .465	P= .000	P= .007	P= .000	P= .884	P= .000
O2DIFF2	.0365	-.8931	.1137	.3658	-.0153	.2778
	(170)	(171)	(171)	(171)	(171)	(171)
	P= .636	P= .000	P= .139	P= .000	P= .843	P= .000
P_PNS	.1316	-.1164	-.0289	.0431	-.1748	.2498
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .086	P= .125	P= .706	P= .559	P= .017	P= .001
PHW_PSP	-.0552	.0484	-.1211	.0925	-.0043	-.1477
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .473	P= .525	P= .112	P= .209	P= .953	P= .044
PNS_BA	.0172	-.1299	-.2705	.1978	-.0710	.0080
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .823	P= .087	P= .000	P= .007	P= .335	P= .913

(Coefficient / (Cases) / 2-tailed Significance)

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- - Correlation Coefficients - -

	AVR_HYP	AVR_O2	BASELINE	BMI	CI_FI	H_HP
RAM_MCF	.1058	-.0664	-.0193	-.1163	-.0238	-.0426
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .168	P= .383	P= .801	P= .114	P= .748	P= .564
RDI	-.0535	-.6403	-.4456	.5194	-.0396	.5127
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .487	P= .000	P= .000	P= .000	P= .591	P= .000
T__AREA	-.0053	-.3532	-.3154	.3052	-.2228	.4573
	(170)	(174)	(172)	(185)	(185)	(185)
	P= .946	P= .000	P= .000	P= .000	P= .002	P= .000
T__INT.M	.0722	-.3154	-.1481	.1267	.1629	.7103
	(169)	(173)	(171)	(184)	(184)	(184)
	P= .351	P= .000	P= .053	P= .087	P= .027	P= .000
TL	-.0467	-.3320	-.2480	.3056	-.1510	.5003
	(171)	(175)	(173)	(186)	(186)	(186)
	P= .544	P= .000	P= .001	P= .000	P= .040	P= .000

(Coefficient / (Cases) / 2-tailed Significance)

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- - Correlation Coefficients - -

	INT.MK.L	LONGEST1	LONGEST_	LOWEST_O	MCF	O2DIFF
@_BASN	.2435	.0602	-.1677	-.0350	.5176	-.0100
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .001	P= .434	P= .028	P= .644	P= .000	P= .896
@_C2C4SN	-.1142	-.0469	.1161	-.2082	-.1560	.2125
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .121	P= .543	P= .129	P= .006	P= .033	P= .005
@FH_HOR	-.0776	-.0456	.1348	-.1942	-.2047	.1880
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .292	P= .554	P= .078	P= .010	P= .005	P= .013

A_PNS	.4369	.0627	0067	-.0917	.1606	.0989
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .000	P= .416	P= .931	P= .226	P= .029	P= .195
AGE	.0303	.2379	.3173	-.1885	-.1601	.1946
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .682	P= .002	P= .000	P= .012	P= .029	P= .010
AVR_APNE	-.1287	.1821	.6552	-.2844	-.1133	.3196
	(172)	(170)	(172)	(172)	(172)	(172)
	P= .092	P= .017	P= .000	P= .000	P= .139	P= .000
AVR_HYP	-.0013	.5946	.1519	-.0523	-.0146	.0565
	(171)	(171)	(170)	(171)	(171)	(170)
	P= .987	P= .000	P= .048	P= .497	P= .850	P= .465
AVR_O2	-.1047	-.0857	-.1935	.6946	-.0604	-.6949
	(175)	(171)	(171)	(174)	(175)	(171)
	P= .168	P= .265	P= .011	P= .000	P= .427	P= .000
BASELINE	-.2406	-.1067	-.0096	.4088	-.1790	-.2033
	(173)	(170)	(172)	(173)	(173)	(173)
	P= .001	P= .166	P= .901	P= .000	P= .018	P= .007
BMI	.2763	.1977	.1962	-.5506	.1711	.5098
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .000	P= .010	P= .010	P= .000	P= .020	P= .000
CI_FI	-.1428	-.0495	.0867	.0429	-.1012	-.0111
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .052	P= .520	P= .258	P= .572	P= .169	P= .884

(Coefficient / (Cases) / 2-tailed Significance)

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- - Correlation Coefficients - -

	INT.MX.L	LONGEST1	LONGEST_	LOWEST_O	MCF	O2DIFF
H_MP	-.1365	.0714	.2925	-.4346	-.2461	.4143
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .063	P= .353	P= .000	P= .000	P= .001	P= .000
INT.MX.L	1.0000	.1097	-.0984	-.1306	.5039	.1015
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .	P= .153	P= .199	P= .084	P= .000	P= .184
LONGEST1	.1097	1.0000	.2494	-.2032	.0339	.1904
	(171)	(171)	(170)	(171)	(171)	(170)
	P= .153	P= .	P= .001	P= .008	P= .659	P= .013
LONGEST_	-.0984	.2494	1.0000	-.2964	-.1045	.3157
	(172)	(170)	(172)	(172)	(172)	(172)
	P= .199	P= .001	P= .	P= .000	P= .173	P= .000
LOWEST_O	-.1306	-.2032	-.2964	1.0000	-.0593	-.9767
	(176)	(171)	(172)	(176)	(176)	(173)
	P= .084	P= .008	P= .000	P= .	P= .434	P= .000
MCF	.5039	.0339	-.1045	-.0593	1.0000	.0178
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .000	P= .659	P= .173	P= .434	P= .	P= .816
O2DIFF	.1015	.1904	.3157	-.9767	.0178	1.0000
	(173)	(170)	(172)	(173)	(173)	(173)
	P= .184	P= .013	P= .000	P= .000	P= .816	P= .
O2DIFF2	.0257	.0402	.1860	-.6311	.0067	.6829
	(171)	(170)	(171)	(171)	(171)	(171)
	P= .739	P= .603	P= .015	P= .000	P= .931	P= .000

P_PNS	.2360	.2312	.2443	-.1882	.0341	.1943
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .001	P= .002	P= .001	P= .012	P= .644	P= .010
PHW_PSP	.3309	-.0709	-.2163	.1109	.3386	-.1309
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .000	P= .357	P= .004	P= .143	P= .000	P= .086
PNS_BA	.6080	.0738	.0096	- 1870	.5987	.1421
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .000	P= .337	P= .902	P= .013	P= .000	P= .062

(Coefficient / (Cases) / 2-tailed Significance)

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- - Correlation Coefficients - -

	INT.MX.L	LONGEST1	LONGEST_	LOWEST_O	MCF	O2DIFF
RAM_MCF	-.0266	.1067	.0465	-.0611	.2391	.0521
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .718	P= .165	P= .545	P= .420	P= .001	P= .496
RDI	.1712	.1160	.3713	-.7118	.0225	.6583
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .019	P= .131	P= .000	P= .000	P= .760	P= .000
T__AREA	.5258	.1342	.1788	-.3572	.0483	.3359
	(185)	(170)	(171)	(175)	(185)	(172)
	P= .000	P= .081	P= .019	P= .000	P= .514	P= .000
T__INT.M	-.3676	.0900	.2842	-.2941	-.2740	.2845
	(184)	(169)	(170)	(174)	(184)	(171)
	P= .000	P= .245	P= .000	P= .000	P= .000	P= .000
TL	.4418	.0912	.2035	-.3666	.0774	.3521
	(186)	(171)	(172)	(176)	(186)	(173)
	P= .000	P= .235	P= .007	P= .000	P= .293	P= .000

(Coefficient / (Cases) / 2-tailed Significance)

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- - Correlation Coefficients - -

	O2DIFF2	P_PNS	PHW_PSP	PNS_BA	RAM_MCF	RDI
0_BASN	-.0173	-.0710	.2134	.4779	.2231	-.0113
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .822	P= .336	P= .003	P= .000	P= .002	P= .878
0_C2C4SN	.1711	.0336	-.1527	-.1990	-.1614	.2745
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .025	P= .649	P= .037	P= .006	P= .028	P= .000
0PH_MOR	.1413	-.0039	-.0783	-.1001	-.0313	.2115
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .065	P= .958	P= .288	P= .174	P= .672	P= .004
A_PNS	.0115	.3158	-.0063	.3906	.0188	.0794
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .881	P= .000	P= .932	P= .000	P= .799	P= .281
AGE	.0197	.2631	-.2070	.0226	.0704	.1443
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .798	P= .000	P= .005	P= .759	P= .340	P= .049
AVR_APNE	.2776	.2106	-.1959	-.0362	.0198	.3054
	(171)	(172)	(172)	(172)	(172)	(172)
	P= .000	P= .006	P= .010	P= .637	P= .797	P= .000

AVR_HYP	.0365	.1316	-.0552	.0172	.1058	-.0535
	(170)	(171)	(171)	(171)	(171)	(171)
	P= .636	P= .086	P= .473	P= .823	P= .168	P= .487
AVR_O2	-.8931	-.1164	.0484	-.1299	-.0664	-.6403
	(171)	(175)	(175)	(175)	(175)	(175)
	P= .000	P= .125	P= .525	P= .087	P= .383	P= .000
BASELINE	.1137	-.0289	-.1211	-.2705	-.0193	-.4456
	(171)	(173)	(173)	(173)	(173)	(173)
	P= .139	P= .706	P= .112	P= .000	P= .801	P= .000
BMI	.3658	.0431	.0925	.1978	-.1163	.5194
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .000	P= .559	P= .209	P= .007	P= .114	P= .000
CI_FI	-.0153	-.1748	-.0043	-.0710	-.0238	-.0396
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .843	P= .017	P= .953	P= .335	P= .748	P= .591

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- - Correlation Coefficients - -

	O2DIFF2	P_PNS	PHW_PSP	PNS_BA	RAM_MCF	RDI
H_MP	.2778	.2498	-.1477	.0080	-.0426	.5127
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .000	P= .001	P= .044	P= .913	P= .564	P= .000
INT.MX.L	.0257	.2360	.3309	.6080	-.0266	.1712
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .739	P= .001	P= .000	P= .000	P= .718	P= .019
LONGEST1	.0402	.2312	-.0709	.0738	.1067	.1160
	(170)	(171)	(171)	(171)	(171)	(171)
	P= .603	P= .002	P= .357	P= .337	P= .165	P= .131
LONGEST_	.1860	.2443	-.2163	.0094	.0465	.3713
	(171)	(172)	(172)	(172)	(172)	(172)
	P= .015	P= .001	P= .004	P= .902	P= .545	P= .000
LOWEST_O	-.6311	-.1582	.1109	-.1870	-.0611	-.7118
	(171)	(176)	(176)	(176)	(176)	(176)
	P= .000	P= .012	P= .143	P= .013	P= .420	P= .000
MCF	.0067	.0341	.3386	.5987	.2391	.0225
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .931	P= .644	P= .000	P= .000	P= .001	P= .760
O2DIFF	.6829	.1943	-.1309	.1421	.0521	.6583
	(171)	(173)	(173)	(173)	(173)	(173)
	P= .000	P= .010	P= .086	P= .062	P= .496	P= .000
O2DIFF2	1.0000	.0768	-.0869	.0356	.0328	.5209
	(171)	(171)	(171)	(171)	(171)	(171)
	P= .	P= .318	P= .258	P= .644	P= .670	P= .000
P_PNS	.0768	1.0000	-.3956	.2818	.0683	.0990
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .318	P= .	P= .000	P= .000	P= .354	P= .179
PHW_PSP	-.0869	-.3956	1.0000	.2129	.0410	-.0347
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .258	P= .000	P= .	P= .004	P= .579	P= .638
PNS_BA	.0356	.2818	.2129	1.0000	.1963	.1982
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .644	P= .000	P= .004	P= .	P= .007	P= .007

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- - Correlation Coefficients - -

	O2DIFF2	P_PNS	PNN_PSP	PNS_BA	RAM_MCF	RDI
RAM_MCF	.0328	.0683	.0410	.1963	1.0000	-.0282
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .670	P= .354	P= .579	P= .007	P= .	P= .702
RDI	.5209	.0990	-.0347	.1982	-.0282	1.0000
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .000	P= .179	P= .638	P= .007	P= .702	P= .
T__AREA	.2037	.4787	-.1116	.4259	-.0255	.4662
	(170)	(185)	(185)	(185)	(185)	(185)
	P= .008	P= .000	P= .130	P= .000	P= .730	P= .000
T__INT.M	.2324	.1155	-.3306	-.0301	.1132	.3810
	(169)	(184)	(184)	(184)	(184)	(184)
	P= .002	P= .118	P= .000	P= .685	P= .126	P= .000
TL	.2202	.4380	-.0951	.3628	-.0616	.4942
	(171)	(186)	(186)	(186)	(186)	(186)
	P= .004	P= .000	P= .197	P= .000	P= .403	P= .000

(Coefficient / (Cases) / 2-tailed Significance)

