The Effect of Office Chair Backrest Design on the Body's Metabolic Response to Office Work

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By

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ABSTRACT

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Most office chairs have a backrest that is wider at the shoulders than at the hips. Recently, a new office chair was developed that has a backrest that is narrower at the shoulders and wider at the hips (upwardly tapered backrest). The upwardly tapered backrest should allow users to increase their ventilatory efficiency, compared to a conventional, wide backrest. This new backrest design will hypothetically allow a user to retract their scapulae, increase expansion of the chest cavity, thus allowing the lungs more space to expand. Specific measures of improved ventilatory efficiency are an increase in tidal volume (V_t - liters/breath) and a decrease in respiratory rate (RR - breaths/min).

Ventilatory and cardiovascular metabolic variables were measured from 31 office workers sitting in 2 chairs (conventional and upwardly tapered). The Cortex Metamax 3B system (Leipzig, Germany) was used to measure $\dot{V}O_2$, RR, V_t and heart rate (HR - beats per min). Each participant performed 8 tasks in each chair. The tasks included typing, searching the internet, creating a spreadsheet, and watching a movie. Physiologic data were collected throughout testing. The subjects were blinded to which chair the test chair was. Results indicated no significant differences in users' RR and V_t between the two chairs, but the users did have a significantly lower HR when they sat in the chair with the upwardly tapered backrest (3 to 7 bpm less). Heart rate has been shown to be a risk factor of heart disease, and thus the test chair could reduce the impact of a risk factor of heart disease in office workers. Analysis of subjective assessment data did not show any overall preference for either chair.

ACKNOWLEDGEMENTS

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1 Introduction

Computer use is becoming more prevalent in people's daily lives, not only at work but at school and home as well. In 2003, 63.7% of people reported using a computer at work, school, or home (U.S. Census Bureau, 2003). Over half of the population is made up of computer users, which makes it important for office furniture producers and all computer users to understand how the body reacts to this type of work. The office furniture industry has been trying to create "health-positive" items that provide the user with some form of health benefit. Herman Miller has been striving to develop a health-positive chair for many years, and they believe that they have found it in their test chair. The test chair has a unique upwardly tapered backrest (see Figure 1.1) that distinguishes it from the traditionally wide backrest found on many conventional office chairs.

Figure 1.1: Test Chair Backrest (left) vs. Conventional Backrest (right)

The theory behind the new backrest design was that it will allow users to retract their scapulae more than with a traditional backrest. This would in turn open the user's chest cavity allowing the lungs more room to expand. This position is not common in office workers. A more prevalent position is “slouching” in the chair. This position is defined by forward trunk flexion, which decreases the amount of interabdominal space available for lung expansion. The hypothesized result of allowing increased scapula retraction is an increase in tidal volume (the volume of air in each breath) and a decrease in respiratory rate (the number of breaths users take per minute). These two hypothesized advantages would increase ventilatory efficiency.

2 Literature Review

2.1 Background Information and Studies

2.1.1 The Seated Position

Most computer workstations force the user to sit while working. This means that many office workers remain in the seated position for the majority of their work day. In ANSI/HFES's *Human Factors Engineering of Computer Workstations* (2007), two seated postures are described, the upright sitting and declined sitting postures:

> "In the upright sitting posture, the user's torso and neck are approximately vertical and in line (between 90 and 105 degrees to the horizontal), the thighs are approximately horizontal and the lower legs are vertical. In the declined sitting posture, the user's thighs are inclined below the horizontal, the torso in vertical or slightly reclined behind the vertical, and the angle between the thighs and the torso is greater than 90 degrees." (ANSI/HFES, 2007)

The seated position is not a natural one for the human body to assume. There are many risks that come along with sitting in one position for an extended period of time, especially when this position is repeated daily. When in the natural standing position, the lumbar portion of the human spine has a lordotic curve. In a study run by Schoberth (1962), it was found that this lordotic curve is flattened by an average of 30.4° when sitting down (Mandal, 1981). This is problematic because when the lordotic curve in the lumbar region of the spine is lost [see Figure 2.1], the disks in this region of the spine become compressed which can lead to injury (Mandal, 1981).

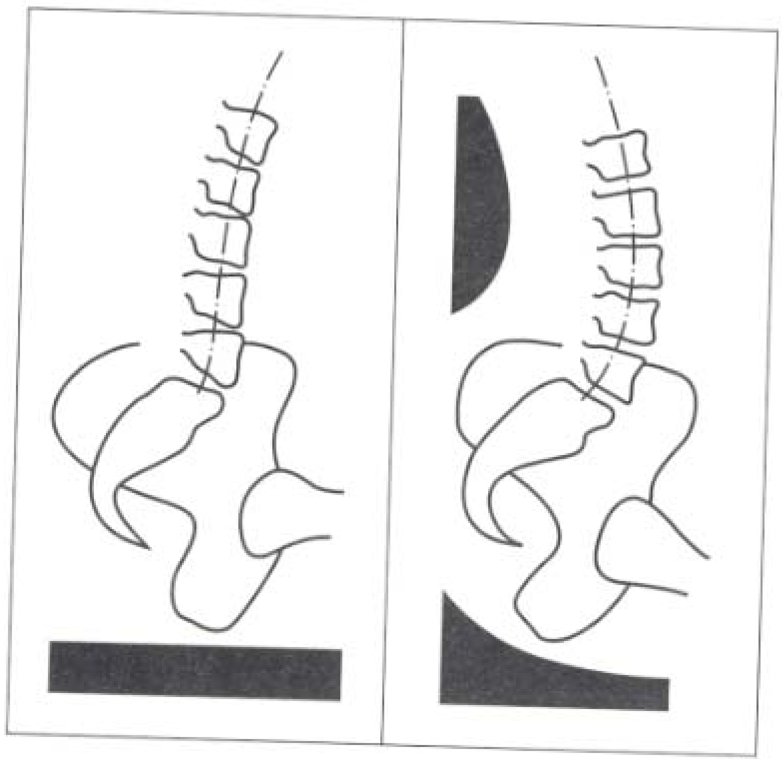


Figure 2.1: Left Shows Flattened Lordotic Curve, Right Shows Proper Lordotic Curve (Kroemer, 2001)

The changes the body experiences when changing postures is not limited to the spine. There are also notable changes in ventilatory function with changes in posture. During ventilation, the rib cage expands more when the trunk is in an upright posture than when the trunk is supine (Druz and Sharp, 1981). These researchers measured electromyography (EMG) of the rib cage muscles of 9 subjects who were in 3 postures: supine, standing and sitting erect. With the trunk upright (standing and sitting erect), the inspiratory muscles (those that that move the rib cage for breathing -- scalene, sternocleidomatoid and parasternal muscles) were more active with phasic [un-toned muscle] (breathing motions) and tonic [muscle that is toned] (postural support) than when the trunk was supine. The mean percentage of tidal volume due to rib cage motion was 32% from a supine posture but was significantly greater in the 2 upright positions (62% and 68% for the standing and sitting erect positions with respect to the supine position). It appears there was not a statistical difference in the percentage of tidal volume between standing and sitting erect as the researchers conducted only a t-test between supine and the upright postures (they did not report results from an ANOVA with 3 levels). These authors conclude that the increased expansion of the rib cage with an upright trunk posture is due to 2 factors. The first factor is greater utilization of the inspiratory muscles, and the second factor is a decrease in stiffness of the abdominal region, due to gravity and tonic contraction of the abdominal muscles. The application of results from the Druz and Sharp (1981) study to office chairs is that ventilation (breathing) function of a user is equally effective whether the user is standing or sitting erect in an office chair.

In 1991, Lalloo et al. conducted a study that tested whether there was a difference in ventilation between standing and sitting postures. They tested healthy, non-obese males (n=41) and females (n=53). Among their dependent measures were forced expiratory volume [the amount of air an individual can forcefully breathe out in one second] (FEV_1, in liters) and peak expiratory rate (PEFR, in liters/min). With the data segregated according to gender, there was no significant difference in any of the dependent measures, including FEV_1, between standing and sitting positions for males. There was a significant decrease in FEV_1 for females ($p < 0.001$) in the sitting position. However, the difference between the means was small – a decrement of 1.1 % FEV_1 for the sitting position (mean of 3.53 liters for standing and a decrease of 0.04 liters for sitting posture). When the male and female data were merged, the sitting position resulted in a lower FEV_1 ($p < 0.002$), although the difference was small.

Further testing of the effect of sitting postures on lung function was conducted by Lin et al. (2006). They tested 3 sitting postures: slumped (trunk flexed forward, decreasing the amount of interabdominal space), normal, and sitting erect with a lumbar support see (Figure 2.2). The study concluded that posture had a significant effect on all of the spirometric parameters tested (FVC, FEV_1, PEF, $FEF_{25\%}$, etc.).

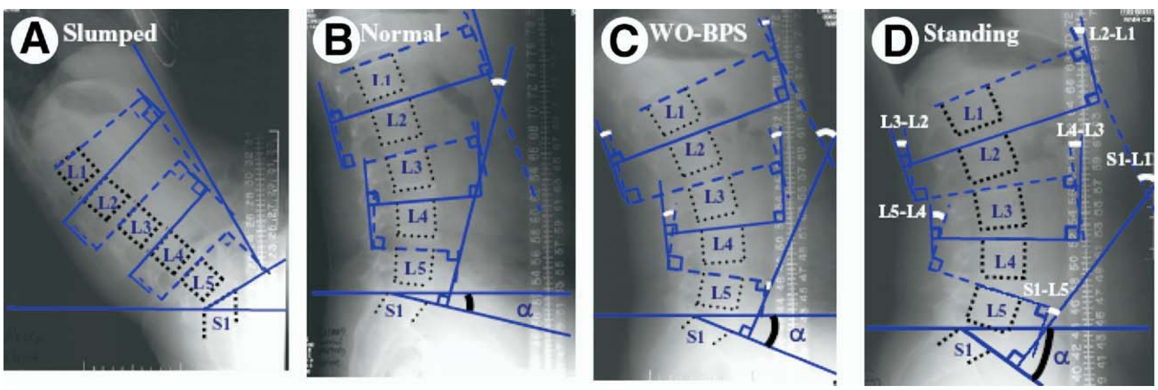


Figure 2.2: The Position of the Lumbar Spine in Each of the Postures (Lin et al., 2006)

They found that sitting erect with a lumbar support significantly improved ventilatory efficiency, compared to the slumped and normal sitting postures.

It is possible that ventilatory function is adversely affected by slumping while in the seated position instead of sitting in an erect posture. “In young healthy subjects with a normally positioned diaphragm, the slumped sitting posture results in increased intra-abdominal pressure by approximating the ribs to the pelvis, making it difficult for the diaphragm to descend caudally during inspiration” (Landers, 2006). In a 1985 study, Crosbie and Myles found a significant difference in forced expiratory volume in one second (FEV_1) between a slumped half-lying posture and all other postures. A study conducted by Landers et al. in 2003 found that minute ventilation and tidal volume are adversely affected by assuming a slumped sitting position rather than an erect sitting posture. This study also determined that overall ventilatory function is decreased in the slumped sitting posture when compared to an erect one. A third study examined the effect that shoulder position has on ventilatory function. This study conducted by Robles-Ribiero et al. in 2005 studied both asthmatic and healthy participants. The study found that as the participants flexed their shoulders forward, their ventilatory function (peak expiratory flow rate) was impaired significantly. This could indicate that any sitting posture other than erect will have some impact on ventilatory function.

These studies indicate that any subject who happens to slump while participating in this study's research may not be breathing as fully or efficiently as they would normally. It is important to note changes in the posture of each participant, and attempt to keep posture as consistent as possible across all subjects.

2.1.2 Chair Design

Many aspects need to be considered when making a comfortable chair. Every piece of the chair must be designed to provide a wide array of users the ability to fit in the chair and enjoy using it. Since the focus of this research is on the backrest of the chair, some recommendations and standards for backrest design follow. The backrest is to serve the user in two facets. First, it needs to support the weight of the upper extremities and head [if reclined], and second, it should allow the user's muscles to relax (Kroemer, 2001). Many standards are available for backrest dimensions. It is suggested in the ANSI/HFES *Human Factors Engineering of Computer Workstations* (2007) that the top of the backrest should be at least 45 cm above the compressed seat height. The lumbar support (if fixed) should be located between 15 and 25 cm from the compressed seat height, and the width of the backrest should be at least 36 cm (ANSI/HFES, 2007). These dimensional standards come, in part, from a study by Andersson (1987) that determined that allowing a chair to recline and support the user's weight can reduce the compressive loading of the spine [see Figure 2.3] (ANSI/HFES, 2007) . In order for a chair to have this effect, the backrest must be tall and wide enough to support the weight or the user's trunk, arms, and head.

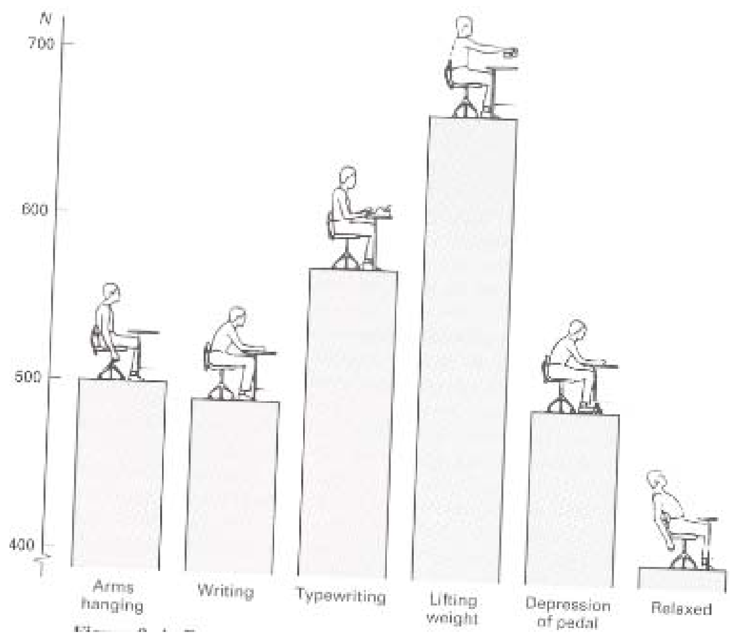


Figure 2.3: Loading (N) of the Lumbar Spine in Various Positions (Kroemer, 2001)

Konz suggests the ideal backrest dimensions are: 32.5 to 37.5 cm wide and 12.5 cm above the lumbar region tall, since this allows for the maximal range of motion in the arms while performing tasks (Konz, 1979). In a study by K.H. Kroemer (2001), a number of proposed dimensions for backrests were studied. These dimensions can be found in Table 2.1.

Table 2.1: Proposed Shapes and Dimension of Backrests from Kroemer (1971)

References	Size	Remarks	Shop	Office
Akerblom	Full	Back rest up to the shoulder. Upper part of the rest about 115 degrees reclined		Yes
Arbeidsinspectic	Small	Tiltable about a horizontal axis in the center of the back rest. Axis adjustable from 20-30 cm above seat. Dimensions 30 x 16 cm	Yes	Yes
Burandt	Small	Slightly convex in side view. Height Adjustable. Should adjust to back contour. Dimensions maximum 37 x 20cm.		Yes
Floyd and Roberts	Small	Shape essentially as proposed by Akerblom.		Yes
Grandjean; Grandjean and Burandt	Small	Lumbar pad about one-quarter of the height of the back rest; adjustable from 14-24cm above the seat. Back rest tiltable from 90 to 120 degrees about a horizontal axis at the height of the pad. Dimensions 32 (maximum) x 20cm.	Yes	Yes
Keegan	Small	Slightly convex in the side view. Inclined by 105 degrees.		Yes
Kroemer	Full	Shape as recommended by Akerblom.	Yes	Yes
Lehmann	Full	Shape as recommended by Akerblom. Overall inclination 110-115 degrees. Tiltable about a horizontal axis. Height adjustable.	Yes	Yes
Schoberth	Full	Shape as recommended by Akerblom. Lumbar pad 16-20cm above seat. Upper part of the back rest 104 -110 degrees inclined.		Yes
Stier	Full	Shape as proposed by Akerblom.	Yes	Yes

Kroemer (2001) also suggests that the backrest be located 38 to 42 cm behind the front of the seat pan. Konz adds that the angle between the backrest and the seat pan should be between 95° and 110° (Konz, 1979).

In a 2003 study conducted by Gossens et al., the team set out to show that not leaning against the top of the backrest can increase the support of the lumbar spine. The theory behind this study was that increasing the space between your scapulae and the top of the backrest would increase the force acting at the lumbar support of the backrest [see Figure 2.4 for experimental set up]. The study concluded that lumbar support force is increased with an increase in horizontal distance between the scapula and the backrest. It also determined that back muscle activity decreases as shoulder space and backrest inclination are increased (Goossens et al., 2003).

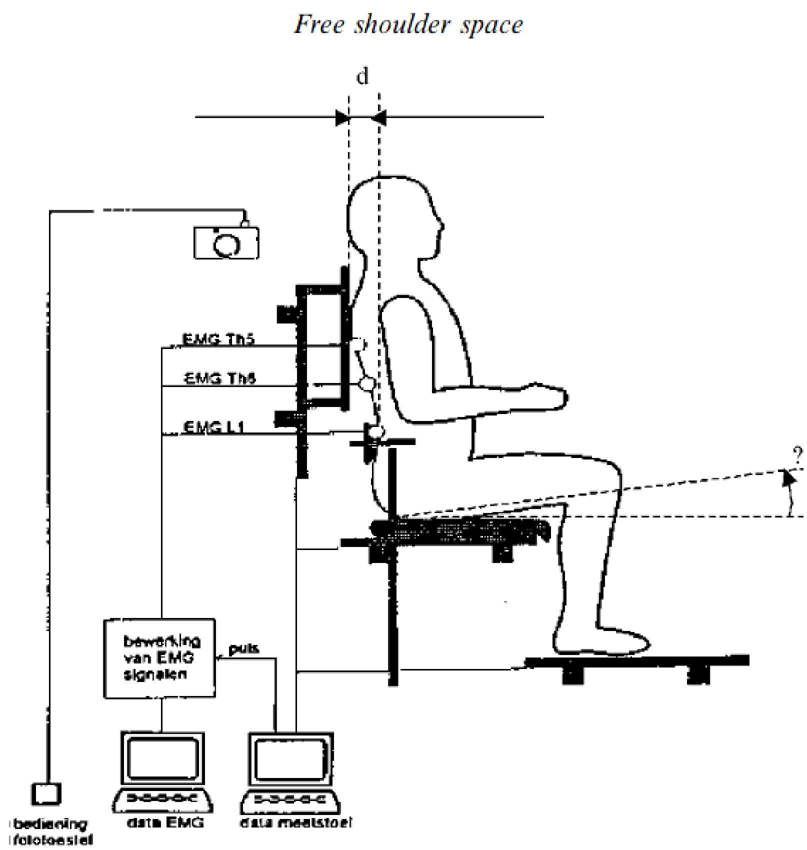


Figure 2.4: Experimental Setup from (Goossens et al., 2003) Adjusted d and α to Test Theory

Based on this result, the team recommends that a minimum of 6 cm of space should exist between the scapulae and the top of the backrest to provide more lumbar support to the user (Goossens et al., 2003). This indicates it might be better to avoid leaning back onto the top of the backrest altogether.

2.1.3 Metabolic Equivalents (METs)

Resting metabolic rate is defined as the amount of energy required to maintain the basic functional state of an organism, and this provides a baseline for energy consumption (Bowers & Fox, 1988). Metabolic equivalents (MET) define the oxygen or energy cost of an activity. One MET defines the amount of oxygen required per minute under resting conditions (Fox et al., 1989). A single MET is the equivalent of 3.5 ml/kg/min O_2. This means that resting requires 3.5 milliliters of oxygen per kilogram body weight per minute. This unit of measurement for energy expenditure depends on the fact that resting metabolic rate does not change based on the population being considered. The resting metabolic rate is indistinguishable between athletes and non-athletes, nor is it affected by age or body composition, which allows for this standard unit of energy consumption (MET) to be created (Garrett & Kirkendall, 2000). This is an important tool in exercise physiology, because multiples of this basic unit of energy consumption are used to quantify activity levels by energy requirements (Garrett & Kirkendall, 2000). For instance, running 10 minutes/mile requires 10.2 METs, dancing requires anywhere from 6-9 METs, and soccer can require anywhere from 5-12 METs (Buschbacher & Braddom, 1994). This quantification of energy requirements can also be helpful when prescribing activity levels to people recovering from heart failure, surgery, or people at risk for a cardiac event (Buschbacher & Braddom, 1994). This unit of measurement for energy expenditure can also help stratify activities based on how much energy they require [see Table 2.2].

A common stratification follows (Ainsworth, 2000):

- Activities requiring less than 3 (1-2.9) METs are light intensity activities
- Activities requiring between 3-5.9 METs are moderate intensity activities
- Activities requiring 6 or more METs are vigorous intensity activities.

Table 2.2: Examples of Activities and their Intensity According to the METs Scale (Ainsworth, 2000)

Physical Activity	MET
Light Intensity Activities	**< 3**
sleeping	0.9
watching television	1.0
writing, desk work, typing	1.8
walking, less than 2.0 mph (3.2 km/h), level ground, strolling, very slow	2.0
Moderate Intensity Activities	**3 to 6**
bicycling, stationary, 50 watts, very light effort	3.0
sexual activity (position dependent)	3.3
calisthenics, home exercise, light or moderate effort, general	3.5
bicycling, <10 mph (16 km/h), leisure, to work or for pleasure	4.0
bicycling, stationary, 100 watts, light effort	5.5
Vigorous Intensity Activities	**> 6**
jogging, general	7.0
calisthenics (e.g. pushups, situps, pullups,jumping jacks), heavy, vigorous effort	8.0
running jogging, in place	8.0

2.1.4 Validity of the Metamax 3B

The data collection system used in this study was the Metamax 3B (Cortex, Leipzig, Germany). This system has proved to be valid, reliable, and repeatable in a number of studies. The results of these studies follow.

A study conducted by Peggy Wong in 2005 at the University of Hong Kong sought to validate the Metamax 3B. The validity, repeatability, and reliability of the Metamax 3B were compared to the Douglas Bag Method. This study tested the Metamax in two different ways. The first test used a mechanical pump to simulate gas exchange, and the second used human exercise to collect data. The results of this study showed that during the simulated gas exchange, the Metamax 3B had a percentage error of less than 3% in measuring minute ventilation when compared to the Douglas Bag method. The Metamax 3B also had a repeatability of ICC (r=1.00) in the repeated trials of $\dot{V}_E$, $\dot{V}O_2$, and $\dot{V}CO_2$ measurements. However, the data collected during exercise showed variations that exceeded the validity limits. This study determined that under controlled conditions the Metamax 3B is valid, repeatable, and reliable, but more research is needed to determine its validity when measuring data from human subjects during exercise.

In 1999, Karl Cornelius-Lorenz and Ralf Henker validated the Metamax 3B at the Technologie-Institut Medizin GmbH (TIM) at the University of Göttingen in Germany. This validation protocol included three tests. The first test examined the T_{90} response times of the O_2 and CO_2 sensors. The second test determined the absolute and relative accuracy and linearity of the O_2 and CO_2 sensors, and the third test measured the synchronicity between the flow sensor and gas sensor systems. All of these tests compared the results of the Metamax 3B to result produced by a mass spectrometer (MAG-1 100). The specifications for this mass spectrometer can be found in Appendix B.

The results of the first test showed that the T_{90} response times of the O_2 and CO_2 sensors in the Metamax 3B and the mass spectrometer were both 200ms (Cornelius-

Lorenz & Henker, 1999). The test also revealed that the results produced by the two systems show high agreement see Figure 2.5 and Figure 2.6.

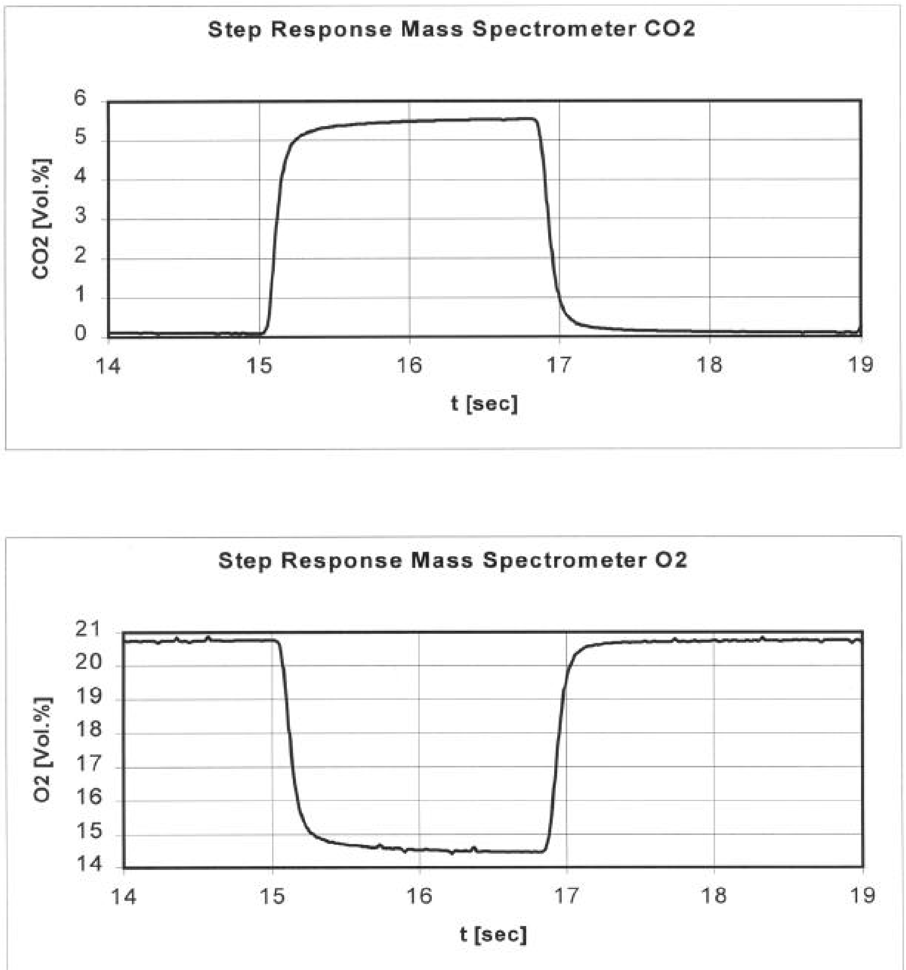


Figure 2.5: Mass Spectrometer Result for Validation Test 1 (Cornelius-Lorenz & Henker, 1999)

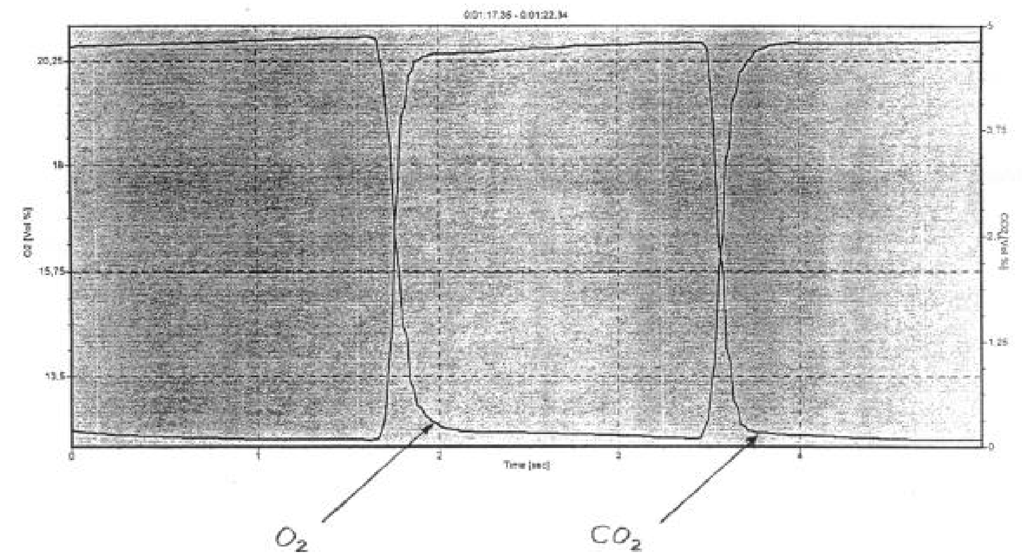


Figure 2.6: Metamax 3B Result for Validation Test 1 (Cornelius-Lorenz & Henker, 1999)

The result of the second validation "shows a good linearity of O_2- and CO_2-measurement with the Metamax 3B. The offset between the two measurements could be caused by tolerance of the examining gases for the 2 point calibration, which were different for both devices (analysis precision given by the manufacturer was +2% rel.)" (Cornelius-Lorenz & Henker, 1999). The graphical representations of the data can be found in Figure 2.7.

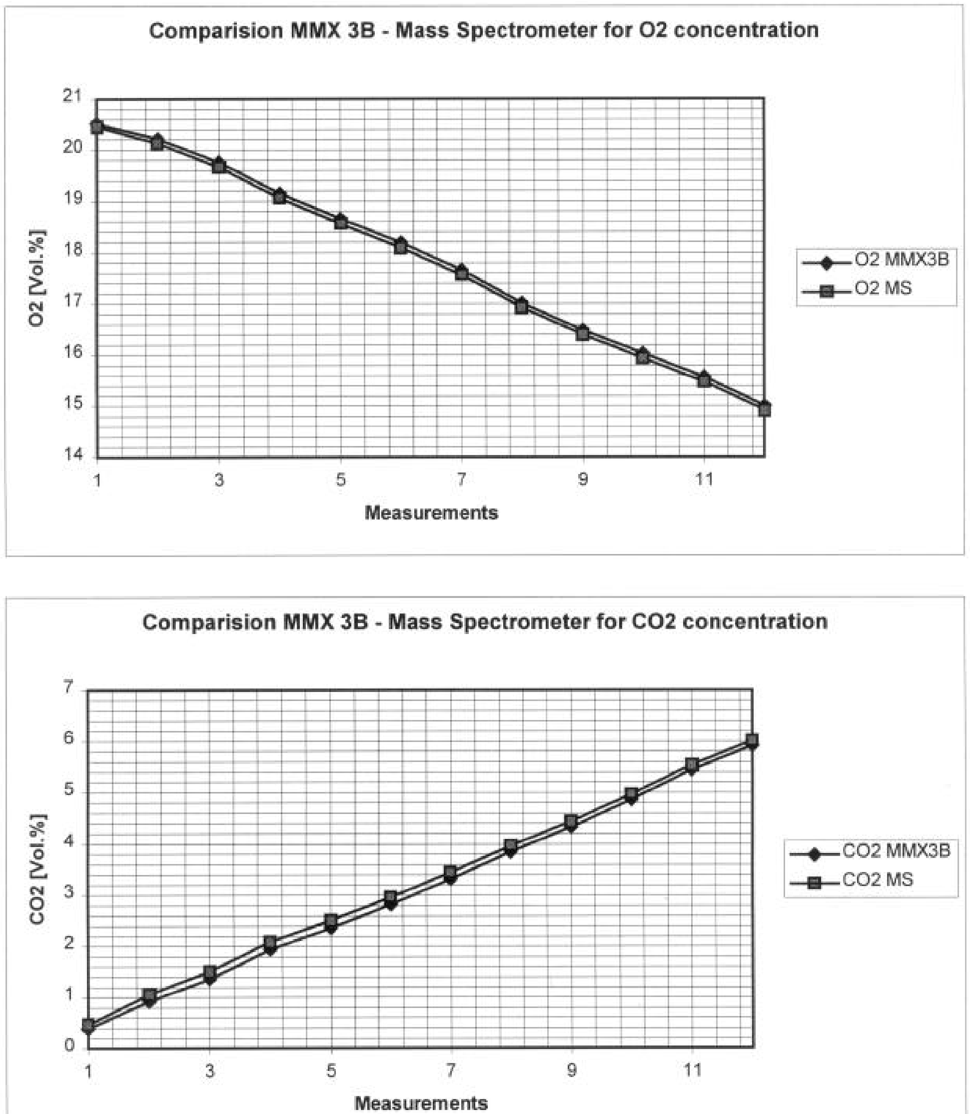
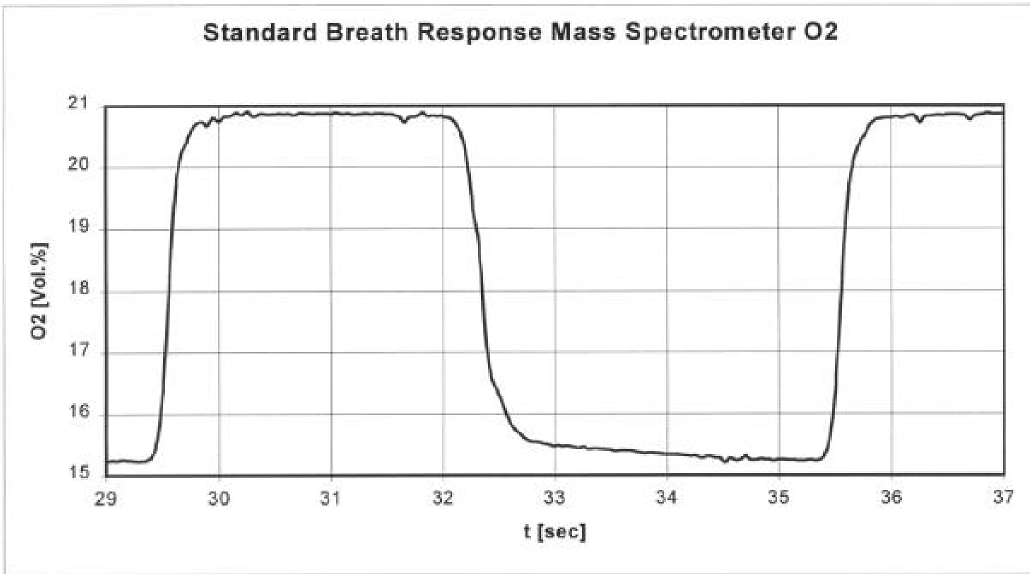


Figure 2.7: O_2 and CO_2 Concentration Results from Validation Test 2

The results of the third validation test show that the "visual comparison of the graphics [see Figure 2.8 and Figure 2.9] shows a very good agreement of the characteristics of the breathing course of Metamax 3B and the mass-spectrometer, which was expected after the comparison of the step response" (Cornelius-Lorenz & Henker, 1999).