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- - Correlation Coefficients - -

	T__AREA	T__INT.M	TL
0_BASN	-.0677	-.1166	-.0198
	(185)	(184)	(186)
	P= .360	P= .115	P= .788
0_C2C4SN	.1168	.2730	.3834
	(185)	(184)	(186)
	P= .113	P= .000	P= .000
0FM_HOR	.1010	.2150	.2234
	(185)	(184)	(186)
	P= .171	P= .003	P= .002
A_PNS	.5000	-.0032	.4062
	(185)	(184)	(186)
	P= .000	P= .965	P= .000
AGE	.1332	.1668	.1143
	(185)	(184)	(186)
	P= .071	P= .024	P= .120
AVR_APNE	.0986	.2050	.2061
	(171)	(170)	(172)
	P= .200	P= .007	P= .007
AVR_HYP	-.0053	.0722	-.0467
	(170)	(169)	(171)
	P= .946	P= .351	P= .544
AVR_O2	-.3532	-.3154	-.3320
	(174)	(173)	(175)
	P= .000	P= .000	P= .000
BASELINE	-.3154	-.1481	-.2480
	(172)	(171)	(173)

	P= .000	P= .053	P= .001
BMI	.3052	.1267	.3056
	(185)	(184)	(186)
	P= .000	P= .087	P= .000
CI_FI	-.2228	.1629	-.1510
	(185)	(184)	(186)
	P= .002	P= .027	P= .040

(Coefficient / (Cases) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

- - Correlation Coefficients - -

	T__AREA	T__INT.M	TL
H_MP	.4573	.7103	.5003
	(185)	(184)	(186)
	P= .000	P= .000	P= .000
INT.MX.L	.5258	-.3676	.4418
	(185)	(184)	(186)
	P= .000	P= .000	P= .000
LONGEST1	.1342	.0900	.0912
	(170)	(169)	(171)
	P= .081	P= .245	P= .235
LONGEST_	.1788	.2842	.2035
	(171)	(170)	(172)
	P= .019	P= .000	P= .007
LOWEST_O	-.3572	-.2941	-.3666
	(175)	(174)	(176)
	P= .000	P= .000	P= .000
MCF	.0483	-.2740	.0774
	(185)	(184)	(186)
	P= .514	P= .000	P= .293
O2DIFF	.3359	.2845	.3521
	(172)	(171)	(173)
	P= .000	P= .000	P= .000
O2DIFF2	.2037	.2324	.2202
	(170)	(169)	(171)
	P= .008	P= .002	P= .004
P_PNS	.4787	.1155	.4380
	(185)	(184)	(186)
	P= .000	P= .118	P= .000
PHW_PSP	-.1116	-.3306	-.0951
	(185)	(184)	(186)
	P= .130	P= .000	P= .197
PNS_BA	.4259	-.0301	.3628
	(185)	(184)	(186)
	P= .000	P= .685	P= .000

(Coefficient / (Cases) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

- - Correlation Coefficients - -

	T__AREA	T__INT.M	TL
RAM_MCF	-.0255	.1132	-.0616

	(185)	(184)	(186)
	P= .730	P= .126	P= .403
RDI	.4662	.3810	.4942
	(185)	(184)	(186)
	P= .000	P= .000	P= .000
T__AREA	1.0000	.3660	.7981
	(185)	(184)	(185)
	P= .	P= .000	P= .000
T__INT.M	.3660	1.0000	.3659
	(184)	(184)	(184)
	P= .000	P= .	P= .000
TL	.7981	.3659	1.0000
	(185)	(184)	(186)
	P= .000	P= .000	P= .

(Coefficient / (Cases) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

This software is functional through August 31, 1996.

>Warning # 9431. Text: ID NUMBER changed to ID_NUMBE
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: VA persona changed to VA_PERSO
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: VA family changed to VA_FAMIL
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: Lowest O2 changed to LOWEST_O
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: AVR Apnea changed to AVR_APNE
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: Longest Ap changed to LONGEST_
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: Longest Hy changed to LONGEST1
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: WEIGHT lb changed to WEIGHT_L
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: Refer Sour changed to REFER_SO
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: Head Form changed to HEAD_FOR
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: Face Form changed to FACE_FOR
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: T/ Int.Mx changed to T__INT.M
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: ID NUMBER changed to ID_NUMB1
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: Ant.Mx.Ht. changed to ANT.MX.H
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: Post.Mx.Ht changed to POST.MX.
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: Int.Mx.Lth changed to INT.MX.L
>A long variable name was truncated to 8 characters.

>Warning # 9431. Text: ID NUMBER changed to ID_NUMB2
>A long variable name was truncated to 8 characters.

```
>Warning # 9431.  Text: Low/Mid % changed to LOW_MID_
>A long variable name was truncated to 8 characters.

>Warning # 9431.  Text: BRW(birama changed to BRW_BIRA
>A long variable name was truncated to 8 characters.

>Warning # 9430.  Text: MP
>A variable name is missing.  The variable has been dropped.

>Warning # 9437.  Text: VA_PERSO
>One or more cases in the file had invalid data.

>Warning # 9437.  Text: VA_FAMIL
>One or more cases in the file had invalid data.

>Warning # 9438.  Text: NAME
>One or more cases contained text wider than the variable width.

>Warning # 9438.  Text: REFER_SO
>One or more cases contained text wider than the variable width.

>Warning # 9437.  Text: T__INT.M
>One or more cases in the file had invalid data.

Data written to the working file.
67 variables and 120 cases written.
Variable: ID_NUMBE    Type: String   Format: A10
Variable: USED        Type: Number   Format: F9
Variable: PHASE       Type: Number   Format: F9
Variable: CT          Type: Number   Format: F9
Variable: VA_PERSO    Type: Number   Format: F9
Variable: VA_FAMIL    Type: Number   Format: F9
Variable: LOWEST_O    Type: Number   Format: F9.1
Variable: AVR_O2      Type: Number   Format: F9.1
Variable: AVR_APNE    Type: Number   Format: F9.1
Variable: AVR_HYP     Type: Number   Format: F9.1
Variable: LONGEST_    Type: Number   Format: F9.1
Variable: LONGEST1    Type: Number   Format: F9.1
Variable: CONSENT     Type: Number   Format: F9
Variable: NAME        Type: String   Format: A15
Variable: RACE        Type: String   Format: A10
Variable: SEX         Type: String   Format: A10
Variable: AGE         Type: Number   Format: F9
Variable: WEIGHT__    Type: Number   Format: F9.1
Variable: WEIGHT_L    Type: Number   Format: F9.2
Variable: NECK_CM     Type: Number   Format: F9.1
Variable: R._D._I.    Type: Number   Format: F9.2
Variable: N.N.P       Type: Number   Format: F9.1
Variable: BMI         Type: Number   Format: COMMA9.2
Variable: ESS         Type: Number   Format: F9
Variable: MOUSE       Type: Number   Format: F9
Variable: REFER_SO    Type: String   Format: A10
Variable: CI          Type: Number   Format: F9.1
Variable: HEAD_FOR    Type: String   Format: A10
Variable: FI          Type: Number   Format: F9.1
Variable: FACE_FOR    Type: String   Format: A10
Variable: T__AREA     Type: Number   Format: F9
Variable: T__INT.M    Type: Number   Format: F9.2
Variable: ID_NUMB1    Type: String   Format: A10
Variable: G_BASN      Type: Number   Format: F9.1
Variable: MCF         Type: Number   Format: F9.1
Variable: GSMA        Type: Number   Format: F9.1
```

```
Variable: ARN_PH      Type: Number   Format: F9.1
Variable: A_PNS       Type: Number   Format: F9.1
Variable: PNS_SA      Type: Number   Format: F9.1
Variable: @SNB        Type: Number   Format: F9.1
Variable: RAM_MCF     Type: Number   Format: F9.1
Variable: ARA_ARB     Type: Number   Format: F9.1

Variable: P_PNS       Type: Number   Format: F9.1
Variable: PHW_PSP     Type: Number   Format: F9.1
Variable: TL          Type: Number   Format: F9.1
Variable: H_MP        Type: Number   Format: F9.1
Variable: H_VER       Type: Number   Format: F9.1
Variable: @FH_HOR     Type: Number   Format: F9.1
Variable: @C2SN       Type: Number   Format: F9.1
Variable: @_C2C4SN    Type: Number   Format: F9.1
Variable: ANT.MX.H    Type: Number   Format: F9.1
Variable: POST.MX.    Type: Number   Format: F9.1
Variable: INT.MX.L    Type: Number   Format: F9.1
Variable: FAC.HT.     Type: Number   Format: F9.1
Variable: AR_GO       Type: Number   Format: F9.1
Variable: GO_GN       Type: Number   Format: F9.1
Variable: @GO         Type: Number   Format: F9.1
Variable: FH_GO       Type: Number   Format: F9.1
Variable: @FH__A      Type: Number   Format: F9.1
Variable: @FH__B      Type: Number   Format: F9.1
Variable: @_PAL_PH    Type: Number   Format: F9.1
Variable: RGN_H       Type: Number   Format: F9.1
Variable: ID_NUMB2    Type: String   Format: A10
Variable: P_WIDTH     Type: Number   Format: F9.1
Variable: @C3RGNH     Type: Number   Format: F9.1
Variable: LOW_MID_    Type: Number   Format: F9.1
Variable: BRW_SIRA    Type: Number   Format: F10.2

>Warning # 9431.  Text: ID NUMBER changed to ID_NUMBE
>A long variable name was truncated to 8 characters.


>Warning # 9431.  Text: VA persona changed to VA_PERSO
>A long variable name was truncated to 8 characters.


>Warning # 9431.  Text: VA family changed to VA_FAMIL
>A long variable name was truncated to 8 characters.


>Warning # 9431.  Text: baseline O changed to BASELINE
>A long variable name was truncated to 8 characters.


>Warning # 9431.  Text: Lowest O2 changed to LOWEST_O
>A long variable name was truncated to 8 characters.


>Warning # 9431.  Text: Longest Ap changed to LONGEST_
>A long variable name was truncated to 8 characters.


>Warning # 9431.  Text: AVR Apnea changed to AVR_APNE
>A long variable name was truncated to 8 characters.


>Warning # 9431.  Text: Longest My changed to LONGEST1
>A long variable name was truncated to 8 characters.


>Warning # 9431.  Text: WEIGHT lb changed to WEIGHT_L
>A long variable name was truncated to 8 characters.


>Warning # 9431.  Text: Refer Sour changed to REFER_SO
>A long variable name was truncated to 8 characters.
```

```
>Warning # 9431.  Text: Head Form changed to HEAD_FOR
>A long variable name was truncated to 8 characters.

>Warning # 9431.  Text: Face Form changed to FACE_FOR
>A long variable name was truncated to 8 characters.

>Warning # 9431.  Text: T/ Int.Mx changed to T__INT.M
>A long variable name was truncated to 8 characters.

>Warning # 9431.  Text: ID NUMBER changed to ID_NUMB1
>A long variable name was truncated to 8 characters.

>Warning # 9431.  Text: Ant.Mx.Ht. changed to ANT.MX.H
>A long variable name was truncated to 8 characters.

>Warning # 9431.  Text: Post.Mx.Ht changed to POST.MX.
>A long variable name was truncated to 8 characters.

>Warning # 9431.  Text: Int.Mx.Lth changed to INT.MX.L
>A long variable name was truncated to 8 characters.

>Warning # 9431.  Text: ID NUMBER changed to ID_NUMB2
>A long variable name was truncated to 8 characters.


>Warning # 9431.  Text: Low/Mid % changed to LOW_MID_
>A long variable name was truncated to 8 characters.

>Warning # 9431.  Text: BRN(birama changed to BRN_BIRA
>A long variable name was truncated to 8 characters.

>Warning # 9430.  Text: BQ
>A variable name is missing.  The variable has been dropped.

>Warning # 9437.  Text: VA_PERSO
>One or more cases in the file had invalid data.

>Warning # 9437.  Text: VA_FAMIL
>One or more cases in the file had invalid data.

>Warning # 9438.  Text: NAME
>One or more cases contained text wider than the variable width.

>Warning # 9437.  Text: HOUSE
>One or more cases in the file had invalid data.

>Warning # 9438.  Text: REFER_SO
>One or more cases contained text wider than the variable width.

>Warning # 9437.  Text: T__AREA
>One or more cases in the file had invalid data.

>Warning # 9437.  Text: T__INT.M
>One or more cases in the file had invalid data.
```

```
Data written to the working file.
68 variables and 186 cases written.
Variable: ID_NUMBE    Type: String   Format: A10
Variable: USED        Type: Number   Format: F9
Variable: PHASE       Type: Number   Format: F9
Variable: CT          Type: Number   Format: F9
Variable: VA_PERSO    Type: Number   Format: F9
Variable: VA_FAMIL    Type: Number   Format: F9
Variable: BASELINE    Type: Number   Format: F9
Variable: LOWEST_O    Type: Number   Format: F9.1
Variable: AVR_O2      Type: Number   Format: F9.1
Variable: LONGEST_    Type: Number   Format: F9.1

Variable: AVR_APNE    Type: Number   Format: F9.1
Variable: LONGEST1    Type: Number   Format: F9.1
Variable: AVR_HYP     Type: Number   Format: F9.1
Variable: CONSENT     Type: Number   Format: F9
Variable: NAME        Type: String   Format: A15
Variable: RACE        Type: String   Format: A10
Variable: SEX         Type: String   Format: A10
Variable: AGE         Type: Number   Format: F9
Variable: HEIGHT__    Type: Number   Format: F9.1
Variable: WEIGHT_L    Type: Number   Format: F9.2
Variable: NECK_CM     Type: Number   Format: F9.1
Variable: R._D._I.    Type: Number   Format: F9.2
Variable: N.H.P       Type: Number   Format: F9.1
Variable: BMI         Type: Number   Format: COMMA9.2
Variable: ESS         Type: Number   Format: F9
Variable: MOUSE       Type: Number   Format: F9
Variable: REFER_SO    Type: String   Format: A10
Variable: CI          Type: Number   Format: F9.1
Variable: HEAD_FOR    Type: String   Format: A10
Variable: FI          Type: Number   Format: F9.1
Variable: FACE_FOR    Type: String   Format: A10
Variable: T__AREA     Type: Number   Format: F9
Variable: T__INT.M    Type: Number   Format: F9.2
Variable: ID_NUMB1    Type: String   Format: A10
Variable: @_BASN      Type: Number   Format: F9.1
Variable: MCF         Type: Number   Format: F9.1
Variable: @SNA        Type: Number   Format: F9.1
Variable: ARN_FM      Type: Number   Format: F9.1
Variable: A_FNS       Type: Number   Format: F9.1
Variable: FNS_SA      Type: Number   Format: F9.1
Variable: @SNB        Type: Number   Format: F9.1
Variable: RAM_MCF     Type: Number   Format: F9.1
Variable: ARA_ARB     Type: Number   Format: F9.1
Variable: P_FNS       Type: Number   Format: F9.1
Variable: FNN_FSP     Type: Number   Format: F9.1
Variable: TL          Type: Number   Format: F9.1
Variable: M_MP        Type: Number   Format: F9.1
Variable: M_VER       Type: Number   Format: F9.1
Variable: @FM_NOR     Type: Number   Format: F9.1
Variable: @C2SN       Type: Number   Format: F9.1
Variable: @_C2C4SN    Type: Number   Format: F9.1
Variable: ANT.MX.M    Type: Number   Format: F9.1
Variable: POST.MX.    Type: Number   Format: F9.1
Variable: INT.MX.L    Type: Number   Format: F9.1
Variable: FAC.HT.     Type: Number   Format: F9.1
Variable: AR_GO       Type: Number   Format: F9.1
Variable: GO_GN       Type: Number   Format: F9.1
Variable: @GO         Type: Number   Format: F9.1
Variable: PN_GO       Type: Number   Format: F9.1
Variable: @PN__A      Type: Number   Format: F9.1
Variable: @PN__B      Type: Number   Format: F9.1
Variable: @_PAL_PM    Type: Number   Format: F9.1
Variable: BGN_M       Type: Number   Format: F9.1

Variable: ID_NUMB2    Type: String   Format: A10
Variable: P_WIDTH     Type: Number   Format: F9.1
Variable: @C3BGNM     Type: Number   Format: F9.1
Variable: LOW_MID_    Type: Number   Format: F9.1
Variable: BNN_BIRA    Type: Number   Format: F10.2
```

Number of valid observations (listwise) = 168.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
CI_FI	.84	.08	.63	1.13	186	
T__INT.M	.91	.09	.70	1.15	184	
MCF	.97	3.16	-10.9	8.3	186	
RAM_MCF	2.33	3.19	-6.6	11.8	186	
0FH_HOR	3.77	5.57	-9.6	20.6	186	
O2DIFF2	4.97	4.48	-1.00	36.00	171	
PHW_PSP	5.31	3.18	.0	13.4	186	
O2DIFF	15.21	10.44	.00	45.00	173	
AVR_HYP	16.05	4.49	5.0	40.0	171	
AVR_APNE	16.78	5.90	5.0	35.0	172	
H_MP	20.77	7.13	.1	36.9	186	
RDI	26.86	30.64	.00	133.79	186	
BMI	30.98	7.58	17.23	66.46	186	
LONGEST1	30.98	16.90	9.0	160.0	171	
LONGEST_	35.14	26.35	8.0	267.0	172	
P_PNS	45.99	6.81	28.9	63.9	186	
AGE	46.04	10.44	25	65	186	
PNS_BA	47.33	3.95	34.8	58.4	186	
A_PNS	51.01	3.97	41.3	64.9	186	
LOWEST_O	80.46	11.27	35.0	96.0	176	
INT.MX.L	83.63	7.28	65.0	112.7	186	
TL	86.19	7.99	69.2	109.1	186	
AVR_O2	91.10	4.74	64.0	97.0	175	
BASELINE	95.88	2.46	80	100	173	
0_C2C4SN	112.48	9.83	89.3	139.3	186	
0_BASN	128.94	5.26	114.8	141.2	186	
T__AREA	4253.28	589.77	2928	6120	185	

t-tests for independent samples of RDIGRP

Variable	Number of Cases	Mean	SD	SE of Mean
AVR_APNE				
RDIGRP 0	102	15.1569	5.185	.513
RDIGRP 1	70	19.1571	6.114	.731

Mean Difference = -4.0003

Levene's Test for Equality of Variances: F= 2.002 P= .159

t-test for Equality of Means					95%
Variances	t-value	df	2-Tail Sig	SE of Diff	CI for Diff
Equal	-4.62	170	.000	.866	(-5.711, -2.290)
Unequal	-4.48	131.96	.000	.893	(-5.767, -2.233)

Variable	Number of Cases	Mean	SD	SE of Mean
AVR_HYP				
RDIGRP 0	101	15.8119	4.449	.443
RDIGRP 1	70	16.4000	4.557	.545

Mean Difference = -.5881

Levene's Test for Equality of Variances: F= .563 P= .454

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
	t-test for Equality of Means				
Equal	-.84	169	.401	.699	(-1.968, .792)
Unequal	-.84	146.24	.403	.702	(-1.976, .799)

t-tests for independent samples of RDIGRP

Variable	Number of Cases	Mean	SD	SE of Mean
AVR_O2				
RDIGRP 0	103	92.9883	2.141	.211
RDIGRP 1	72	88.4000	6.002	.707

Mean Difference = 4.5883

Levene's Test for Equality of Variances: F= 34.747 P= .000

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
	t-test for Equality of Means				
Equal	7.14	173	.000	.642	(3.320, 5.857)
Unequal	6.22	83.73	.000	.738	(3.120, 6.056)

Variable	Number of Cases	Mean	SD	SE of Mean
BASELINE				
RDIGRP 0	102	96.5686	1.570	.155
RDIGRP 1	71	94.8873	3.096	.367

Mean Difference = 1.6813

Levene's Test for Equality of Variances: F= 4.650 P= .032

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
	t-test for Equality of Means				
Equal	4.69	171	.000	.359	(.973, 2.389)
Unequal	4.21	95.19	.000	.399	(.889, 2.474)

t-tests for independent samples of RDIGRP

Variable	Number of Cases	Mean	SD	SE of Mean
LONGEST1				
RDIGRP 0	101	27.3000	12.280	1.222
RDIGRP 1	70	36.3014	20.886	2.496

Mean Difference = -9.0014

Levene's Test for Equality of Variances: F= 5.429 P= .021

t-test for Equality of Means 95%

Variances	t-value	df	2-Tail Sig	SE of Diff	CI for Diff
Equal	-3.54	169	.001	2.543	(-14.022, -3.981)
Unequal	-3.24	101.98	.002	2.779	(-14.516, -3.487)

Variable	Number of Cases	Mean	SD	SE of Mean
LONGEST_				
RDIGRP 0	102	26.2431	14.299	1.416
RDIGRP 1	70	48.1143	33.669	4.024

Mean Difference = -21.8711

Levene's Test for Equality of Variances: F= 8.385 P= .004

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	-5.84	170	.000	3.743	(-29.262, -14.481)
Unequal	-5.13	86.24	.000	4.266	(-30.354, -13.389)

t-tests for independent samples of RDIGRP

Variable	Number of Cases	Mean	SD	SE of Mean
LOWEST_O				
RDIGRP 0	102	86.6902	6.533	.647
RDIGRP 1	74	71.8716	10.778	1.253

Mean Difference = 14.8186

Levene's Test for Equality of Variances: F= 23.605 P= .000

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	11.32	174	.000	1.309	(12.234, 17.403)
Unequal	10.51	111.38	.000	1.410	(12.024, 17.613)

Variable	Number of Cases	Mean	SD	SE of Mean
O2DIFF				
RDIGRP 0	102	9.8784	6.524	.646
RDIGRP 1	71	22.8803	10.258	1.217

Mean Difference = -13.0019

Levene's Test for Equality of Variances: F= 22.453 P= .000

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	-10.19	171	.000	1.277	(-15.522, -10.481)
Unequal	-9.43	108.98	.000	1.378	(-15.734, -10.270)

t-tests for independent samples of RDIGRP

Variable	Number of Cases	Mean	SD	SE of Mean
O2DIFF2				
RDIGRP 0	102	3.6196	2.200	.218
RDIGRP 1	69	6.9739	6.012	.724

Mean Difference = -3.3543

Levene's Test for Equality of Variances: F= 26.211 P= .000

t-test for Equality of Means					95%
Variances	t-value	df	2-Tail Sig	SE of Diff	CI for Diff
Equal	-5.15	169	.000	.651	(-4.640, -2.069)
Unequal	-4.44	80.43	.000	.756	(-4.859, -1.850)

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. O2DIFF

Block Number 1. Method: Enter
@_BASN @_C2C4SN @FH_HOR A_PNS AGE BMI CI_FI M_MP
INT.MX.L MCF P_PNS PHW_PSP PNS_BA RAM_MCF T__AREA T__INT.M
TL

Variable(s) Entered on Step Number
1.. TL
2.. @_BASN
3.. AGE
4.. RAM_MCF
5.. @FH_HOR
6.. CI_FI
7.. PHW_PSP
8.. BMI
9.. A_PNS
10.. T__INT.M
11.. P_PNS
12.. MCF
13.. @_C2C4SN
14.. PNS_BA
15.. M_MP
16.. INT.MX.L
17.. T__AREA

Multiple R .63876
R Square .40801
Adjusted R Square .34224
Standard Error 8.50249

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	17	7623.32877	448.43110
Residual	153	11060.73310	72.29237

F = 6.20302 Signif F = .0000

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. O2DIFF

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	Tolerance	VIF	T
@_BASN	-.117996	.171484	-.059324	.520535	1.921	-.688
@_C2C4SN	.083487	.111952	.077534	.357936	2.794	.746
@FH_HOR	.024878	.150153	.013227	.607059	1.647	.166
A_PNS	.279700	.220722	.106646	.546289	1.831	1.267
AGE	.166636	.072982	.167440	.719451	1.390	2.283
BMI	.643262	.101021	.463778	.729386	1.371	6.368
CI_FI	-8.122636	9.210105	-.064023	.734198	1.362	-.882
H_MP	.389478	.160186	.266675	.321641	3.109	2.431
INT.MX.L	-.100340	.194198	-.068947	.217291	4.602	-.517
MCF	.140834	.318279	.042940	.410862	2.434	.442
P_PNS	-.095331	.134177	-.062254	.503957	1.984	-.710
PHW_PSP	-.403914	.279749	-.121864	.543137	1.841	-1.444
PNS_BA	.193620	.292577	.071051	.335665	2.979	.662
RAM_MCF	.336325	.230867	.100999	.804981	1.242	1.457
T__AREA	-4.59474E-04	.002639	-.026190	.171043	5.846	-.174
T__INT.M	-8.677917	13.610667	-.078830	.253113	3.951	-.638
TL	.050394	.174281	.038377	.219654	4.553	.289
(Constant)	-11.581255	26.061157				-.444

------ in -------

Variable	Sig T
@_BASN	.4924
@_C2C4SN	.4570
@FH_HOR	.8686
A_PNS	.2070
AGE	.0238
BMI	.0000
CI_FI	.3792
H_MP	.0162
INT.MX.L	.6061
MCF	.6588
P_PNS	.4785
PHW_PSP	.1508
PNS_BA	.5091
RAM_MCF	.1472
T__AREA	.8620
T__INT.M	.5247
TL	.7729
(Constant)	.6574