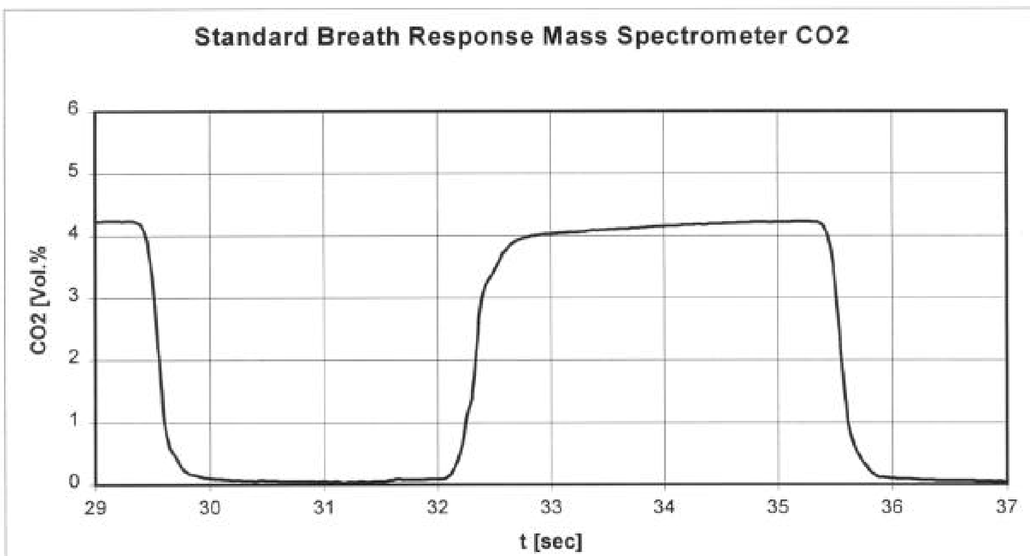


Figure 2.8: Mass Spectrometer Result from Validation Test 3

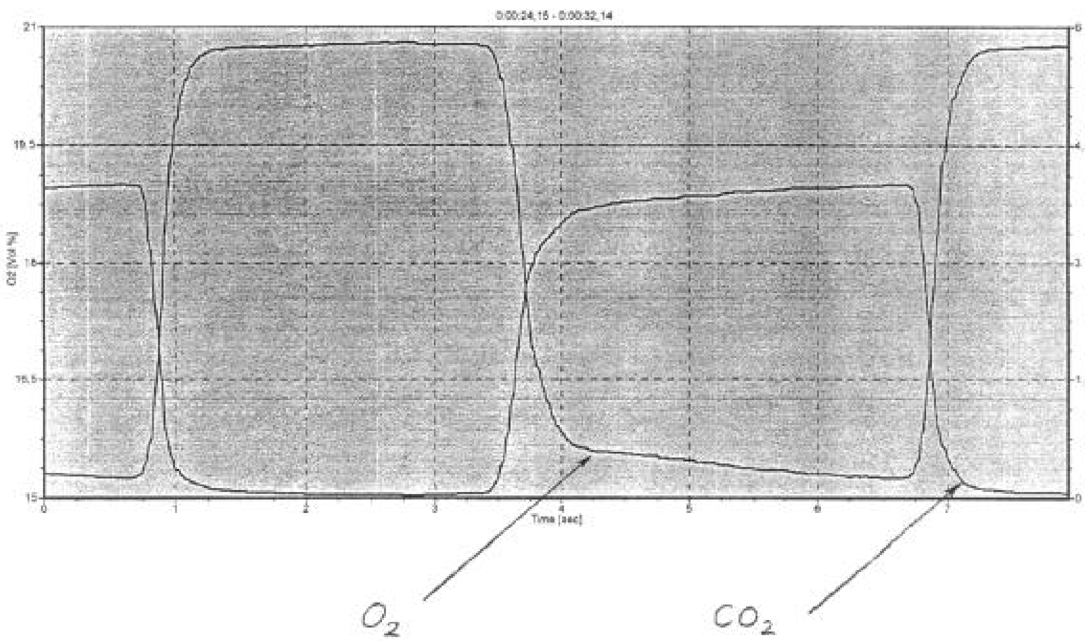


Figure 2.9: Metamax 3B Result from Validation Test 3

The overall findings of this validation study determined that when compared to a mass spectrometer, the Metamax 3B gas sensor system has a similar response time, linearity, and accuracy. The study also finds the Metamax 3B's gas sensor system to be valid and reliable.

Another validation study was conducted and presented as a poster at the Sportmedizin conference. The study was conducted by Carsten Wüpper, U Hillmer-Vogel, and A Niklas at Göttingen University in Germany, and it compared the Metamax 3B unit to the Douglas Bag Method, the traditional gold standard for metabolic data collection. The study collected data in two ways: the first was parallel measurement (alternating), and the second was simultaneous measurement. The study did not consider stress over 350 watts. The results for the deviation of the reference method (Douglas Bag) showed a marked decrease in variance of results in simultaneous measurement when compared to parallel (alternating) measurement. The investigators found the measurements of both systems to be consistent to a very high degree and note that the recorded data exhibit satisfactory results regarding accuracy and reproducibility.

The studies show that data collected with the Metamax 3B is valid, repeatable, and reliable in a controlled laboratory setting and in the field. While concerns about the device's validity for human testing were brought up in the study conducted by Wong in 2005, this system still seems reliable in this case based on the findings of Wüpper et al. from 2003.

2.1.5 Metabolic Function During High Energy Load Tasks

In order to gain a better perspective of the amount of energy sedentary office work requires, activities with higher workloads will be discussed first. Many types of activities ranging from light intensity to vigorous intensity exist. The following studies examined the body's metabolic response to various vigorous intensity activities. A vigorous intensity activity is one that requires 6.0 or more METs. This type of activity is considered good for improving cardiovascular health (Li et al., 2001). The first batch of studies concerns recreational or athletic activities.

In 2008, Conti et al. measured and compared the cardiac and ventilatory demands of running in place in shallow water to running on a treadmill. Trained and untrained men were observed. The study collected data from twelve subjects while they ran on a treadmill and while they ran in the shallow end of a swimming pool at a maximal aerobic level (Conti et al., 2008). The temperature of the water in the pool ranged from 29°C to 30°C, and the air in the laboratory where the out-of-water tests took place ranged from 24° to 26°C. The study measured the oxygen consumption, breathing frequency (respiratory rate), minute ventilation (liters/min), and heart rate of the subjects while running in shallow water. The goal of this study was to establish a relationship between heart rate, oxygen consumption, and exercise intensity [see Table 2.3 for results].

Table 2.3: Mean Results with Standard Deviations

	TMR	SWR
$\dot{V}E$ ($L \cdot min^{-1}$)		
UT	100.5±19.8**	102.2±38.1**
T	153.8±3.7**	129.5±19.2**
$\dot{V}O_2$ ($mL \cdot Kg^{-1} \cdot min^{-1}$)		
UT	47.9±3.6**	45.2±6.8**
T	68.9±5.1*,**	57.2±3.9*,**
HR ($b \cdot min^{-1}$)		
UT	185±6.9	182±8.9
T	191±8.1*	177±7.1*
RER		
UT	1.2±0.05*	1.1±0.09*
T	1.1±0.09	1.0±0.04
SF(stride min^{-1})		
UT	174±9*,**	200±10*,**
T	208±9**	214±4**

TMR: treadmill running; SWR: shallow water running; UT: untrained; T: trained; $\dot{V}E$: pulmonary ventilation; $\dot{V}O_2$: oxygen consumption; HR: heart rate; RER: respiratory exchange ratio; SF: stride frequency. *Denotes a significant difference between TMR and SWR condition. **Denotes a significant difference between UT and T group.

The study found that being submerged in water significantly reduces heart rate and respiratory exchange ratio in trained and untrained subjects at rest (Conti et al., 2008). While running on a treadmill in the laboratory, the average heart rate of untrained participants was 185 ±6.9 beats/min, and the average heart rate in trained participants was 191±8.1 (Conti et al., 2008).

A study conducted in 2008 by Koepp and Janot determined, and subsequently compared, the maximal demands of treadmill running and skating. Sixteen high school male hockey players ages 15-19 participated in the study. All of the participants were members of the junior varsity or varsity hockey teams, so they were proficient skaters. Each of the subjects completed a treadmill running test and two separate treadmill skating [see Figure 2.10] tests (continuous and discontinuous). The study provided the following results:

Table 2.4: Metabolic Data from Koepp and Janot (2008)

Variable	Discontinuous skating (mean ±S.D.)	Continuous Skating (mean ± S.D.)	Treadmill Running (mean ± S.D.)
$\dot{V}_{O2,\ max}$(mL/kg/min)	60.84±6.25	62.66±7.81	66.91±4.92
METs	17.38±1.79	17.90±2.23	19.12±1.41
$\dot{V}_{O2}$ (L/min)	4.44±0.51	4.53±0.49	4.83±0.52
$\dot{V}_{CO2}$ (L/min)	4.32±0.50	4.69±0.65	5.08±0.59
RER	1.18±0.09	1.02±0.06	1.05±0.05
$\dot{V}_{E}$ (L/min)	103.8±17.83	105.5±16.35	102.7±10.32
HR (beats/min)	185.0±10.84	183.0±16.68	190.5±8.19

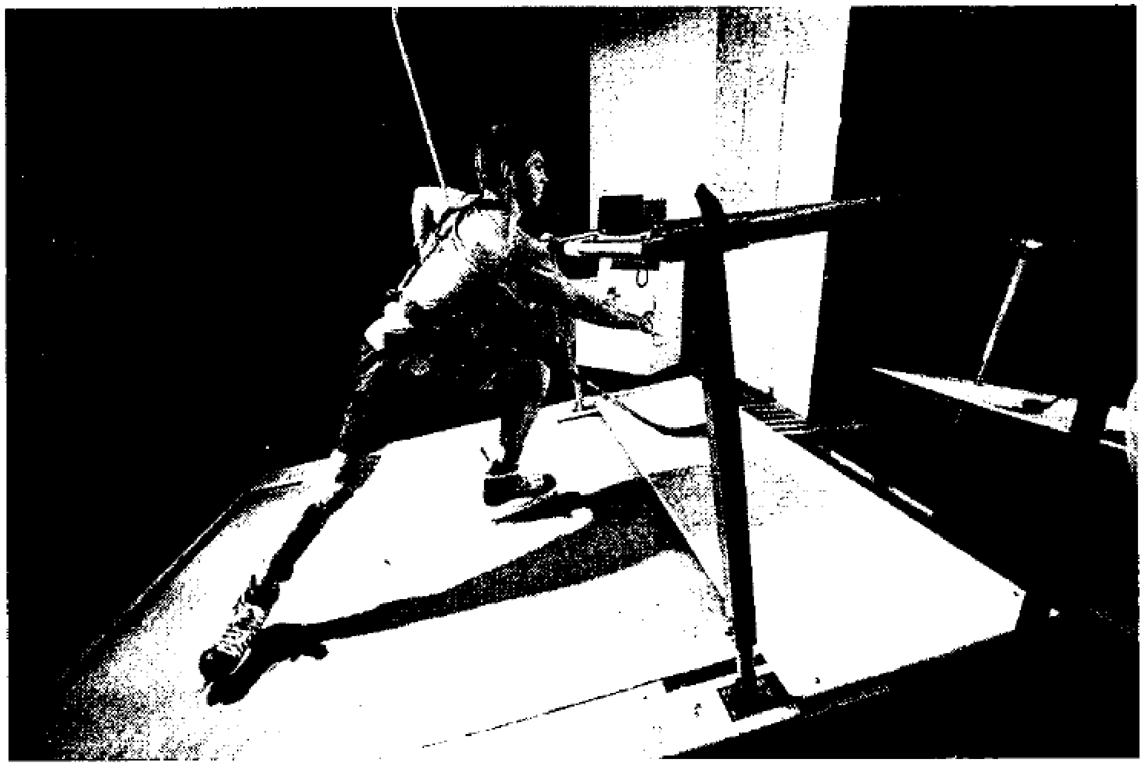


Figure 2.10: Participant Skating on a Treadmill

The increase in relative oxygen consumption in treadmill running indicates that running is more demanding than skating.

These articles describe the body's metabolic response to vigorous intensity activities. A summary of additional studies and their results can be found in Appendix A.

2.1.6 Metabolic Function for Activities of Daily Living

The energy requirements for activities of daily living are less than that for high energy load tasks. Activities of daily living consist of moderate intensity (3-5.9 METs) and light intensity activities (<3 METs). Yoga is a light intensity activity that requires a lower energy load and will be discussed first.

Yoga has been a popular relaxation and exercise technique for centuries. In 2007, Hagins et al. set out to determine whether or not Ashtanga yoga satisfied the recommended intensity for maintaining cardiovascular health. Such an activity requires a participant to use 50 to 85% of their maximal oxygen uptake reserve, or 250-300 kcal per session (Clay et al., 2005). The study included 20 experienced yoga practitioners whose average age was 31.4±8.3 years. Each participant went through an exercise routine that included sitting still while reading for thirty minutes, practicing yoga for 56 minutes [see Table 2.5 for specific yoga exercises], and walking on a treadmill at two different speeds (3.2 kph and 4.8 kph) for ten minutes. The investigators measured participants' mean oxygen consumption, heart rate, metabolic equivalents (METs), and energy expenditure. The yoga portion of the protocol was broken into three sections, and the average results across those sections can be found in Table 2.5. The values for $\dot{V}O_2$ in both of these tables appear to be incorrect. The unit in most publications for this metabolic variable is ml/kg/min, however, in this article the unit is L/kg/min. This is most likely an error in the dissemination of results. The study determined that the metabolic cost of performing the given Ashtanga yoga exercises is not significantly different than the metabolic cost of walking on a treadmill at 3.2km/hr (Hagins et al., 2007). This value does not meet the level of physical activity required to maintain cardiovascular health (Hagins et al., 2007).

Table 2.5: Mean and S.D. Values from Yoga Segments (Hagins et al., 2007)

Task	Task / Length	HR (bpm)	Energy (kcal/min)	$\dot{V}O_2$ (L/min)	METs
Yoga	Across entire session (52 min)	93.2 (25.9)	3.2 (1.1)	0.6 (0.2)	2.5 (0.8)
	Sun Salutation (24 min)	103.5 (25.2)	3.73 (1.01)	0.76 (0.21)	2.9 (0.8)
	Non-sun salutation standing pose (20 min)	89.7 (23.9)	3.01 (0.810)	0.61 (0.16)	2.34 (0.6)
	Sitting / lying poses (8 min)	72.5 (16.1)	1.93 (0.78)	0.40 (0.18)	1.5 (0.58)
Treadmill	3.2 kph	97.8 (21.2)	3.1 (0.6)	0.7 (0.1)	2.5 (0.4)
	4.8 kph	110.3 (23.1)	4.2 (0.4)	0.9 (0.1)	3.3 (0.4)

A study conducted in 2005 by Clay et al. sought to measure the ventilatory and cardiovascular responses of the human body to the practice of hatha yoga. In this study, 26 women ages 19-40 participated in a three-phase protocol. These phases included data collection while sitting in a chair, performing hatha yoga exercises, and walking on a treadmill at 3.5 mph. The portions that require the participants to rest in a chair and walk on a treadmill were later used for comparison. The mean values of the data collected can be found in Table 2.6.

Table 2.6: Mean Values of Metabolic Data Collected During Hatha Yoga (Clay et al., 2005)

Variable	**Yoga Routine**	**Treadmill Walk**
$\dot{V}O_2$ (L/min)	0.45±0.12	0.97±0.23
$\dot{V}O_2$ (ml/kg/min)	7.59±1.35	16.17±1.88
METs	2.17±0.39	4.62±0.54
EE (kcal/min)	2.23±0.57	4.76±1.15
HR (beats/min)	105.28±14.92	133.41±17.13
%MHR	56.89±8.37	71.81±7.70

The mean values for oxygen uptake, relative oxygen uptake, percent of oxygen uptake reserve, METs, energy expenditure, and heart rate were all significantly lower ($p<0.05$) while participants performed hatha yoga than when they walked on a treadmill (Clay et al., 2005). The study revealed that hatha yoga requires significantly less energy than walking at 3.5 mph on a treadmill. This study also determined that hatha yoga does not provide adequate amounts of physical activity to elicit cardiovascular benefits.

As we move further toward the metabolic cost of sedentary tasks, we encounter some everyday activities. Chores around the house like sweeping and gardening require the body to use energy. A study conducted by Gunn et al. in 2002 measured how much energy the body requires to perform household tasks including: moderate walking, sweeping, window cleaning, vacuuming, and lawn mowing. A total of 24 people (12 men and 12 women) participated in this study. The participants had an average age of 39.3±3.4 years. The study also tried to include participants who fit into different weight ranges. Specifically, they aimed to have an even mix of light, medium, and heavy men and women. Each of the participants performed all five of the tasks on two separate days. The results from the study can be found in Table 2.7.

Table 2.7: Metabolic Data (Gunn et al., 2002)

	Men (N=12)		Women (N=12)		Combined (N=24)	
	Mean	SD	Mean	SD	Mean	SD
Walking						
$\dot{V}$ O2 mL/min	1100.0	194.0	1000.0	218.0	1050.0	208.0
$\dot{V}$ O2 mL/kg/min	13.0	2.8	13.5	3.4	13.3	3.1
Kcal/min	5.4	1.0	4.9	1.1	5.1	1.1
Kcal/Kg/min	0.06	0.01	0.07	0.02	0.06	0.02
METs	3.6	0.8	3.9	1.0	3.7	0.9
HR (beats/min)	96.0	12.0	111.0	17.0	104.0	16.0
Sweeping						
$\dot{V}$ O2 mL/min	931.0	183.0	872.0	121.0	901.0	155.0
$\dot{V}$ O2 mL/kg/min	10.9	1.8	11.8	2.4	11.4	2.1
Kcal/min	4.5	0.9	4.2	0.6	4.4	0.8
Kcal/Kg/min	0.05	0.01	0.06	0.01	0.06	0.01
METs	3.1	0.5	3.4	0.7	3.2	0.6
HR (beats/min)	97.0	10.0	118.0	18.0	107.0	18.0
Window Cleaning						
$\dot{V}$ O2 mL/min	1061.0	193.0	942.0	161.0	1002.0	184.0
$\dot{V}$ O2 mL/kg/min	12.4	1.9	12.8	3.2	12.6	2.6
Kcal/min	5.2	0.9	4.5	0.8	4.9	0.9
Kcal/Kg/min	0.06	0.01	0.06	0.02	0.06	0.01
METs	3.5	0.5	3.7	0.9	3.6	0.7
HR (beats/min)	102.0	11.0	119.0	17.0	111.0	16.0
Vacuuming						
$\dot{V}$ O2 mL/min	831.0	164.0	743.0	109.0	787.0	143.0
$\dot{V}$ O2 mL/kg/min	9.7	1.2	10.0	1.8	9.8	1.5
Kcal/min	4.0	0.8	3.6	0.5	3.8	0.7
Kcal/Kg/min	0.05	0.01	0.05	0.01	0.05	0.01
METs	2.8	0.3	2.9	0.5	2.8	0.4
HR (beats/min)	96.0	12.0	111.0	12.0	103.0	14.0
Lawn Mowing						
$\dot{V}$ O2 mL/min	1491.0	149.0	1298.0	247.0	1394.0	223.0
$\dot{V}$ O2 mL/kg/min	17.5	2.6	17.3	2.4	17.4	2.5
Kcal/min	7.2	0.8	6.3	1.2	6.8	1.1
Kcal/Kg/min	0.09	0.01	0.08	0.01	0.09	0.01
METs	5.0	0.8	4.9	0.7	5.0	0.7
HR (beats/min)	115.0	10.0	133.0	17.0	124.0	17.0

The study found that there was no significant difference in energy expenditure (kJ/kg/hr) between men and women in any of the household tasks completed. This allows for the data from both genders to be combined in the remainder of the statistical analysis (Gunn et al., 2002). These results show that the household tasks studied here can be considered moderate to light activities. All of the activities observed required more than 3 METs except for vacuuming. The results also show that there is no significant difference in energy requirement between the genders for tasks of this level of intensity.

These studies provide a view into how the body reacts to less strenuous forms of exercise. Up to this point, all of the exercises encountered have been classified as vigorous intensity activities. In order to have an appropriate perception of how the body should respond to mostly sedentary tasks like typing, it is important to see the how the body reacts to different intensities of physical activity.

2.1.7 Metabolic Function While Sitting

Very few resources provide data for the body's metabolic reaction to sedentary tasks like typing. For the most part, metabolic function is measured while subjects are seated to determine their resting metabolic rate as a point of comparison. This was the case in many of the studies mentioned previously. While the main focus of the studies was not purely to obtain data while people were seated and at rest, it does give some insight into how the body responds to the seated position.

In a 2001 study, Kanade et al. aimed to determine the metabolic cost of sitting, standing, and resting. The study included a total of 64 people (24 men and 40 women) between the ages of 20 and 50. The subjects were all healthy, non-smoking people who were free of any metabolic disease at the time of the study. Each of the subjects was measured in all three states: resting, sitting, and standing. In order to ensure that the subjects were in a resting state, the study was performed at 9pm, and subjects were asked to lie in the supine position for 30 minutes before data collection was started. Following the 30 minutes of rest, the data collection mask was put on the subjects, and they were given one to two minutes to acclimate to the mask before data was collected for six minutes. The data for the sitting and standing positions were collected in a similar fashion. The study found that energy cost for standing was higher than the energy cost of sitting (by 14.8% in men and 7.9% in women) and resting (by 24.7% in men and 13.8% in women) (Kanade et al., 2001). The results also showed that men used more energy than women did while resting, sitting, and standing (illustrated in Figure 2.11). This was shown to be a significant difference ($p<0.001$) in all three cases (Kanade et al., 2001).

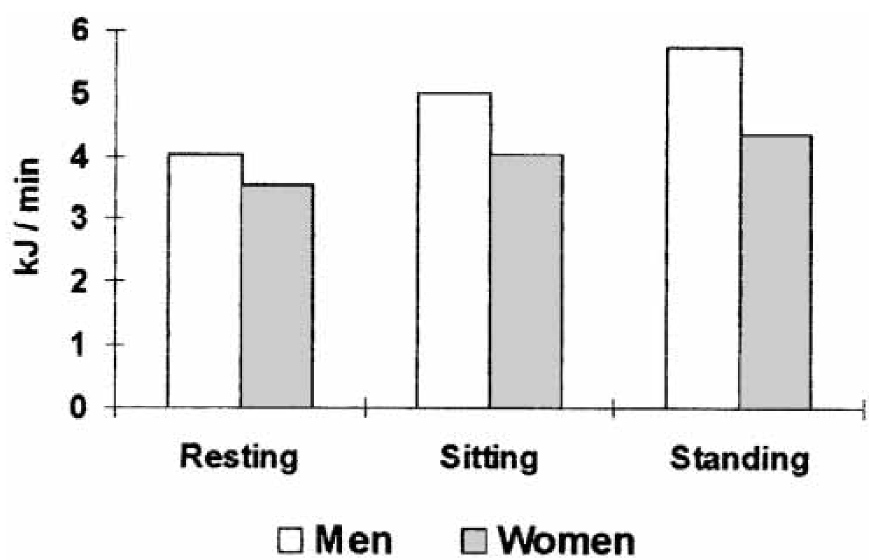


Figure 2.11: Energy Expenditure during Normal Tasks (Kanade et al., 2001)

The average energy costs for men and women for all three activities can be found in Table 2.8. This table also includes values that are adjusted for body weight and fat free mass.

Table 2.8: Energy Cost of Normal Tasks (Kanade et al., 2001)

Energy Costs (kcal/min)	Resting	Sitting	Standing
Observed			
Men	0.958±0.098	1.195±0.172	1.372±0.165
Women	0.846±0.067	0.963±0.081	1.040±0.124
Adjusted for body weight by ANCOVA			
Men	0.925±0.050	1.164±0.091	1.317±0.091
Women	0.868±0.041	0.992±0.084	1.076±0.091
Adjusted for fat free mass by ANCOVA			
Men	0.884±0.048	1.059±0.091	1.233±0.091
Women	0.889±0.038	1.042±0.074	1.126±0.074

These results indicate that men require more energy when resting than females do. This study also shows how much energy the body needs when it is stationary. We now have a better sense of how much energy should be required when people are in one of these positions, and performing relatively sedentary activities.

One study that included metabolic data collection while subjects were seated was conducted by Clay et al. in 2005. The results of this data collection are outlined below.

Table 2.9: Metabolic Data for Sitting (Clay et al., 2005)

Variable	Chair Rest	Yoga Routine	Treadmill Walk
$\dot{V}O_2$ (L/min)	0.21±0.06	0.45±0.12	0.97±0.23
$\dot{V}O_2$ (ml/kg/min)	3.59±0.71	7.59±1.35	16.17±1.88
METs	1.03±0.20	2.17±0.39	4.62±0.54
EE (kcal/min)	1.07±0.27	2.23±0.57	4.76±1.15
HR (beats/min)	84.87±11.79	105.28±14.92	133.41±17.13
%MHR	45.73±5.67	56.89±8.37	71.81±7.70

These data show that resting in the sitting position requires significantly less energy than hatha yoga or walking on a treadmill. The study states that sitting in a chair requires 114% less oxygen uptake, 111% fewer METs, 108% less energy expenditure, and 24% lower heart rate than hatha yoga (Clay et al., 2005). This indicates that the metabolic requirements of sitting in a chair are significantly lower than even light to moderate intensity activities like walking and simple yoga practices.

2.2 Research Voids

The research conducted to this point has focused mainly on the metabolic cost of moderate to vigorous or resting activities. Very few studies have measured the metabolic cost of low intensity activities such as gardening, and to this point, no studies have examined the amount of energy the body requires when performing office work. Not much research has been done in the realm of seated office work, and not many studies have used portable metabolic data collection systems (like the Metamax 3B).

2.3 Research Objectives

This study involved two chairs, one with a wide backrest and one with an upwardly tapered backrest. One objective was to determine whether the shape of the backrest impacted the ventilatory function of the user. A second objective was to determine the amount of energy expended during various office tasks performed in one chair as opposed to the other.

3 Methodology

3.1 General Approach

The objective of this study was to determine whether or not the chair with the upwardly tapered backrest (the test chair) improved the ventilatory efficiency of users by increasing tidal volume and decreasing respiratory rate. The study also measured other lung function parameters and heart rate using the Metamax 3B (Cortex Leipzig, Germany). The Metamax 3B is a portable metabolic measurement system that uses a flow meter and a gas sampling line to measure bulk flow of air, O_2, CO_2, and respiratory rate, and then calculates $\dot{V}O_2$, $\dot{V}CO_2$, ventilation rate, and respiratory exchange ratio (RER). It can also interface with Polar heart rate monitors to collect the user's heart rate. This allowed conclusions to be made about the test chair's impact on the user's ventilatory and cardiovascular efficiency.

3.2 Hypotheses

Hypothesis 1: The test chair will enable users to increase tidal volume (the amount of air in each breath) by letting users retract their scapulae, thus increasing the size of their chest cavity.

Hypothesis 2: The test chair will enable users to decrease their respiratory rate (breaths taken per minute) by increasing tidal volume.

3.3 Experimental Design

This was a laboratory controlled mixed design suggested by the primary investigators (Dr. Paula Papanek and Dr. Richard Marklin). The experimental design (Figure 3.1) includes three independent variables – chair, age, and gender. Chair is a within-subjects independent variable and age and gender are between-subjects independent variables. All of the independent variables had two levels. This experimental design resulted in eight testing conditions with each subject participating in two of them depending on their gender and age.

	Age	**Test Chair**	**Conventional Chair**
Females (N=16)	Younger (18 to 35)	9 females	
	Older (36 to 55)	7 females	
Males (N=15)	Younger (18 to 35)	8 males	
	Older (36 to 55)	7 males	

Figure 3.1: Mixed Experimental Design with 3 Independent Variables

3.3.1 Dependent Variables

The dependent variables measured in this study included a variety of lung function parameters and one cardiovascular parameter:

- Respiratory Rate (RR), the number of breaths taken per minute (breaths/min)
- Tidal Volume (V_t), the amount of air in each breath (liters/breath)

- Respiratory Exchange ratio (RER), the ratio of CO_2 / O_2 (unit less)
- Relative O_2 Uptake ($\dot{V}O_2$), the amount of oxygen consumed per minute per kilogram body weight (ml/min/kg)
- Volume CO_2 Produced ($\dot{V}CO_2$), the amount of carbon dioxide produced per minute (ml/kg/min)
- Heart Rate (HR), the number of heart beats per minute (beats/min)

The dependent variables were all measured using the Metamax 3B. All of the data were transmitted wirelessly to a computer via telemetry. The data from the Polar heart rate monitor were also transmitted wirelessly to the Metamax 3B.

3.3.2 Independent Variables

This study sought to determine the effects that three independent variables had on the metabolic responses of chair users. The three variables were age, gender, and chair. Each of the three variables was evaluated on two levels. Age was broken into two levels, older and younger, with the younger level including participants between the ages of 18 and 35, and the older group consisting of participants between the ages of 36 and 55. The two levels of gender were male and female, and the two levels of chair were blue and black. In the experiment the name “blue” was used to represent the chair with the narrow backrest, and the name “black” was used to denote the chair with the wide backrest. Subjects did not know which chair was the new design and were told the experiment was designed to determine the metabolic costs of different office tasks.

3.3.3 Control Conditions

The protocol for this experiment was designed to control as many confounding variables as possible to ensure that the data collected and the conclusions derived from it were valid. In order to ensure that all of the data were collected accurately, all of the participants used the same computer setup. This is important, because it is possible that different keyboards, mice, or keyboard trays could yield different ventilatory and cardiovascular responses to office work. The environment was also controlled. The tests were all conducted in the same dedicated office space with the same lighting and the same ambient noise. These factors could have an impact on an individual's comfort level, which in turn could impact their metabolic outputs. The work that the participants completed was also controlled. During the office tasks, the participants all typed from the same script, conducted their internet searches from the same list of items, and used the same computer programs to complete the tasks. It was also vital to make sure that the movies the participants watched were neutral films. This means that the film should not cause them to laugh or become scared, since both of these activities will alter the variables being measured and could skew the final results. Taking these steps helped to reduce the possibility that confounding variables impacted the results of the study.

3.4 Participants

3.4.1 Determination of Sample Size

The sample size for this study is dependent on three factors: age, gender, and chair. It is necessary to choose a sample size large enough to maintain 80% statistical power when analyzing the data collected from the subject pool. Since this study involves three factors, the sample size needs to be determined in terms of all three factors. The greatest number of subjects required to maintain 80% statistical power will be used. Extra participants will be included in case some of the data cannot be used. The calculation of sample size is an iterative process. An initial "guess" at the sample size is entered into a set of equations [see Appendix V]. The resulting phi squared value and the v_2 value are used in conjunction with an operating characteristic curve to determine the value of β (type II error). The statistical power is then the value of $1-\beta$. A sample calculation, as well as a table containing the iterations, for all factors can be found in Appendix V. Power analysis showed that a minimum of 25 participants were required for this study.

3.4.2 Description of All Subjects

The participants in this study went through a screening process prior to being accepted. This process consisted of a phone interview that included questions concerning the potential participant's current health, health history, and general background information. The questions asked in the phone interview can be found in Appendix D. Ideal participants in the study met a few main criteria. These included being office workers who spent two to four hours per day working with a computer at a desk, being a non or light smoker, and being free of any respiratory diseases such as asthma or emphysema. The participants also had to be between the ages of 18 and 55, free of injuries that could be made worse by participating, and taking any prescribed medication consistently. If all of these qualifications were met, the person was invited to participate in the study. The participants were instructed to avoid eating, smoking, consuming caffeine, or taking any type of medication for at least two hours prior to testing. This ensured that the body was not doing any additional work (i.e. digestion, breaking down medication, or processing caffeine) during data collection. The participants were also asked to avoid strenuous activity on the test date. Since this study involved human subjects, the test protocol was approved by the Institutional Review Board (IRB) at Marquette University. This also required that each participant read and sign an informed consent form before participating in the study.

3.4.3 Subject Testing Order

The subjects reported to the test office for testing on two separate occasions. On one occasion, the participants were tested in the blue chair, and on the other they were tested in the black chair. In order to avoid order or carryover effects, the order in which the chairs were presented to the participants was counterbalanced.

3.5 Testing Location

3.5.1 Room

All of the tests were conducted in the same location, which was an office located in the Program in Exercise Science at Marquette University (Figure 3.2). The room included a wall mounted desk, a standard university grade desktop computer with a flat screen monitor, a window (with blinds), and fluorescent lighting. This office space is typical of an actual office.

Figure 3.2: Office Setup

3.5.2 Computer

A Windows™ based PC with a wired keyboard and wired mouse was used. The keyboard and mouse used in testing were not ergonomically designed. The keyboard had the ability to be set at two different angles. The keyboard angle used during testing was left to the discretion of the participant. The computer screen was an issue for some of the older participants. Many of them had larger screens or had set a larger screen display on their work computers. In order to accommodate them, the monitor was moved as close as possible to the user. In order to make typing from a script easier, all of the participants were given the option of using a document holder. A photo of the computer can be seen in Figure 3.3.

Figure 3.3: PC Used by Participants

3.5.3 Keyboard Stand

The room in which the testing was conducted had a desk that was mounted to the wall. This did not allow for any height adjustments, and with the wide range of participant heights, some adjustability was necessary. A keyboard stand was used to provide the option of adjustability to each of the participants. The keyboard stand can be seen in Figure 3.4.

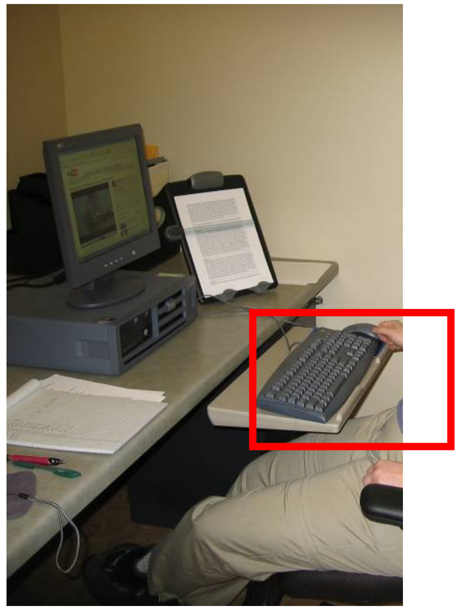


Figure 3.4: Keyboard Stand (Highlighted in Red)

3.6 Equipment

3.6.1 Metamax 3B Portable CPX System (Cortex) Description

The Metamax 3B is a portable cardiopulmonary exercise testing system used to collect metabolic data. The device consists of two parts, a central unit and a mask. The central unit houses the data collection equipment, data storage equipment, and a rechargeable battery. This portion of the Metamax 3B rests over the subject's shoulders and around the back of the subject's neck (seen in Figure 3.5). The mask covers the subject's nose and mouth to collect and perform breath-by-breath analyses of volume, O_2 concentration, and CO_2 concentration.

Figure 3.5: Metamax 3B

The mask is held on the subject's face by a bonnet that runs around the back of the subject's head (seen in Figure 3.6).