Collinearity Diagnostics

Number	Eigenval	Cond Index	Variance Proportions Constant	@_BASN	@_C2C4SN	@FH_HOR	A_PNS	AGE
1	15.33333	1.000	.00000	.00000	.00001	.00063	.00001	.00015
2	1.10472	3.726	.00000	.00000	.00001	.06216	.00000	.00011
3	.57868	5.148	.00001	.00001	.00001	.30391	.00004	.00004
4	.53635	5.347	.00000	.00000	.00000	.26949	.00001	.00033
5	.22581	8.240	.00000	.00000	.00002	.00414	.00002	.00145
6	.08152	13.715	.00018	.00030	.00046	.04375	.00083	.00237
7	.05088	17.360	.00000	.00000	.00029	.00048	.00000	.29740
8	.03428	21.149	.00015	.00016	.00143	.00161	.00288	.48093
9	.02220	26.283	.00072	.00147	.00527	.01170	.00103	.00575
10	.01010	38.957	.00017	.00023	.00364	.00010	.00894	.03204
11	.00703	46.709	.00082	.00254	.17022	.09827	.02296	.08283
12	.00413	60.960	.00001	.00061	.04990	.06409	.00590	.01190
13	.00387	62.917	.00457	.02146	.01645	.02017	.22144	.00007
14	.00292	72.514	.00062	.00924	.00004	.01157	.52585	.04861
15	.00169	95.204	.01947	.01171	.00016	.00995	.00270	.01664
16	.00124	111.198	.02096	.01031	.33563	.05175	.07133	.01348
17	.00079	139.516	.06906	.44384	.41604	.03965	.13123	.00152
18	.00045	183.623	.88325	.49811	.00043	.00656	.00483	.00437

	BMI	CI_FI	M_MP	INT.MX.L	MCF	P_PMS	PMM_PSP	PMS_BA
1	.00017	.00003	.00014	.00001	.00017	.00005	.00045	.00001
2	.00000	.00001	.00054	.00000	.23058	.00000	.00335	.00000
3	.00027	.00005	.00000	.00002	.00368	.00008	.00352	.00001
4	.00020	.00002	.00000	.00000	.16904	.00004	.00419	.00000
5	.00045	.00000	.00241	.00000	.08918	.00148	.52407	.00001
6	.01687	.00198	.33139	.00051	.01171	.00116	.01889	.00037
7	.41713	.00017	.02363	.00002	04302	.00039	.01374	.00000
8	.44510	.00012	.02483	.00003	.00048	.00322	.00017	.00044
9	.00002	.09324	.01301	.00226	.04581	.10013	.05129	.00004
10	.00740	.00529	.02329	.00336	.00015	.64339	.06656	.00027
11	.00005	.34070	.01207	.00202	.00894	.01829	.00339	.00907
12	.01505	.09880	.25341	.05805	.00150	.06433	.09867	.03410
13	.03036	.32229	.20136	.00412	.04108	.07505	.10700	.05923
14	.04954	.00077	.05787	.05524	.12735	.02533	.06686	.23714
15	.01237	.00455	.03286	.16340	.05711	.02157	.00312	.36948
16	.00049	.12435	.00968	.29698	.00479	.00037	.02439	.04943
17	.00012	.00057	.00657	.25174	.02394	.00047	.00360	.19774
18	.00441	.00707	.00694	.16223	.14149	.04468	.00684	.04263

	RAN_MCF	T__AREA	T__INT.M	TL
1	.00087	.00001	.00001	.00001
2	.04375	.00000	.00001	.00000
3	.43255	.00003	.00001	.00001
4	.34687	.00000	.00001	.00000
5	.01517	.00014	.00006	.00004
6	.00407	.00008	.00014	.00001
7	.02840	.00029	.00000	.00007
8	.00025	.00173	.00203	.00120
9	.00900	.03165	.01143	.00196
10	.00034	.08185	.00601	.00524
11	.00001	.00483	.00583	.00852
12	.10355	.01049	.33285	.02875
13	.00045	.11260	.02653	.03492
14	.00022	.01120	.02436	.01672
15	.00000	.10403	.02981	.42227
16	.00186	.46791	.23459	.29146
17	.00717	.11502	.18826	.17715
18	.00547	.05814	.13805	.01167

End Block Number 1 All requested variables entered.

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. O2DIFF

Block Number 1. Method: Stepwise Criteria PIN .0500 POUT .1000
O_BASN O_C2C4SN OFN_HOR A_PMS AGE BMI CI_FI M_MP
INT.MX.L MCF P_PMS PMM_PSP PMS_BA RAN_MCF T__AREA T__INT.M
TL

Variable(s) Entered on Step Number
1.. BMI

Multiple R .50863
R Square .25870
Adjusted R Square .25432
Standard Error 9.05291

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	4833.63365	4833.63365

```
Residual          169        13850.42822        81.95520

F =      58.97898       Signif F =  .0000

------------------ Variables in the Equation ------------------

Variable            B         SE B       Beta         T  Sig T

BMI              .705471     .091861    .508629     7.680  .0000
(Constant)     -6.456468    2.912671               -2.217  .0280

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..   O2DIFF

------------- Variables not in the Equation -------------

Variable     Beta In  Partial  Min Toler         T  Sig T

@_BASN      -.062693 -.072401    .988630     -.941  .3481
@_C2C4SN     .121976  .138958    .962087     1.819  .0707
@FH_HOR      .123610  .142448    .984454     1.865  .0639
A_PNS        .088322  .102570    .999745     1.337  .1832
AGE          .230445  .267117    .996000     3.593  .0004
CI_FI       -.026161 -.030372    .999135     -.394  .6942
H_MP         .309780  .346798    .929048     4.792  .0000
INT.MX.L    -.039769 -.044431    .925309     -.576  .5651
MCF         -.070624 -.080933    .973502    -1.052  .2941
P_PNS        .149708  .173101    .991059     2.278  .0240
PHW_PSP     -.168620 -.195396    .995418    -2.582  .0107
PNS_BA       .040988  .046583    .957507      .604  .5464
RAM_MCF      .085741  .099352    .995325     1.294  .1974
T__AREA      .191252  .209402    .888677     2.776  .0061
T__INT.M     .216961  .249459    .980006     3.339  .0010
TL           .222273  .244547    .897307     3.269  .0013

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

Variable(s) Entered on Step Number
   2..     H_MP

Multiple R            .58960  .
R Square              .34766
Adjusted R Square     .34009
Standard Error       8.51632

Analysis of Variance
                 DF        Sum of Squares      Mean Square
Regression        2          6499.41011       3249.70506
Residual        168         12184.65176         72.52769

F =      44.80641       Signif F =  .0000

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..   O2DIFF

------------------ Variables in the Equation ------------------

Variable            B         SE B       Beta         T  Sig T

BMI              .591021     .089655    .426114     6.592  .0000
H_MP             .452432     .094405    .309780     4.792  .0000
(Constant)   -12.203501    2.990782               -4.080  .0001
```

---------- Variables not in the Equation ----------

Variable	Beta In	Partial	Min Toler	T	Sig T
0_BASN	.007479	.008957	.878901	.116	.9080
0_C2C4SN	.037514	.043639	.852174	.564	.5732
0FH_HOR	.039160	.046022	.849998	.595	.5524
A_PNS	.078246	.096825	.927971	1.257	.2105
AGE	.154312	.181843	.844718	2.390	.0180
CI_FI	-.050629	-.062463	.922982	-.809	.4198
INT.MX.L	.031243	.036272	.831703	.469	.6397
MCF	.023780	.027673	.842818	.358	.7210
P_PNS	.087361	.105001	.883153	1.364	.1743
PHW_PSP	-.120574	-.146732	.901393	-1.917	.0570
PNS_BA	.055591	.067285	.887659	.871	.3847
RAM_MCF	.100527	.124045	.926428	1.615	.1081
T__AREA	.075679	.080819	.743736	1.048	.2962
T__INT.M	.010806	.009446	.472376	.122	.9030
TL	.095181	.098556	.699210	1.280	.2024

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. O2DIFF

Variable(s) Entered on Step Number
3.. AGE

Multiple R .60780
R Square .36942
Adjusted R Square .35810
Standard Error 8.39937

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	3	6903.31791	2300.77264
Residual	167	11781.74396	70.54937

F = 32.61224 Signif F = .0000

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
AGE	.153571	.064262	.154312	2.390	.0180
BMI	.622343	.089390	.448696	6.962	.0000
H_MP	.382127	.097646	.261643	3.913	.0001
(Constant)	-18.758369	4.027929		-4.657	.0000

---------- Variables not in the Equation ----------

Variable	Beta In	Partial	Min Toler	T	Sig T
0_BASN	.004205	.005120	.800751	.066	.9475
0_C2C4SN	.055657	.065430	.765346	.845	.3994
0FH_HOR	.030682	.036613	.785521	.472	.6375
A_PNS	.081723	.102813	.843400	1.332	.1848
CI_FI	-.078756	-.097293	.844186	-1.260	.2096
INT.MX.L	.010269	.012013	.790462	.155	.8772
MCF	.037156	.043816	.783019	.565	.5728
P_PNS	.059528	.071297	.823517	.921	.3584
PHW_PSP	-.100016	-.122313	.832275	-1.588	.1142
PNS_BA	.045364	.055702	.841009	.719	.4733
RAM_MCF	.086447	.107918	.839685	1.399	.1638
T__AREA	.066286	.071874	.725892	.928	.3545
T__INT.M	.018964	.016845	.443982	.217	.8284
TL	.097004	.102141	.669990	1.323	.1877

```
          * * * *  M U L T I P L E   R E G R E S S I O N  * * * *

Equation Number 1     Dependent Variable..    O2DIFF

End Block Number   1   PIN =      .050 Limits reached.

          * * * *  M U L T I P L E   R E G R E S S I O N  * * * *

Listwise Deletion of Missing Data

Equation Number 1     Dependent Variable..    O2DIFF2

Block Number  1.  Method:  Enter
   @_BASN    @_C2C4SN @FH_HOR  A_FNS     AGE       BMI       CI_FI     H_MP
   INT.MX.L MCF       P_FNS     FHW_FSP   FNS_BA    RAM_MCF   T__AREA   T__INT.M
   TL

Variable(s) Entered on Step Number
   1..     TL
   2..     MCF
   3..     CI_FI
   4..     RAM_MCF
   5..     AGE
   6..     @FH_HOR
   7..     FHW_FSP
   8..     BMI
   9..     A_FNS
  10..     @_BASN
  11..     T__INT.M
  12..     P_FNS
  13..     @_C2C4SN
  14..     FNS_BA
  15..     H_MP
  16..     INT.MX.L
  17..     T__AREA

Multiple R            .43643
R Square              .19047
Adjusted R Square     .09933
Standard Error       4.26942

Analysis of Variance
                 DF        Sum of Squares        Mean Square
Regression       17             647.59754           38.09397
Residual        151            2752.42033           18.22795

F =       2.08987       Signif F =  .0099

          * * * *  M U L T I P L E   R E G R E S S I O N  * * * *

Equation Number 1     Dependent Variable..    O2DIFF2

------------------ Variables in the Equation ------------------

Variable            B         SE B       Beta          T  Sig T

@_BASN       -.009110     .086235   -.010654     -.106  .9160
@_C2C4SN      .005369     .056246    .011627      .095  .9241
@FH_HOR       .031857     .075654    .039520      .421  .6743
A_FNS         .014317     .111018    .012783      .129  .8976
AGE          -.007288     .036766   -.017102     -.198  .8431
BMI           .188916     .051327    .311430     3.681  .0003
CI_FI       -3.178634    4.653078   -.058474     -.683  .4956
H_MP          .112167     .081184    .178952     1.382  .1691
```

```
INT.MX.L          .010552      .098598     .016671       .107   .9149
MCF               .074806      .161160      053091       .464   .6432
P_PNS            -.035655      .068024    -.054258      -.524   .6009
PHW_PSP          -.135797      .141066    -.095318      -.963   .3373
PNS_BA           -.046644      .148107    -.039648      -.315   .7532
RAM_MCF           .090568      .116318     .063389       .779   .4374
T__AREA     -1.27576E-04      .001328    -.016995      -.096   .9236
T__INT.M         1.920173     6.850903     .040451       .280   .7796
TL                .015702      .087710     .027853       .179   .8582
(Constant)        .486427    13.099781                    .037   .9704

End Block Number   1   All requested variables entered.

          * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Listwise Deletion of Missing Data

Equation Number 1     Dependent Variable..   O2DIFF2

Block Number  1.  Method:  Stepwise      Criteria   PIN  .0500   POUT  .1000
   @_BASN    @_C2C4SN @FH_HOR  A_PNS     AGE        BMI        CI_FI     H_MP
   INT.MX.L MCF       P_PNS     PHW_PSP   PNS_BA     RAM_MCF    T__AREA   T__INT.M
   TL


Variable(s) Entered on Step Number
   1..     BMI


Multiple R            .36431
R Square              .13272
Adjusted R Square     .12753
Standard Error       4.20206

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression           1             451.24846        451.24846
Residual           167            2948.76941         17.65730

F =       25.55591       Signif F =  .0000

------------------ Variables in the Equation ------------------

Variable              B         SE B       Beta          T  Sig T

BMI             .220992      .043715     .364307      5.055  .0000
(Constant)    -1.779871     1.378865                 -1.291  .1985

          * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Equation Number 1     Dependent Variable..   O2DIFF2

------------- Variables not in the Equation -------------

Variable     Beta In  Partial  Min Toler         T  Sig T

@_BASN      -.045299 -.048477    .993227      -.625  .5326
@_C2C4SN     .106589  .112168    .960447      1.454  .1477
@FH_HOR      .098336  .104912    .987155      1.359  .1759
A_PNS        .003474  .003730    .999806       .048  .9617
AGE          .037905  .040660    .997935       .524  .6008
CI_FI       -.030790 -.033032    .998215      -.426  .6708
H_MP         .203519  .210747    .929970      2.778  .0061
INT.MX.L    -.067271 -.070066    .940856      -.905  .3668
MCF         -.050038 -.053180    .979594      -.686  .4936
P_PNS        .037059  .039528    .986684       .510  .6110
PHW_PSP     -.104705 -.112330    .998201     -1.456  .1471
```