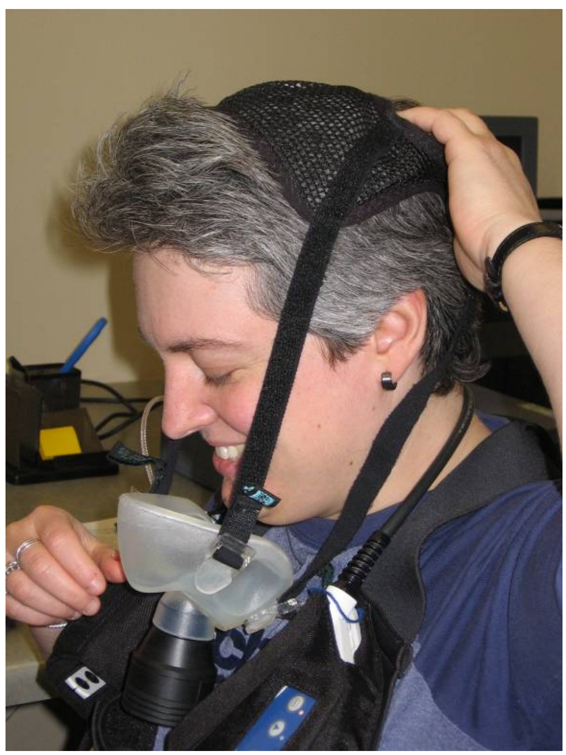


Figure 3.6: Participant Putting Mask On

A volume meter connects to the front of the mask. This volume meter houses a digital turbine and a temperature sensor that allows the Metamax 3B to collect data defining the amount of air flowing into and out of the subject with each breath. The temperature sensor is calibrated before each test to match ambient temperature. This is an effort to ensure that there is no condensation present in the turbine that could inhibit it from spinning properly. The digital turbine in the volume meter is accurate over a range of 0.05-20 L/sec with a resolution of 7 ml, and it is accurate to within 2%. The sensor goes through a two-point calibration process. The digital turbine was calibrated using a Hans-Rudolf syringe. This syringe is available in a number of sizes. In this study, a 0.5L syringe was used for calibration, because it reflects the amount of air that will be passing through the digital turbine during data collection.

A gas sampling line runs from the volume meter to the central unit. This sampling line allows the equipment to determine and analyze the concentration of O_2 and CO_2 of the air the subject is breathing. It can determine the amount of oxygen and carbon dioxide in the air, and this data can be used to derive other metabolic measurements. The sampling line contains an electro-chemical cell oxygen sensor. This sensor is functional when sampling from air containing 0-35% oxygen, and it is accurate to within 0.1 volume %. The sampling line also houses an infrared carbon dioxide sensor. This sensor is functional when sampling from air containing 0-15% carbon dioxide, and it is accurate to within 0.1 volume %. These sensors are calibrated using ambient air and a “standard air” (15% O_2, 5% CO_2, and 80% Nitrogen) prior to each test.

The digital turbine, temperature sensor, O_2 and CO_2 sensors are all calibrated before each test begins. Each sensor goes through a two-point calibration process. A more detailed explanation of the calibration process can be found in Appendix C.

The Metamax 3B calibration is largely dependent on the abilities of the tester. For instance, the calibrator is required to pump at the same rate as a bar moves across the computer screen. This portion of the calibration process can be rejected by the computer software, but this may not indicate an error in the instrumentation. It could simply mean that the calibrator did not pump the syringe at the correct rate or speed. Since this process can be affected by the experience and ability of the user, a failed step in the calibration process is not necessarily indicative of a defect in the instrumentation. This could be corrected by developing a mechanized calibration process for future studies.

The Metamax 3B also features wireless data acquisition capabilities. Data is transmitted wirelessly via telemetry. The telemetry system is bidirectional, transmits a 19.6 kbaud signal, and operates on frequencies between 433-434 MHz. This system has a range of up to 1000 meters as well. The Metamax also allows for data collection in the absence of a computer. In this case, the data are stored on an 8 MB hard drive within the device, and can be accessed later via a wired computer connection. The Metamax 3B allows for the metabolic analysis of almost any bodily function, and its compact and portable nature makes it easy to use. A picture of a participant with the Metamax 3B on completely can be seen in Figure 3.7.

Figure 3.7: Participant with the Entire Metamax 3B System On

3.7 Experimental Protocol

The following is a step-by-step outline for the data collection on each day of testing. Testing was completed during the same period of the day to avoid potential confounding variables. The second test began on the second day within two hours of the previous appointment time.

Day 1 Data Collection Outline

1. Have the prospective subject read the informed consent form (seated in chair).
2. Read through the informed consent form with the prospective subject and ensure they understand it completely.
3. Complete the anthropometric measurements:
    a. Measure weight
    b. Measure stature [see Figure 3.8]
    c. Measure acromial height [see Figure 3.8]
    d. Have the subject bend elbows to 90°
    e. Measure Shoulder-elbow length on dominant side [see Figure 3.8]
    f. Measure elbow wrist length on the dominant side [see Figure 3.8]
    g. Measure forearm had length on dominant side [see Figure 3.8]

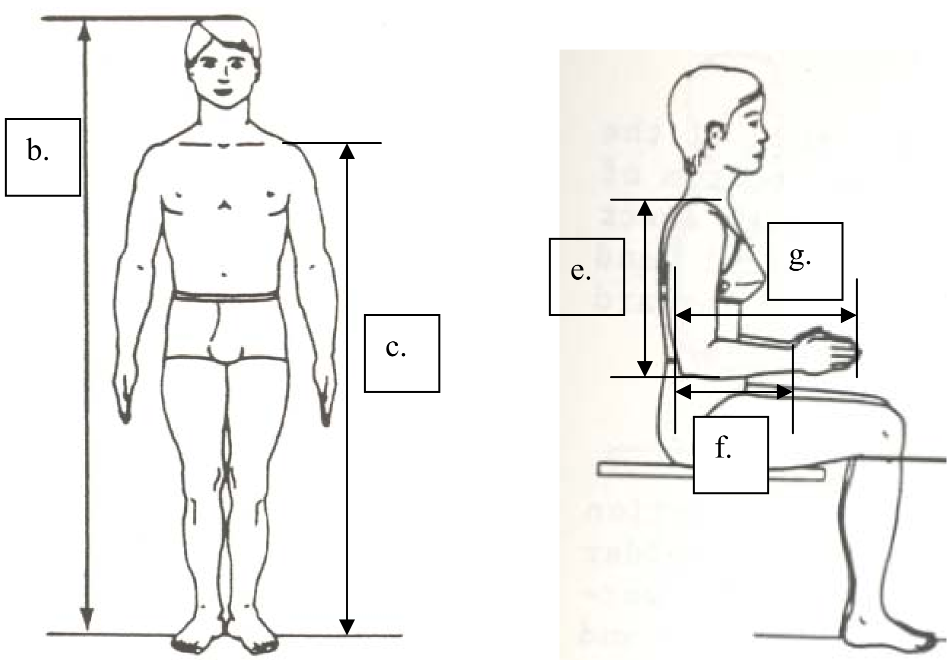


Figure 3.8: Anthropometric Measures

h. Have the subject sit with knees bent at 90° and feet flat

i. Measure popliteal height [see Figure 3.9]

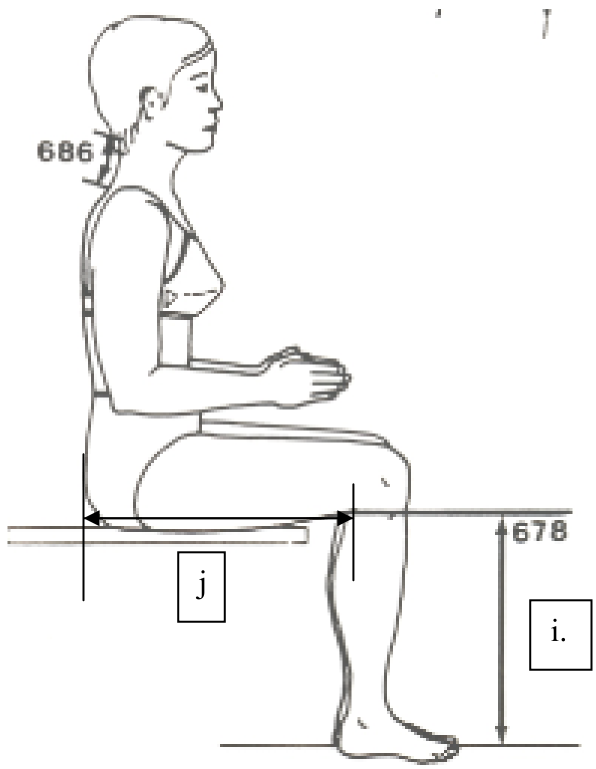


Figure 3.9: Popliteal Height Measurement #678 (Measurement taken to popliteal crease at the back of the knee)

j. Measure buttock-popliteal length [see Figure 3.9]

*Measurement taken to popliteal crease at the back of the knee.

4. Explain how the chair adjustment mechanisms work the subject.
5. Subject fills out the Occupational and Health Background Form while sitting in the chair.
6. Ask any follow up questions needed based on the responses on the Occupational and Health Background Form.

7. Fit the subject to the chair: knees at 90°, angle between leg and torso is 90°, feet are flat on the ground, and the elbows are as close to 90° as possible.
8. Have the subject go to the bathroom and put on the heart rate monitor:
    a. Plastic sensor should be at the bottom of the chest bone (sternum)
    b. Make it tight enough to stay in place, but not so tight it causes discomfort.
9. Put the Metamax 3B collar on the subject.
10. Secure the mask to the subject's face.
11. Fit the keyboard table to the subject (same height as the arm rests).
12. Allow the subject to get used to wearing the mask and the environment before beginning actual data collection.
13. Begin video recording.
14. Subject will type from an essay for 15 minutes.
15. Subject will search the internet for prices for 10 minutes.
16. Subject will create a table with the prices for 5 minutes.
17. Stop video recording.
18. Subject will get a 5 minute break.
19. Measure the seat height during the break.
20. Restart video recording.
21. Subject will recline and watch a movie for 30 minutes.
22. Stop video recording.
23. Subject will take a 5 minute break.
24. Measure the seat height during the break.
25. Restart video recording.

26. Subject will type from and essay for 15 minutes.
27. Subject will search the internet for prices for 10 minutes.
28. Subject will put the prices into a table for 5 minutes.
29. Stop data collection.
30. Stop video recording.
31. The mask and collar are removed from the subject.
32. Subject fills out the Subjective Assessment Form.
33. Escort subject to the exit.
34. Complete the Post Experimental Measurements Form:
    a. Measures Seat Height
    b. Measures arm rest height
    c. Measures back rest position
    d. Measures seat pan depth
    e. Measures keyboard stand height.
35. Bring the equipment back to the lab and sterilize the mask.
36. Replace the telemetry on the work station in the lab.
37. Create a folder for the subject and put all the forms inside.
38. Put the folder in a LOCKED cabinet.
39. Begin analysis of the data collected.

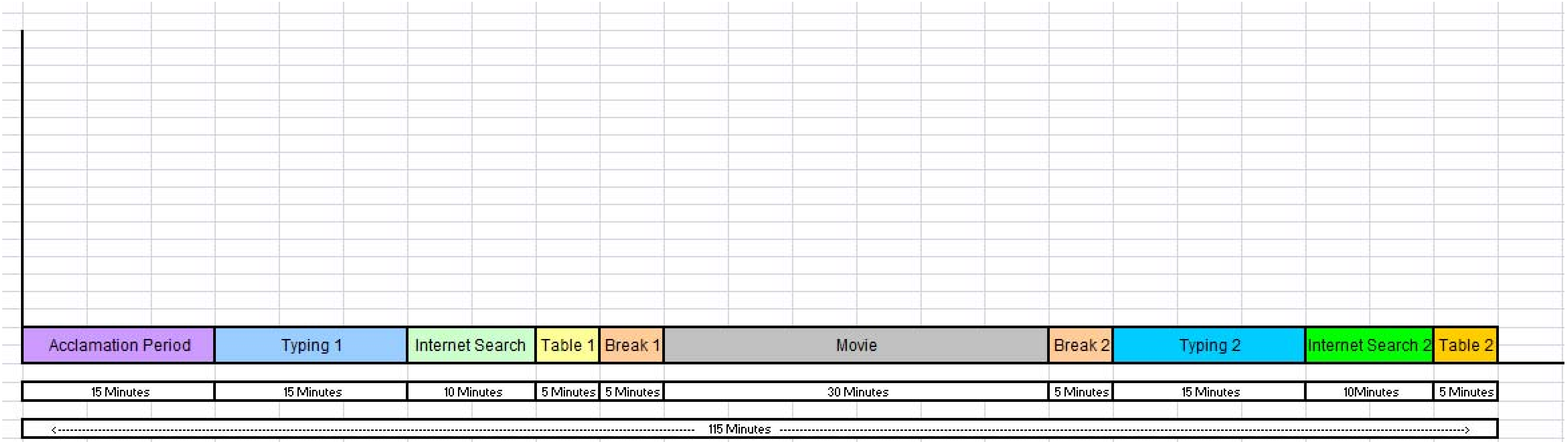
Day 2 Data Collection Outline

1. Have the subject fill out the Day of Study Form while sitting in the chair.
2. Explain how the chair adjustment mechanisms work to the subject.

3. Fit the subject to the chair: knees at 90°, angle between leg and torso is 90°, feet are flat on the ground, and the elbows are as close to 90° as possible.
4. Have the subject go to the bathroom and put on the heart rate monitor:
    a. Plastic sensor should be at the bottom of the chest bone (sternum)
    b. Make it tight enough to stay in place, but not so tight it causes discomfort.
5. Put the Metamax 3B collar on the subject.
6. Secure the mask to the subject's face.
7. Fit the keyboard table to the subject (same height as the arm rests).
8. Allow the subject to get used to wearing the mask and the environment before beginning actual data collection.
9. Begin video recording.
10. Subject will type from an essay for 15 minutes.
11. Subject will search the internet for prices for 10 minutes.
12. Subject will create a table with the prices for 5 minutes.
13. Stop video recording.
14. Subject will get a 5 minute break.
15. Measure the seat height during the break.
16. Restart video recording.
17. Subject will recline and watch a movie for 30 minutes.
18. Stop video recording.
19. Subject will take a 5 minute break.
20. Measure the seat height during the break.
21. Restart video recording.

22. Subject will type from and essay for 15 minutes.
23. Subject will search the internet for prices for 10 minutes.
24. Subject will put the prices into a table for 5 minutes.
25. Stop data collection.
26. Stop video recording.
27. The mask and collar are removed from the subject.
28. Subject fills out the Subjective Assessment Form.
29. Subject is asked to fill out the Receipt for subject payment form.
30. Fill out the cash reimbursement voucher and staple it to the receipt for subject payment form.
31. Subject is escorted to the exit.
32. Complete the Post Experimental Measurements Form:
    a. Measure Seat Height
    b. Measure arm rest height
    c. Measure back rest position
    d. Measure seat pan depth
    e. Measure keyboard stand height.
33. Brings the equipment back to the lab and sterilize the mask.
34. Replaces the telemetry on the work station in the lab.
35. Put the subject’s forms in their folder, and return it to the LOCKED cabinet.
36. Begin analysis of the data collected.

A graphical representation of the experimental time line can be found in Figure 3.10.



Interval Descriptions:

Acclamation Period: Gives the subject time to adapt to the new enviroment, wearing the mask, being videotaped, and wearing the equipment.

Typing 1: The participant retypes a report titles "Analysis of To Kill a Mockingbird by Harper Lee"

Internet Search 1: The participant searches for items provided on a list at the specified websites, and record the prices on a note pad.

Table 1: The participant creates a table and enters the results from their internet search.

Break 1: The participant can move around, stretch, talk, and use the restroom if necessary.

Movie: The participant chooses a movie to watch for 30 minutes.

Break 2: The participant can move around, stretch, talk, and use the restroom if necessary.

Typing 2: The participant retypes a report titles "Analysis of To Kill a Mockingbird by Harper Lee"

Figure 3.10: Experimental Timeline

3.7.1 Test Sections

The data collection process was broken up into eight different time frames, or tasks. Before testing began for any of the subjects, they were afforded a 15-minute acclamation period to familiarize themselves with the new workstation setup, and having the Metamax 3B mask and Polar heart rate monitor on. Once data collection began, the subjects went through three 30-minute test sections: 30 minutes of office work, 30 minutes of watching a movie, and 30 more minutes of office work. The subjects received a five minute break between the three test sections. These three test sections were broken into eight tasks including, typing 1, internet 1, table 1, movie 1, movie 2, typing 2, internet 2, and table 2. The duration of these tasks can be found in Table 3.1.

Table 3.1: Task and Section Duration

Test section	Task	Duration	Section Duration
1	Typing 1	15 min.	30 min.
	Internet 1	10 min.	
	Table 1	5 min.	
2	Movie 1	15 min.	30 min.
	Movie 2	15 min.	
3	Typing 2	15 min.	30 min.
	Internet 2	10 min.	
	Table 2	5 min.	

While data were collected for the entirety of each task, only three minutes were analyzed. In order to obtain the best representation of the subject's metabolic function, the final three minutes of each task were analyzed. When a person switches tasks, there is a ramp-up period that will produce inaccurate data. This ramp-up period usually lasts for about a minute. After this ramp-up period ends, the subject's metabolic parameters settle into a steady state. This is the time period when the most accurate data can be collected. Thus, using the final three minutes of each task in further analysis should render the most accurate results and assessment of the test chair's impact on users' metabolic function. A graph that defines the three minute regions of data used in the analysis can be seen in Appendix E.

3.7.2 Postures

Data were collected in two separate positions in this study.

Position 1: Sitting erect in the chair. This position requires subjects to be seated with their feet on the ground. It requires a 90° angle bend in the arms at the elbow, a 90° bend in the legs at the knee, and a 90° angle between the torso and the upper leg (Figure 3.11).

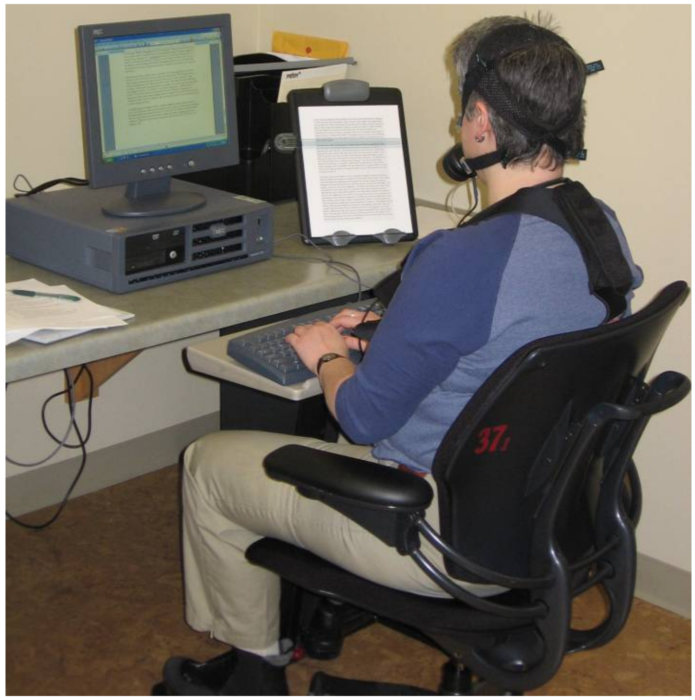


Figure 3.11: Participant Sitting Erect in the Conventional Chair

Position 2: Sitting in a reclined position in the chair. This position requires the subject to lean backwards in the chair. The only requirement for this position is that the subject was clearly reclining, not simply slouching in the chair (Figure 3.12).

Figure 3.12: Participant in the Reclined Position

3.8 Data Collected vs. Data Analyzed

3.8.1 Data Collected

The experiment involved collection of 6 dependent, physiological variables including: heart rate, respiratory rate, respiratory exchange ratio, relative oxygen uptake, carbon dioxide output, and tidal volume. The data were collected on a breath-by-breath basis. This means that there is no set sampling rate. The sampling rate is dependent on how often the participant breathes. With every breath, air samples are collected, and the relevant data are recorded. This process was occurring during the entirety of testing. In the end, a total of about two hours worth of data were collected during each day's session.

3.8.2 Data Analyzed

While data were collected throughout the testing period, not all of it was analyzed nor was it all suitable for analysis. In order for analyses to be accurate, data collected during a steady state of activity need to be filtered from the entire data set. It takes at least one minute to adjust to a new task and reach a steady metabolic state. Taking this into account, the data to be analyzed were taken from the final 3 minutes of each task. This time period provided an ample data set that was collected while the participant was in a steady metabolic state. A pictorial representation of the overall amount of data collected versus the amount of data analyzed can be found in Appendix E.

3.9 Statistical Analysis

This study took three approaches to analyzing the dependent variable data. Analysis of variance (ANOVA), paired t-tests, and regression analysis were conducted on the collected data. The ANOVA and paired t-tests aimed to determine which, if any, of the independent variables had a significant impact on the dependent variables. The regression analysis was performed to determine whether or not any of the anthropometric measures taken were good predictors of the dependent variables.

This study also included the collection of subjective data from each of the participants. These data were collected to determine if any preference existed between the two chairs being tested in terms of ease of use, comfort, positioning, etc. A non-parametric test (Friedman's statistic method) was used to determine if such a preference existed. If a preference did exist, it could be considered a confounding variable, because discomfort could cause abnormal fluctuation in the metabolic variables being measured.

4 Results

4.1 Anthropometrical Data

The tables below show the summary statistics from all of the anthropometric measurements taken. These measurements represent the size of each participant in relation to a chair. The majority of the measures were taken in the seated position. This gave a clear picture of how well the adjustability of the test chair and the conventional chair accommodated the population of participants. The results could also help explain aberrations in the collected data. If a participant did not "fit" into the chair, it could cause discomfort and abnormal responses to the test protocol. The statistics reflect the entire participant population. The average participant age was 36.13±11.92 years, the average weight was 202.36±60.92 lbs., and the average height was 67.45±4.59 inches. The raw anthropometric data can be found in Appendix G.

Table 4.1: Summary Statistics of Anthropometric Data from All Participants

Statistic	Age	Weight (lbs.)	Stature [height] (in.)	Stature [height] (cm)	BMI
Mean	36.13	202.36	67.45	166.35	31.11
Median	33.00	187.10	67.91	172.50	31.53
Std. Dev	11.92	60.92	4.59	26.76	8.04
Minimum	19.00	103.80	57.05	73.50	18.46
Maximum	55.00	336.20	76.50	194.30	49.68

Table 4.2: Summary Statistics of Anthropometric Data from All Participants (cm)

Statistic	Acromial Height	Shoulder-Elbow Length	Elbow-wrist Length	Forearm -hand Length	Shoulder Width	Popliteal Height	Buttock-popliteal length
Mean	146.20	37.65	29.18	47.36	45.96	43.13	48.61
Median	147.80	38.00	29.50	47.80	45.40	43.00	48.60
Std. Dev	9.27	3.01	2.41	3.31	4.95	2.40	2.90
Minimum	131.00	30.40	23.40	39.90	37.00	39.40	44.00
Maximum	162.10	42.70	33.30	53.10	55.50	49.10	56.30

Anthropometric data divided by gender can be found in Appendix H.

4.2 Analysis of Variance

Analysis of variance (ANOVA) was used to determine which, if any, independent variables in the experiment had a significant impact on any of the dependent variables. Summary statistics for all 6 of the dependent variables can be found in Appendices I-N. Summary statistics of the dependent variables by task (for tasks movie 2, typing 2, internet 2, and table 2) can be found in Appendices O-R.

4.2.1 ANOVA All Subjects

The ANOVA results were obtained using the software program SAS. The codes used can be found in Figure 4.2 and Figure 4.3**.** Two separate analyses were conducted: one included the independent variables chair and gender, and the other included the independent variables chair and age. The p-values for these tests can be found in Table 4.3 and Table 4.4**.** The analysis showed that the interaction between chair and gender had a significant impact on respiratory rate in the internet 1 task. The following graph portrays this interaction:

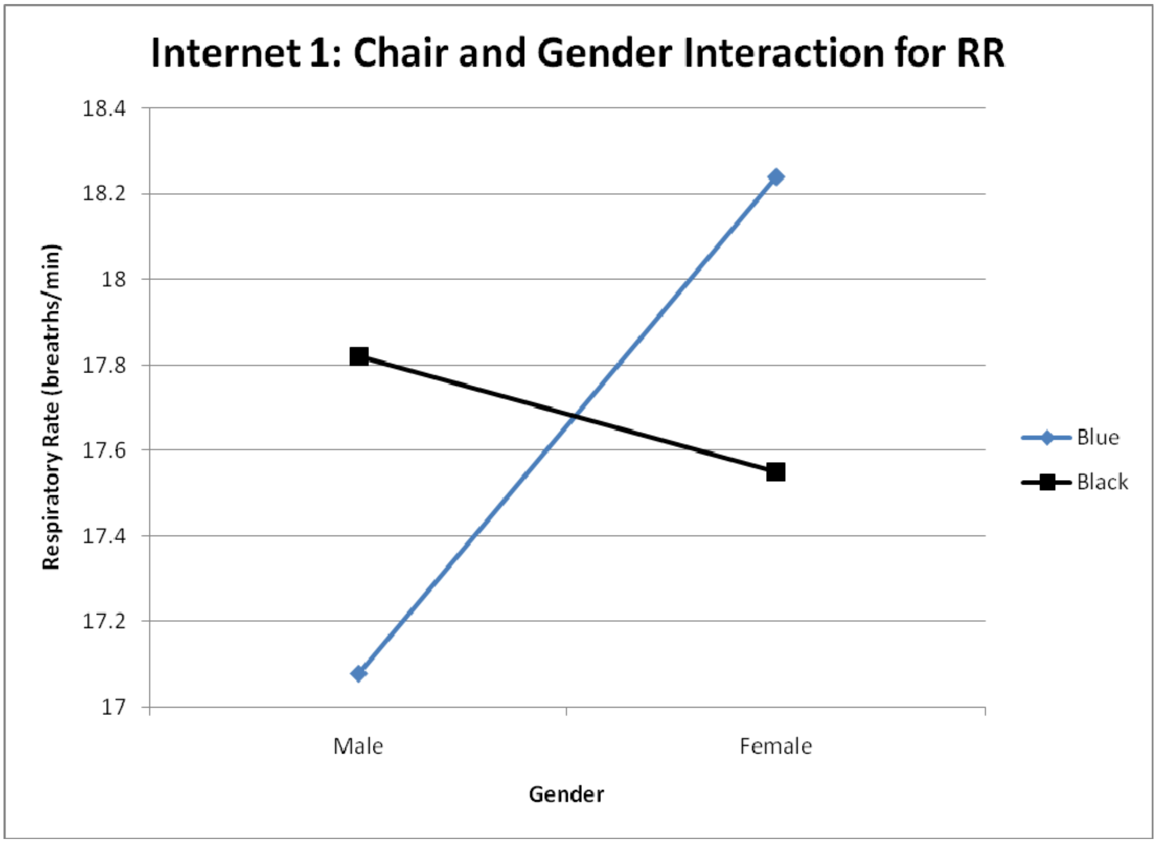


Figure 4.1: Graph of the Interaction between Chair and Gender for RR in Internet 1

```
proc mixed method=type1 data=F;
class chair gender subject;
model TV=gender chair gender*chair;
random subject(gender);
run;
```

Figure 4.2: SAS Code Used in Mixed ANOVA Analysis Including Gender and Chair.

```
proc mixed method=type1 data=F;
class chair age subject;
model TV=age chair age*chair;
random subject(age);
run;
```

Figure 4.3: SAS Code Used in Mixed ANOVA Analysis Including Age and Chair.

Table 4.3: Mixed ANOVA Results for Analysis Including Chair and Gender

Results of Mixed ANOVA Analysis for Chair and Gender (p-values)									
		Task							
D.V.	Effect	Typing 1	Internet 1	Table 1	Movie 1	Movie 2	Typing 2	Internet 2	Table 2
HR (beats/min)	Gender	0.3889	0.5561	0.4906	0.6160	0.4906	0.7488	0.6140	0.7663
	Chair	0.0014	0.0013	0.0008	0.0063	0.0116	0.0086	0.0023	0.0002
	Chair*Gender	0.2737	0.2495	0.2080	0.3564	0.5981	0.2801	0.2057	0.0966
RR (breaths/min)	Gender	0.1037	0.6408	0.1906	0.9419	0.4856	0.0719	0.8511	0.1972
	Chair	0.0185	0.9389	0.1957	0.8860	0.8927	0.1748	0.1247	0.0856
	Chair*Gender	0.1078	0.0491	0.1721	0.3234	0.3146	0.3866	0.2426	0.1087
TV (liters)	Gender	<0.0001	<0.0001	<0.0001	0.0056	0.0073	<0.0001	0.0006	<0.0001
	Chair	0.2928	0.5602	0.7573	0.7775	0.9847	0.2041	0.1837	0.5975
	Chair*Gender	0.0703	0.0486	0.5652	0.0605	0.0961	0.3256	0.2897	0.0673
CO2 (ml/kg/min)	Gender	<0.0001	0.0002	0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
	Chair	0.7279	0.9162	0.9818	0.7246	0.5209	0.9496	0.6082	0.0479
	Chair*Gender	0.6478	0.4681	0.3190	0.6650	0.9142	0.9000	0.8598	0.5971
O2 (ml/kg/min)	Gender	0.8934	0.7451	0.7262	0.4864	0.4846	0.9398	0.8576	0.7785
	Chair	0.9936	0.8843	0.4591	0.9820	0.8431	0.4266	0.7230	0.0015
	Chair*Gender	0.4274	0.5612	0.2595	0.6302	0.6945	0.5626	0.5925	0.5353
Respiratory Exchange Ratio (RER)	Gender	0.1705	0.2558	0.2952	0.4298	0.0618	0.2172	0.1507	0.1064
	Chair	0.4445	0.4484	0.7166	0.7936	0.5485	0.8751	0.6583	0.8118
	Chair*Gender	0.6377	0.7336	0.8326	0.4997	0.5205	0.9674	0.7497	0.5325
**** Cells Highlighted in Yellow Indicate p-value Less Than 0.05**									

Table 4.4: Mixed ANOVA Results for Analysis Including Chair and Age

Results of Mixed ANOVA Analysis for Chair and Age (p-values)									
		Task							
D.V.	Effect	Typing 1	Internet 1	Table 1	Movie 1	Movie 2	Typing 2	Internet 2	Table 2
HR (beats/min)	Age	0.7454	0.4597	0.6849	0.6523	0.6220	0.7600	0.5167	0.6303
	Chair	0.0017	0.0015	0.0010	0.0079	0.0093	0.0107	0.0027	0.0002
	Chair*Age	0.7302	0.5891	0.5546	0.9205	0.3556	0.9153	0.5307	0.3813
RR (breaths/min)	Age	0.1440	0.0616	0.0885	0.0223	0.0350	0.0663	0.0273	0.0184
	Chair	0.0242	0.9292	0.2056	0.9021	0.8740	0.1940	0.1527	0.1190
	Chair*Age	0.6454	0.4198	0.5729	0.6093	0.9555	0.9185	0.7240	0.6677
TV (liters)	Age	0.7507	0.9330	0.6939	0.6220	0.8268	0.8737	0.6482	0.8075
	Chair	0.3930	0.5302	0.8589	0.8407	0.9045	0.2412	0.2113	0.6998
	Chair*Age	0.3047	0.8003	0.2312	0.9572	0.3799	0.6108	0.8503	0.5610
CO2 (ml/kg/min)	Age	0.5179	0.5696	0.4503	0.4760	0.7076	0.8058	0.7193	0.4339
	Chair	0.8266	0.9652	0.9135	0.7416	0.5828	0.9447	0.5909	0.0459
	Chair*Age	0.1118	0.3826	0.2274	0.9483	0.3115	0.9136	0.8254	0.6268
O2 (ml/kg/min)	Age	0.3998	0.2718	0.4049	0.4750	0.3230	0.1524	0.2393	0.3454
	Chair	0.9574	0.8044	0.4180	0.9935	0.9057	0.4345	0.8104	0.0016
	Chair*Age	0.3710	0.2248	0.2590	0.8762	0.4891	0.7933	0.3032	0.8045
Respiratory Exchange Ratio (RER)	Age	0.6979	0.5094	0.6624	0.4270	0.5817	0.3772	0.6901	0.4475
	Chair	0.5207	0.4692	0.7236	0.8129	0.6006	0.8846	0.6839	0.8236
	Chair*Age	0.0744	0.6516	0.9934	0.9984	0.5880	0.8955	0.8136	0.9394
**** Cells Highlighted in Yellow Indicate p-value less than 0.05**									

4.3 Paired t-test Analysis

Paired t-tests were conducted to determine whether or not statistically significant differences in the dependent variables existed between the chairs. The analysis was conducted for all of the dependent variables across all 8 of the protocol segments. This study was most concerned with the results of the t-tests pertaining to tidal volume, heart rate, and respiratory rate. Summary statistics for all 6 of the dependent variables can be found in Appendices I-N. Summary statistics of the dependent variables by task (for tasks movie 2, typing 2, internet 2, and table 2) can be found in Appendices O-R.

4.3.1 Paired t-test All Subjects

The table below shows the results of the paired t-tests that included the entire participant population. The results showed that there was a significant ($p<0.05$) lowering of participant's heart rate in the blue chair when compared to the black chair across all eight of the protocol segments. The t-tests also showed that there were very few protocol segments that showed significant differences between the chairs in terms of tidal volume and respiratory rate. Tidal volume did not show a significant difference in any of the protocol segments, and respiratory rate showed a significant difference in only one of eight protocol segments.

Table 4.5: Summary Table of Paired t-test Results for All Subjects (n=31)

Significant Differences Between Chairs All Subjects (N=31)						
Task	**HR**	**RER**	**RR**	**CO2 Output**	**O2 Intake**	**TV**
Typing 1	P(T<=t) one-tail 0.000766	P(T<=t) one-tail 0.2135	P(T<=t) one-tail 0.012043	P(T<=t) one-tail 0.3544	P(T<=t) one-tail 0.487	P(T<=t) one-tail 0.472
Internet 1	P(T<=t) one-tail 0.0007108	P(T<=t) one-tail 0.2162	P(T<=t) one-tail 0.495	P(T<=t) one-tail 0.448	P(T<=t) one-tail 0.449	P(T<=t) one-tail 0.268
Table 1	P(T<=t) one-tail 0.0004726	P(T<=t) one-tail 0.357	P(T<=t) one-tail 0.108	P(T<=t) one-tail 0.499	P(T<=t) one-tail 0.242	P(T<=t) one-tail 0.384
Movie 1	P(T<=t) one-tail 0.003252	P(T<=t) one-tail 0.403	P(T<=t) one-tail 0.430	P(T<=t) one-tail 0.363	P(T<=t) one-tail 0.497	P(T<=t) one-tail 0.426
Movie 2	P(T<=t) one-tail 0.005482	P(T<=t) one-tail 0.279	P(T<=t) one-tail 0.433	P(T<=t) one-tail 0.254	P(T<=t) one-tail 0.425	P(T<=t) one-tail 0.483
Typing 2	P(T<=t) one-tail 0.004707	P(T<=t) one-tail 0.433	P(T<=t) one-tail 0.090	P(T<=t) one-tail 0.475	P(T<=t) one-tail 0.205	P(T<=t) one-tail 0.107
Internet 2	P(T<=t) one-tail 0.001345	P(T<=t) one-tail 0.334	P(T<=t) one-tail 0.067	P(T<=t) one-tail 0.289	P(T<=t) one-tail 0.365	P(T<=t) one-tail 0.697
Table 2	P(T<=t) one-tail 0.000124	P(T<=t) one-tail 0.412	P(T<=t) one-tail 0.051	P(T<=t) one-tail 0.022532	P(T<=t) one-tail 0.0006913	P(T<=t) one-tail 0.329
***Yellow highlighting indicates a p-value < 0.05 **Orange highlighting indicates 0.05 < p-value <0.10**						

4.3.2 Paired t-test Females Only

This table shows the results of the paired t-test when only the female portion of the participant population was examined. Once again, participant heart rates were significantly lower in the blue chair when compared to the black chair. In this case, this was true in six of the eight protocol segments rather than in all eight. Respiratory rate and tidal volume both showed no significant differences between the chairs in any of the eight protocol segments. This indicates that there was no statistically significant difference between the chairs for the ventilatory efficiency of the females in this study.

Table 4.6: Summary Table of Paired t-test Results for Female Subjects (n=16)

Significant Differences Between Chairs Females (N=16)						
Task	**HR**	**RER**	**RR**	**CO2 Output**	**O2 Intake**	**TV**
Typing 1	P(T<=t) one-tail 0.02059	P(T<=t) one-tail 0.236	P(T<=t) one-tail 0.233	P(T<=t) one-tail 0.311	P(T<=t) one-tail 0.328	P(T<=t) one-tail 0.303
Internet 1	P(T<=t) one-tail 0.01154	P(T<=t) one-tail 0.247	P(T<=t) one-tail 0.106	P(T<=t) one-tail 0.304	P(T<=t) one-tail 0.401	P(T<=t) one-tail 0.055
Table 1	P(T<=t) one-tail 0.01373	P(T<=t) one-tail 0.464	P(T<=t) one-tail 0.476	P(T<=t) one-tail 0.282	P(T<=t) one-tail 0.410	P(T<=t) one-tail 0.426
Movie 1	P(T<=t) one-tail 0.065	P(T<=t) one-tail 0.451	P(T<=t) one-tail 0.152	P(T<=t) one-tail 0.482	P(T<=t) one-tail 0.372	P(T<=t) one-tail 0.133
Movie 2	P(T<=t) one-tail 0.0305	P(T<=t) one-tail 0.487	P(T<=t) one-tail 0.196	P(T<=t) one-tail 0.376	P(T<=t) one-tail 0.457	P(T<=t) one-tail 0.114
Typing 2	P(T<=t) one-tail 0.10	P(T<=t) one-tail 0.451	P(T<=t) one-tail 0.373	P(T<=t) one-tail 0.480	P(T<=t) one-tail 0.146	P(T<=t) one-tail 0.389
Internet 2	P(T<=t) one-tail 0.03414	P(T<=t) one-tail 0.473	P(T<=t) one-tail 0.374	P(T<=t) one-tail 0.337	P(T<=t) one-tail 0.452	P(T<=t) one-tail 0.405
Table 2	P(T<=t) one-tail 0.011957	P(T<=t) one-tail 0.420	P(T<=t) one-tail 0.460	P(T<=t) one-tail 0.460	P(T<=t) one-tail 0.130	P(T<=t) one-tail 0.126
***Yellow highlighting indicates a p-value < 0.05** ****Orange highlighting indicates 0.05 < p-value <0.10**						

4.3.3 Paired t-test Males Only

These results show how the chairs influenced the metabolic reactions of the male portion of the participant population. Much like the results of the entire population, the male segment showed significantly lower ($p<0.05$) heart rates in the blue chair when compared to the black chair. The difference between the chairs was statistically significant in all eight of the protocol segments for the men. When respiratory rate was tested, the results showed a statistically significant difference in three of the eight segments. The male population also had an additional three protocol segments that showed a p-value between 0.05 and 0.10. This same type of trend was present in the tidal volume results. The men showed significant differences in only one protocol segment but had an additional three segments with p-values between 0.05 and 0.10.

Table 4.7: Summary Table of Paired t-test Results for Male Subjects (n=15)

Significant Differences Between Chairs Males (N=15)						
Task	**HR**	**RER**	**RR**	**CO2 Output**	**O2 Intake**	**TV**
Typing 1	P(T<=t) one-tail 0.008396	P(T<=t) one-tail 0.379	P(T<=t) one-tail 0.013636	P(T<=t) one-tail 0.463	P(T<=t) one-tail 0.164	P(T<=t) one-tail 0.01630
Internet 1	P(T<=t) one-tail 0.0098275	P(T<=t) one-tail 0.360	P(T<=t) one-tail 0.059	P(T<=t) one-tail 0.305	P(T<=t) one-tail 0.220	P(T<=t) one-tail 0.125
Table 1	P(T<=t) one-tail 0.0064127	P(T<=t) one-tail 0.290	P(T<=t) one-tail 0.051	P(T<=t) one-tail 0.169	P(T<=t) one-tail 0.02666	P(T<=t) one-tail 0.248
Movie 1	P(T<=t) one-tail 0.013307	P(T<=t) one-tail 0.175	P(T<=t) one-tail 0.311	P(T<=t) one-tail 0.306	P(T<=t) one-tail 0.363	P(T<=t) one-tail 0.064
Movie 2	P(T<=t) one-tail 0.0411392	P(T<=t) one-tail 0.161	P(T<=t) one-tail 0.283	P(T<=t) one-tail 0.212	P(T<=t) one-tail 0.20	P(T<=t) one-tail 0.129
Typing 2	P(T<=t) one-tail 0.011488	P(T<=t) one-tail 0.457	P(T<=t) one-tail 0.038566	P(T<=t) one-tail 0.423	P(T<=t) one-tail 0.444	P(T<=t) one-tail 0.10
Internet 2	P(T<=t) one-tail 0.009180	P(T<=t) one-tail 0.215	P(T<=t) one-tail 0.056	P(T<=t) one-tail 0.364	P(T<=t) one-tail 0.257	P(T<=t) one-tail 0.820
Table 2	P(T<=t) one-tail 0.001844	P(T<=t) one-tail 0.198	P(T<=t) one-tail 0.024567	P(T<=t) one-tail 0.052	P(T<=t) one-tail 0.01248	P(T<=t) one-tail 0.082

***Yellow highlighting indicates a p-value < 0.05**
****Orange highlighting indicates 0.05 < p-value <0.10**

4.4 Regression Analysis

4.4.1 Regression Analysis All Subjects

The goal of the regression analysis was two-fold. The first objective was to determine if any of the anthropometric measures were good predictors of heart rate, tidal volume, or respiratory rate. The second objective was to determine if the size (weight and BMI) of the participants had an effect on the metabolic responses recorded during testing. Ultimately, it was determined that none of the anthropometric measures were good predictors of the three main dependent variables.

Overall, the regression analysis did not provide any indication that any of the anthropometric measures had an effect on any of the dependent variables. The R^2 values for most lines of best fit were well below 0.2 indicating no correlation. However, tidal volume showed some correlation with weight [see Figure 30.24, Figure 30.36, and Figure 30.48]. This indicates a possible size correlation ($R^2 \approx 0.4$) with tidal volume as well. The regression charts for heart rate, respiratory rate, and tidal volume can be found in Appendix U.

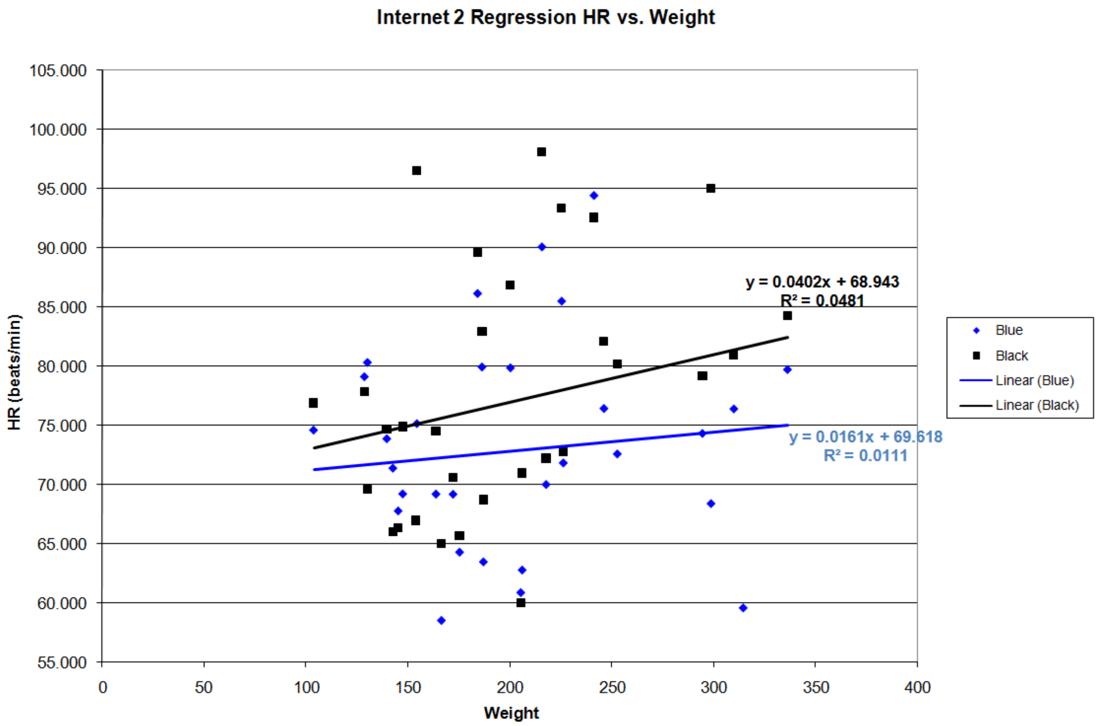


Figure 4.4: Regression analysis Heart Rate vs. Weight

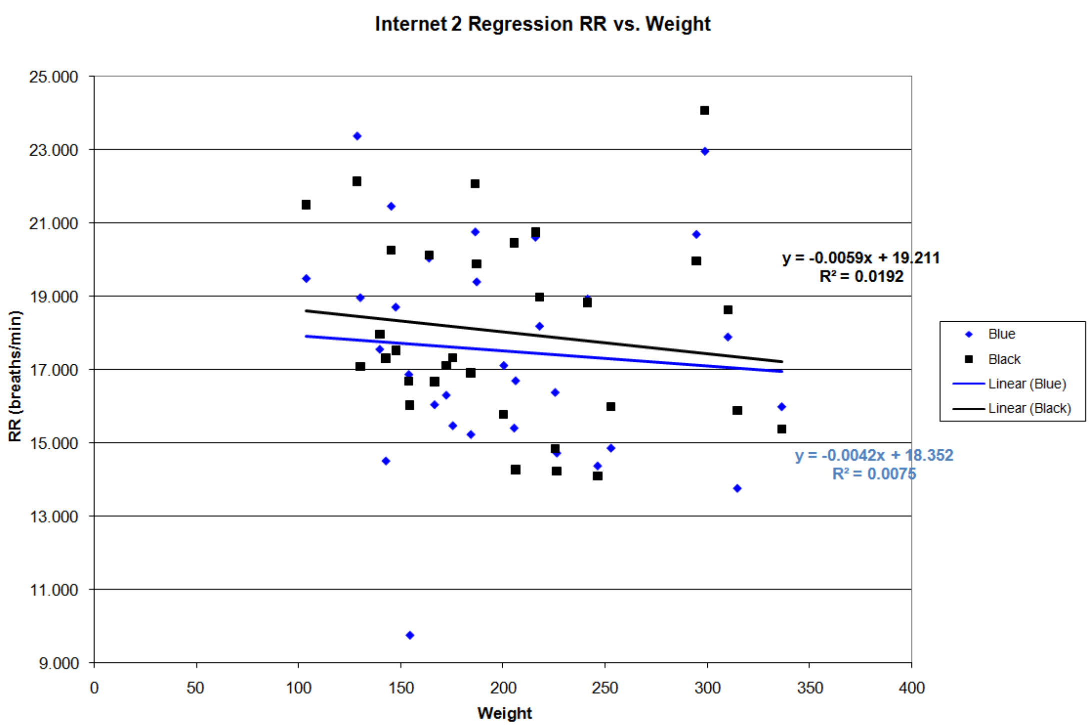


Figure 4.5: Regression analysis Respiratory Rate vs. Weight.

4.5 Subjective Data

All participants were asked to complete a subjective assessment of each chair. The assessment form was completed at the conclusion of the testing period on each of the two testing days. The data collected paint a picture of what the participants thought of each chair and allows for testing to determine if one chair was preferred over the other. The following tables contain the summary statistics from this subjective survey. The raw subjective data for the blue chair can be found in Appendix S, and the raw subjective data for the black chair can be found in Appendix T.

Table 4.8: Summary Statistics of Subjective Data for Blue Chair

	Blue Chair						
	Subjective Assessment						
Statistic	Ease of Use	Comfort	Overall Evaluation	Back of Seat Comfort	Chair tilts too far	Chair tilts too Little	Front of Seat Uncomfortable
Mean	6.61	7.71	7.53	4.23	1.81	1.97	4.26
Median	7.00	8.00	8.00	4.00	2.00	2.00	4.00
Std. Dev	2.28	1.77	1.76	0.84	0.87	1.11	0.82
Minimum	3.00	4.00	3.00	2.00	1.00	1.00	2.00
Maximum	10.00	10.00	10.00	5.00	4.00	5.00	5.00

Table 4.9: Summary Statistics of Subjective Data for Black Chair

Black Chair							
Subjective Assessment							
Statistic	Ease of Use	Comfort	Overall Evaluation	Back of Seat Comfort	Chair tilts too far	Chair Tilts too Little	Front of Seat Uncomfortable
Mean	7.16	6.97	7.00	3.79	1.94	1.84	3.61
Median	8.00	7.00	7.00	4.00	2.00	2.00	4.00
Std. Dev	1.88	1.80	1.84	0.79	1.09	0.93	0.88
Minimum	3.00	4.00	2.00	2.00	1.00	1.00	2.00
Maximum	10.00	10.00	10.00	5.00	5.00	4.00	5.00

Since the data are subjective, it is imperative to use a non-parametric test to determine if a significant difference exists between the two chairs in question. The Friedman's statistic was used to determine if one of the chairs was preferred over the other. This statistic is derived by ranking each of the chairs within each subject (Glantz, 1992). Since there are only two treatments in this experiment, black and blue chair, there are only two possible ranks, one or two. The lower value is assigned a rank of one, the higher value is assigned a rank of two, and if it is a tie, a rank of one and a half is assigned to both treatments. Next, the sum of the ranks is taken for each treatment, and the data are used to compute the Friedman's statistic (χ_r^2) (Glantz, 1992). The process of arriving at the χ_r^2 value begins with finding the S value using the following equation (Glantz, 1992):

$$k = \#\ treatments \quad n = \#\ subjects \quad R_t = sum\ of\ ranks\ for\ treatment$$

$$S = \sum \left[R_t - \left(\frac{n(k+1)}{2} \right) \right]^2 \qquad \text{eq (1)}$$

Then, this result is inserted into the following equation to obtain the Friedman's value (Glantz, 1992):

$$\chi_r^2 = \frac{12 * S}{n * k(k+1)} \qquad \text{eq (2)}$$

The result is compared to the chi squared distribution to determine whether a significant difference exists between the chairs. The following tables show the test data for the entire test population, just the male portion, and just the female portion.

Table 4.10: Friedman Test Results for Entire Population (n=31)

	Friedman Test Results for Entire Population (n=31)						
	Ease of Use	Comfort	Overall Evaluation	Back of Seat Comfort	Chair tilts too far	Chair Tilts too Little	Front of Seat Uncomfortable
χ_r^2 value	0.806	2.065	0.516	2.065	0.290	0.032	3.903
test p-value	0.05	0.05	0.05	0.05	0.05	0.05	0.05
χ^2 value	3.84	3.84	3.84	3.84	3.84	3.84	3.84
Significant Δ?	NO	NO	NO	NO	NO	NO	YES

Table 4.11: Friedman Test Results for Female Population (n=16)

	Friedman Test Results for Female Population (n=16)						
	Ease of Use	Comfort	Overall Evaluation	Back of Seat Comfort	Chair tilts too far	Chair Tilts too Little	Front of Seat Uncomfortable
χ_r^2	1.563	0.063	0.063	1.563	0.000	1.000	2.250
test p-value	0.05	0.05	0.05	0.05	0.05	0.05	0.05
χ^2 value	3.84	3.84	3.84	3.84	3.84	3.84	3.84
Significant Δ?	NO	NO	NO	NO	NO	NO	NO

Table 4.12: Friedman Test Results for Female Population (n=15)

	Friedman Test Results for Male Population (n=15)						
	Ease of Use	Comfort	Overall Evaluation	Back of Seat Comfort	Chair tilts too far	Chair Tilts too Little	Front of Seat Uncomfortable
χ_r^2	0.000	3.267	1.667	0.600	0.600	1.667	1.667
test p-value	0.05	0.05	0.05	0.05	0.05	0.05	0.05
χ^2 value	3.84	3.84	3.84	3.84	3.84	3.84	3.84
Significant Δ?	NO	NO	NO	NO	NO	NO	NO

This analysis shows rather clearly that there is no significant difference in the participants' reaction to sitting in one chair versus the other.

4.6 Analysis of Data Relative to Anthropometric Measures

In each of the following graphs, the dependent variables have been normalized by weight. This was an effort to determine whether or not the participants' weight had an effect on their metabolic response. If this were the case, it could have an impact on the validity of the conclusions derived from the data. This form of analysis will also help to determine how many of the participants were affected by the chair. These graphs will show how many participants experienced a difference (in a particular metabolic variable) in the blue chair whether it was statistically significant or not.

4.6.1 Analysis of Heart Rate Data Relative to Weight

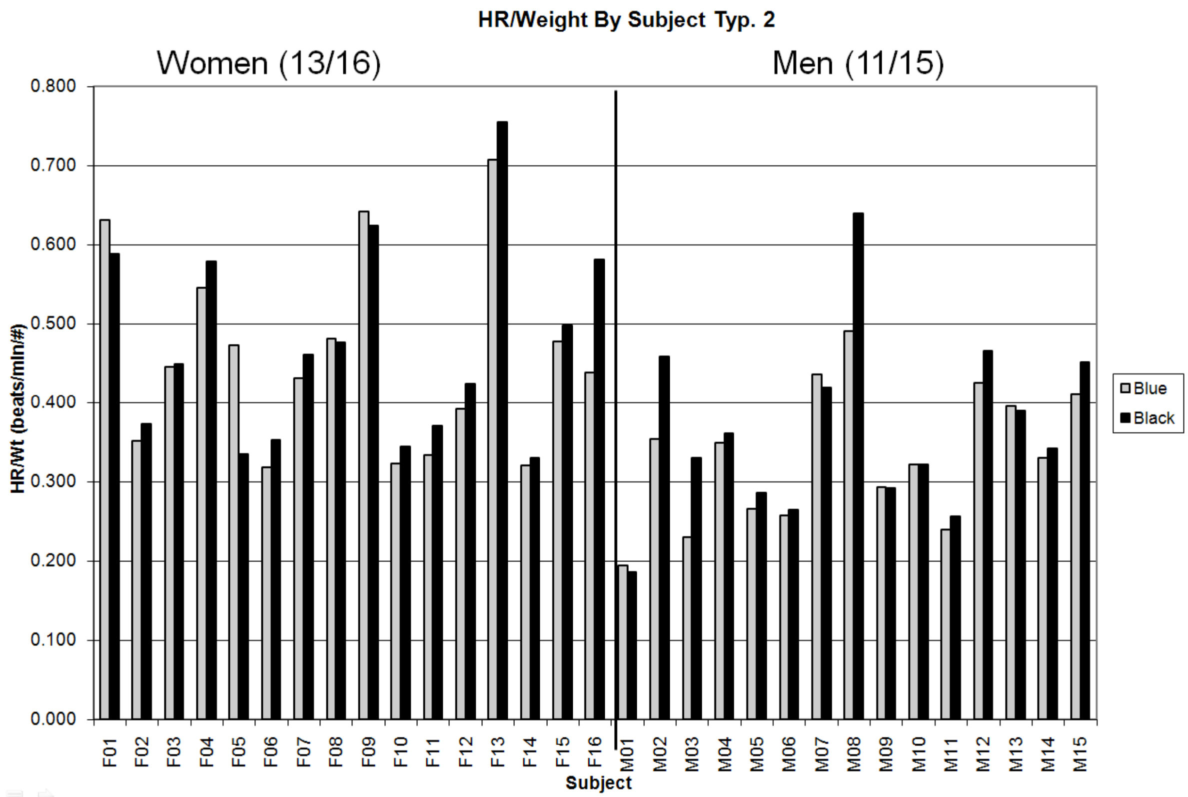


Figure 4.6: Normalized Heart Rate by Participant

This bar chart shows the normalized heart rate data for each participant in each chair for the typing 2 segment of the testing protocol. This data indicates that thirteen of the sixteen female participants and eleven of fifteen male participants showed a decrease in heart rate in the blue chair when compared to the black chair. These differences are not necessarily statistically significant; they are simply measurable differences.

4.6.2 Analysis of Respiratory Rate Data Relative to Weight

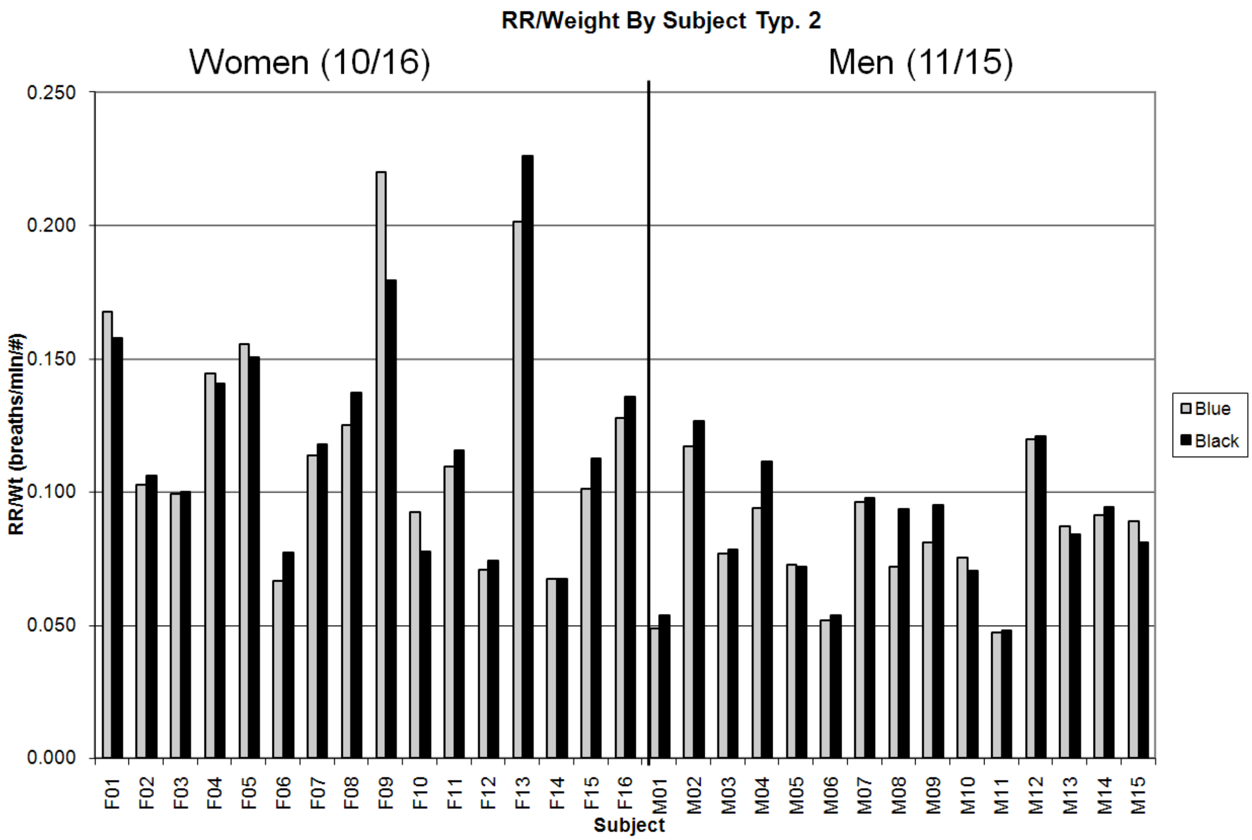


Figure 4.7: Normalized Respiratory Rate by Participant

This bar chart shows the normalized respiratory rate data for each participant in each chair for the typing 2 segment of the testing protocol. This data indicates that ten of the sixteen female participants and eleven of fifteen male participants showed a decrease in respiratory rate in the blue chair when compared to the black chair. These differences are not necessarily statistically significant; they are simply measurable differences. This indicates that even though the t-test did not detect a significant difference between the chairs, the participants did tend to have a lower respiratory rate in the blue chair than the black chair.

4.6.3 Analysis of Tidal Volume Relative to Weight

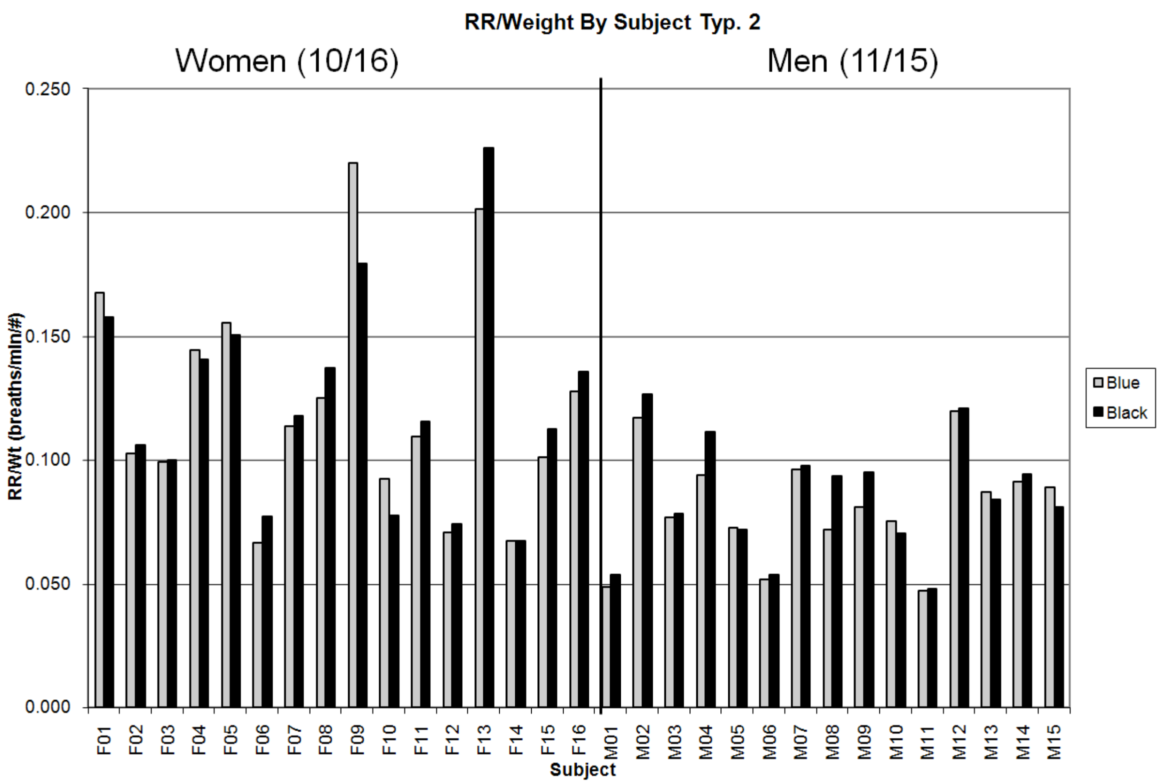


Figure 4.8: Normalized Tidal Volume by Participant

This bar chart shows the normalized tidal volume data for each participant in each chair for the typing 2 segment of the testing protocol. This data indicates that seven of the sixteen female participants and seven of fifteen male participants showed a decrease in tidal volume in the blue chair when compared to the black chair. These differences are not necessarily statistically significant; they are simply measurable differences. These results are less definitive than those for respiratory rate, but they still show that the test chair could potentially help a user increase their tidal volume.

5 Discussion

The majority of the published studies that involve metabolic data collection focuses on tasks or activities that are considered to be vigorous. Therefore, there is no comparison to the results of this study. This does not make these results trivial, however, since the lives of many Americans have become more and more sedentary. Many Americans currently have jobs that require a lot of seated computer work, and this type of work is considered to be sedentary, or having a low energy cost. While it is important to understand how the human body reacts to strenuous activities, it is becoming more important to understand how the body reacts to the sedentary work people are spending more time doing. In 2003, 63.7% of people reported using a computer at work, school, or home (U.S. Census Bureau, 2003).

This investigation sought to explore the human body's metabolic reaction to sedentary office tasks such as typing and searching the internet. This required collecting data pertaining to heart and lung function and observing how the data changed from task to task. It is important to first understand the bodily system from which these data are collected before analyzing the results. Data were collected from two major systems: the cardiovascular system and the respiratory system. The cardiovascular system is made up of the heart, blood vessels, and blood found in the human body (Robergs & Roberts, 1997). This system is responsible for transporting oxygen and nutrients throughout the body and aiding in energy creation (Robergs & Roberts, 1997).

The cardiovascular system's efficiency can be described by the following equation:

$$CO(L/\min) = HR(beats/\min) * SV(L/beat) \qquad \text{(eq. 3)}$$

In equation 3, the variables are defined as follows: CO = cardiac output (l/min), HR = heart rate (beats/min) and SV = stroke volume (l/beat). The efficient system will do less work to achieve the same result. In the case of the heart, the efficient system pumps more blood fewer times. This would include having a low heart rate and pumping more blood per beat.

The ventilatory system is what allows humans to breathe. This is called ventilation (the bulk flow of air into and out of the lungs), and this consists of two activities: inspiration which is an active process and expiration which is a passive process (Robergs & Roberts, 1997). This system's efficiency can be measured using an equation similar to the one governing the cardiovascular system:

$$\dot{V}e(L/\min) = TV(L/breath) * RR(breaths/\min) \qquad \text{(eq. 4)}$$

The variables in the equation above represent the following values: V_E = minute ventilation (L/min), RR = respiratory rate (breaths/min) and V_T = tidal volume (L/breath). The lungs are most efficient when the most air is being moved in the fewest breaths. Both of these systems are essential to maintaining life, and therefore, it is crucial to know how they react to all activities that people engage in, including sedentary ones.

The objective of this study was to determine whether or not a new chair with an upwardly tapered backrest design had an impact on the tidal volume and respiratory rate of the user. It was found that this was not the case. However, if more participants were added to the study, the results may have been different. As can be seen in Table 4.5, the paired t-tests indicated that the new chair lowered the respiratory rate significantly in one of the eight tasks. However, in three other tasks, the new chair had p-values between 0.05 and 0.1, which were close to the a priori cutoff value of 0.05. This indicates that there could be a trend towards the chair having a significant impact on this metabolic variable, particularly if the sample size were greater. The same cannot be said for tidal volume. It appears that the new backrest design has no significant impact on the user's tidal volume.

An interesting trend regarding respiratory rate developed when the male and female genders were examined separately. It appeared that the new backrest design had a more significant impact on the ventilatory function of the male participants than the female participants. As can be seen in Table 4.6 and Table 4.7, the new chair significantly lowered the males' respiratory rates in 3 of 8 tasks while failing to lower the respiratory rate of females in any of the tasks. An additional 3 tasks showed a p-value between 0.05 and 0.1 for the men, while none of the tasks fell into this category for the females. This would seem to indicate that the chair had some impact on the respiratory rate of the males, while it clearly did not affect that of the female participants. This same type of trend was noted in tidal volume. The male population had a p-value less than 0.1 in 4 of the 8 tasks, while the females reported a p-value in this range for only one of 8 tasks. Again, this seems to indicate that the new chair was having a larger impact on the male participants than the female participants.

These t-test results [see Table 4.6 and Table 4.7] indicated a possible gender effect on respiratory rate and tidal volume. It is possible that the test chair's lack of effect on tidal volume and respiratory rate is not so much a gender effect, as it is a size effect. During testing it was noted that the majority of the men had broad shoulders, while most women had narrower shoulders. It appeared that while the backrest was narrower at the top, it still restricted the shoulder movement of most women and some smaller men. The hypotheses of this experiment were dependent on the belief that this new backrest design would allow for free shoulder movement of all users, which may not have been the case. This could explain why the hypotheses were not validated.

The ANOVA results helped to paint a clearer picture of the results. Mixed design ANOVA analysis was performed in two ways: one included the variables gender and chair plus the interaction of the two, and the other included the variables age and chair plus the interaction between the two. The test that included the variable gender showed that the chair had a significant impact on the heart rate of the user across all 8 test tasks [see Table 4.3]. This test also showed that gender had a significant impact on the tidal volume data collected [Table 4.3]. The ANOVA results showed that men had a significantly higher tidal volume than women. This result is not unexpected and could be attributed to the fact that women have smaller lungs than men, and therefore cannot take in as large a volume of air (Robergs & Roberts, 1997).

The second test, including age as a variable, also showed that chair had a significant impact on the heart rate of users across all 8 test tasks. This test also showed that age had an impact on the respiratory rate data collected [see Table 4.4]. The ANOVA results showed that older people had higher respiratory rates than younger people. This result is again easily explained by natural physiology. It is common for older people to have higher respiratory rates, because lung capacity and function decreases with age (Robergs & Robert, 1997).

While regression analysis did not determine a connection between the anthropometric measures and the dependent variables, the plots did provide indications of a possible trend. The results of this analysis showed a possible size impact on heart rate. As can be seen in Figure 4.4, the lines of best fit diverge as the weight of the individuals increases. This opens up the interesting possibility that the difference between the chairs in terms of heart rate grows as the size of the participant does. The R^2 values of the lines of best fit are very low, so no conclusions can be drawn about the existence of this trend without further research.

This type of trend was not reflected in the respiratory variables. Respiratory rate consistently showed that the size of the participant did not have a determinable impact on the metabolic response to testing (see Figure 4.5).