PNS_BA	-.030169	-.031873	.967958	-.411	.6817
RAM_MCF	.049106	.052668	.997636	.680	.4978
T__AREA	.096547	.097805	.890028	1.266	.2072
T__INT.M	.177765	.188328	.973413	2.471	.0145
TL	.122503	.124485	.895575	1.616	.1079

* *

Variable(s) Entered on Step Number
2.. H_MP

Multiple R .41381
R Square .17124
Adjusted R Square .16125
Standard Error 4.12004

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	582.21553	291.10777
Residual	166	2817.80234	16.97471

F = 17.14950 Signif F = .0000

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. O2DIFF2

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
BMI	.188321	.044446	.310449	4.237	.0000
H_MP	.127566	.045925	.203519	2.778	.0061
(Constant)	-3.382309	1.469893		-2.301	.0226

---------- Variables not in the Equation ----------

Variable	Beta In	Partial	Min Toler	T	Sig T
@_BASN	.001128	.001200	.878422	.015	.9877
@_C2C4SN	.054905	.056751	.857322	.730	.4663
@FH_HOR	.045286	.047338	.853100	.609	.5435
A_PNS	-.002353	-.002583	.929151	-.033	.9736
AGE	-.023966	-.025057	.844212	-.322	.7479
CI_FI	-.048628	-.053157	.922628	-.684	.4951
INT.MX.L	-.024216	-.025178	.849858	-.324	.7467
MCF	.012830	.013258	.840144	.170	.8650
P_PNS	-.005851	-.006234	.886663	-.080	.9363
PHW_PSP	-.073328	-.079296	.902908	-1.022	.3084
PNS_BA	-.021294	-.022991	.898432	-.295	.7681
RAM_MCF	.060170	.065915	.927119	.849	.3974
T__AREA	.015853	.015056	.747567	.193	.8469
T__INT.M	.075558	.058495	.474533	.753	.4527
TL	.033623	.030974	.703283	.398	.6911

End Block Number 1 PIN = .050 Limits reached.

* * * * MULTIPLE REGRESSION * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. LOWEST_O

```
Block Number  1.  Method:  Enter
   @_BASN    @_C2C4SN @FM_HOR  A_PNS     AGE       BMI       CI_FI     H_MP
   INT.MX.L  MCP      P_PNS     PMW_PSP   PNS_BA    RAM_MCP   T__AREA   T__INT.M
   TL

Variable(s) Entered on Step Number
   1..     TL
   2..     @_BASN
   3..     AGE
   4..     @FM_HOR
   5..     RAM_MCP
   6..     CI_FI
   7..     PMW_PSP
   8..     BMI
   9..     A_PNS
  10..     T__INT.M
  11..     P_PNS
  12..     MCP
  13..     @_C2C4SN
  14..     PNS_BA
  15..     H_MP
  16..     INT.MX.L
  17..     T__AREA

Multiple R            .67875
R Square              .46070
Adjusted R Square     .40194
Standard Error       8.75037

Analysis of Variance
                 DF        Sum of Squares      Mean Square
Regression       17          10204.05074        600.23828
Residual        156          11944.74955         76.56891

F =       7.83919       Signif F =  .0000

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..   LOWEST_O

------------------ Variables in the Equation ------------------

Variable              B         SE B        Beta         T  Sig T

@_BASN          .063108     .174616     .029272      .361  .7183
@_C2C4SN       -.061267     .113896    -.052664     -.538  .5914
@FM_HOR        -.060492     .153800    -.029856     -.393  .6946
A_PNS          -.237946     .224893    -.084215    -1.058  .2917
AGE            -.177636     .074930    -.164115    -2.371  .0190
BMI            -.737847     .103793    -.488823    -7.109  .0000
CI_FI         14.810488    9.443446     .107269     1.568  .1188
H_MP           -.472342     .163105    -.299036    -2.896  .0043
INT.MX.L        .066939     .199378     .042437      .336  .7375
MCP            -.182799     .326978    -.051371     -.559  .5769
P_PNS           .168796     .138059     .089577     1.078  .2828
PMW_PSP         .465179     .285179     .129681     1.631  .1049
PNS_BA         -.279680     .300141    -.094716     -.932  .3529
RAM_MCP        -.335457     .237178    -.093060    -1.414  .1592
T__AREA     5.77736E-04     .002685     .030443      .215  .8299
T__INT.M       7.415719   13.985439     .062087      .530  .5967
TL             -.042195     .178463    -.029592     -.236  .8134
(Constant)   113.461114   26.781553                4.237  .0000

End Block Number   1   All requested variables entered.

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *
```

```
Listwise Deletion of Missing Data

Equation Number 1    Dependent Variable..    LOWEST_O

Block Number  1.  Method:  Stepwise     Criteria   PIN  .0500   POUT  .1000
   @_BASN    @_C2C4SN @FN_HOR  A_PNS     AGE       BMI       CI_FI     H_MP
   INT.MX.L MCF       P_PNS     PNW_PSP   PNS_BA    RAM_MCF   T__AREA   T__INT.M
   TL


Variable(s) Entered on Step Number
   1..     BMI


Multiple R            .54957
R Square              .30203
Adjusted R Square     .29797
Standard Error       9.48045

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression           1          6689.62713        6689.62713
Residual           172         15459.17316          89.87891

F =       74.42933       Signif F =  .0000


------------------ Variables in the Equation ------------------

Variable             B         SE B       Beta          T  Sig T

BMI           -.829547      .096154   -.549574    -8.627  .0000
(Constant)   105.958903     3.047671               34.767  .0000

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..    LOWEST_O

------------- Variables not in the Equation -------------

Variable     Beta In  Partial  Min Toler         T  Sig T

@_BASN       .021620  .025733    .988760      .337  .7368
@_C2C4SN    -.107702 -.126413    .961549    -1.666  .0975
@FN_HOR     -.123760 -.146938    .983882    -1.943  .0537
A_PNS       -.083307 -.099708    .999859    -1.310  .1918
AGE         -.226615 -.270696    .995916    -3.677  .0003
CI_FI        .059383  .071048    .999127      .931  .3529
H_MP        -.319866 -.369170    .929724    -5.194  .0000
INT.MX.L     .019622  .022605    .926340      .296  .7678
MCF          .033332  .039381    .974266      .515  .6070
P_PNS       -.140487 -.167442    .991496    -2.221  .0277
PNW_PSP      .151302  .180692    .995450     2.402  .0174
PNS_BA      -.080966 -.094908    .959038    -1.247  .2142
RAM_MCF     -.097324 -.116224    .995378    -1.530  .1278
T__AREA     -.200265 -.226161    .890149    -3.036  .0028
T__INT.M    -.220877 -.261730    .980038    -3.546  .0005
TL          -.223774 -.253903    .898573    -3.433  .0007


          . . . . . .

Variable(s) Entered on Step Number
   2..     H_MP


Multiple R            .63020
R Square              .39715
```

```
Adjusted R Square     .39010
Standard Error       8.83649

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression           2          8796.50459       4398.25229
Residual           171         13352.29570         78.08360

F =       56.32748       Signif F =  .0000

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1     Dependent Variable..   LOWEST_O

------------------ Variables in the Equation ------------------

Variable               B         SE B       Beta         T  Sig T

BMI             -.701554      .092949   -.464779    -7.548  .0000
H_MP            -.505243      .097266   -.319866    -5.194  .0000
(Constant)    112.410289     3.100298                36.258  .0000

------------- Variables not in the Equation -------------

Variable     Beta In  Partial  Min Toler         T  Sig T

@_BASN      -.049384 -.061680    .884260      -.806  .4215
@_C2C4SM    -.022765 -.027638    .859137      -.360  .7189
@FH_HOR     -.039892 -.048928    .856955      -.639  .5239
A_PNS       -.074984 -.096532    .929038     -1.265  .2078
AGE         -.147267 -.180597    .846338     -2.394  .0178
CI_FI        .083754  .107501    .924160      1.410  .1604
INT.MX.L    -.056461 -.068142    .832663      -.891  .3744
MCF         -.064382 -.078209    .848919     -1.023  .3078
P_PNS       -.074372 -.092918    .882371     -1.217  .2254
PHW_PSP      .099705  .126099    .900590      1.657  .0993
PNS_BA      -.094831 -.119496    .890098     -1.569  .1184
RAM_MCF     -.108584 -.139436    .926796     -1.836  .0681
T__AREA     -.082341 -.091647    .746799     -1.200  .2318
T__INT.M    -.003319 -.003007    .469475      -.039  .9688
TL          -.092022 -.099375    .703038     -1.302  .1946

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1     Dependent Variable..   LOWEST_O

Variable(s) Entered on Step Number
   3..     AGE


Multiple R            .64561
R Square              .41682
Adjusted R Square     .40653
Standard Error       8.71672

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression           3          9231.99219       3077.33073
Residual           170         12916.80810         75.98122

F =       40.50120       Signif F =  .0000

------------------ Variables in the Equation ------------------

Variable               B         SE B       Beta         T  Sig T

AGE             -.159400      .066581   -.147267    -2.394  .0178
```

```
BMI              -.734026      .092687    -.486291     -7.919   .0000
H_MF             -.433142      .100563    -.274219     -4.307   .0000
(Constant)    119.231204     4.179764                   28.526   .0000

------------- Variables not in the Equation -------------

Variable     Beta In  Partial  Min Toler         T  Sig T

@_BASN      -.046366 -.058866    .806353     -.767  .4444
@_C2C4SN    -.039562 -.048538    .772922     -.632  .5284
@FH_HOR     -.031728 -.039503    .792116     -.514  .6080
A_PNS       -.077865 -.101896    .845472    -1.332  .1848
CI_FI        .111673  .143501    .845922     1.885  .0611
INT.MX.L    -.037248 -.045300    .790492     -.590  .5563
MCF         -.077420 -.095281    .788771    -1.244  .2151
P_PNS       -.047335 -.058910    .824064     -.767  .4441
PHW_PSP      .079461  .100938    .832973     1.319  .1890
PNS_BA      -.085276 -.108988    .843047    -1.425  .1559
RAM_MCF     -.095597 -.124198    .842853    -1.627  .1056
T__AREA     -.074150 -.083797    .728055    -1.093  .2759
T__INT.M    -.011201 -.010310    .441649     -.134  .8935
TL          -.093781 -.102962    .673636    -1.346  .1802

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..   LOWEST_O

End Block Number   1   PIN =     .050 Limits reached.

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Listwise Deletion of Missing Data

Equation Number 1    Dependent Variable..   LONGEST_

Block Number  1.  Method:  Enter
   @_BASN    @_C2C4SN @FH_HOR  A_PNS     AGE       BMI       CI_FI     H_MF
   INT.MX.L  MCF      P_PNS     PHW_PSP   PNS_BA    RAM_MCF   T__AREA   T__INT.M
   TL

Variable(s) Entered on Step Number
   1..     TL
   2..     MCF
   3..     CI_FI
   4..     RAM_MCF
   5..     AGE
   6..     @FH_HOR
   7..     PHW_PSP
   8..     BMI
   9..     A_PNS
  10..     @_BASN
  11..     T__INT.M
  12..     P_PNS
  13..     @_C2C4SN
  14..     PNS_BA
  15..     H_MF
  16..     INT.MX.L
  17..     T__AREA

Multiple R          .51261
R Square            .26277
Adjusted R Square   .18031
Standard Error    23.98337

Analysis of Variance
                 DF        Sum of Squares        Mean Square
```

Regression	17	31162.56474	1833.09204
Residual	152	87430.68326	575.20186

F = 3.18687 Signif F = .0001

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. LONGEST_

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
@_BASN	-.956292	.483882	-.190775	-1.976	.0499
@_C2C4SN	.103314	.315792	.037882	.327	.7440
@FH_HOR	.172150	.424237	.036234	.406	.6855
A_PNS	.272612	.623533	.041215	.437	.6626
AGE	.742471	.205867	.296102	3.607	.0004
BMI	.798358	.284977	.228459	2.801	.0057
CI_FI	10.711864	26.043752	.033407	.411	.6814
H_MP	-.150204	.451887	-.040609	-.332	.7401
INT.MX.L	-1.057689	.569246	-.288032	-1.926	.0560
MCF	.925870	.903482	.111930	1.025	.3071
P_PNS	.530124	.379435	.137054	1.397	.1644
PHN_PSP	-.039775	.790708	-.004763	-.050	.9599
PNS_BA	.438762	.827734	.063905	.530	.5968
RAM_MCF	.308779	.651229	.036771	.474	.6361
T__AREA	4.01209E-04	.007443	.009060	.054	.9571
T__INT.M	15.211945	38.463371	.054426	.395	.6930
TL	.313916	.492119	.094324	.638	.5245
(Constant)	67.256816	73.517859		.915	.3617

End Block Number 1 All requested variables entered.

**** MULTIPLE REGRESSION ****

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. LONGEST_

Block Number 1. Method: Stepwise Criteria PIN .0500 POUT .1000
@_BASN @_C2C4SN @FH_HOR A_PNS AGE BMI CI_FI H_MP
INT.MX.L MCF P_PNS PHN_PSP PNS_BA RAM_MCF T__AREA T__INT.M
TL

Variable(s) Entered on Step Number
1.. AGE

Multiple R	.32147
R Square	.10334
Adjusted R Square	.09801
Standard Error	25.15871

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	12255.87005	12255.87005
Residual	168	106337.37795	632.96058

F = 19.36277 Signif F = .0000

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
AGE	.806085	.183188	.321471	4.400	.0000

```
(Constant)     -1.673929     8.607986                    -.194   .8460

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..  LONGEST_

------------ Variables not in the Equation ------------

Variable     Beta In  Partial  Min Toler        T  Sig T

G_BASN      -.148775 -.156868    .996859   -2.053  .0417
G_C2C4SN     .128190  .135330    .999320    1.765  .0794
GFH_HOR      .092910  .097280    .982975    1.263  .2083
A_PNS        .007927  .008371    .999846     .108  .9140
BMI          .216790  .228485    .996014    3.033  .0028
CI_FI        .027797  .028835    .964849     .373  .7098
H_MP         .226210  .229629    .923960    3.049  .0027
INT.MX.L    -.110175 -.116268    .998565   -1.513  .1322
MCF         -.050988 -.053013    .969259    -.686  .4936
P_PNS        .177904  .182077    .939213    2.393  .0178
PHW_PSP     -.159052 -.164584    .960124   -2.156  .0325
PNS_BA    7.608E-05  .000080    .998588     .001  .9992
RAM_MCF      .018383  .019340    .992475     .250  .8029
T__AREA      .139985  .146360    .980196    1.912  .0576
T__INT.M     .234766  .244035    .968854    3.252  .0014
TL           .180416  .189427    .988463    2.493  .0136

          * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

Variable(s) Entered on Step Number
   2..    T__INT.M


Multiple R            .39591
R Square              .15674
Adjusted R Square     .14664
Standard Error      24.47101

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression           2          18588.59380       9294.29690
Residual           167         100004.65420        598.83026

F =       15.52075       Signif F =  .0000

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..  LONGEST_

------------------ Variables in the Equation ------------------

Variable             B         SE B       Beta         T  Sig T

AGE            .702195     .181022    .280039     3.879  .0002
T__INT.M     65.616169   20.177505    .234766     3.252  .0014
(Constant)  -56.353053   18.783552               -3.000  .0031

------------ Variables not in the Equation ------------

Variable     Beta In  Partial  Min Toler        T  Sig T

G_BASN      -.124420 -.134427    .956708   -1.748  .0823
G_C2C4SN     .066658  .069435    .887078     .897  .3711
GFH_HOR      .052299  .055527    .936888     .717  .4747
A_PNS        .009903  .010783    .968743     .139  .8897
```

```
BMI             .185307   .198951     .945500     2.616   .0097
CI_FI          -.012136  -.012797     .937524     -.165   .8692
H_MP            .114902   .086864     .481940     1.123   .2629
INT.MX.L       -.026719  -.026926     .830897     -.347   .7290
MCF             .010396   .010766     .904082      .139   .8898
P_PNS           .164671   .173497     .915834     2.270   .0245
PHW_PSP        -.094701  -.096008     .866695    -1.243   .2157
PNS_BA          .008511   .009256     .967027      .119   .9052
RAM_MCF    -9.761E-04  -.001055     .962111     -.014   .9892
T__AREA         .068361   .069288     .856260      .895   .3722
TL              .114348   .116350     .855734     1.509   .1331

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..   LONGEST_

Variable(s) Entered on Step Number
   3..     BMI


Multiple R            .43603
R Square              .19012
Adjusted R Square     .17548
Standard Error      24.05394

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression           3          22546.93134       7515.64378
Residual           166          96046.31666        578.59227

F =       12.98953       Signif F =  .0000

------------------ Variables in the Equation ------------------

Variable                B         SE B        Beta         T  Sig T

AGE              .744441     .178668     .296887     4.167  .0000
BMI              .647563     .247578     .185307     2.616  .0097
T__INT.M       57.462951   20.077077     .205595     2.862  .0048
(Constant)    -70.841641   19.276459                -3.675  .0003

------------- Variables not in the Equation -------------

Variable     Beta In  Partial  Min Toler         T  Sig T

G_BASN       -.149308 -.163360    .929454    -2.127  .0349
G_C2C4SN      .037576  .039444    .877211      .507  .6128
GFM_HOR       .032272  .034755    .919978      .447  .6557
A_PNS         .006916  .007683    .945386      .099  .9215
CI_FI        -.015391 -.016557    .920144     -.213  .8318
H_MP          .048624  .036170    .448146      .465  .6426
INT.MX.L     -.114685 -.109691    .740885    -1.418  .1582
MCF          -.029962 -.031000    .866297     -.398  .6909
P_PNS         .146310  .156412    .904150     2.034  .0435
PHW_PSP      -.118116 -.121423    .845526    -1.571  .1180
PNS_BA       -.032855 -.035584    .925978     -.457  .6480
RAM_MCF       .013439  .014781    .937027      .190  .8496
T__AREA       .006954  .006822    .779568      .088  .9303
TL            .061353  .060785    .794945      .782  .4352

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..   LONGEST_

Variable(s) Entered on Step Number
   4..     G_BASN
```

```
Multiple R            .46014
R Square              .21173
Adjusted R Square     .19262
Standard Error      23.80262

Analysis of Variance
                 DF        Sum of Squares      Mean Square
Regression        4          25110.06510       6277.51627
Residual        165          93483.18290        566.56474

F =      11.07996       Signif F =  .0000

------------------ Variables in the Equation ------------------

Variable             B        SE B       Beta         T  Sig T

@_BASN        -.748431     .351877   -.149308    -2.127  .0349
AGE            .735174     .176855    .293192     4.157  .0001
BMI            .712099     .246863    .203775     2.885  .0044
T__INT.M     51.910760   20.038060    .185730     2.591  .0104
(Constant)   29.083113   50.704733                .574  .5670

------------- Variables not in the Equation -------------

Variable     Beta In  Partial  Min Toler         T  Sig T

@_C2C4SN     .051999  .055102    .857567      .707  .4807
@FH_HOR      .031246  .034106    .905036      .437  .6627
A_PNS        .020865  .023392    .929452      .300  .7648
CI_FI       -.007648 -.008328    .902907     -.107  .9152
M_MP         .005346  .003951    .630573      .051  .9597
INT.MX.L    -.085623 -.081532    .714742    -1.048  .2964
MCF          .058021  .053562    .671760      .687  .4931
P_PNS        .137338  .148531    .904080     1.923  .0562
PHW_PSP     -.095833 -.098656    .835396    -1.270  .2060
PNS_BA       .046313  .045147    .749074      .579  .5636
RAM_MCF      .052956  .057239    .911443      .734  .4639
T__AREA     -.004433 -.004399    .775935     -.056  .9551
TL           .053532  .053696    .793099      .689  .4920

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..   LONGEST_

End Block Number   1   PIN =     .050 Limits reached.

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Listwise Deletion of Missing Data

Equation Number 1    Dependent Variable..   AVR_02

Block Number  1.  Method:  Enter
   @_BASN   @_C2C4SN @FH_HOR  A_PNS    AGE      BMI      CI_FI    M_MP
   INT.MX.L MCF      P_PNS    PHW_PSP  PNS_BA   RAM_MCF  T__AREA  T__INT.M
   TL

Variable(s) Entered on Step Number
   1..     TL
   2..     MCF
   3..     CI_FI
   4..     RAM_MCF
   5..     AGE
   6..     @FH_HOR
   7..     PHW_PSP
```

```
  8..     BMI
  9..     @_BASN
 10..     A_PNS
 11..     T__INT.M
 12..     P_PNS
 13..     @_C2C4SN
 14..     PNS_BA
 15..     M_MP
 16..     INT.MX.L
 17..     T__AREA

Multiple R            .58134
R Square              .33796
Adjusted R Square     .26535
Standard Error       4.08600

Analysis of Variance
                 DF        Sum of Squares      Mean Square
Regression       17           1321.00552         77.70621
Residual        155           2587.78235         16.69537

F =       4.65436       Signif F =  .0000

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1     Dependent Variable..   AVR_02

------------------ Variables in the Equation ------------------

Variable              B         SE B       Beta          T  Sig T

@_BASN          .002982     .081488     .003270       .037  .9709
@_C2C4SN       -.011223     .052747    -.022855      -.213  .8318
@FH_HOR        -.053145     .070670    -.062758      -.752  .4532
A_PNS           .021635     .105195     .018210       .206  .8373
AGE            -.004222     .035067    -.009266      -.120  .9043
BMI            -.231546     .048557    -.360318     -4.769  .0000
CI_FI          5.826883    4.435559     .100035      1.314  .1909
H_MP           -.126538     .076874    -.190011     -1.646  .1018
INT.MX.L        .001495     .094011     .002222       .016  .9873
MCF            -.140327     .153777    -.093411      -.913  .3629
P_PNS           .045686     .064271     .065964       .711  .4783
PHW_PSP         .052984     .133737     .035221       .396  .6925
PNS_BA          .028677     .140489     .022875       .204  .8385
RAM_MCF        -.123814     .110952    -.081670     -1.116  .2662
T__AREA        -.001208     .001255    -.151130      -.963  .3373
T__INT.M      -4.343559    6.546841    -.085859      -.663  .5080
TL              .010901     .083511     .018084       .131  .8963
(Constant)    100.771418   12.502672                 8.060  .0000

End Block Number   1   All requested variables entered.

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Listwise Deletion of Missing Data

Equation Number 1     Dependent Variable..   AVR_02

Block Number  1.  Method:  Stepwise     Criteria   PIN  .0500   POUT  .1000
   @_BASN   @_C2C4SN @FH_HOR  A_PNS     AGE       BMI       CI_FI     H_MP
   INT.MX.L MCF       P_PNS    PHW_PSP  PNS_BA    RAM_MCF   T__AREA   T__INT.M
   TL

Variable(s) Entered on Step Number
   1..     BMI
```

```
Multiple R              .46477
R Square                .21601
Adjusted R Square       .21143
Standard Error         4.23328

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression           1             844.35263       844.35263
Residual           171            3064.43523        17.92067

F =       47.11612       Signif F =  .0000

------------------ Variables in the Equation ------------------

Variable            B         SE B       Beta         T  Sig T

BMI           -.298670      .043512   -.464773    -6.864  .0000
(Constant)  100.270288     1.376407                72.849  .0000

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..   AVR_02

------------- Variables not in the Equation -------------

Variable     Beta In  Partial  Min Toler         T  Sig T

@_BASN       .023800  .026778    .992514      .349  .7273
@_C2C4SN    -.116674 -.129036    .958916    -1.697  .0916
@FH_HOR     -.128685 -.144714    .991457    -1.907  .0582
A_FNS       -.034728 -.039220    .999952     -.512  .6095
AGE         -.073970 -.083419    .997066    -1.091  .2766
CI_FI        .088792  .100183    .998053     1.313  .1910
H_MP        -.283268 -.309777    .937590    -4.248  .0000
INT.MX.L     .014439  .015787    .937120      .206  .8371
MCF          .013352  .014913    .978021      .194  .8460
P_FNS       -.078092 -.087873    .992675    -1.150  .2517
PHW_PSP      .080333  .090554    .996181     1.186  .2375
PNS_BA      -.046611 -.051777    .967404     -.676  .5000
RAM_MCF     -.093870 -.105813    .996169    -1.387  .1671
T__AREA     -.229838 -.245895    .897353    -3.308  .0011
T__INT.M    -.251328 -.280633    .977472    -3.812  .0002
TL          -.212651 -.227868    .900203    -3.051  .0026

          * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

Variable(s) Entered on Step Number
   2..     H_MP

Multiple R              .53967
R Square                .29125
Adjusted R Square       .28291
Standard Error         4.03686

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression           2            1138.42188       569.21094
Residual           170            2770.36598        16.29627

F =       34.92891       Signif F =  .0000

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..   AVR_02
```

```
------------------ Variables in the Equation ------------------

Variable            B         SE B       Beta          T  Sig T

BMI          -.253195     .042852   -.394007    -5.909  .0000
H_MP         -.188642     .044408   -.283268    -4.248  .0000
(Constant)  102.731180    1.434703                71.604  .0000


------------- Variables not in the Equation -------------

Variable     Beta In  Partial  Min Toler         T  Sig T

@_BASN      -.040190 -.046340    .890113      -.603  .5473
@_C2C4SN    -.045499 -.051023    .871468      -.664  .5075
@FH_HOR     -.053924 -.061084    .860044      -.796  .4274
A_PNS       -.027989 -.033235    .937021      -.432  .6661
AGE          .010824  .012226    .850357       .159  .8739
CI_FI        .112553  .133095    .931026      1.746  .0827
INT.MX.L    -.052658 -.058967    .852542      -.768  .4436
MCF         -.077866 -.087166    .851456     -1.137  .2569
P_PNS       -.014464 -.016643    .886251      -.216  .8289
PHW_PSP      .030073  .035026    .904908       .456  .6492
PNS_BA      -.058688 -.068503    .905374      -.893  .3733
RAM_MCF     -.102892 -.121920    .935065     -1.597  .1122
T__AREA     -.135063 -.139079    .751527     -1.826  .0696
T__INT.M    -.110726 -.092169    .471061     -1.203  .2305
TL          -.100283 -.100170    .707159     -1.309  .1924


End Block Number   1   PIN =     .050 Limits reached.

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Listwise Deletion of Missing Data

Equation Number 1    Dependent Variable..   AVR_APNE

Block Number  1.  Method:  Enter
   @_BASN   @_C2C4SN @FH_HOR  A_PNS    AGE      BMI      CI_FI    H_MP
   INT.MX.L MCF      P_PNS    PHW_PSP  PNS_BA   RAM_MCF  T__AREA  T__INT.M
   TL


Variable(s) Entered on Step Number
   1..     TL
   2..     MCF
   3..     CI_FI
   4..     RAM_MCF
   5..     AGE
   6..     @FH_HOR
   7..     PHW_PSP
   8..     BMI
   9..     A_PNS
  10..     @_BASN
  11..     T__INT.M
  12..     P_PNS
  13..     @_C2C4SN
  14..     PNS_BA
  15..     H_MP
  16..     INT.MX.L
  17..     T__AREA


Multiple R            .50821
R Square              .25828
Adjusted R Square     .17532
Standard Error       5.38537
```