In addition to the regression analysis, scatter plots were created [see Figure 5.1 and Figure 5.2]. These scatter plots include all participants' raw heart rate data for the typing 1 and table 2 tasks. Of the 31 participants, 15 were male and 16 were female. The plots were created to determine if the test chair had an increased impact on heavier people. The graphs show that in the first task during data collection (typing 1) the test chair seems to have the same effect, in terms of magnitude, regardless of weight [see Figure 5.1]. By the time the participant reached the last task (table 2), the test chair was having little or no impact on the heart rates of the lighter people but was impacting the heart rates of the larger people [see Figure 5.2]. This graph does not show that the test chair has a larger effect on larger people. However, it does show that the test chair impacts people of varying sizes differently. This is a more sound indication that the size of the participants may impact how much effect the test chair has on heart rate. Further testing would need to be done to determine the validity of this assertion.

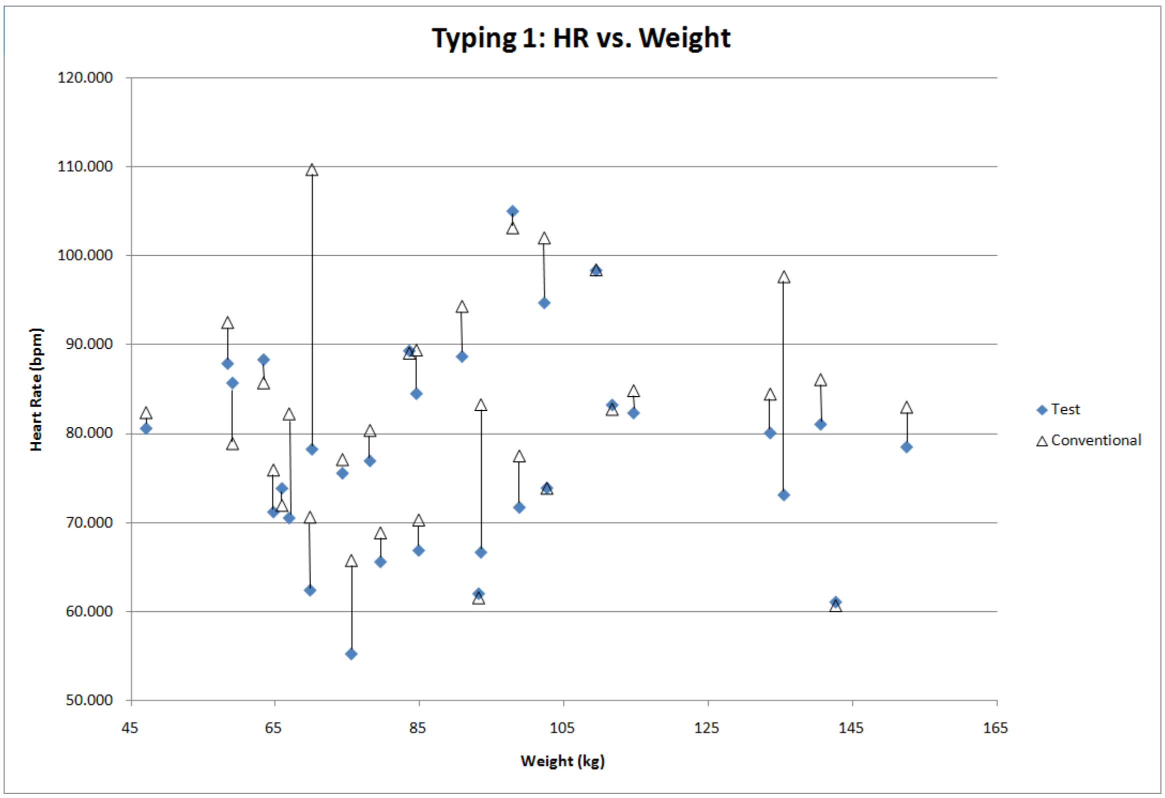


Figure 5.1: Heart Rate vs. Weight Typing 1 (No Evident Size Effect)

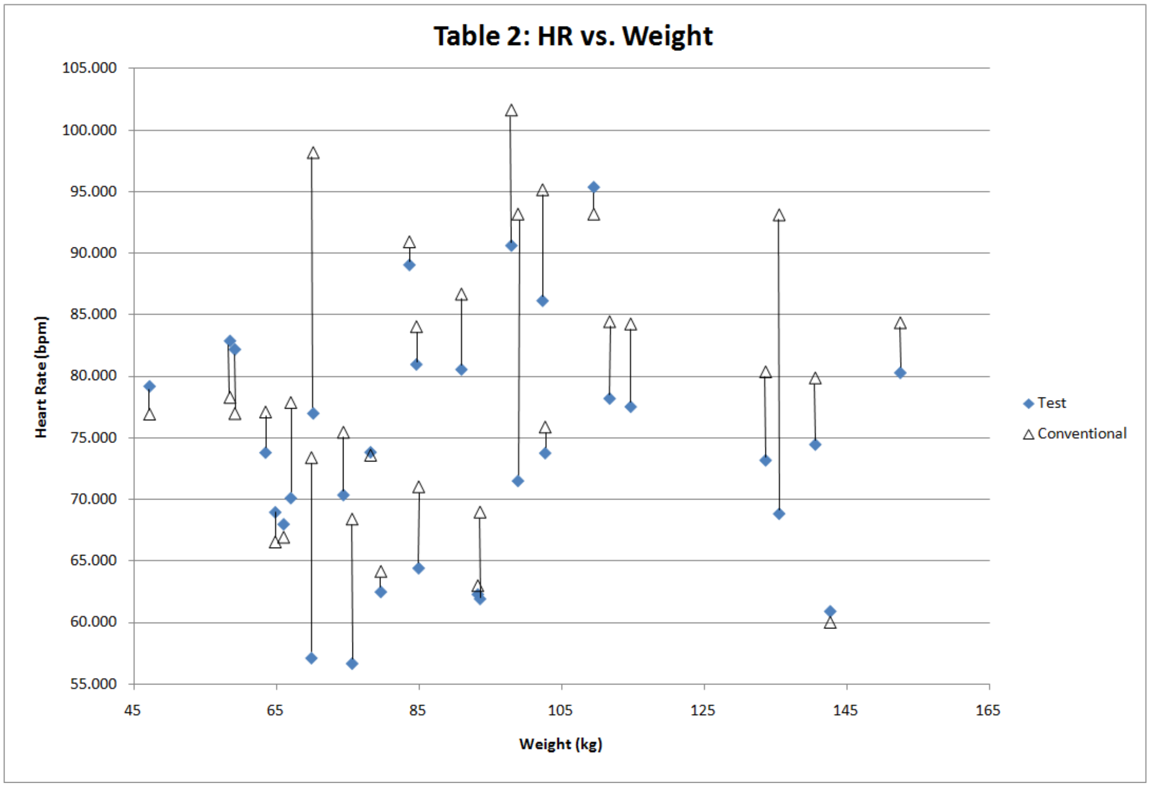


Figure 5.2: Heart Rate vs. Weight Table 2 (Size Effect Evident)

A third significant result was uncovered while performing analyses on the collected data. While there was no original hypothesis concerning heart rate, the chair with the new backrest design had a significant impact on the heart rate of its users. As seen in Table 4.5, Table 4.6, and Table 4.7, the new chair significantly lowered the heart rate of users in all 8 tasks (statistical power of 72%). This was true for men and women, analyzed separately and as a one group. The quantifiable decrease averaged 3-5 beats per minute less in females and 5-7 beats per minute less in males. This is a significant reduction in the amount of work the body's cardiovascular system exerts when this is extrapolated over time. It amounts to a decrease of 1440-2400 beats per 8-hour work day for women and 2400-3360 beats per day for men. If it is taken one step further, this would decrease the number of heart beats over the course of a 365 day year by 525,600-876,000 beats for women and 876,000-1,226,400 beats for men.

The reduction in heart rate while using the new chair has a particularly strong value to users because high resting heart rate is a risk factor for cardiovascular disease (Ferrari et al., 2005). Based on a study of 25,000 patients, resting heart rate was shown to be an independent risk predictor of cardiovascular mortalities (Diaz et al, 2005). A study conducted by Cook et al. in 2006 found that the likelihood of death from cardiovascular and coronary disease increased as resting heart rate increased for otherwise healthy individuals in the general population based on a 36-year follow-up to the Framingham Study (Figure 5.3). A similar study conducted by Savonen et al. in 2006 found that a 40-100% increase in maximal workload during an exercise test was associated with an increase in the probability of dying from cardiovascular disease, coronary heart disease, and all-cause mortality (all-cause mortality includes any manner in which a person dies). This study consisted of middle-aged male participants who were free of cardiovascular disease. Two other studies found similar results. A 2000 study conducted by Kristal-Boneh et al. found that resting heart rate is associated with mortality caused by cardiovascular disease and all-cause mortality. This study also controlled for other known risk factors and determined that heart rate on its own is a risk factor. The same can be said for a 1997 study conducted by Mensink and Hoffmeister. This study also found that resting heart rate is an independent risk factor for mortality.

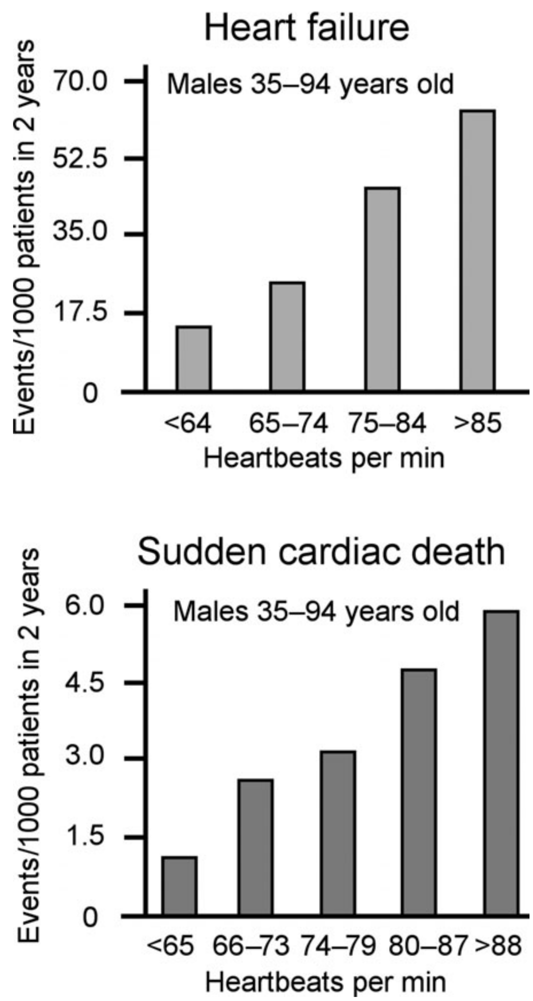


Figure 5.3: Graphs showing the connection between resting heart rate and mortality (Cook et al., 2006)

It is a possibility that this connection is caused by the health of the people being studied (Mensink & Hoffmeister, 1997). Heart rate is an indicator of physical fitness and physical activity level, and those who are not physically fit or active are more likely to have a high resting heart rate. However, if one other risk factor for cardiovascular disease is present in an individual, the risk for mortality remains (Mensink & Hoffmeister, 1997). This was the result after the 1997 study by Mensink & Hoffmeister corrected for physical fitness levels.

All of these studies indicate that high resting heart rate can lead to increased risk of cardiovascular disease, coronary heart disease, and all-cause mortality. These results are even more important, because heart disease is the number one killer of people in the United States (Heron, 2007). Anything that people can do to lower their risk of contracting any form of heart disease increases their chances of living a longer life. The chair with the new backrest design significantly lowers the user's heart rate, and it could potentially reduce the user's risk of contracting these diseases.

It is important to note that these results may not be attributed solely to the new backrest design. A chair is made up of much more than the backrest alone, and any of the other components, most notably the seat pan, could have had an impact on the results in this study. The new chair had a new backrest design, but it also had a new suspension system under the seat pan. Prior testing was done on this portion of the chair as well, and the results showed improved tissue profusion in the legs. This finding indicates that the seat pan design may help the cardiovascular system overcome the challenges of a long duration in a seated position. The seat pan may also reduce the amount of work that the heart has to do (fewer heart beats):

> Under the ischial tuberosities, the prototype chair, Embody, was best at maintaining the oxygen levels measured in the unimpeded standing posture. Subjects' average tissue oxygen perfusion levels at these locations were significantly higher while seated in the Embody chair than while seated in the Foam B and Suspension B chairs. Given the high pressures the buttock tissues are normally subjected to in the seated posture, these results suggest that Embody

> presents a healthier alternative. Furthermore, the Embody chair results most closely reflect those of the standing posture, where tissue oxygen perfusion levels are nearly identical across all three measurement locations: ischial tuberosities, proximal thigh, and middle thigh. This underlines the ability of the bi-compliant design of the Embody seat to spread the load across the seat, rather than concentrate it. (Makhsous et al., 2008 from Herman Miller)

The specific contributions to the reduction in heart rate from either the new backrest design or the new suspension system under the seat pan is not known. However, it is likely that both factors contributed to the substantial decrease in heart rate experienced the users in this study.

6 Conclusions

The hypotheses about the new upwardly tapered back rest's impact on user's metabolic reactions to sedentary work were found to be false. The new back rest design did not have a significant impact on the user's respiratory rate or their tidal volume. However, an unexpected result was discovered. The analysis showed that the chair with the new backrest design caused a significant decrease in user heart rate. This difference amounts to 3-5 beats per minute in women and 5-7 beats per minute in men. It is possible that this difference in heart rate could have a positive effect on user health when extrapolated over a long period of time.

7 Limitations

A number of limitations exist in this study. First, the position of the participants in the chair was not standardized or closely monitored during testing. The hypotheses of this study were derived largely from the erect seated position that the test chair's backrest would allow the user to obtain (scapulae retracted, chest cavity space increased). Since the participants did not know what the ideal sitting position was (scapulae retracted) and no measure for how well the population maintained the desired position throughout testing existed, it is possible that the participants were not trying to achieve or maintain this position.

Another possible effect is the amount of work the participant exerts. In this study, the oxygen consumption values showed no significant difference between the chairs, indicating the same amount of work was done in each chair. However, if a difference had appeared, it could be attributed to an increase of muscle activity due to differing postures. A 2005 study conducted by Kera and Maruyama examined the effect of posture on lung function and the activity of the surrounding musculature. The following results are derived from data collected during normal breathing. The study determined that sitting with elbows on knees (a slumped posture) results in increased activity in the external oblique abdominis during inspiration and expiration. The study also observed a decrease in activity in the internal oblique abdominis during expiration in the same position. The differences were reported in mV and can be found in [Table 7.1 & Table 7.2]. Since these differences are not equal in magnitude, this could indicate that one position requires more muscular work, which will have an impact on the data being collected.

Table 7.1: Expiration Data Including Differences Between the Postures

EMG Data (mV)			
Position	**External Oblique Abdominis**	**Rectus Abdominis**	**Internal Oblique Abdominis**
Seated (elbows on knees) (SEK)	0.23	0.26	0.19
Supine	0.14	0.24	0.47
Sitting	0.15	0.26	0.52
Standing	0.14	0.26	0.69
Differences Between Postures			
SEK - Supine	0.09	0.02	-0.28
SEK -Sitting	0.08	0	-0.33
SEK - Standing	0.09	0	-0.5

Table 7.2: Inspiration Data Including Differences Between the Postures

EMG Data (mV)			
Position	**External Oblique Abdominis**	**Rectus Abdominis**	**Internal Oblique Abdominis**
Seated (elbows on knees) (SEK)	0.22	0.24	0.16
Supine	0.12	0.2	0.16
Sitting	0.13	0.23	0.24
Standing	0.12	0.22	0.41
Differences Between Postures			
SEK - Supine	0.1	0.04	0
SEK -Sitting	0.09	0.01	-0.08
SEK - Standing	0.1	0.02	-0.25

The difference may be slight but causes a need for more strict regulation of posture in future studies.

Finally, the seat pan and the backrest of the chair were not tested independently of one another. This makes it impossible to attribute the dramatic drop in heart rate to one part of the chair, and it makes the only possible conclusion that the chair as a whole has a lowering effect on the heart rate of users.

8 Future Work

A vast amount of work still needs to be done concerning the body's metabolic response to sedentary activity. As the people of this country and the world seem to be becoming more and more sedentary at work and at home, this work will take on a new found importance as well.

Future versions of this study could test how variance in size affects the body's metabolic reaction to sedentary work. This study should include a number of different sizes of people, and the groups should be determined by their BMI or weight.

The same type of experiments could be conducted with different independent variables found in the workplace as well. A study might try to determine if things like desk height, the availability of armrests, and the type of keyboard (conventional versus ergonomic design) have an effect on the body's metabolic response to sedentary work.

9 References

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10 Appendix A: Expanded Literature Review of Metabolic Function for High Energy Load Task

Competitive swimming, running, and cycling place high demand on the cardiovascular and ventilatory systems of participants. In a study conducted by Rodriguez in 2000, the cardiorespiratory responses of trained swimmers were measured during three activities: swimming, treadmill running, and ergometer cycling. The study was conducted in two separate series. In series A, comparisons among three cardiorespiratory variables were made after a 400 meter swim, during incremental treadmill running, and while ergometer cycling. In series B, comparisons were made after a 400 meter swim and during ergometer cycling (Rodriguez, 2000). The study included 15 participants in series A (10 male and 5 female) and 33 participants in series B (22 male and 11 female). The participants in series A and B included competitive Spanish swimmers who competed at a national level. The study determined that significant differences between the activities in many of the variables measured in series A were apparent. The most compelling data was found in the analysis of heart rate, peak tidal volume, peak respiratory exchange ratio, and peak respiratory rate. These variables showed a significant difference in two of the three activity comparisons (Rodriguez, 2000). The following tables include the results obtained from series A and series B:

Table 10.1: Metabolic Data from Rodriguez, 2000 Series A

Parameter	Free Swimming SW	Treadmill Running TR	Ergometer Cycling EC	Difference (p-value)		
				SW-TR	SW-EC	TR-EC
$\dot{V}$ O_2 peak (L/min)	3.94±0.63	3.77±0.74	3.77±0.70	ns	ns	ns
$\dot{V}$ O2 peak/BM (mL/kg/min)	60.3±6.2	57.3±4.8	57.3±4.7	ns	ns	ns
$\dot{V}$ E peak (L/min, BTPS)	139.1±22.7	137.4±30.0	130.6±28.0	ns	ns	0.019
VT Peak (L, BTPS)	2.94±0.65	2.54±0.57	2.56±0.52	<0.001	0.003	ns
R peak	1.18±0.08	1.23±0.08	1.15±0.03	0.038	ns	0.009
fR peak (breaths/min)	47.5±5.3	53.1±5.7	51.1±4.8	0.004	0.039	ns
fH peak (beats/min)	183.1±7.5	196.1±7.5	189.0±6.6	<0.001	0.003	<0.001

Table 10.2: Metabolic Data from Rodriguez, 2000 Series B

Parameter	Free Swimming SW	Ergometer Cycling EC	Difference (p-value)
			SW-EC
$\dot{V}$ O_2 peak (L/min)	3.83±0.78	3.74±0.77	ns
$\dot{V}$ O2 peak/BM (mL/kg/min)	57.1±7.8	56.0±7.0	ns
fH peak (beats/min)	182.0±8.4	188.9±7.2	<0.001

The study determined that the body responds to different activities in different ways. For instance, the response to the 400 meter swim exhibited lower peak heart rates, higher tidal volumes, and lower respiratory rates than the other activities at comparable pulmonary ventilation levels (Rodriguez, 2000). It also shows that significant differences can be found between activities that would appear to have similar metabolic demands.

Many studies, including some listed above, have measured the metabolic demand that walking or running puts on the body. The following study aims to measure the same data while the subjects are walking in snow shoes. Two types of snow shoes (the rotating toe-cored system and the fixed toe-cord design) were tested in the 2003 study performed by Dalleck et al. The variables measured included heart rate, oxygen consumption, and energy cost. Eight men were selected to participate in the study. Their vital statistics can be found in Table 10.3. They were asked to avoid strenuous activity for 24 hours prior to the test to avoid any errors in the metabolic data collection. The testing consisted of two 1600 meter trials in each type of snowshoe.

Table 10.3: Vital Data of Eight Subjects (mean±S.D.) (Dalleck et al., 2003)

Weight (kg)	Height (cm)	Age (years)	Resting Heart rate (beats/min)	Maximal heart Rate (beats/min)	Maximal Oxygen Consumption (ml/kg/min)
76.3±8.6	181.5±7.8	24.9±2.4	52±6	190±10	60.8±9.1

The study discovered that the snowshoeing in the fixed toe-cord design produced significantly higher responses in terms of heart rate ($p=0.005$), oxygen consumption ($p=0.007$), and energy cost ($p=0.005$) (Dalleck et al., 2003). These results indicated that snowshoeing is a strenuous exercise and requires a great deal from the cardiovascular and respiratory systems. It is recommended that activities as strenuous as snowshoeing not be required for an entire eight hour work day (Dalleck et al., 2003).

Another popular form of exercise among athletes is “Junkyard Training.” This form of exercise requires participants to push or pull heavy objects, such as cars, to get their workout. This is an especially appealing training tool to athletes in sports that require great physical strength. A study performed by Berning et al. in 2007 measured the oxygen consumption, heart rate, and lactate build up in six participants to determine the metabolic demands of this form of athletic training. The six subjects had an average age of 29±5 years, average weight of 89±12kg, and average height of 178±7cm (Berning et al., 2007). Each subject had a background in power lifting, weight lifting, and body building movements. Each participant's schedule involved training four to five times a week. All of the subjects completed the following activities: pushing a motor vehicle 400 meters, pulling a motor vehicle 400 meters, and a maximal oxygen consumption test on a treadmill. The results of the study can be found in Table 10.4. The study determined that the maximal heart rate and oxygen uptake showed no significant difference between the two activities, but they did reach their peak values in the first 100 meters of the test (Berning et al., 2007).

Table 10.4: Metabolic Data of Junkyard Training (Berning et al., 2007)

		Variable		
		$\dot{V}\,O_2$ (ml/kg/min)	Heart Rate (beats/min)	Blood Lactate (mmol/L)
Treadmill Max Value		50.3±5.0	193.7±3.8	11.9±3.6
Distance (m)	Activity			
50	Push	22.2±8.4	175.2±14.9	
	Pull	24.8±2.4	178.7±6.0	
100	Push	31.3±6.1	184.8±5.1	
	Pull	35.1±4.4	183.0±4.6	
150	Push		186.0±5.0	
	Pull		183.2±3.4	
200	Push	32.2±5.3	186.8±4.2	
	Pull	36.7±4.4	184.5±3.8	
250	Push		185.5±6.9	
	Pull		185.5±6.3	
300	Push	29.1±5.3	186.2±7.6	
	Pull	34.2±4.4	185.7±5.3	
350	Push		185.5±6.5	
	Pull		185.8±5.6	
400	Push	30.5±5.5	183.0±5.8	15.0±2.0
	Pull	34.4±4.6	187.2±5.1	16.1±1.3

While a significant difference between the tasks does not exist, both placed a large metabolic load on the body. It was determined that the activities caused participants to reach 96% of their maximal heart rate and 65% of their maximal oxygen uptake (Berning et al., 2007). This indicates that both of these tasks are strenuous in nature and require a great deal of energy from the body.

Many careers force people to move constantly and carry large loads. Any warehouse or construction job would have this type of effect. It is necessary for people in these industries to take into account the energy requirements that they put on employees. An excessive amount of any task can lead to injury, and that is something all companies are looking to avoid. A study conducted in 2000 by Kumar et al. measured the metabolic reactions of 21 blue collar workers while palletizing (stacking) boxes. The subjects were required to lift a wooden box weighing 22kg to a shelf 125cm high. This lift occurred six times per minute for five minutes in each of the twelve experimental conditions. These conditions were made up of combinations of two planes of lifting, two shelf heights, and three headroom clearances. The participants were allowed 35 minutes of rest between trials. The study found that the mean heart rate across the twelve conditions ranged from 104.1 to 113.8 beats per minute, and the caloric cost of the activities ranged from 5.2 to 6.5 kcal/min (Kumar et al., 2000). It was determined that none of the independent variables had a significant impact on the heart rate of the workers. It was discovered that within each of the lifting planes, headroom did have a significant effect on heart rate ($p<0.02$). Headroom also had a two-way interaction with clearance to impact heart rate $p<0.03$ in the symmetric lifting plane and $p<0.01$ in the asymmetric lifting plane (Kumar et al., 2000). Analysis of variance also revealed that headroom was a main effect for energy expenditure ($p<0.02$). This indicates that the more headroom there was, the less energy workers had to expend (Kumar et al., 2000). The study also measured the amount of time it took for the metabolic variables to decline after the exertion. Investigators observed that the heart rate and caloric cost declined rapidly in the first minute after the exertion and continued slowing over a five minute period (Kumar et al., 2000). This shows that even after a short exertion it takes the body a lot of time to normalize its metabolic function. The effect of lifting something is felt long after the task is finished.

Physical activity is crucial to maintaining your health. Something as simple as playing games with children could qualify as a beneficial physical activity. In 2004, Fischer et al. conducted a study to determine if playing games with children can meet the recommended physical activity for a day. A total of forty volunteers (20 adults and 20 children) participated in the study. The children were between the ages of 5 and 12, and of the twenty adults, 9 were men and 11 were women. All of the participants were asked to participate in two games: soccer and tag. Data were collected for five minutes prior to the testing for comparison, and a portable metabolic measuring device was used to measure heart, rate, oxygen uptake, METs, and energy expenditure during the activities (Fischer et al., 2001). The results indicated that the average heart rate during the soccer activity was 162.34±14.74 beats/min, which corresponds to 88.5±1.26% of their age related maximum. The average oxygen uptake was 1.16±0.44 L/min, the average MET level was 6.02±1.52 METs, and the average energy expenditure was 8.32±2.21 kcal/min (Fischer et al., 2001). In the tag activity, the average heart rate was 158.67±13.23 beats/min (86.57±1.23% age related maximum), the average oxygen uptake was 1.59±0.39 L/min, the average MET level was 5.73±1.29 METs, and the average energy expenditure was 7.97±1.93 kcal/min (Fischer et al., 2001). Analysis of variance indicated that no significant effect of the game on heart rate, oxygen uptake, or energy expenditure was evident. However, game had a significant effect on MET level ($p<0.05$) (Fischer et al., 2001). Again, MET level was the only metabolic variable significantly

($p<0.05$) impacted by the independent variables: parent age and gender. This study determined that an activity as simple as playing tag with your child for 20-30 minutes a day fulfills the suggested amount of physical activity in a day.

11 Appendix B: Technical Specifications of Mass Spectrometer

Table 11.1: Specifications for Mass Spectrometer

Specifications Mass Spectrometer MAG-1 100:

Parameter	Value	Commentary
a. Power Input	700 VA start up, 400 VA running	
b. Input	Refer to Figure 4-2	Selector switch allows any one output to be displayed. up to 2000 counts on special order. Two additional displays optional.
c. Electrical Output	All outputs available as 10 V full scale analog signals at connector J202 located on back of instrument	< 1 ? output impedance. Recommended load impedance > 2000 ? .
d. Accuracy	Breath-to-Breath 0.1%	% of full scale range
e. Stability	+1% /day, +2% /month	% of full scale range
f. Mass Range	m/e 2-136	
g. Resolution	> 1:22 for primary gases with zero crosstalk	1:40 at 10% crosstalk
h. Signal-to-Noise Ratio	> 1600:1 @ 100% concentration > 600:1 @ 5% concentration	R.M.S. values
i. Response	Breath-to-Breath Analysis 90% in < 100 ms 63% in 55 ms	Typically < 70 ms to 90%
j. Lag	Approx, 250 ms @ 760 mmHg	For a standard capillary approx 6' long
k. Inlet Sample Flow Rate	1 cc/s + 15% at sea level	Reduced flow available on special request
l. Pressure Sensitivity	A 2 to 1 change in pressure causes less than 1 % change in output	Unobservable over normal atmospheric changes
m. Linearity	+2% of full scale over concentration	
n. Shutdown	Instantaneous lautomatic on power failure or removal or overpressure	
o. Maximum leakage current	< 30 μA chassis to ground < 10 μA cathater to patient	Per U.L. 544

12 Appendix C: Metamax3B Calibration

Metamax 3B Calibration Process

1. Turn on the Metamax 3B and allow it to "warm up" thirty minutes.
2. Go into Metasoft 2 and click on "Pressure" in the calibration menu.

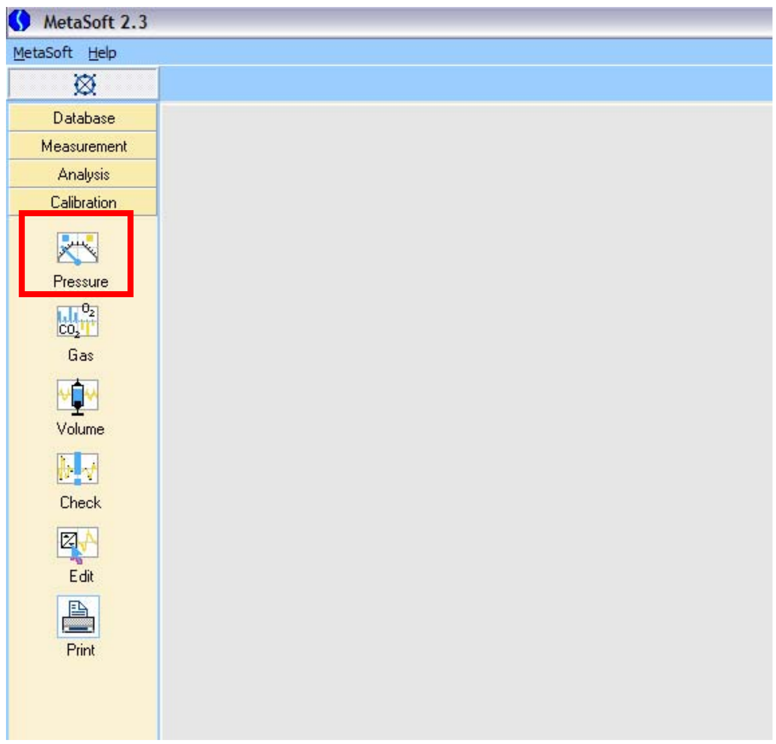

Figure 12.1: Metamax 3B Calibration Screen

3. Go to www.weather.com and change the units to metric. Find the pressure in millibars.

4. Enter the pressure in to the space provided in the pop-up in Metasoft 2.

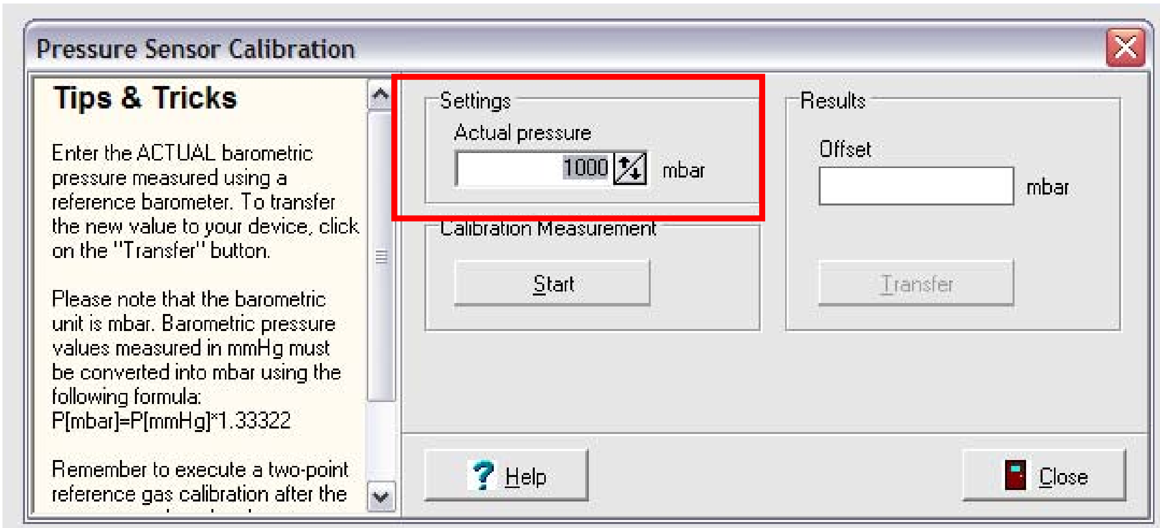

Figure 12.2: Metamax 3B Pressure Calibration Screen

4. When the following pop-up appears, click on Ignore and the test will proceed.

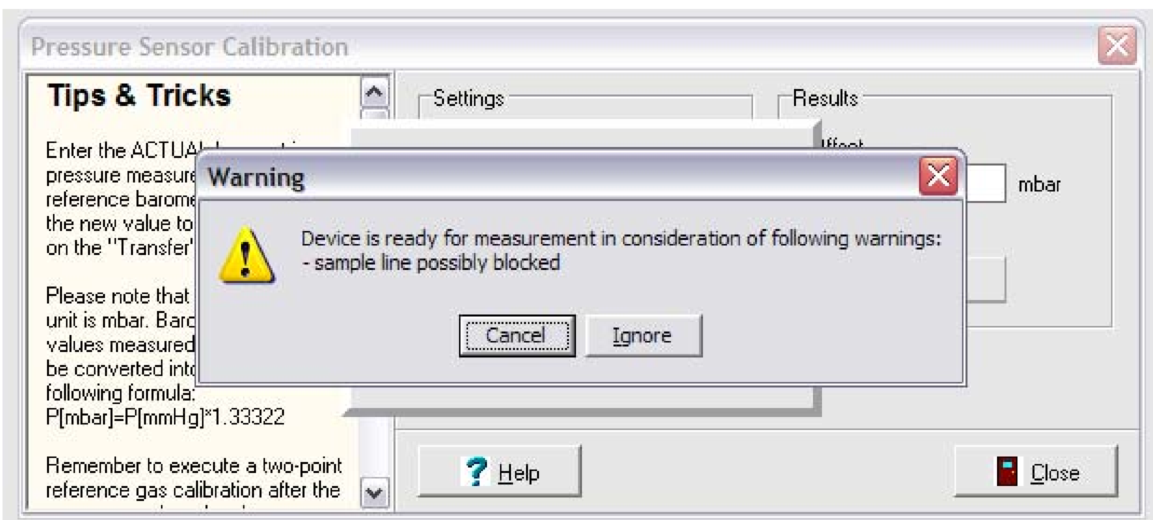

Figure 12.3: Metamax 3B Warning Screen

5. When the Metamax 3B beeps, the Transfer button will become an option. Click on this button to transfer the calibration value. Then click OK when the values are transferred.