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	17	1535.01872	90.29522
Residual	152	4408.32834	29.00216

F = 3.11340 Signif F = .0001

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. AVR_APNE

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
@_BASN	-.066067	.108654	-.058875	-.608	.5441
@_C2C4SN	.016961	.070910	.027781	.239	.8113
@FH_HOR	-.083204	.095261	-.078230	-.873	.3838
A_PNS	.087154	.140012	.058859	.622	.5346
AGE	.209011	.046227	.372344	4.521	.0000
BMI	.031148	.063990	.039815	.487	.6271
CI_FI	-.588184	5.848016	-.008194	-.101	.9200
H_MP	.065437	.101469	.079027	.645	.5200
INT.MX.L	-.286030	.123331	-.347944	-2.319	.0217
MCF	.190658	.202873	.102960	.940	.3488
P_PNS	.056393	.085201	.065126	.662	.5091
PHW_PSP	-.031081	.177550	-.016624	-.175	.8613
PNS_BA	.010660	.185864	.006935	.057	.9543
RAM_MCF	.015216	.146231	.008094	.104	.9173
T__AREA	-.001306	.001671	-.131704	-.781	.4359
T__INT.M	-6.749736	8.636790	-.107876	-.782	.4357
TL	.264766	.110503	.355375	2.396	.0178
(Constant)	17.603096	16.508130		1.066	.2880

End Block Number 1 All requested variables entered.

* * * * MULTIPLE REGRESSION * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. AVR_APNE

Block Number 1. Method: Stepwise Criteria PIN .0500 POUT .1000
@_BASN @_C2C4SN @FH_HOR A_PNS AGE BMI CI_FI H_MP
INT.MX.L MCF P_PNS PHW_PSP PNS_BA RAM_MCF T__AREA T__INT.M
TL

Variable(s) Entered on Step Number
1.. AGE

Multiple R .37143
R Square .13796
Adjusted R Square .13283
Standard Error 5.52236

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	819.93693	819.93693
Residual	168	5123.41013	30.49649

F = 26.88627 Signif F = .0000

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T

AGE	.208496	.040210	.371428	5.185	.0000
(Constant)	7.269735	1.889462		3.848	.0002

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. AVR_APNE

---------- Variables not in the Equation ----------

Variable	Beta In	Partial	Min Toler	T	Sig T
0_BASN	-.093291	-.100322	.996859	-1.303	.1944
0_C2C4SN	.127807	.137608	.999320	1.795	.0744
0FH_HOR	.008719	.009311	.982975	.120	.9044
A_PNS	.031641	.034076	.999846	.441	.6601
BMI	.033271	.035763	.996014	.462	.6444
CI_FI	-.023658	-.025029	.964849	-.324	.7467
H_MP	.183068	.189529	.923960	2.494	.0136
INT.MX.L	-.141839	-.152659	.998565	-1.996	.0475
MCF	-.051227	-.054319	.969259	-.703	.4830
P_PNS	.129881	.135570	.939213	1.768	.0788
PHN_PSP	-.127348	-.134398	.960124	-1.753	.0815
PNS_BA	-.046970	-.050553	.998588	-.654	.5139
RAM_MCF	-.013153	-.014113	.992475	-.182	.8555
T__AREA	.051908	.055351	.980196	.716	.4747
T__INT.M	.143910	.152565	.968854	1.995	.0477
TL	.180071	.192823	.988463	2.539	.0120

* *

Variable(s) Entered on Step Number
2.. TL

Multiple R	.41232
R Square	.17001
Adjusted R Square	.16007
Standard Error	5.43493

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	1010.42969	505.21484
Residual	167	4932.91737	29.53843

F = 17.10365 Signif F = .0000

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. AVR_APNE

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
AGE	.197639	.039804	.352087	4.965	.0000
TL	.134159	.052829	.180071	2.539	.0120
(Constant)	-3.776181	4.730489		-.798	.4259

---------- Variables not in the Equation ----------

Variable	Beta In	Partial	Min Toler	T	Sig T
0_BASN	-.085130	-.093195	.985913	-1.206	.2295
0_C2C4SN	.066798	.067161	.829923	.867	.3870

@FH_HOR	-.031628	-.033613	.937401	- 433	.6653
A_PNS	-.053618	-.053334	.811860	-.688	.4923
BMI	-.029261	-.030251	.880332	-.390	.6971
CI_FI	.010055	.010658	.932495	.137	.8909
M_MP	.119787	.109341	.691540	1.417	.1583
INT.MX.L	-.265310	-.263619	.811152	-3.521	.0006
MCF	-.064333	-.069349	.955728	-.896	.3717
P_PNS	.061343	.058808	.762808	.759	.4489
PHW_PSP	-.106834	-.114063	.946110	-1.479	.1410
PNS_BA	-.118413	-.122709	.882271	-1.593	.1131
RAM_MCF	.005250	.005711	.978159	.074	.9414
T__AREA	-.246412	-.163159	.363890	-2.131	.0346
T__INT.M	.092569	.093993	.855734	1.216	.2256

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. AVR_APNE

Variable(s) Entered on Step Number
3.. INT.MX.L

Multiple R .47717
R Square .22769
Adjusted R Square .21373
Standard Error 5.25844

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	3	1353.24249	451.08083
Residual	166	4590.10457	27.65123

F = 16.31323 Signif F = .0000

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
AGE	.196472	.038512	.350006	5.102	.0000
INT.MX.L	-.218100	.061942	-.265310	-3.521	.0006
TL	.218303	.056424	.293011	3.869	.0002
(Constant)	7.296823	5.553167		1.314	.1907

---------- Variables not in the Equation ----------

Variable	Beta In	Partial	Min Toler	T	Sig T
@_BASN	-.016520	-.017938	.750186	-.230	.8180
@_C2C4SN	-.035372	-.034236	.598733	-.440	.6605
@FH_HOR	-.084837	-.091563	.747958	-1.181	.2393
A_PNS	.039194	.038099	.728176	.490	.6250
BMI	.012000	.012693	.762446	.163	.8707
CI_FI	-.023755	-.025867	.800941	-.332	.7400
M_MP	-.015586	-.013115	.490537	-.168	.8664
MCF	.099724	.093199	.573118	1.202	.2309
P_PNS	.086566	.085689	.699541	1.105	.2709
PHW_PSP	-.011905	-.012122	.693606	-.156	.8764
PNS_BA	.022488	.020499	.590018	.263	.7926
RAM_MCF	.007587	.008555	.803581	.110	.9126
T__AREA	-.122844	-.079063	.319906	-1.019	.3098
T__INT.M	-.106798	-.088800	.511299	-1.145	.2538

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. AVR_APNE

End Block Number 1 PIN = .050 Limits reached.

F = 7.91056 Signif F = .0001

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
AGE	.342545	.122097	.211207	2.806	.0056
BMI	.427181	.168222	.186554	2.539	.0120
P_PNS	.399171	.187732	.161007	2.126	.0350
(Constant)	-16.067321	10.114411		-1.589	.1141

---------- Variables not in the Equation ----------

Variable	Beta In	Partial	Min Toler	T	Sig T
@_BASN	.070066	.074506	.920615	.957	.3401
@_C2C4SN	-.088227	-.092488	.923201	-1.190	.2360
@FH_HOR	-.099849	-.104791	.913024	-1.349	.1791
A_PNS	.009234	.009326	.824210	.119	.9051
CI_FI	-.072927	-.073484	.854515	-.944	.3468
H_MP	-.086652	-.083993	.821438	-1.079	.2820
INT.MX.L	.016304	.016305	.863150	.209	.8348
MCP	.040641	.042109	.898382	.540	.5901
PHW_PSP	.035509	.034328	.789295	.440	.6606
PNS_BA	-.019398	-.019389	.836869	-.248	.8042
RAM_MCP	.095789	.102045	.924010	1.314	.1908
T__AREA	-.045965	-.040612	.682502	-.521	.6034
T__INT.M	.005883	.006086	.902850	.078	.9380
TL	-.077736	-.070743	.724043	-.908	.3651

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. LONGEST1

End Block Number 1 PIN = .050 Limits reached.

* * * * MULTIPLE REGRESSION * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. AVR_HYP

Block Number 1. Method: Enter
@_BASN @_C2C4SN @FH_HOR A_PNS AGE BMI CI_FI H_MP
INT.MX.L MCP P_PNS PHW_PSP PNS_BA RAM_MCP T__AREA T__INT.M
TL

Variable(s) Entered on Step Number
1.. TL
2.. MCP
3.. CI_FI
4.. RAM_MCP
5.. AGE
6.. @FH_HOR
7.. PHW_PSP
8.. BMI
9.. A_PNS
10.. @_BASN
11.. T__INT.M
12.. P_PNS
13.. @_C2C4SN
14.. PNS_BA
15.. H_MP
16.. INT.MX.L
17.. T__AREA

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. LONGEST1

Block Number 1. Method: Enter
@_BASN @_C2C4SN @FH_HOR A_PNS AGE BMI CI_FI M_MP
INT.MX.L MCF P_PNS PNW_PSP PNS_BA RAM_MCF T__AREA T__INT.M
TL

Variable(s) Entered on Step Number
1.. TL
2.. MCF
3.. CI_FI
4.. RAM_MCF
5.. AGE
6.. @FH_HOR
7.. PNW_PSP
8.. BMI
9.. A_PNS
10.. @_BASN
11.. T__INT.M
12.. P_PNS
13.. @_C2C4SN
14.. PNS_BA
15.. M_MP
16.. INT.MX.L
17.. T__AREA

Multiple R	.41998
R Square	.17638
Adjusted R Square	.08365
Standard Error	16.24514

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	17	8533.87088	501.99240
Residual	151	39849.58214	263.90452

F = 1.90217 Signif F = .0216

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. LONGEST1

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
@_BASN	.360067	.327875	.111509	1.098	.2739
@_C2C4SN	-.192128	.213545	-.109738	-.900	.3697
@FH_HOR	-.109767	.289180	-.036091	-.380	.7048
A_PNS	.001133	.418501	2.695E-04	.003	.9978
AGE	.379181	.142509	.233796	2.661	.0086
BMI	.524488	.195289	.229048	2.686	.0080
CI_FI	-21.322577	17.709193	-.103799	-1.204	.2305
M_MP	-.300615	.307769	-.127488	-.977	.3303
INT.MX.L	.325455	.377616	.135915	.862	.3901
MCF	-.116575	.625538	-.021770	-.186	.8524
P_PNS	.579400	.259194	.233702	2.235	.0269
PNW_PSP	.261244	.537262	.048450	.486	.6275
PNS_BA	-.767780	.562394	-.172926	-1.365	.1742
RAM_MCF	.292573	.441979	.054440	.662	.5090
T__AREA	-.003286	.005089	-.115979	-.646	.5195
T__INT.M	42.020323	26.142014	.233647	1.607	.1101

```
TL              .045186     .333756     .021247      .135  .8925
(Constant)   -50.357776   50.803958                  -.991  .3232

End Block Number   1   All requested variables entered.

          * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Listwise Deletion of Missing Data

Equation Number 1     Dependent Variable..   LONGEST1

Block Number  1.  Method:  Stepwise      Criteria   PIN  .0500   POUT  .1000
   @_BASN    @_C2C4SN @FH_MOR  A_FNS     AGE       BMI       CI_FI     H_MP
   INT.MX.L MCF       P_FNS     PHW_PSP   PNS_BA    RAM_MCF   T__AREA   T__INT.M
   TL

Variable(s) Entered on Step Number
   1..     AGE

Multiple R            .24318
R Square              .05914
Adjusted R Square     .05350
Standard Error      16.51024

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression           1          2861.25797       2861.25797
Residual           167         45522.19505        272.58799

F =       10.49664       Signif F =  .0014

------------------ Variables in the Equation ------------------

Variable              B         SE B        Beta         T  Sig T

AGE             .394403     .121735     .243181     3.240  .0014
(Constant)    13.043041    5.711808                 2.284  .0237

          * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Equation Number 1     Dependent Variable..   LONGEST1

------------- Variables not in the Equation -------------

Variable     Beta In  Partial  Min Toler         T  Sig T

@_BASN       .076277  .078581    .998552     1.016  .3113
@_C2C4SN    -.039739 -.040966    .999840     -.528  .5980
@FH_MOR     -.083176 -.084967    .981822    -1.099  .2735
A_FNS        .061550  .063450    .999865      .819  .4139
BMI          .206691  .212912    .998356     2.808  .0056
CI_FI       -.100343 -.101473    .962169    -1.314  .1906
H_MP         .007223  .007125    .915487      .092  .9270
INT.MX.L     .104311  .107433    .998027     1.392  .1657
MCF          .082653  .083707    .965005     1.082  .2807
P_FNS        .185796  .185680    .939694     2.435  .0160
PHW_PSP     -.022019 -.022218    .958009     -.286  .7750
PNS_BA       .067549  .069560    .997731      .898  .3703
RAM_MCF      .087915  .090370    .994134     1.169  .2440
T__AREA      .107082  .109307    .980381     1.417  .1584
T__INT.M     .045794  .046367    .964541      .598  .5506
TL           .073451  .075244    .987347      .972  .3324
```

. . . . . .

Variable(s) Entered on Step Number
2.. BMI

Multiple R .31904
R Square .10179
Adjusted R Square .09097
Standard Error 16.18020

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	4924.85553	2462.42776
Residual	166	43458.59749	261.79878

F = 9.40580 Signif F = .0001

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. LONGEST1

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
AGE	.407995	.119399	.251562	3.417	.0008
BMI	.473293	.168578	.206691	2.808	.0056
(Constant)	-2.107974	7.775331		-.271	.7866

---------- Variables not in the Equation ----------

Variable	Beta In	Partial	Min Toler	T	Sig T
8_BASN	.060293	.063372	.992098	.816	.4159
8_C2C4SN	-.083284	-.086175	.960226	-1.111	.2682
8FH_HOR	-.110065	-.114225	.967388	-1.477	.1416
A_FNS	.059124	.062376	.998217	.803	.4232
CI_FI	-.110780	-.114522	.959839	-1.481	.1406
H_MP	-.059776	-.057800	.839811	-.744	.4581
INT.MX.L	.056305	.057480	.936084	.740	.4606
MCF	.053379	.054747	.944840	.704	.4822
P_PNS	.161007	.163308	.924077	2.126	.0350
PHW_PSP	-.030105	-.031069	.956617	-.399	.6902
PNS_BA	.030847	.031965	.964507	.411	.6817
RAM_MCF	.097105	.102062	.992254	1.318	.1894
T__AREA	.040061	.039298	.864326	.505	.6141
T__INT.M	.010089	.010301	.936271	.132	.8949
TL	.005463	.005407	.879837	.069	.9447

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. LONGEST1

Variable(s) Entered on Step Number
3.. P_PNS

Multiple R .35460
R Square .12574
Adjusted R Square .10985
Standard Error 16.01128

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	3	6083.87931	2027.95977
Residual	165	42299.57371	256.36105

```
Multiple R            .29349
R Square              .08614
Adjusted R Square    -.01675
Standard Error       4.55237

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression          17             294.95470         17.35028
Residual           151            3129.32933         20.72404

F =         .83721       Signif F =  .6483

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Equation Number 1     Dependent Variable..    AVR_HYP

------------------ Variables in the Equation ------------------

Variable                B         SE B        Beta         T  Sig T

@_BASN           -.057575      .091880    -.067023     -.627  .5318
@_C2C4SN          .013502      .059842     .028989      .226  .8218
@FH_HOR          -.008211      .081037    -.010148     -.101  .9194
A_PNS             .106454      .117276     .095197      .908  .3655
AGE               .066760      .039935     .154728     1.672  .0967
BMI          6.13464E-04       .054726     .001007      .011  .9911
CI_FI            -3.432814    4.962637    -.062815     -.692  .4902
H_MP              -.024707      .086246    -.039386     -.286  .7749
INT.MX.L          .109594      .105819     .172038     1.036  .3020
MCP              -.011005      .175294    -.007725     -.063  .9500
P_PNS             .120436      .072634     .182601     1.658  .0994
PHW_PSP           .069420      .150557     .048395      .461  .6454
PNS_BA           -.032784      .157599    -.027755     -.208  .8355
RAM_MCP           .097095      .123855     .067911      .784  .4343
T__AREA          -.001360      .001426    -.180474     -.954  .3417
T__INT.M        12.176002    7.325762     .254489     1.662  .0986
TL               -.104896      .093528    -.185404    -1.122  .2638
(Constant)       6.883718    14.236764                 .484  .6294

End Block Number   1   All requested variables entered.

          * * * *  M U L T I P L E  R E G R E S S I O N  * * * *

Listwise Deletion of Missing Data

Equation Number 1     Dependent Variable..    AVR_HYP

Block Number  1.  Method:  Stepwise     Criteria   PIN  .0500   POUT  .1000
   @_BASN   @_C2C4SN @FH_HOR  A_PNS     AGE       BMI       CI_FI     H_MP
   INT.MX.L MCP      P_PNS    PHW_PSP   PNS_BA    RAM_MCP   T__AREA   T__INT.M
   TL


Variable(s) Entered on Step Number
   1..     AGE


Multiple R            .18041
R Square              .03255
Adjusted R Square     .02675
Standard Error       4.45391

Analysis of Variance
                    DF        Sum of Squares      Mean Square
Regression          1              111.45163         111.45163
Residual          167             3312.83240          19.83732
```

F = 5.61828 Signif F = .0189

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
AGE	.077840	.032840	.180409	2.370	.0189
(Constant)	12.504241	1.540855		8.115	.0000

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. AVR_HYP

---------- Variables not in the Equation ----------

Variable	Beta In	Partial	Min Toler	T	Sig T
@_BASN	-.017964	-.018250	.998552	-.235	.8144
@_C2C4SN	-.063458	-.064511	.999840	-.833	.4061
@FH_HOR	-.058157	-.058587	.981822	-.756	.4506
A_PNS	.042836	.043547	.999865	.562	.5751
BMI	-.033712	-.034246	.998356	-.441	.6596
CI_FI	-.036862	-.036761	.962169	-.474	.6362
H_MP	-.018357	-.017857	.915487	-.230	.8183
INT.MX.L	-.007540	-.007658	.998027	-.099	.9215
MCF	.019794	.019769	.965005	.255	.7992
P_PNS	.094347	.092983	.939694	1.203	.2306
PHW_PSP	-.018988	-.018895	.958009	-.243	.8079
PNS_SA	.010973	.011144	.997731	.144	.8860
RAM_MCF	.092314	.093578	.994134	1.211	.2276
T__AREA	-.029169	-.029363	.980381	-.378	.7056
T__INT.M	.039585	.039526	.964561	.510	.6110
TL	-.065774	-.066447	.987347	-.858	.3921

End Block Number 1 PIN = .050 Limits reached.

Hi-Res Chart # 1:Histogram of o2diff

Hi-Res Chart # 2:Histogram of o2diff2

APPENDIX B

Human Investigation Consent Form

Human Investigation Consent Form

Consent to Participate in Research Study

I have been asked to participate in a research study entitled: **Cephalometric Assessment in** Obstructive Sleep Apnea

by:	Mark G.Hans, D.D.S., M.S.D.	**Co-investigator**
	Suchitra Nelson, M.S., Ph.D.	**Co-investigator**
	Seung-Jin Baek, D.D.S., M.S.D., Ph.D.	**Co-investigator**

I understand that this study involves:

A) A lateral and frontal cephalometric radiographs while sitting.
B) Polysomnographic testing (sleep monitoring) for diagnosis of Obstructive Sleep Apnea Syndrome.

I further understand that:

1. The cephalometric radiographs will be taken using the effective minimum X-ray dosage, and a lead apron will be used to further reduce radiation exposure. A spoon of radiographic contrast media (Esophotrast, Rorer Pharmaceutical Corp.) will be required to be swallowed prior to the radiograph being taken.

2. Polysomnographic testing (sleep monitoring) will be used to accurately diagnose Obstructive Sleep Apnea Syndrome (OSAS).

3. I will not be required to pay any cost for the cephalograph. All radiographs will be taken in the Bolton-Brush Growth Study Center, School of Dentistry, Case Western Reserve University, Cleveland, Ohio.

4. The information from the study is confidential and will be contained in a data base for future study.

5. Dr. Hans, Dr. Nelson, Dr. Luks and Mr. Paul Lorkovich will be coordinating this study and will be available to answer any questions about the study. The telephone numbers in the department of Orthodontics are (216) 368-3469 and 368-4649.

6. I have the right to refuse to participate in this study. In this case, my refusal will not affect the medical or dental care I can receive in the School of Dentistry at Case Western Reserve University, University Hospitals, the V.A. Hospital or Metro Health Medical Center.

I have read the above information and understand the risks and benefits involved in participation in this study.

_____ _____

Date Subject/Parent

APPENDIX C

Approval of University Review Committee for Human Studies

CASE WESTERN RESERVE UNIVERSITY
REVIEW COMMITTEE FOR HUMAN STUDIES
NOTICE OF APPROVAL

TO: Hans, Mark G.

Dept/School: Dentistry

Subject: Notice of (X) Review and approval
( ) Exemption

The committee has reviewed and approved your proposal entitled: Cephalometric Assessment in Obstructive Sleep Apnea

Please be advised that with respect to: (1) the rights and welfare of the individual(s) involved, (2) the appropriateness of the methods to be used to secure informed consent, and (3) the risks and potential benefits of the investigation, the Committee considers your project:

( ) Exempt
(X) Fully acceptable
( ) Acceptable with reservations noted
( ) Not acceptable for reasons noted

Follow-up: The Committee wishes to have a status report on this project on 9/10/1996

SIGNED FOR THE COMMITTEE BY:

Approval Date:
9/25/1995

Ellen Durand

Ellen Durand
Assistant Director
Office of Research Administration

ED

ORA USE ONLY**********

Type Project: ( ) NEW (X) RENEWAL
Human Risk: ( ) Yes (X) No
Source of Support: (X) Outside Funding ( ) Department/other
Agency (Potential): NIH Agency No.

Are any of the following involved: ( ) Yes (X) No
If yes, which category(ies):

() Minors () Fetuses () Abortuses () Pregnant Women
() Prisoners () Mentally Retarded () Mentally Disabled

cc: Dean
Department Chairman
Follow-up (Book)
File

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