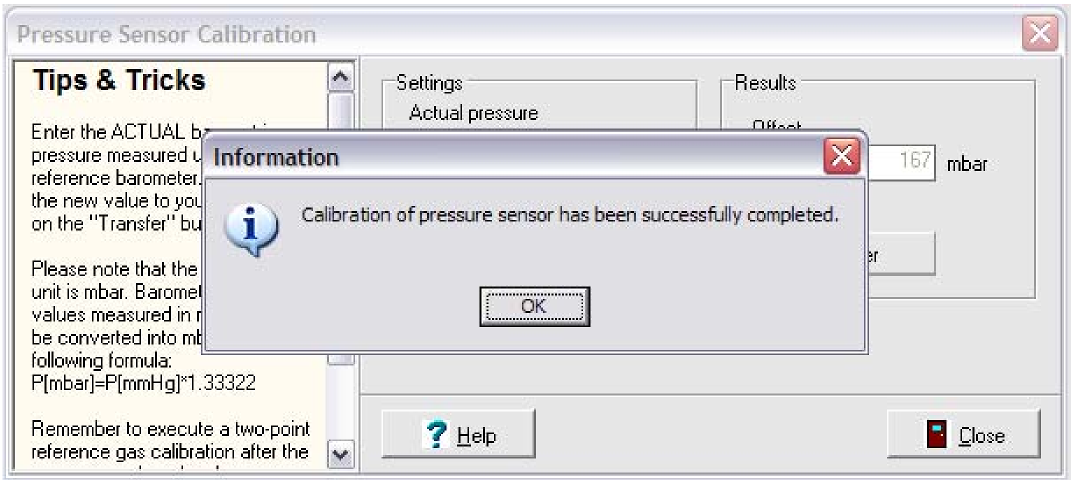

Figure 12.4: Metamax 3B Successful Calibration Screen

6. Once this step is completed, close out of the Pressure calibration window and open the Gas calibration window.

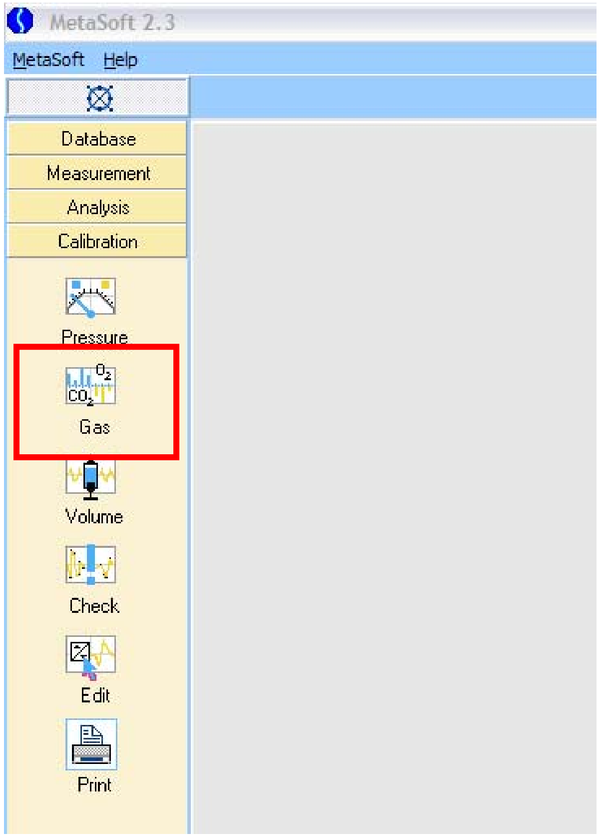

Figure 12.5: Metamax 3B Calibration Menu

7. The following pop-up will appear. Make sure that the O2 sample line (the white tube) is not plugged into the fan.

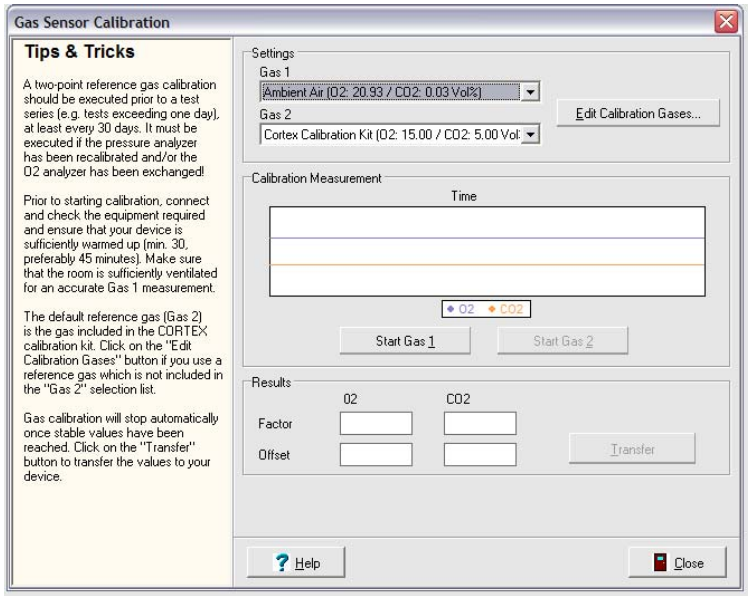

Figure 12.6: Metamax 3B Gas Sensor Calibration Screen

8. Click on the "Start Gas 1" button, and the following pop-up will appear. Click on the ignore button and the test will proceed.

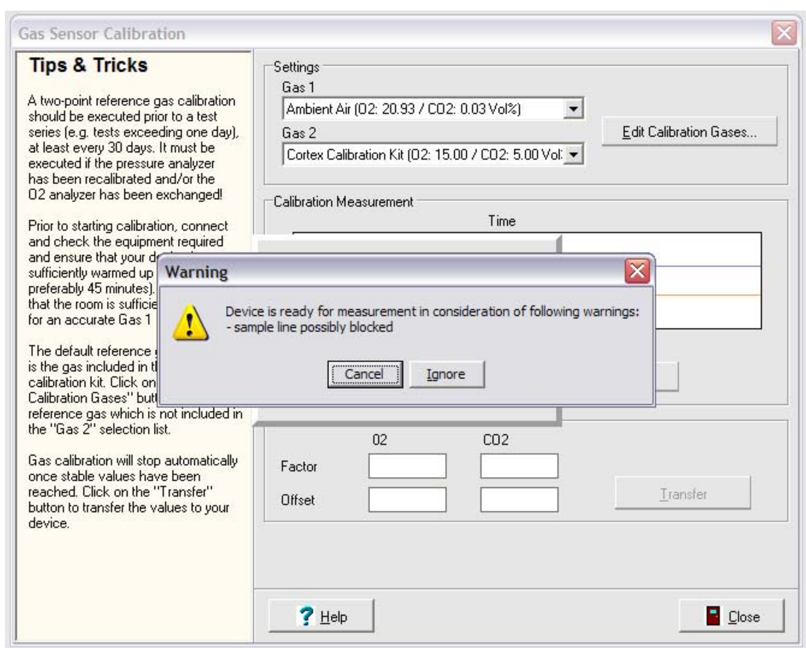

Figure 12.7: Metamax 3B Warning Screen

9. While that test is running, set-up the calibration gas system. The first step is to screw the pressure regulator onto the gas canister.

Figure 12.8: Metamax 3B Gas Sensor Calibration Equipment

10. Then connect the clear hose to the pressure regulator and screw the other end of the hose into the P IN port on the Calibration Gas Safer.

Figure 12.9: Metamax 3B Gas Sensor Calibration Set-Up

11. Next screw the clear plastic adapter onto the P OUT port on the Calibration Gas Safer

Figure 12.10: Metamax 3B Gas Safer

12. Finally plug the DC adapter into an outlet, and plug the other end into the DC IN port on the Calibration Gas Safer.

Figure 12.11: Metamax 3B Complete Gas Sensor Test Set-Up

13. When the Gas 1 test is complete, plug the black tip of the O2 sample line into the plastic adapter that is attached to the P OUT port on the Calibration Gas Safer. Next, you need to turn the black valve on the right side of the pressure regulator to allow gas flow. You also need to turn the gold valve on the top of the pressure regulator to release the gas. The Calibration Gas Safer will beep until the pressure is within allowable limits. Once the unit stops beeping, click on the Start Gas 2 button. If the unit begins to beep during the test, simply adjust the valves until it stops. This will cause the test to last longer, but will not affect the results.

14. Once the test is complete, the transfer button will become an option, click on it and the following pop-up will show up when the values are transferred; click the OK button to proceed.

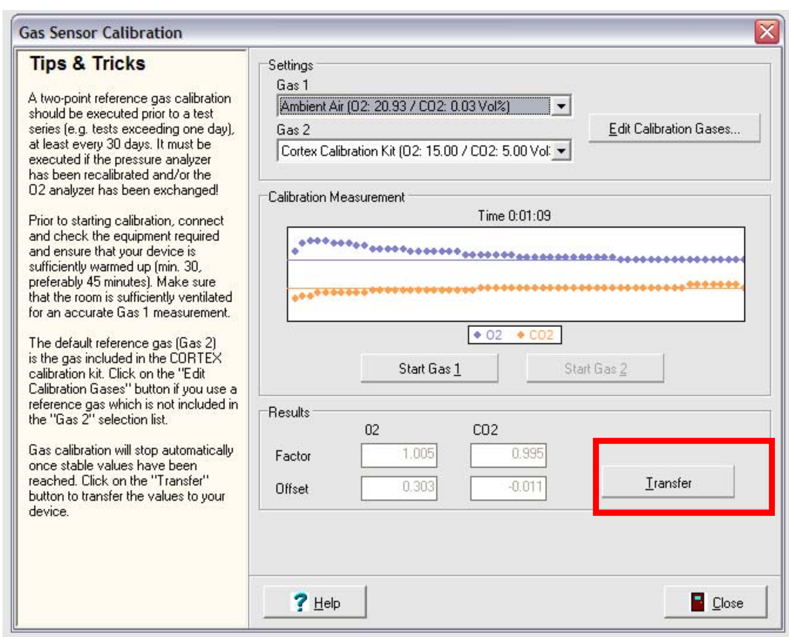

Figure 12.12: Metamax 3B Gas Sensor Calibration Screen

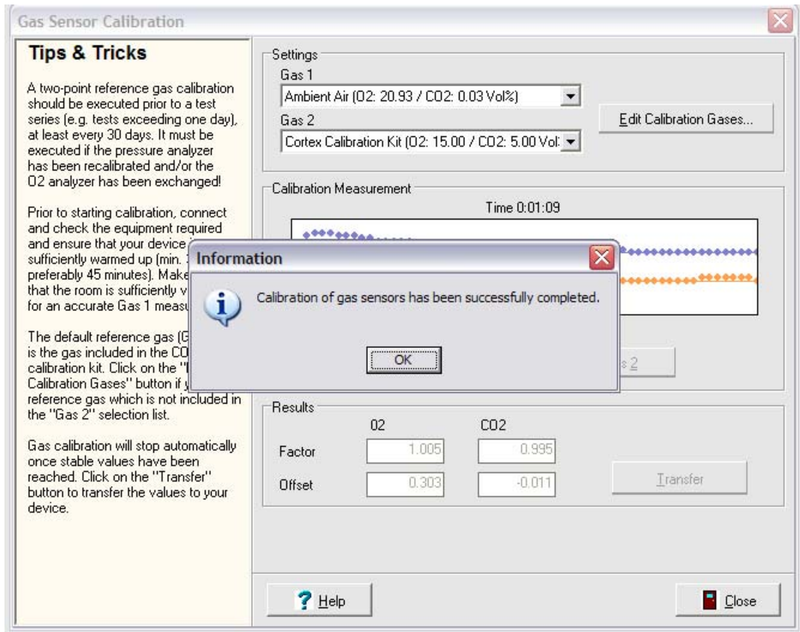

Figure 12.13: Metamax 3B Gas Sensor Calibration Success Screen

15. Close out of the Gas calibration window, and open the Volume Calibration Window.

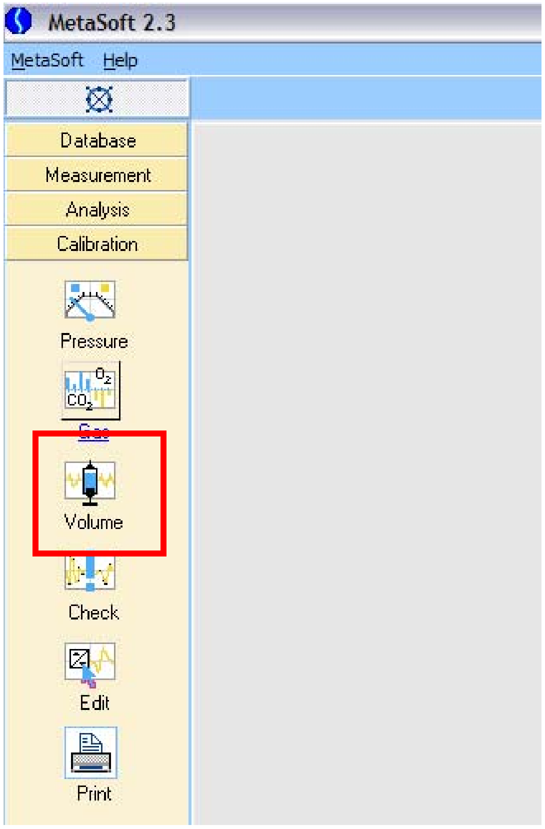

Figure 12.14: Metamax 3B Calibration Menu

16. The following window will appear, when it does, prepare the 3L Calibration Syringe for use.

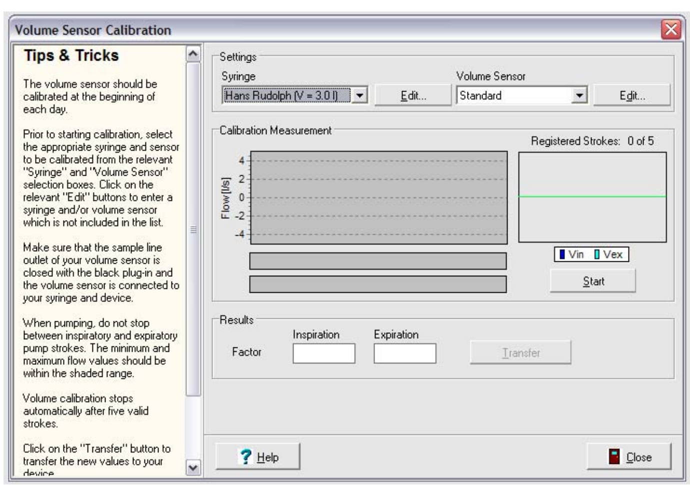

Figure 12.15: Metamax 3B Volume Sensor Calibration Screen

17. Plug the fan from the Metamax 3B into the end of the syringe and, plug the O2 sample line hole with the plug connected to the syringe.

Figure 12.16: Metamax 3B Volume Sensor test Syringe

Figure 12.17: Metamax 3B Volume Calibration Syringe Set-Up

18. When this is complete, click on the start button in the Volume Calibration window. The following pop-up will appear; click on the Ignore button to proceed with the test.

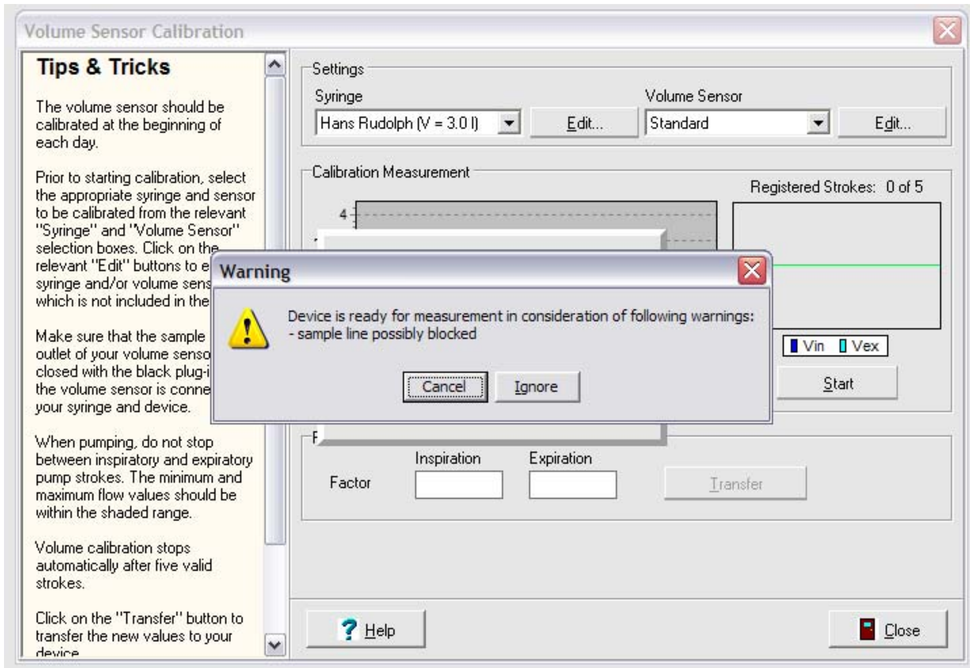

Figure 12.18: Metamax 3B Error Screen

19. Next, pull the hand out and push it in to follow the bar that moves across the screen, you will need to be close to this bar for a total of 5 cycles to calibrate the Metamax 3B.

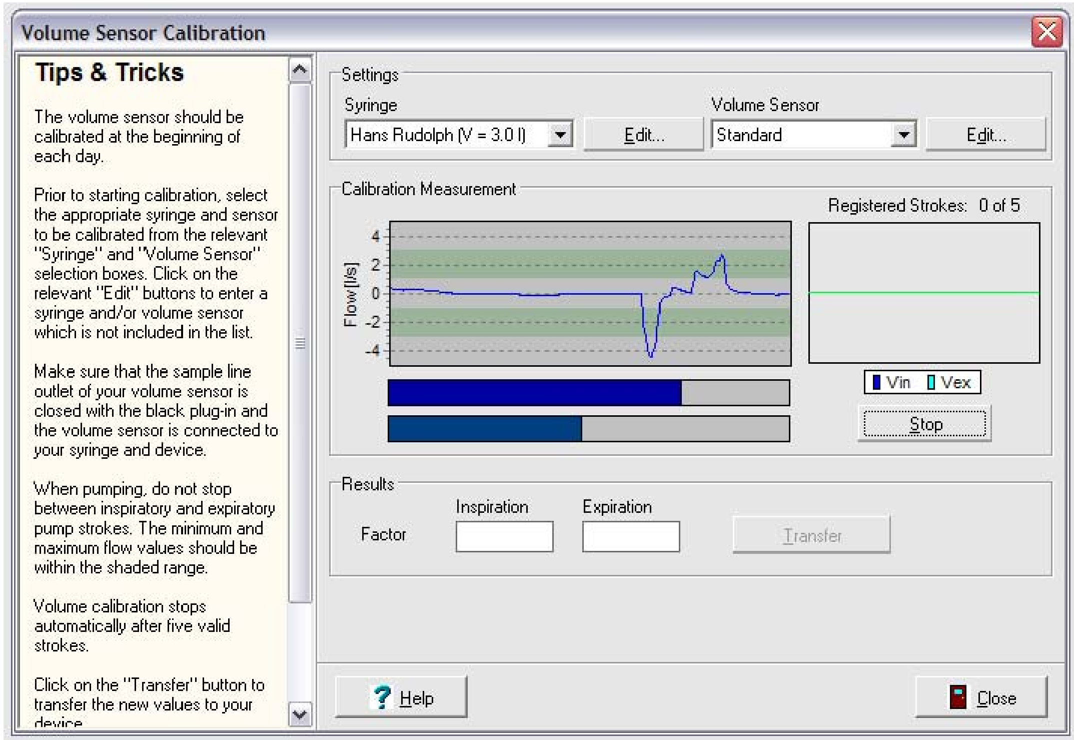

Figure 12.19: Metamax 3B Volume Calibration Screen

20. Once this process is completed, the Transfer button will become an option, click on it to transfer the calibration values.

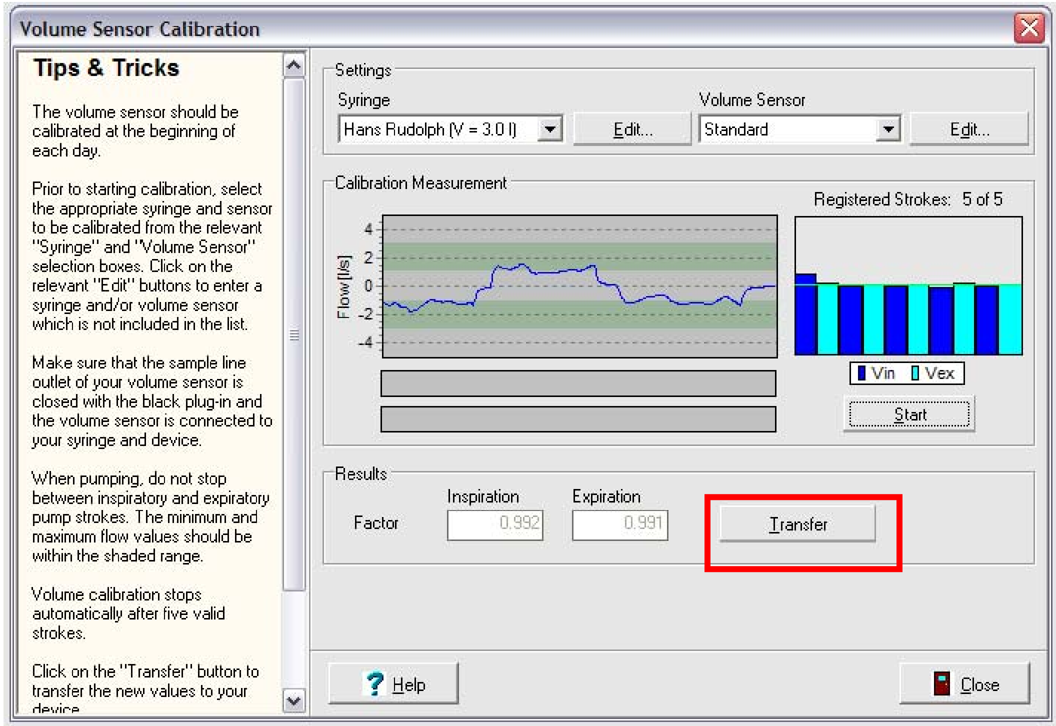

Figure 12.20: Metamax 3B Screen Upon Completion of Volume Sensor Calibration

21. The following pop-up will appear once the values are transferred. Click on the OK button and close out of the Volume calibration window to complete calibration.

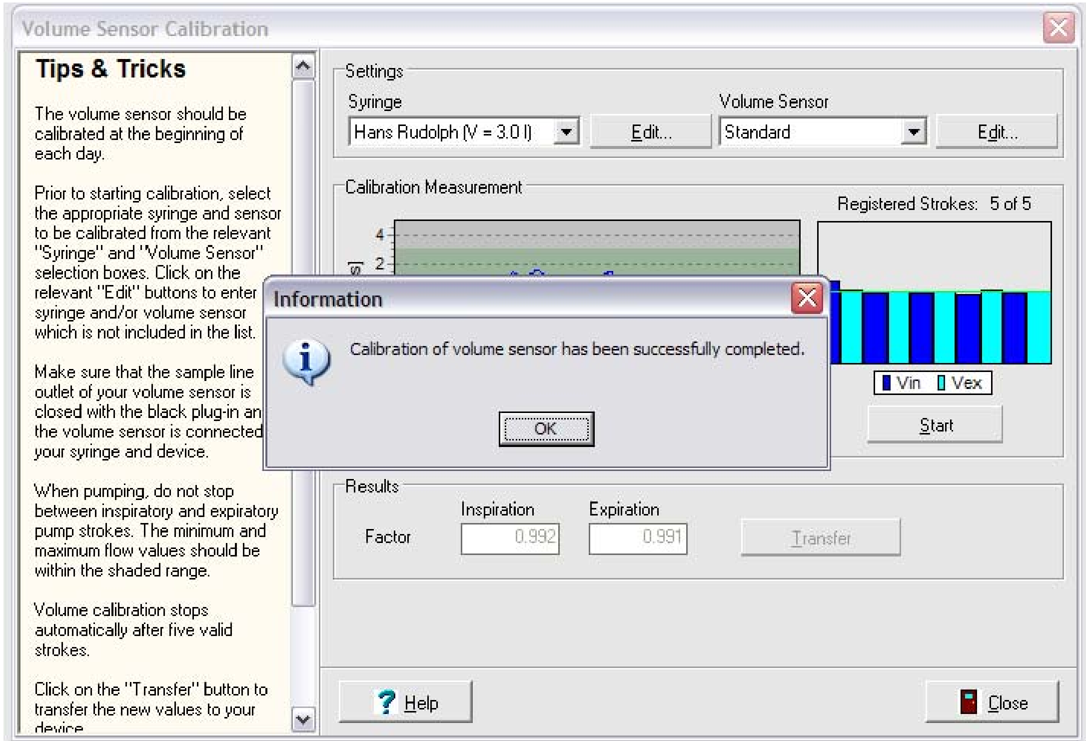

Figure 12.21: Metamax 3B Volume Sensor Calibration Successful

22. The Metamax 3B is now calibrated. Click on the Measurement tab to begin a test.

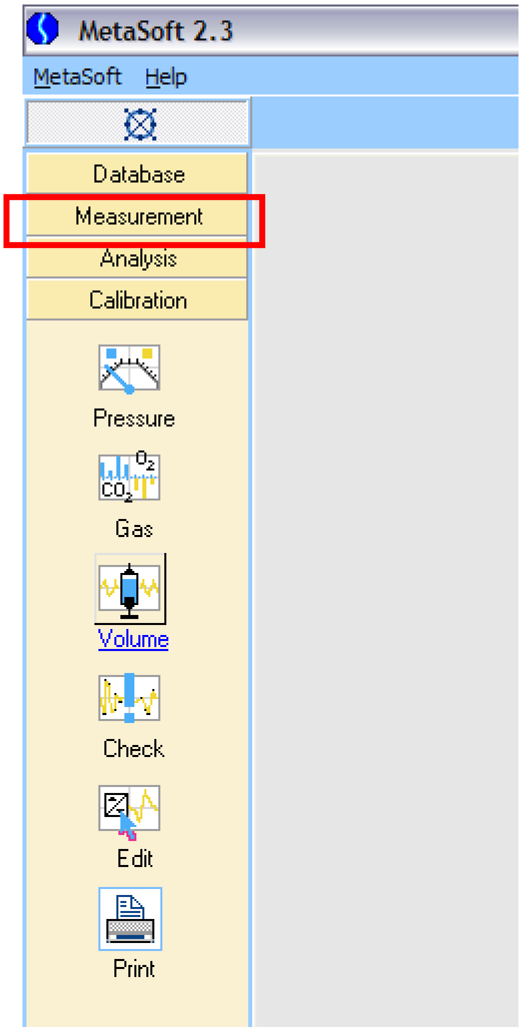

Figure 12.22: Metamax 3B Main Menu

23. Once in the Measurement tab, click on select a subject to open the subject database. Click on the subjects name and hit the OK button.

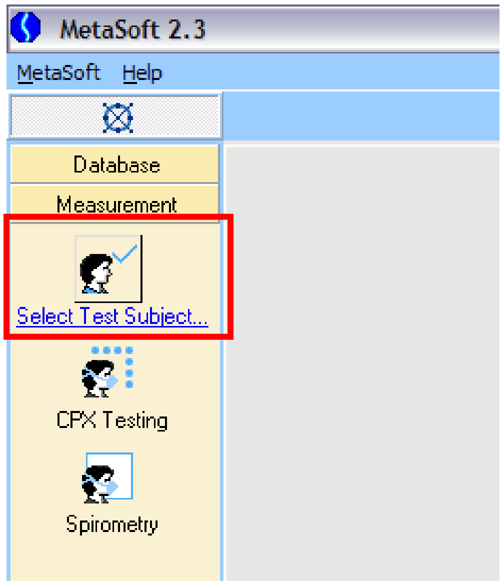

Figure 12.23: Metamax 3B Measurement Menu

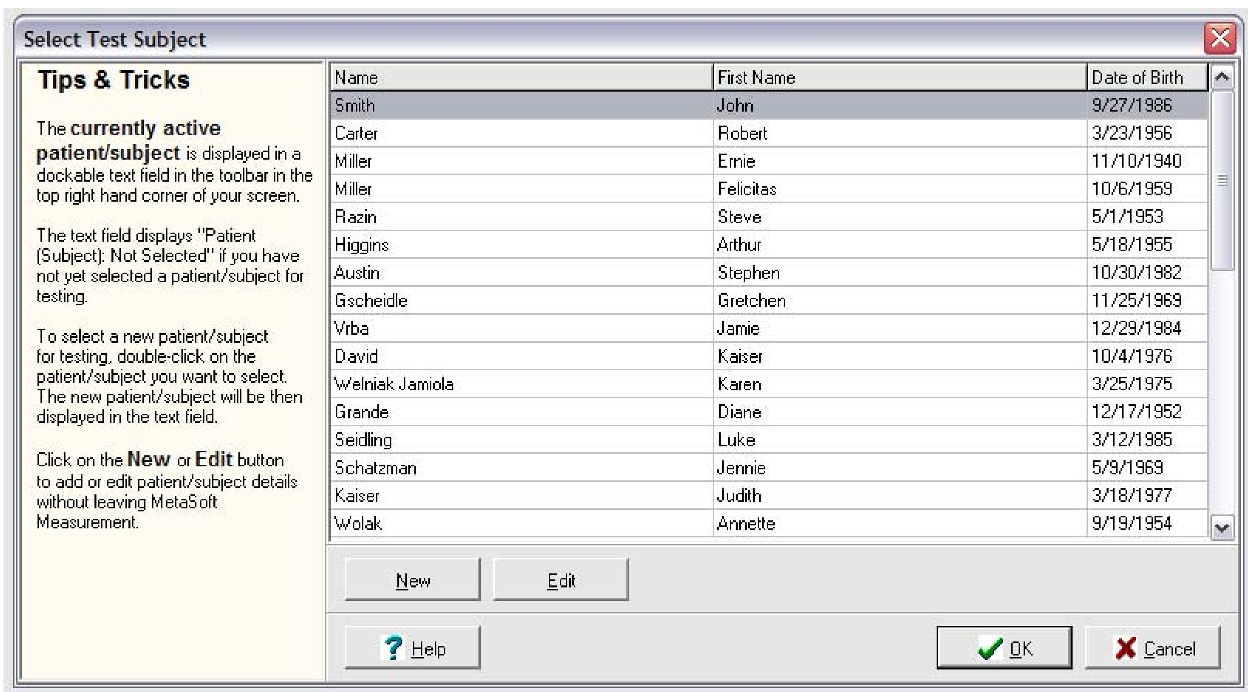

Figure 12.24: Metamax 3B Test Subject Selection screen

24. Once the subject is selected, click on the CPX testing button, and this screen will pop up.

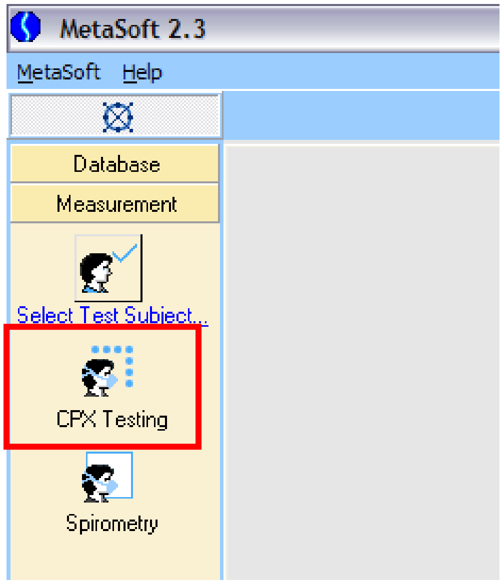

Figure 12.25: Metamax 3B Measurement Menu

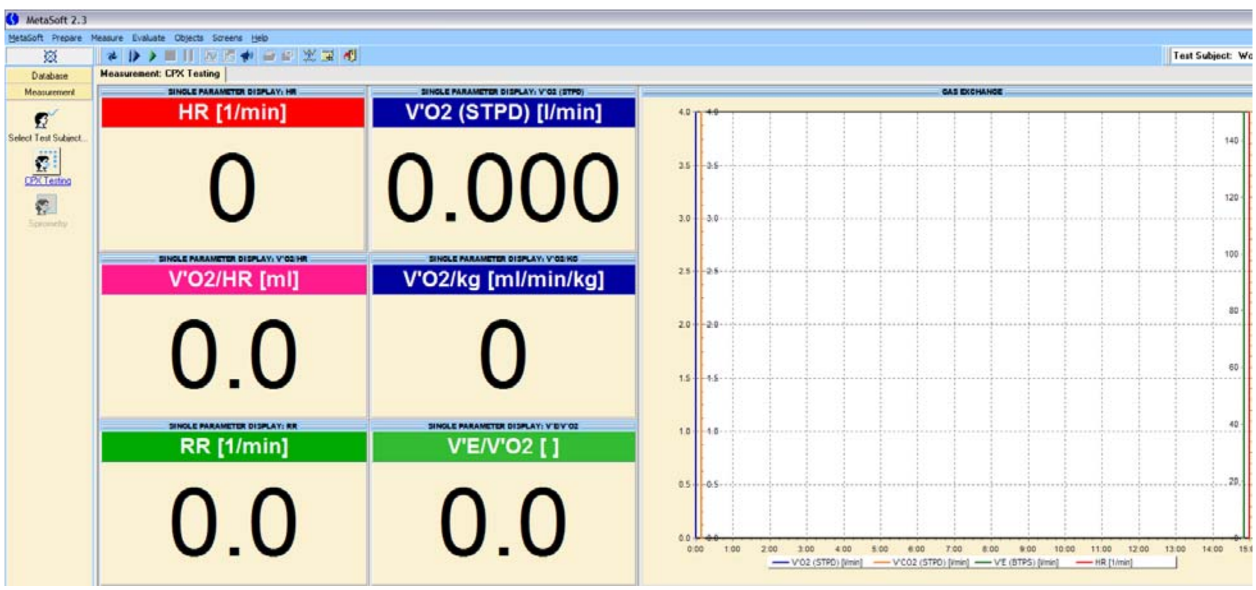

Figure 12.26: Metamax 3B Main Test Screen

25. Once this screen appears, hit the play button at the top of the screen to begin the final ambient air test. The following pop-up will appear, click the OK button to

begin the test. The sample line error will appear, click on ignore button to proceed.

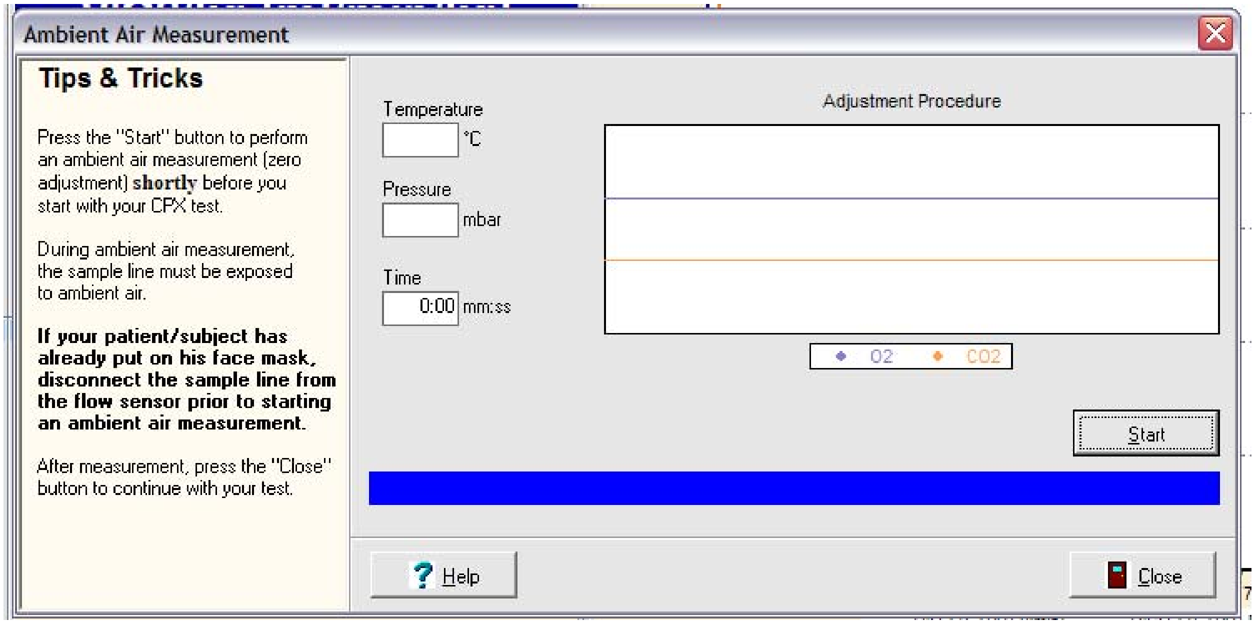

Figure 12.27: Metamax 3B Ambient air Test Screen

26. When the test is complete, this pop-up will appear. Click OK to proceed.

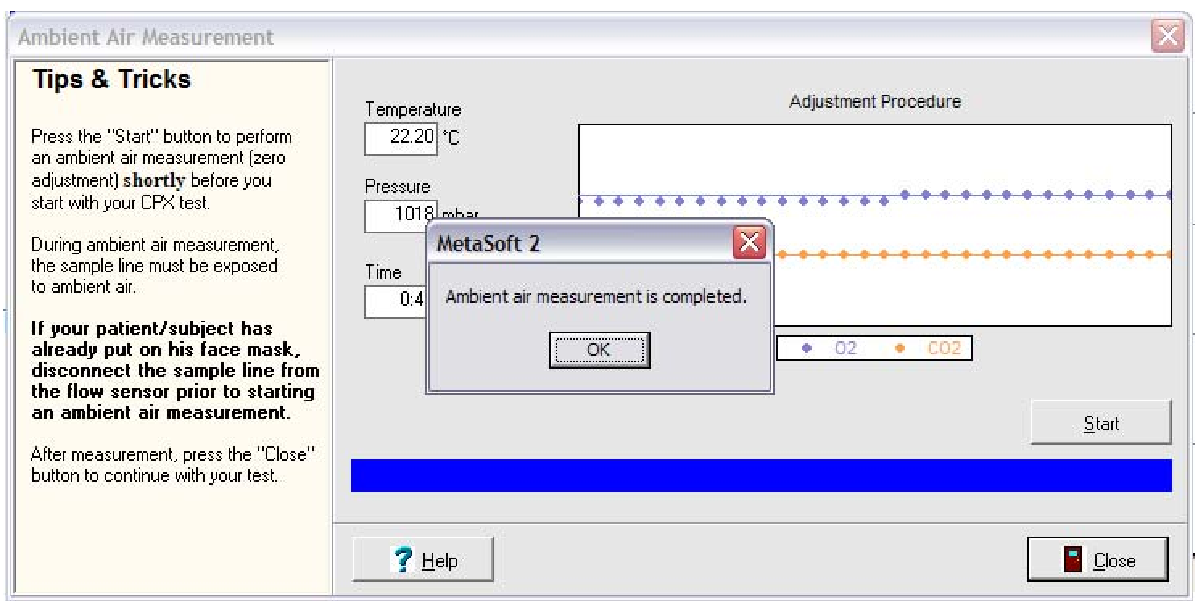

Figure 12.28: Metamax 3B Ambient air Test Complete Screen

27. When the device attempts to prepare, this error will pop up. Click Ignore to proceed.

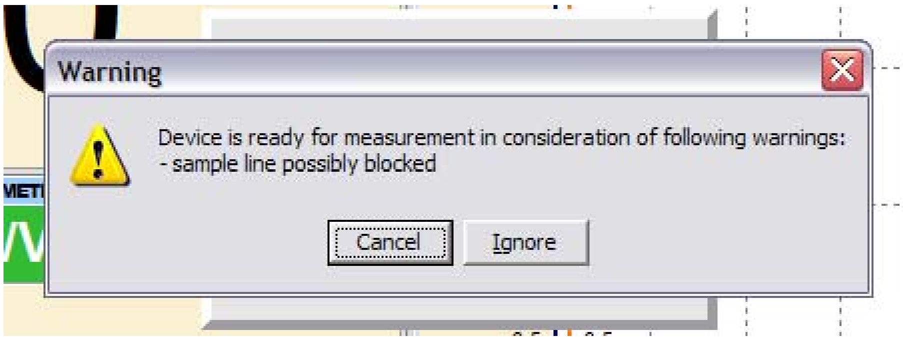

Figure 12.29: Metamax 3B Error Message

28. When the device attempts to prepare, this error will pop up. Click Ignore to proceed.

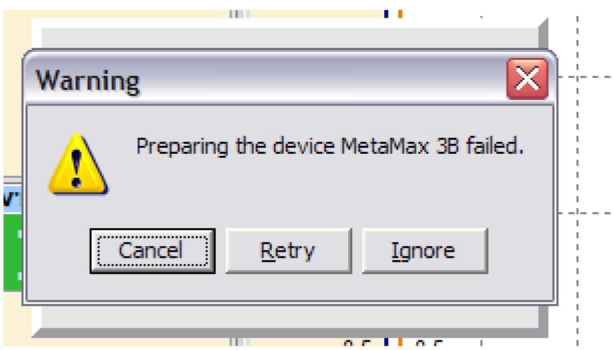

Figure 12.30: Metamax 3B Error Message

The Metamax 3B is now ready to begin collecting data.

13 Appendix D: Forms

Telephone Script

Hello.

My name is Steve Freier and I am conducting a metabolic study on office chairs at Marquette University. The study includes two separate sessions both approximately 3 hours in length. During these sessions you will be wearing a mask that covers your nose and mouth and a collar that fits loosely around your shoulders while working at a computer. Are you still interested?

I am going to ask you a few quick questions to ensure that you are qualified…

1. How old are you?
2. Do you usually do at least 4 hours of work per day at your desk using a computer?
3. Do you have any respiratory diseases?
4. Do you have any injuries to a bone or muscle?
    a. What type?
    b. Would this condition be worsened by sitting for extended periods?
5. Do you use tobacco products?
    a. What kind?
    b. How often?
6. Are you comfortable wearing a mask over your nose and mouth?
7. Do you wear glasses?
8. Are you claustrophobic?

If they are disqualified for any reason the response is:

I am sorry but you do not fit the qualifications we are looking for in this particular study, thank you for your interest and taking the time to contact me. Have a good day.

If they qualify:

You are qualified to participate in this study. Each time you come in to be tested we ask that you avoid strenuous exercise, eating or drinking anything that contains caffeine, alcoholic beverages, tobacco use of any kind, and using any products that may alter your metabolic state, such as cold medicine, caffeine, and narcotics. When are you available to come in and begin testing?

Then set up a time for the first test.

Closing:
Thank you for taking the time to contact me and I look forward to seeing you on _____ at ____. Have a good day.

Telephone Interview Results

_________________________ has been disqualified from participation in this study for:

- Age: Too old Too Young
- Lack of computer interaction
- Respiratory disease ________________________
- Musculoskeletal injury ______________________
- Tobacco use
- Unwilling to wear mask
- Glasses
- Claustrophobia

________________________ has been accepted as a participant in this study, and their first test is scheduled for __________am / pm on ______________.

Occupational and Health Background Information Form

Date: ______/_____/______

Participant's Name: ____

Age: ______________ Gender: ____________ Race ____________

Occupation: ____

How long have you been in this occupation? ___________________________________
(If Student, how many years in college?)

How satisfied are you with your current occupation? Select from 1 to 7.

Very Dissatisfied										Very Satisfied
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*

On average, how many hours do you work with a computer (desktop or laptop) each day at work, not for recreation?

____

Have you ever had an injury or illness affecting a bone or muscle? *YES* or *NO*.
If *YES*, please describe.

____

Do you have any ***current*** injury, illness or pain affecting a bone or muscle? *YES* or *NO*. If *YES*, please describe. ____

____

If *YES*, would participating in this experiment worsen your injury, illness or pain?
YES or *NO*. ___________________

Please list all medications including supplements, vitamins and any other aid you take by mouth or injection (and their dosages) that you are currently taking:

____

____

____

Can you sit for a prolonged time (30 minutes at a time) with breaks for a total of 2 ½ hours?

YES *NO*

Are you claustrophobic or afraid of having things on your face? *YES* *NO*

Do you have asthma or any other respiratory disease or condition?YES *NO*
Please explain if you answer yes.

Do you have any known cardiovascular condition? *YES* *NO*
Please explain if you answer yes.

Overall, how would you describe your general health? Please indicate your answer by putting a line on the scale below.

Very poor *Exceptional*
0 *10*

|--|

Day of Study Form

Did you exercise today (e.g. running, bicycling, workout at club, etc.?) *YES* *NO*

Did you smoke or use any other tobacco products today? *YES* *NO*

Did you consume any alcohol products today? *YES* *NO*

Did you drink caffeinated coffee or consume any other substances with caffeine today? *YES* *NO*

Within the last 2 days (?), did you consume any substances that would stimulate your heart or metabolic system? (i.e. caffeine, cold medicine, marijuana…) *YES* *NO*

How much sleep did you get last night? ________________________ *(hrs)*

Is this typical for you (number of hours) *YES* *NO*
If no, is it more or less? Please provide typical number.

How long ago did you last eat? ________________________ (hrs)

How do you feel today? Please indicate your answer by putting a line on the scale below.

Very poor Exceptional
0 10

|--|

Anthropometry Form

Date: ____/____/____ Time:_________ Humidity:________ Temperature:________

Participant's Name: ____

Dominant Hand/Arm Left Right

Gross Anthropometric dimensions (# NASA 1024 Dimensions)

Standing Posture

#957 Weight ………………………………………………………………_________lbs

#805 Stature…………………………………………………………….._________cm

#23 Acromial (shoulder) height…………………………………………_________cm
(Dominant Side)

Elbow Bent at 90 Degrees
#751 Shoulder-elbow length (acromium)……………………………__________cm
(Dominant Side)

#324 Elbow-Wrist length……………………………………………..__________cm
(Dominant Side)

#381 Forearm-Hand length…………………………………………..__________cm
(Dominant Side)

Seated Position

678 Popliteal Height……………………..……………………………__________cm

#200 Buttock – Popliteal Length……..…………………..…………...__________cm

Post Experimental Measurements Form

Seat Height after first office portion…………………………………..__________cm
(Top of seat pan to floor)

Seat Height after movie viewing portion……………………………..__________cm
(Top of seat pan to floor)

Seat Height after second office portion…………….………………..__________cm
(Top of seat pan to floor)

Arm Rest Height…………………………………………………….__________cm
(Top of arm rest to the floor)

Back Rest Position………………………………………………….__________degrees

Seat Pan Depth……………………………………………………..__________cm

Height of keyboard stand……………………………………………..__________cm
(Top of home row keys to floor)

Subjective Assessment Form

Date:______/_______/______

Please rate the chair that you used today according to the following:

Ease of Use

Very Difficult To Use			Difficult to Use				Easy to Use			Very Easy to Use
0	1	2	3	4	5	6	7	8	9	10

Comfort

Very Uncomfortable			Uncomfortable				Comfortable			Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

Overall Evaluation

Poor			Fair				Good			Excellent
0	1	2	3	4	5	6	7	8	9	10

Please rate the following on a scale of 1 to 5:

The back of the seat (buttock area) feels comfortable.

Strongly Disagree				Strongly Agree
1	2	3	4	5

This chair tilts back too far.

Strongly Disagree				Strongly Agree
1	2	3	4	5

This chair doesn't tilt back far enough for me.

Strongly Disagree				Strongly Agree
1	2	3	4	5

The front of the seat (thigh area) feels comfortable.

Strongly Disagree				Strongly Agree
1	2	3	4	5

14 Appendix E: Graph of Data Collection and Periods Analyzed

Figure 14.1: Graphical Representation of the Data Collected vs. Data Analyzed

15 Appendix F: Background Data of Subjects

Table 15.1: Subject Background Data

Subject	Age	Gender	Race	Satisfaction w Occupation (0 to 10)	General Health (0 to 10)
F01	32	F	White	8	8
F04	30	F	White	7	8.5
F06	32	F	African-American	7	9.9
F08	31	F	White	8	7
F09	31	F	White	8	9.1
F11	24	F	White	8	7.9
F12	21	F	Asian	10	6.5
F13	24	F	White	8	7.5
F14	26	F	Hispanic	7	7
F02	55	F	Hispanic	7	5.7
F03	38	F	White	7	8.2
F05	53	F	White	10	8.5
F07	49	F	White	7	7
F10	51	F	White	10	8.8
F15	46	F	White	6	7.4
F16	39	F	African-Am/Hispanic	9	7
M01	31	M	White	10	6.2
M02	22	M	White	6	8.8
M06	24	M	White	7	7.5
M07	20	M	White	7	8
M08	19	M	White	7	7
M10	33	M	White	8	8.9
M11	33	M	African-American	10	6
M12	22	M	White	7	10
M03	52	M	White	3	3
M04	36	M	White	9	8.7
M05	51	M	White	7	7
M09	55	M	White	9	6.8
M13	40	M	Native American	8	5.8
M14	51	M	White	6	8.5
M15	49	M	White	7	6.3

16 Appendix G: Anthropometry of Subjects (Raw Data)

Table 16.1: Subject Anthropometry Raw Data

Participant	Weight (lbs)	Stature (in)	BMI	Stature (cm)	Acromial Height (cm)	Shoulder-Elbow Length (cm)	Elbow-wrist Length (cm)	Forearm-hand Length (cm)	Shoulder Width (cm)	Popliteal Height (cm)	Buttock-popliteal length (cm)
F01	130.2	63.937	22.39	162.4	136.9	33.8	27.5	43.8		44.5	44
F04	139.7	69.685	20.224	177	148.7	39	29.9	46.9		45.5	48.6
F06	246.2	63.661	42.706	161.7	136	34.1	29	47.8	49.1	39.4	48.5
F08	142.7	65.472	23.402	166.3	137.5	35.8	27.3	43.9	41.2	41.9	44.4
F09	128.7	67.913	19.617	172.5	146.7	38	26.7	44.4	39.3	43.1	47.6
F11	166.5	63.031	29.461	160.1	133	35.6	26.4	45.3	43.4	40.4	44.9
F12	225.46	65.394	37.064	166.1	139.9	36.9	28.5	45.3	44.2	40.1	50.5
F13	103.8	62.874	18.459	159.7	134	33.4	23.4	39.9	37	40.5	45.1
F14	252.74	66.929	39.664	170	147.8	36.2	27.8	45.5	46.1	41.8	54
F02	175.4	61.85	32.233	157.1	134	30.4	28.2	45.2		40.9	45.6
F03	215.8	63.031	38.185	160.1	134.5	35.7	26.7	44.1		41.7	46.9
F05	145.3	61.929	26.634	157.3	131	34.9	25	40.9	39.6	40.4	50
F07	186.4	63.78	32.214	162	137.8	34.6	28.3	45.1		41.2	47.7
F10	206.1	65.472	33.8	166.3	137.5	36.7	28.8	47.7	43.5	39.6	48.3
F15	184.23	64.094	31.526	162.8	137.9	33.3	26.5	43.4	44.7	42.1	48
F16	147.5	73.8	19.04	187.5	144.9	38.5	26.8	47.8	40.4	43.6	49.3
M01	314.5	72.638	41.904	184.5	156.3	37	32.2	48.6		43.4	44.4
M02	153.9	71.024	21.448	180.4	152.5	39.7	30.8	51.1		47.3	48.5
M06	309.9	72.441	41.515	184	157.8	40	33.3	51.8	54.3	46.7	51.2
M07	172.2	70.157	24.595	178.2	150	39	30.7	47.1	42.7	42.6	44.4
M08	154.47	69.488	22.489	176.5	148.8	38	30.3	49.8	43.9	42.1	49.4
M10	226.27	76.496	27.183	194.3	162.1	42.5	31.5	53.1	49.8	49.1	56.3
M11	336.2	68.976	49.677	175.2	151.5	39.6	32.6	51.8	55.5	44.1	49.2

M12	163.8	73.346	21.405	186.3	157.1	40	29.7	50.5	44.1	45.1	49.7
M03	298.7	73.425	38.949	186.5	157.3	40.1	31.8	51.5	51	42.8	48.7
M04	187.1	73.5	24.34	186.7	157	42.7	32.7	51	46.7	45.8	51.9
M05	294.5	72.047	39.885	183	157.8	42.3	30.4	48.8	54.1	43.6	49.7
M09	205.4	72.48	27.486	184.1	153.8	39.6	31.8	48.5	46.3	46.6	52.8
M13	241.3	70.472	34.157	179	152.5	41.4	29.5	50	51.3	43	47.6
M14	217.84	70.039	31.218	177.9	152.4	39.3	30.6	48.1	47.5	44	49.9
M15	200.34	70.118	28.646	178.1	147.2	39	29.9	49.5	47.3	44.1	49.8

Note: Shoulder widths of 5 females and 2 males were not recorded

17 Appendix H: Anthropometry of Subjects (Summary Statistics)

Table 17.1: Anthropometry Summary Statistics for All Subjects and By Gender

Age	**All Females**				**All Males**				**All Subjects**	
	Mean		36.4		Mean		35.9		Mean	36.1
	S.D.		11.2		S.D.		13.0		S.D.	11.9
	Min.		21.0		Min.		19.0		Min.	19.0
	Max.		55.0		Max.		55.0		Max.	55.0
	18-35		**36-55**		**18-35**		**36-55**			
	Mean	27.9	Mean	47.3	Mean	25.5	Mean	47.7		
	S.D.	4.2	S.D.	6.7	S.D.	5.9	S.D.	7.0		
	Min.	21.0	Min.	38.0	Min.	19.0	Min.	36.0		
	Max.	32.0	Max.	55.0	Max.	33.0	Max.	55.0		
Weight (lbs)	**All Females**				**All Males**				**All Subjects**	
	Mean		174.8		Mean		231.8		Mean	195.7
	S.D.		44.5		S.D.		63.5		S.D.	65.9
	Min.		103.8		Min.		153.9		Min.	44.5
	Max.		252.7		Max.		336.2		Max.	336.2
	18-35		**36-55**		**18-35**		**36-55**			
	Mean	170.7	Mean	180.1	Mean	228.9	Mean	235.0		
	S.D.	56.0	S.D.	26.8	S.D.	79.3	S.D.	45.3		
	Min.	103.8	Min.	145.3	Min.	153.9	Min.	187.1		
	Max.	252.7	Max.	215.8	Max.	336.2	Max.	298.7		
Stature (cm)	**All Females**				**All Males**				**All Subjects**	
	Mean		158.5		Mean		174.8		Mean	159.7
	S.D.		23.2		S.D.		28.4		S.D.	38.0
	Min.		73.8		Min.		73.5		Min.	23.2
	Max.		177.0		Max.		194.3		Max.	194.3
	18-35		**36-55**		**18-35**		**36-55**			
	Mean	166.2	Mean	148.5	Mean	182.4	Mean	166.0		
	S.D.	6.0	S.D.	33.1	S.D.	6.2	S.D.	40.9		
	Min.	159.7	Min.	73.8	Min.	175.2	Min.	73.5		
	Max.	177.0	Max.	166.3	Max.	194.3	Max.	186.5		
BMI	**All Females**				**All Males**				**All Subjects**	
	Mean		29.2		Mean		31.7		Mean	30.4
	S.D.		8.0		S.D.		8.9		S.D.	8.4
	Min.				Min.				Min.	18.5
	Max.				Max.				Max.	49.7
	18-35		**36-55**		**18-35**		**36-55**			
	Mean	28.1	Mean	30.5	Mean	31.3	Mean	32.1		
	S.D.	9.4	S.D.	6.1	S.D.	11.3	S.D.	5.9		
	Min.	18.5	Min.	19.0	Min.	21.4	Min.	24.3		

	Max.	42.7	Max.	38.2	Max.	49.7	Max.	39.9		
Acromial Height (cm)	**All Females**				**All Males**				**All Subjects**	
	Mean		138.6		Mean		154.3		Mean	141.6
	S.D.		5.5		S.D.		4.1		S.D.	25.4
	Min.		131.0		Min.		147.2		Min.	5.5
	Max.		148.7		Max.		162.1		Max.	162.1
	18-35		**36-55**		**18-35**		**36-55**			
	Mean	140.1	Mean	136.8	Mean	154.5	Mean	154.0		
	S.D.	6.1	S.D.	4.4	S.D.	4.5	S.D.	3.8		
	Min.	133.0	Min.	131.0	Min.	148.8	Min.	147.2		
	Max.	148.7	Max.	144.9	Max.	162.1	Max.	157.8		
Shoulder-Elbow Length (cm)	**All Females**				**All Males**				**All Subjects**	
	Mean		35.4		Mean		40.0		Mean	36.4
	S.D.		2.2		S.D.		1.6		S.D.	6.7
	Min.		30.4		Min.		37.0		Min.	2.2
	Max.		39.0		Max.		42.7		Max.	42.7
	18-35		**36-55**		**18-35**		**36-55**			
	Mean	35.9	Mean	34.9	Mean	39.5	Mean	40.6		
	S.D.	1.9	S.D.	2.6	S.D.	1.6	S.D.	1.5		
	Min.	33.4	Min.	30.4	Min.	37.0	Min.	39.0		
	Max.	39.0	Max.	38.5	Max.	42.5	Max.	42.7		
Elbow-Wrist Length (cm)	**All Females**				**All Males**				**All Subjects**	
	Mean		27.3		Mean		31.2		Mean	28.2
	S.D.		1.6		S.D.		1.2		S.D.	5.3
	Min.		23.4		Min.		29.5		Min.	1.6
	Max.		29.9		Max.		33.3		Max.	33.3
	18-35		**36-55**		**18-35**		**36-55**			
	Mean	35.9	Mean	27.2	Mean	31.4	Mean	31.0		
	S.D.	1.9	S.D.	1.3	S.D.	1.2	S.D.	1.2		
	Min.	33.4	Min.	25.0	Min.	29.7	Min.	29.5		
	Max.	39.0	Max.	28.8	Max.	33.3	Max.	32.7		
Forearm-Hand Length	**All Females**				**All Males**				**All Subjects**	
	Mean		44.8		Mean		50.1		Mean	45.8
	S.D.		2.2		S.D.		1.7		S.D.	8.3
	Min.		39.9		Min.		47.1		Min.	2.2
	Max.		47.8		Max.		53.1		Max.	53.1
	18-35		**36-55**		**18-35**		**36-55**			
	Mean	27.4	Mean	27.2	Mean	31.4	Mean	31.0		
	S.D.	1.9	S.D.	1.3	S.D.	1.2	S.D.	1.2		
	Min.	23.4	Min.	25.0	Min.	29.7	Min.	29.5		
	Max.	29.9	Max.	28.8	Max.	33.3	Max.	32.7		
Shoulder	**All Females**				**All Males**				**All Subjects**	

Width (cm)	Mean		42.6		Mean		48.8		Mean	44.1
	S.D.		3.5		S.D.		4.2		S.D.	9.4
	Min.		37.0		Min.		42.7		Min.	3.5
	Max.		49.1		Max.		55.5		Max.	55.5
	18-35		36-55		18-35		36-55			
	Mean	44.8	Mean	44.9	Mean	50.5	Mean	49.6		
	S.D.	2.2	S.D.	2.4	S.D.	1.9	S.D.	1.3		
	Min.	39.9	Min.	40.9	Min.	47.1	Min.	48.1		
	Max.	47.8	Max.	47.8	Max.	53.1	Max.	51.5		
Popliteal Height (cm)	**All Females**				**All Males**				**All Subjects**	
	Mean		41.7		Mean		44.7		Mean	41.9
	S.D.		1.8		S.D.		2.0		S.D.	7.4
	Min.		39.4		Min.		42.1		Min.	1.8
	Max.		45.5		Max.		49.1		Max.	49.1
	18-35		**36-55**		**18-35**		**36-55**			
	Mean	41.9	Mean	41.4	Mean	45.1	Mean	44.3		
	S.D.	2.1	S.D.	1.3	S.D.	2.5	S.D.	1.4		
	Min.	39.4	Min.	39.6	Min.	42.1	Min.	42.8		
	Max.	45.5	Max.	43.6	Max.	49.1	Max.	46.6		
Buttock-popliteal Length (cm)	**All Females**				**All Males**				**All Subjects**	
	Mean		47.7		Mean		49.6		Mean	47.3
	S.D.		2.6		S.D.		3.0		S.D.	8.3
	Min.		44.0		Min.		44.4		Min.	2.6
	Max.		54.0		Max.		56.3		Max.	56.3
	18-35		**36-55**		**18-35**		**36-55**			
	Mean	47.5	Mean	48.0	Mean	49.1	Mean	50.1		
	S.D.	3.3	S.D.	1.5	S.D.	3.8	S.D.	1.8		
	Min.	44.0	Min.	45.6	Min.	44.4	Min.	47.6		
	Max.	54.0	Max.	50.0	Max.	56.3	Max.	52.8		

18 Appendix I: Summary Statistics of Change in Heart Rate (HR)

Table 18.1 and Table 18.2: Change in HR Summary Statistics for Typing 1 and Internet 1

Summary Statistics for ΔHR Typing 1							
All Subjects							
Mean				-4.848			
S.D.				7.743			
Max.				-31.391			
Min.				6.806			
All Females				All Males			
Mean		-3.352		Mean		-6.444	
S.D.		6.004		S.D.		9.196	
Max.		-16.557		Max.		-31.391	
Min.		6.806		Min.		0.483	
18-35		36-55		18-35		36-55	
Mean	-2.375	Mean	-4.609	Mean	-6.684	Mean	-6.170
S.D.	5.216	S.D.	7.110	S.D.	10.379	S.D.	8.455
Max.	-10.460	Max.	-16.557	Max.	-31.391	Max.	-24.495
Min.	6.806	Min.	1.939	Min.	0.444	Min.	0.483

Summary Statistics for ΔHR Internet 1							
All Subjects							
Mean				-4.400			
S.D.				6.971			
Max.				-26.083			
Min.				5.009			
All Females				All Males			
Mean		-2.984		Mean		-5.910	
S.D.		4.718		S.D.		8.692	
Max.		-12.010		Max.		-26.083	
Min.		5.009		Min.		2.245	
18-35		36-55		18-35		36-55	
Mean	-2.087	Mean	-4.138	Mean	-5.667	Mean	-6.187
S.D.	4.560	S.D.	5.016	S.D.	8.893	S.D.	9.156
Max.	-8.429	Max.	-12.010	Max.	-26.083	Max.	-25.444
Min.	5.009	Min.	2.844	Min.	1.994	Min.	2.245

Table 18.3 and Table 18.4: Change in HR Summary Statistics for Table 1 and Movie 1

Summary Statistics for ΔHR Table 1							
All Subjects							
Mean				-4.771			
S.D.				7.244			
Max.				-27.220			
Min.				7.470			
All Females				All Males			
Mean		-3.166		Mean		-6.482	
S.D.		5.186		S.D.		8.806	
Max.		-13.137		Max.		-27.220	
Min.		7.470		Min.		3.809	
18-35		36-55		18-35		36-55	
Mean	-2.313	Mean	-4.262	Mean	-6.019	Mean	-7.011
S.D.	6.509	S.D.	2.874	S.D.	8.166	S.D.	10.125
Max.	-13.137	Max.	-8.211	Max.	-24.640	Max.	-27.220
Min.	7.470	Min.	-1.488	Min.	1.356	Min.	3.809

Summary Statistics for ΔHR Movie 1							
All Subjects							
Mean				-4.410			
S.D.				8.394			
Max.				-25.963			
Min.				9.295			
All Females				All Males			
Mean		-3.039		Mean		-5.872	
S.D.		7.623		S.D.		9.181	
Max.		-20.764		Max.		-25.963	
Min.		9.295		Min.		5.718	
18-35		36-55		18-35		36-55	
Mean	-3.679	Mean	-2.215	Mean	-5.529	Mean	-6.264
S.D.	8.849	S.D.	6.280	S.D.	10.141	S.D.	8.738
Max.	-20.764	Max.	-10.082	Max.	-25.963	Max.	-23.011
Min.	9.295	Min.	8.824	Min.	5.718	Min.	3.211

Table 18.5 and Table 18.6: Change in HR Summary Statistics for Movie 2 and Typing 2

Summary Statistics for ΔHR Movie 2							
All Subjects							
Mean				-3.804			
S.D.				7.810			
Max.				-28.244			
Min.				9.587			
All Females				All Males			
Mean		-3.071		Mean		-4.586	
S.D.		6.066		S.D.		9.488	
Max.		-14.733		Max.		-28.244	
Min.		9.587		Min.		5.833	
18-35		36-55		18-35		36-55	
Mean	-2.007	Mean	-4.440	Mean	-3.281	Mean	-6.077
S.D.	6.056	S.D.	6.261	S.D.	8.892	S.D.	10.627
Max.	-7.689	Max.	-14.733	Max.	-21.544	Max.	-28.244
Min.	9.587	Min.	3.029	Min.	5.833	Min.	5.468

Summary Statistics for ΔHR Typing 2							
All Subjects							
Mean				-4.502			
S.D.				9.034			
Max.				-29.932			
Min.				20.079			
All Females				All Males			
Mean		-2.779		Mean		-6.341	
S.D.		8.387		S.D.		9.618	
Max.		-21.079		Max.		-29.932	
Min.		20.079		Min.		2.833	
18-35		36-55		18-35		36-55	
Mean	-2.848	Mean	-2.691	Mean	-6.023	Mean	-6.704
S.D.	4.765	S.D.	12.065	S.D.	9.255	S.D.	10.754
Max.	-8.657	Max.	-21.079	Max.	-23.113	Max.	-29.932
Min.	5.608	Min.	20.079	Min.	2.833	Min.	1.404

Table 18.7 and Table 18.8: Change in HR Summary Statistics for Internet 2 and Table 2

Summary Statistics for ∆HR Internet 2							
All Subjects							
Mean				-4.203			
S.D.				7.153			
Max.				-26.608			
Min.				10.695			
All Females				All Males			
Mean		-2.611		Mean		-5.902	
S.D.		5.316		S.D.		8.567	
Max.		-8.209		Max.		-26.608	
Min.		10.695		Min.		5.875	
18-35		36-55		18-35		36-55	
Mean	-1.491	Mean	-4.050	Mean	-5.666	Mean	-6.171
S.D.	6.367	S.D.	3.506	S.D.	8.246	S.D.	9.579
Max.	-7.839	Max.	-8.209	Max.	-21.387	Max.	-26.608
Min.	10.695	Min.	1.408	Min.	5.875	Min.	1.879

Summary Statistics for ∆HR Table 2							
All Subjects							
Mean				-5.560			
S.D.				7.454			
Max.				-24.338			
Min.				5.172			
All Females				All Males			
Mean		-3.403		Mean		-7.861	
S.D.		5.419		S.D.		8.752	
Max.		-11.749		Max.		-24.338	
Min.		5.172		Min.		2.127	
18-35		36-55		18-35		36-55	
Mean	-2.539	Mean	-4.515	Mean	-6.657	Mean	-9.238
S.D.	6.295	S.D.	4.243	S.D.	7.939	S.D.	10.053
Max.	-11.749	Max.	-11.081	Max.	-21.253	Max.	-24.338
Min.	5.172	Min.	1.046	Min.	0.902	Min.	2.127

19 Appendix J: Summary Statistics of Change in Respiratory Exchange Ratio (RER)

Table 19.1 and Table 19.2: Change in RER Summary Statistics for Typing 1 and Internet 1

Summary Statistics for ΔRER Typing 1							
All Subjects							
Mean				0.013			
S.D.				0.088			
Max.				-0.156			
Min.				0.253			
All Females				All Males			
Mean		0.020		Mean		0.005	
S.D.		0.109		S.D.		0.061	
Max.		-0.156		Max.		-0.083	
Min.		0.253		Min.		0.134	
18-35		36-55		18-35		36-55	
Mean	0.043	Mean	-0.009	Mean	0.033	Mean	-0.027
S.D.	0.112	S.D.	0.106	S.D.	0.066	S.D.	0.036
Max.	-0.152	Max.	-0.156	Max.	-0.052	Max.	-0.083
Min.	0.253	Min.	0.102	Min.	0.134	Min.	0.023

Summary Statistics for ΔRER Internet 1							
All Subjects							
Mean				0.009			
S.D.				0.066			
Max.				-0.147			
Min.				0.124			
All Females				All Males			
Mean		0.014		Mean		0.005	
S.D.		0.078		S.D.		0.054	
Max.		-0.147		Max.		-0.073	
Min.		0.109		Min.		0.124	
18-35		36-55		18-35		36-55	
Mean	0.008	Mean	0.021	Mean	0.022	Mean	-0.014
S.D.	0.071	S.D.	0.090	S.D.	0.063	S.D.	0.036
Max.	-0.147	Max.	-0.115	Max.	-0.073	Max.	-0.072
Min.	0.088	Min.	0.109	Min.	0.124	Min.	0.038

Table 19.3 and Table 19.4: Change in RER Summary Statistics for Table 1 and Movie 1

Summary Statistics for ΔRER Table 1							
All Subjects							
Mean				0.005			
S.D.				0.074			
Max.				-0.139			
Min.				0.124			
All Females				All Males			
Mean		0.002		Mean		0.008	
S.D.		0.090		S.D.		0.054	
Max.		-0.139		Max.		-0.063	
Min.		0.108		Min.		0.124	
18-35		36-55		18-35		36-55	
Mean	-0.017	Mean	0.027	Mean	0.030	Mean	-0.018
S.D.	0.093	S.D.	0.086	S.D.	0.060	S.D.	0.035
Max.	-0.139	Max.	-0.099	Max.	-0.055	Max.	-0.063
Min.	0.102	Min.	0.108	Min.	0.124	Min.	0.031

Summary Statistics for ΔRER Movie 1							
All Subjects							
Mean				0.004			
S.D.				0.084			
Max.				-0.251			
Min.				0.150			
All Females				All Males			
Mean		-0.006		Mean		0.014	
S.D.		0.103		S.D.		0.058	
Max.		-0.251		Max.		-0.094	
Min.		0.123		Min.		0.150	
18-35		36-55		18-35		36-55	
Mean	-0.017	Mean	0.008	Mean	0.028	Mean	-0.001
S.D.	0.115	S.D.	0.093	S.D.	0.063	S.D.	0.051
Max.	-0.251	Max.	-0.114	Max.	-0.057	Max.	-0.094
Min.	0.099	Min.	0.123	Min.	0.150	Min.	0.058

Table 19.5 and Table 19.6: Change in RER Summary Statistics for Movie 2 and Typing 2

Summary Statistics for ΔRER Movie 2							
All Subjects							
Mean				0.007			
S.D.				0.063			
Max.				-0.113			
Min.				0.128			
All Females				All Males			
Mean		-0.001		Mean		0.015	
S.D.		0.071		S.D.		0.055	
Max.		-0.113		Max.		-0.108	
Min.		0.103		Min.		0.128	
18-35		36-55		18-35		36-55	
Mean	-0.003	Mean	0.003	Mean	0.031	Mean	-0.004
S.D.	0.064	S.D.	0.085	S.D.	0.055	S.D.	0.052
Max.	-0.108	Max.	-0.113	Max.	-0.042	Max.	-0.108
Min.	0.086	Min.	0.103	Min.	0.128	Min.	0.043

Summary Statistics for ΔRER Typing 2							
All Subjects							
Mean				0.003			
S.D.				0.084			
Max.				-0.189			
Min.				0.163			
All Females				All Males			
Mean		0.003		Mean		0.002	
S.D.		0.100		S.D.		0.066	
Max.		-0.189		Max.		-0.092	
Min.		0.145		Min.		0.163	
18-35		36-55		18-35		36-55	
Mean	-0.006	Mean	0.015	Mean	0.016	Mean	-0.015
S.D.	0.098	S.D.	0.110	S.D.	0.083	S.D.	0.040
Max.	-0.189	Max.	-0.137	Max.	-0.092	Max.	-0.082
Min.	0.102	Min.	0.145	Min.	0.163	Min.	0.028

Table 19.7 and Table 19.8: Change in RER Summary Statistics for Internet 2 and Table 2

Summary Statistics for ΔRER Internet 2							
All Subjects							
Mean				0.006			
S.D.				0.074			
Max.				-0.140			
Min.				0.187			
All Females				All Males			
Mean		0.002		Mean		0.010	
S.D.		0.094		S.D.		0.048	
Max.		-0.140		Max.		-0.066	
Min.		0.187		Min.		0.129	
18-35		36-55		18-35		36-55	
Mean	-0.002	Mean	0.006	Mean	0.020	Mean	-0.002
S.D.	0.077	S.D.	0.118	S.D.	0.056	S.D.	0.039
Max.	-0.123	Max.	-0.140	Max.	-0.043	Max.	-0.066
Min.	0.089	Min.	0.187	Min.	0.129	Min.	0.048

Summary Statistics for ΔRER Table 2							
All Subjects							
Mean				0.003			
S.D.				0.080			
Max.				-0.210			
Min.				0.177			
All Females				All Males			
Mean		-0.006		Mean		0.013	
S.D.		0.098		S.D.		0.056	
Max.		-0.210		Max.		-0.077	
Min.		0.177		Min.		0.150	
18-35		36-55		18-35		36-55	
Mean	-0.019	Mean	0.011	Mean	0.026	Mean	-0.002
S.D.	0.093	S.D.	0.109	S.D.	0.072	S.D.	0.028
Max.	-0.210	Max.	-0.127	Max.	-0.077	Max.	-0.050
Min.	0.070	Min.	0.177	Min.	0.150	Min.	0.031

20 Appendix K: Summary Statistics of Change of Respiratory Rate (RR)

Table 20.1 and Table 20.2: Change in RR Summary Statistics for Typing 1 and Internet 1

Summary Statistics for ΔRR Typing 1							
All Subjects							
Mean				-0.657			
S.D.				1.540			
Max.				-3.862			
Min.				3.192			
All Females				All Males			
Mean		-0.225		Mean		-1.118	
S.D.		1.204		S.D.		1.758	
Max.		-2.624		Max.		-3.862	
Min.		2.497		Min.		3.192	
18-35		36-55		18-35		36-55	
Mean	-0.024	Mean	-0.484	Mean	-1.119	Mean	-1.118
S.D.	1.513	S.D.	0.659	S.D.	1.320	S.D.	2.275
Max.	-2.624	Max.	-1.559	Max.	-3.535	Max.	-3.862
Min.	2.497	Min.	0.288	Min.	0.492	Min.	3.192

Summary Statistics for ΔRR Internet 1							
All Subjects							
Mean				-0.004			
S.D.				2.044			
Max.				-3.037			
Min.				5.320			
All Females				All Males			
Mean		0.690		Mean		-0.744	
S.D.		2.123		S.D.		1.728	
Max.		-1.969		Max.		-3.037	
Min.		5.320		Min.		2.914	
18-35		36-55		18-35		36-55	
Mean	1.210	Mean	0.023	Mean	-0.786	Mean	-0.696
S.D.	2.456	S.D.	1.516	S.D.	1.173	S.D.	2.315
Max.	-1.729	Max.	-1.969	Max.	-2.014	Max.	-3.037
Min.	5.320	Min.	2.567	Min.	1.245	Min.	2.914

Table 20.3 and Table 20.4: Change in RR Summary Statistics for Table 1 and Movie 1

Summary Statistics for ΔRR Table 1							
All Subjects							
Mean				-0.416			
S.D.				1.840			
Max.				-5.407			
Min.				2.634			
All Females				All Males			
Mean		0.025		Mean		-0.887	
S.D.		1.664		S.D.		1.957	
Max.		-2.580		Max.		-5.407	
Min.		2.634		Min.		1.957	
18-35		36-55		18-35		36-55	
Mean	0.206	Mean	-0.208	Mean	-0.749	Mean	-1.045
S.D.	1.847	S.D.	1.504	S.D.	1.472	S.D.	2.520
Max.	-2.087	Max.	-2.580	Max.	-2.940	Max.	-5.407
Min.	2.634	Min.	1.785	Min.	1.701	Min.	1.957

Summary Statistics for ΔRR Movie 1							
All Subjects							
Mean				0.063			
S.D.				1.977			
Max.				-6.985			
Min.				2.972			
All Females				All Males			
Mean		0.408		Mean		-0.305	
S.D.		1.535		S.D.		2.360	
Max.		-2.479		Max.		-6.985	
Min.		2.972		Min.		2.797	
18-35		36-55		18-35		36-55	
Mean	1.045	Mean	-0.410	Mean	-0.683	Mean	0.127
S.D.	1.300	S.D.	1.499	S.D.	2.871	S.D.	1.722
Max.	-0.631	Max.	-2.479	Max.	-6.985	Max.	-1.785
Min.	2.972	Min.	1.903	Min.	2.113	Min.	2.797

Table 20.5 and Table 20.6: Change in RR Summary Statistics for Movie 2 and Typing 2

Summary Statistics for ΔRR Movie 2							
All Subjects							
Mean				0.072			
S.D.				2.378			
Max.				-7.908			
Min.				7.027			
All Females				All Males			
Mean		0.495		Mean		-0.379	
S.D.		2.255		S.D.		2.500	
Max.		-2.915		Max.		-7.908	
Min.		7.027		Min.		2.191	
18-35		36-55		18-35		36-55	
Mean	0.982	Mean	-0.130	Mean	-0.904	Mean	0.221
S.D.	2.953	S.D.	0.526	S.D.	3.223	S.D.	1.293
Max.	-2.915	Max.	-0.964	Max.	-7.908	Max.	-1.569
Min.	7.027	Min.	0.714	Min.	1.766	Min.	2.191

Summary Statistics for ΔRR Typing 2							
All Subjects							
Mean				-0.444			
S.D.				1.808			
Max.				-3.304			
Min.				5.245			
All Females				All Males			
Mean		-0.167		Mean		-0.740	
S.D.		2.063		S.D.		1.503	
Max.		-2.589		Max.		-3.304	
Min.		5.245		Min.		1.634	
18-35		36-55		18-35		36-55	
Mean	-0.188	Mean	-0.139	Mean	-0.799	Mean	-0.674
S.D.	2.425	S.D.	1.673	S.D.	1.313	S.D.	1.803
Max.	-2.589	Max.	-2.084	Max.	-3.304	Max.	-3.224
Min.	5.245	Min.	3.095	Min.	1.175	Min.	1.634

Table 20.7 and Table 20.8: Change in RR Summary Statistics for Internet 2 and Table 2

Summary Statistics for ΔRR Internet 2							
All Subjects							
Mean				-0.516			
S.D.				1.874			
Max.				-6.271			
Min.				2.441			
All Females				All Males			
Mean		-0.130		Mean		-0.927	
S.D.		1.586		S.D.		2.115	
Max.		-2.793		Max.		-6.271	
Min.		2.441		Min.		1.346	
18-35		36-55		18-35		36-55	
Mean	-0.218	Mean	-0.016	Mean	-1.085	Mean	-0.747
S.D.	1.613	S.D.	1.672	S.D.	2.276	S.D.	2.081
Max.	-2.793	Max.	-1.850	Max.	-6.271	Max.	-5.047
Min.	1.898	Min.	2.441	Min.	0.629	Min.	1.346

Summary Statistics for ΔRR Table 2							
All Subjects							
Mean				-0.533			
S.D.				1.768			
Max.				-6.877			
Min.				2.383			
All Females				All Males			
Mean		-0.038		Mean		-1.061	
S.D.		1.522		S.D.		1.908	
Max.		-2.042		Max.		-6.877	
Min.		2.383		Min.		1.580	
18-35		36-55		18-35		36-55	
Mean	0.124	Mean	-0.247	Mean	-1.541	Mean	-0.512
S.D.	1.893	S.D.	0.961	S.D.	2.244	S.D.	1.399
Max.	-2.042	Max.	-1.387	Max.	-6.877	Max.	-2.282
Min.	2.383	Min.	0.897	Min.	0.071	Min.	1.580

21 Appendix L: Summary Statistics of Change in CO2

Table 21.1 and Table 21.2: Change in CO2 Summary Statistics for Typing 1 and Internet 1

Summary Statistics for ΔCO2 Typing 1							
All Subjects							
Mean				-0.053			
S.D.				0.567			
Max.				-1.528			
Min.				1.037			
All Females				All Males			
Mean		-0.0984		Mean		-0.0039	
S.D.		0.7182		S.D.		0.3628	
Max.		-1.5283		Max.		-0.6005	
Min.		1.0375		Min.		0.7944	
18-35		36-55		18-35		36-55	
Mean	-0.2570	Mean	0.1056	Mean	-0.1291	Mean	0.1392
S.D.	0.7363	S.D.	0.6930	S.D.	0.2947	S.D.	0.4012
Max.	-1.5283	Max.	-1.0077	Max.	-0.6005	Max.	-0.4012
Min.	0.9399	Min.	1.0375	Min.	0.2918	Min.	0.7944

Summary Statistics for ΔCO2 Internet 1							
All Subjects							
Mean				-0.022			
S.D.				0.466			
Max.				-1.113			
Min.				0.937			
All Females				All Males			
Mean		-0.0697		Mean		0.0285	
S.D.		0.5702		S.D.		0.3334	
Max.		-1.1132		Max.		-0.8366	
Min.		0.9366		Min.		0.5526	
18-35		36-55		18-35		36-55	
Mean	-0.1403	Mean	0.0210	Mean	-0.0365	Mean	0.1027
S.D.	0.5794	S.D.	0.5900	S.D.	0.3986	S.D.	0.2490
Max.	-1.1132	Max.	-0.9196	Max.	-0.8366	Max.	-0.1614
Min.	0.6291	Min.	0.9366	Min.	0.5526	Min.	0.5163

Table 21.3 and Table 21.4: Change in CO2 Summary Statistics for Table 1 and Movie 1

Summary Statistics for ΔCO_2 Table 1							
All Subjects							
Mean				-0.022			
S.D.				0.437			
Max.				-1.191			
Min.				0.663			
All Females				All Males			
Mean		-0.0957		Mean		0.0572	
S.D.		0.5448		S.D.		0.2793	
Max.		-1.1914		Max.		-0.5231	
Min.		0.6630		Min.		0.5095	
18-35		36-55		18-35		36-55	
Mean	-0.1418	Mean	0.4166	Mean	0.0036	Mean	0.1690
S.D.	0.5780	S.D.	0.2369	S.D.	0.0250	S.D.	0.2423
Max.	-1.1914	Max.	-0.5231	Max.	-0.0361	Max.	-0.1241
Min.	0.6630	Min.	0.2667	Min.	0.0365	Min.	0.5095

Summary Statistics for ΔCO_2 Movie 1							
All Subjects							
Mean				-0.026			
S.D.				0.413			
Max.				-0.729			
Min.				0.694			
All Females				All Males			
Mean		0.0104		Mean		-0.0651	
S.D.		0.4744		S.D.		0.3472	
Max.		-0.6889		Max.		-0.7294	
Min.		0.6936		Min.		0.5000	
18-35		36-55		18-35		36-55	
Mean	0.0115	Mean	0.0089	Mean	-0.0983	Mean	-0.0271
S.D.	0.4593	S.D.	0.5304	S.D.	0.4225	S.D.	0.2641
Max.	-0.6889	Max.	-0.4791	Max.	-0.7294	Max.	-0.4921
Min.	0.6936	Min.	0.6577	Min.	0.5000	Min.	0.2877

Table 21.5 and Table 21.6: Change in CO2 Summary Statistics for Movie 2 and Typing 2

Summary Statistics for ΔCO2 Movie 2							
All Subjects							
Mean				-0.059			
S.D.				0.547			
Max.				-1.441			
Min.				1.141			
All Females				All Males			
Mean		-0.0093		Mean		-0.1025	
S.D.		0.6685		S.D.		0.3233	
Max.		-1.4408		Max.		-0.8572	
Min.		1.1414		Min.		0.3075	
18-35		36-55		18-35		36-55	
Mean	-0.1003	Mean	0.1077	Mean	-0.1695	Mean	-0.0260
S.D.	0.6610	S.D.	0.7116	S.D.	0.3450	S.D.	0.3038
Max.	-1.4408	Max.	-0.7105	Max.	-0.8572	Max.	-0.5718
Min.	0.7602	Min.	1.1414	Min.	0.2772	Min.	0.3075

Summary Statistics for ΔCO2 Typing 2							
All Subjects							
Mean				-0.010			
S.D.				0.380			
Max.				-0.810			
Min.				0.700			
All Females				All Males			
Mean		0.0009		Mean		-0.0224	
S.D.		0.4880		S.D.		0.2310	
Max.		-0.8105		Max.		-0.4764	
Min.		0.6997		Min.		0.3389	
18-35		36-55		18-35		36-55	
Mean	0.0211	Mean	-0.0251	Mean	-0.0513	Mean	0.0105
S.D.	0.4564	S.D.	0.5624	S.D.	0.2824	S.D.	0.1704
Max.	-0.7699	Max.	-0.8105	Max.	-0.4764	Max.	-0.2217
Min.	0.6145	Min.	0.6997	Min.	0.2843	Min.	0.3389

Table 21.7 and Table 21.8: Change in CO2 Summary Statistics for Internet 2 and Table 2

Summary Statistics for ΔCO2 Internet 2							
All Subjects							
Mean				-0.045			
S.D.				0.372			
Max.				-0.709			
Min.				1.065			
All Females				All Males			
Mean		-0.0537		Mean		-0.0361	
S.D.		0.4761		S.D.		0.2300	
Max.		-0.7090		Max.		-0.4806	
Min.		1.0648		Min.		0.3109	
18-35		36-55		18-35		36-55	
Mean	-0.0535	Mean	-0.0541	Mean	-0.0392	Mean	-0.0326
S.D.	0.3799	S.D.	0.6118	S.D.	0.2924	S.D.	0.1537
Max.	-0.7090	Max.	-0.6340	Max.	-0.4806	Max.	-0.1758
Min.	0.5758	Min.	1.0648	Min.	0.3109	Min.	0.1689

Summary Statistics for ΔCO2 Table 2							
All Subjects							
Mean				0.103			
S.D.				0.345			
Max.				-0.521			
Min.				0.754			
All Females				All Males			
Mean		0.1221		Mean		0.1293	
S.D.		0.3850		S.D.		0.3793	
Max.		-0.5213		Max.		-0.4280	
Min.		0.7538		Min.		1.0824	
18-35		36-55		18-35		36-55	
Mean	0.0566	Mean	0.2063	Mean	0.1006	Mean	0.1621
S.D.	0.3301	S.D.	0.4589	S.D.	0.3642	S.D.	0.4226
Max.	-0.5213	Max.	-0.4245	Max.	-0.4280	Max.	-0.1909
Min.	0.4261	Min.	0.7538	Min.	0.5319	Min.	1.0824

22 Appendix M: Summary Statistics of Change in Relative Uptake of O_2

Table 22.1 and Table 22.2: Change in O2 Summary Statistics for Typing 1 and Internet 1

Summary Statistics for ∆O2 Typing 1							
All Subjects							
Mean				0.0029			
S.D.				0.5027			
Max.				-0.8632			
Min.				1.5365			
All Females				All Males			
Mean		0.0735		Mean		-0.0724	
S.D.		0.6499		S.D.		0.2777	
Max.		-0.8632		Max.		-0.5896	
Min.		1.5365		Min.		0.5630	
18-35		36-55		18-35		36-55	
Mean	0.2078	Mean	-0.0991	Mean	-0.0689	Mean	-0.0765
S.D.	0.7675	S.D.	0.4570	S.D.	0.1915	S.D.	0.3703
Max.	-0.8632	Max.	-0.5665	Max.	-0.3261	Max.	-0.5896
Min.	1.5365	Min.	0.5778	Min.	0.3269	Min.	0.5630

Summary Statistics for ∆O2 Internet 1							
All Subjects							
Mean				-0.0086			
S.D.				0.3736			
Max.				-0.5892			
Min.				1.2487			
All Females				All Males			
Mean		0.0300		Mean		-0.0497	
S.D.		0.4699		S.D.		0.2428	
Max.		-0.5892		Max.		-0.3184	
Min.		1.2487		Min.		0.3675	
18-35		36-55		18-35		36-55	
Mean	0.1578	Mean	-0.1343	Mean	-0.0369	Mean	-0.0643
S.D.	0.5416	S.D.	0.3241	S.D.	0.2657	S.D.	0.2339
Max.	-0.4843	Max.	-0.5892	Max.	-0.3184	Max.	-0.3026
Min.	1.2487	Min.	0.3952	Min.	0.3144	Min.	0.3675

Table 22.3 and Table 22.4: Change in O2 Summary Statistics for Table 1 and Movie 1

Summary Statistics for ΔO2 Table 1							
All Subjects							
Mean				-0.0427			
S.D.				0.3352			
Max.				-0.6188			
Min.				0.6863			
All Females				All Males			
Mean		0.0241		Mean		-0.1138	
S.D.		0.4173		S.D.		0.2090	
Max.		-0.5512		Max.		-0.6188	
Min.		0.6863		Min.		0.1879	
18-35		36-55		18-35		36-55	
Mean	0.1350	Mean	-0.1185	Mean	-0.1097	Mean	-0.1186
S.D.	0.4507	S.D.	0.3496	S.D.	0.1365	S.D.	0.2830
Max.	-0.5512	Max.	-0.5069	Max.	-0.2306	Max.	-0.6188
Min.	0.6863	Min.	0.3042	Min.	0.1848	Min.	0.1879

Summary Statistics for ΔO2 Movie 1							
All Subjects							
Mean				-0.0005			
S.D.				0.4003			
Max.				-1.1852			
Min.				0.6806			
All Females				All Males			
Mean		0.0339		Mean		-0.0372	
S.D.		0.4085		S.D.		0.4024	
Max.		-0.8373		Max.		-1.1852	
Min.		0.6806		Min.		0.6667	
18-35		36-55		18-35		36-55	
Mean	0.0643	Mean	-0.0053	Mean	-0.0956	Mean	0.0296
S.D.	0.4343	S.D.	0.4030	S.D.	0.5196	S.D.	0.2301
Max.	-0.8373	Max.	-0.7585	Max.	-1.1852	Max.	-0.2865
Min.	0.6806	Min.	0.4559	Min.	0.6667	Min.	0.4350

Table 22.5 and Table 22.6: Change in O2 Summary Statistics for Movie 2 and Typing 2

Summary Statistics for ΔO2 Movie 2							
All Subjects							
Mean				0.0148			
S.D.				0.4335			
Max.				-0.8332			
Min.				1.4848			
All Females				All Males			
Mean		-0.0156		Mean		0.0471	
S.D.		0.5766		S.D.		0.2104	
Max.		-0.8332		Max.		-0.3077	
Min.		1.4848		Min.		0.4710	
18-35		36-55		18-35		36-55	
Mean	0.0813	Mean	-0.1401	Mean	0.0461	Mean	0.0483
S.D.	0.6463	S.D.	0.4921	S.D.	0.1736	S.D.	0.2609
Max.	-0.6667	Max.	-0.8332	Max.	-0.3077	Max.	-0.2703
Min.	1.4848	Min.	0.5481	Min.	0.2289	Min.	0.4710

Summary Statistics for ΔO2 Typing 2							
All Subjects							
Mean				-0.0601			
S.D.				0.4008			
Max.				-0.8113			
Min.				1.1548			
All Females				All Males			
Mean		-0.1014		Mean		-0.0160	
S.D.		0.3727		S.D.		0.4373	
Max.		-0.6864		Max.		-0.8113	
Min.		0.5573		Min.		1.1548	
18-35		36-55		18-35		36-55	
Mean	-0.1250	Mean	-0.0711	Mean	-0.0245	Mean	-0.0063
S.D.	0.4418	S.D.	0.2918	S.D.	0.5827	S.D.	0.2235
Max.	-0.6864	Max.	-0.3809	Max.	-0.8113	Max.	-0.1685
Min.	0.5573	Min.	0.4062	Min.	1.1548	Min.	0.4218

Table 22.7 and Table 22.8: Change in O2 Summary Statistics for Internet 2 and Table 2

Summary Statistics for ΔO2 Internet 2							
All Subjects							
Mean				-0.0158			
S.D.				0.2548			
Max.				-0.5963			
Min.				0.3490			
All Females				All Males			
Mean		0.0083		Mean		-0.0417	
S.D.		0.2727		S.D.		0.2410	
Max.		-0.5963		Max.		-0.5576	
Min.		0.3490		Min.		0.2536	
18-35		36-55		18-35		36-55	
Mean	-0.0106	Mean	0.0327	Mean	-0.1141	Mean	0.0411
S.D.	0.2561	S.D.	0.3117	S.D.	0.2781	S.D.	0.1741
Max.	-0.5651	Max.	-0.5963	Max.	-0.5576	Max.	-0.2858
Min.	0.2546	Min.	0.3490	Min.	0.2199	Min.	0.2536

Summary Statistics for ΔO2 Table 2							
All Subjects							
Mean				-0.2029			
S.D.				0.3205			
Max.				-1.0215			
Min.				0.3088			
All Females				All Males			
Mean		-0.1677		Mean		-0.2405	
S.D.		0.2724		S.D.		0.3711	
Max.		-0.5919		Max.		-1.0215	
Min.		0.3088		Min.		0.2141	
18-35		36-55		18-35		36-55	
Mean	-0.0676	Mean	-0.2963	Mean	-0.3270	Mean	-0.1417
S.D.	0.3122	S.D.	0.1457	S.D.	0.3312	S.D.	0.4148
Max.	-0.5100	Max.	-0.5919	Max.	-0.9821	Max.	-1.0215
Min.	0.3088	Min.	-0.1844	Min.	0.1157	Min.	0.2141

23 Appendix N: Summary Statistics of Change in Tidal Volume (TV)

Table 23.1 and Table 23.2: Change in TV Summary Statistics for Typing 1 and Internet 1

Summary Statistics for ΔTV Typing 1							
All Subjects							
Mean				0.0135			
S.D.				0.0780			
Max.				-0.1463			
Min.				0.1540			
All Females				All Males			
Mean		-0.0110		Mean		0.0396	
S.D.		0.0834		S.D.		0.0646	
Max.		-0.1463		Max.		-0.0488	
Min.		0.1533		Min.		0.1540	
18-35		36-55		18-35		36-55	
Mean	-0.0038	Mean	-0.0202	Mean	0.0609	Mean	0.0152
S.D.	0.0903	S.D.	0.0797	S.D.	0.0703	S.D.	0.0517
Max.	-0.1463	Max.	-0.0980	Max.	-0.0289	Max.	-0.0488
Min.	0.1533	Min.	0.1165	Min.	0.1540	Min.	0.1091

Summary Statistics for ΔTV Internet 1							
All Subjects							
Mean				-0.0081			
S.D.				0.0718			
Max.				-0.1738			
Min.				0.1088			
All Females				All Males			
Mean		-0.0324		Mean		0.0180	
S.D.		0.0765		S.D.		0.0581	
Max.		-0.1738		Max.		-0.0966	
Min.		0.1088		Min.		0.1025	
18-35		36-55		18-35		36-55	
Mean	-0.0402	Mean	-0.0224	Mean	0.0346	Mean	-0.0011
S.D.	0.0899	S.D.	0.0606	S.D.	0.0602	S.D.	0.0534
Max.	-0.1738	Max.	-0.1075	Max.	-0.0768	Max.	-0.0966
Min.	0.1088	Min.	0.0769	Min.	0.1025	Min.	0.0694

Table 23.3 and Table 23.4: Change in TV Summary Statistics for Table 1 and Movie 1

Summary Statistics for ΔTV Table 1							
All Subjects							
Mean				0.0039			
S.D.				0.0726			
Max.				-0.1523			
Min.				0.1262			
All Females				All Males			
Mean		-0.0037		Mean		0.0120	
S.D.		0.0793		S.D.		0.0664	
Max.		-0.1523		Max.		-0.1247	
Min.		0.1262		Min.		0.1072	
18-35		36-55		18-35		36-55	
Mean	0.0070	Mean	-0.0174	Mean	0.0309	Mean	-0.0097
S.D.	0.0909	S.D.	0.0658	S.D.	0.0764	S.D.	0.0496
Max.	-0.1523	Max.	-0.1214	Max.	-0.1247	Max.	-0.0848
Min.	0.1262	Min.	0.0604	Min.	0.1072	Min.	0.0550

Summary Statistics for ΔTV Movie 1							
All Subjects							
Mean				0.0041			
S.D.				0.1073			
Max.				-0.2829			
Min.				0.2882			
All Females				All Males			
Mean		-0.0307		Mean		0.0412	
S.D.		0.1063		S.D.		0.0986	
Max.		-0.2829		Max.		-0.0356	
Min.		0.1653		Min.		0.2882	
18-35		36-55		18-35		36-55	
Mean	-0.0513	Mean	-0.0043	Mean	0.0685	Mean	0.0101
S.D.	0.1255	S.D.	0.0762	S.D.	0.1292	S.D.	0.0329
Max.	-0.2829	Max.	-0.1514	Max.	-0.0356	Max.	-0.0326
Min.	0.1653	Min.	0.0991	Min.	0.2882	Min.	0.0608

Table 23.5 and Table 23.6: Change in TV Summary Statistics for Movie 2 and Typing 2

Summary Statistics for ΔTV Movie 2							
All Subjects							
Mean				-0.0010			
S.D.				0.1383			
Max.				-0.2628			
Min.				0.4786			
All Females				All Males			
Mean		-0.0410		Mean		0.0416	
S.D.		0.1310		S.D.		0.1373	
Max.		-0.2628		Max.		-0.1145	
Min.		0.2849		Min.		0.4786	
18-35		36-55		18-35		36-55	
Mean	-0.0477	Mean	-0.0325	Mean	0.0945	Mean	-0.0188
S.D.	0.1587	S.D.	0.0957	S.D.	0.1634	S.D.	0.0696
Max.	-0.2628	Max.	-0.1925	Max.	-0.0150	Max.	-0.1145
Min.	0.2849	Min.	0.0863	Min.	0.4786	Min.	0.0755

Summary Statistics for ΔTV Typing 2							
All Subjects							
Mean				0.0196			
S.D.				0.0859			
Max.				-0.1481			
Min.				0.3486			
All Females				All Males			
Mean		0.0047		Mean		0.0354	
S.D.		0.0663		S.D.		0.1028	
Max.		-0.1481		Max.		-0.0542	
Min.		0.1149		Min.		0.3486	
18-35		36-55		18-35		36-55	
Mean	0.0069	Mean	0.0019	Mean	0.0494	Mean	0.0194
S.D.	0.0472	S.D.	0.0894	S.D.	0.1357	S.D.	0.0513
Max.	-0.0373	Max.	-0.1481	Max.	-0.0539	Max.	-0.0542
Min.	0.0855	Min.	0.1149	Min.	0.3486	Min.	0.0791

Table 23.7 and Table 23.8: Change in TV Summary Statistics for Internet 2 and Table 2

Summary Statistics for ΔTV Internet 2							
All Subjects							
Mean				0.0207			
S.D.				0.0873			
Max.				-0.0979			
Min.				0.3495			
All Females				All Males			
Mean		0.0044		Mean		0.0382	
S.D.		0.0718		S.D.		0.1009	
Max.		-0.0979		Max.		-0.0364	
Min.		0.1397		Min.		0.3495	
18-35		36-55		18-35		36-55	
Mean	0.0007	Mean	0.0092	Mean	0.0490	Mean	0.0258
S.D.	0.0629	S.D.	0.0870	S.D.	0.1340	S.D.	0.0495
Max.	-0.0804	Max.	-0.0979	Max.	-0.0364	Max.	-0.0276
Min.	0.1278	Min.	0.1397	Min.	0.3495	Min.	0.1239

Summary Statistics for ΔTV Table 2							
All Subjects							
Mean				0.0066			
S.D.				0.0827			
Max.				-0.1582			
Min.				0.3010			
All Females				All Males			
Mean		-0.0197		Mean		0.0347	
S.D.		0.0662		S.D.		0.0913	
Max.		-0.1582		Max.		-0.1236	
Min.		0.1164		Min.		0.3010	
18-35		36-55		18-35		36-55	
Mean	-0.0162	Mean	-0.0242	Mean	0.0493	Mean	0.0179
S.D.	0.0740	S.D.	0.0601	S.D.	0.1256	S.D.	0.0212
Max.	-0.1582	Max.	-0.1132	Max.	-0.1236	Max.	-0.0182
Min.	0.1164	Min.	0.0565	Min.	0.3010	Min.	0.0431

24 Appendix O: Summary Statistics of Movie 2 Task

Table 24.1 and Table 24.2: HR Summary Statistics for Movie 2 in Blue Chair and Black Chair

Summary Statistics for HR Movie 2 Blue Chair							
All Subjects							
Mean				69.477			
S.D.				10.148			
Min				52.886			
Max				91.281			
All Females				All Males			
Mean		71.097		Mean		67.749	
S.D.		10.155		S.D.		10.198	
Min.		54.396		Min.		52.886	
Max.		90.217		Max.		91.281	
18-35		36-55		18-35		36-55	
Mean	71.878	Mean	70.092	Mean	66.259	Mean	69.452
S.D.	10.015	S.D.	11.045	S.D.	8.140	S.D.	12.610
Min.	54.396	Min.	61.000	Min.	52.886	Min.	54.018
Max.	88.163	Max.	90.217	Max.	76.152	Max.	91.281

Summary Statistics for HR Movie 2 Black Chair							
All Subjects							
Mean				73.281			
S.D.				11.709			
Min				51.865			
Max				94.981			
All Females				All Males			
Mean		74.168		Mean		72.335	
S.D.		10.359		S.D.		13.302	
Min.		55.313		Min.		51.865	
Max.		94.981		Max.		94.831	
18-35		36-55		18-35		36-55	
Mean	73.886	Mean	74.532	Mean	69.539	Mean	75.529
S.D.	9.330	S.D.	12.327	S.D.	11.422	S.D.	15.439
Min.	55.313	Min.	59.556	Min.	56.622	Min.	51.865
Max.	88.871	Max.	94.981	Max.	93.250	Max.	94.831

Table 24.3 and Table 24.4: RER Summary Statistics for Movie 2 in Blue Chair and Black Chair

Summary Statistics for RER Movie 2 Blue Chair							
All Subjects							
Mean				0.821			
S.D.				0.049			
Min				0.726			
Max				0.935			
All Females				All Males			
Mean		0.803		Mean		0.841	
S.D.		0.048		S.D.		0.044	
Min.		0.726		Min.		0.751	
Max.		0.909		Max.		0.935	
18-35		36-55		18-35		36-55	
Mean	0.820	Mean	0.782	Mean	0.838	Mean	0.844
S.D.	0.053	S.D.	0.033	S.D.	0.025	S.D.	0.062
Min.	0.726	Min.	0.742	Min.	0.801	Min.	0.751
Max.	0.909	Max.	0.824	Max.	0.866	Max.	0.935

Summary Statistics for RER Movie 2 Black Chair							
All Subjects							
Mean				0.815			
S.D.				0.060			
Min				0.654			
Max				0.910			
All Females				All Males			
Mean		0.804		Mean		0.826	
S.D.		0.067		S.D.		0.051	
Min.		0.654		Min.		0.693	
Max.		0.910		Max.		0.902	
18-35		36-55		18-35		36-55	
Mean	0.823	Mean	0.779	Mean	0.807	Mean	0.847
S.D.	0.056	S.D.	0.075	S.D.	0.061	S.D.	0.029
Min.	0.737	Min.	0.654	Min.	0.693	Min.	0.819
Max.	0.910	Max.	0.886	Max.	0.873	Max.	0.902

Table 24.5 and Table 24.6: RR Summary Statistics for Movie 2 in Blue Chair and Black Chair

Summary Statistics for RR Movie 2 Blue Chair							
All Subjects							
Mean				16.544			
S.D.				3.020			
Min				8.188			
Max				23.175			
All Females				All Males			
Mean		17.068		Mean		15.984	
S.D.		2.737		S.D.		3.296	
Min.		12.640		Min.		8.188	
Max.		23.175		Max.		20.260	
18-35		36-55		18-35		36-55	
Mean	16.791	Mean	17.424	Mean	14.468	Mean	17.717
S.D.	3.149	S.D.	2.289	S.D.	3.152	S.D.	2.680
Min.	12.640	Min.	14.954	Min.	8.188	Min.	12.691
Max.	23.175	Max.	21.672	Max.	18.858	Max.	20.260

Summary Statistics for RR Movie 2 Black Chair							
All Subjects							
Mean				16.471			
S.D.				2.544			
Min				11.184			
Max				20.959			
All Females				All Males			
Mean		16.573		Mean		16.363	
S.D.		2.817		S.D.		2.312	
Min.		11.184		Min.		12.200	
Max.		20.959		Max.		20.156	
18-35		36-55		18-35		36-55	
Mean	15.809	Mean	17.554	Mean	15.372	Mean	17.497
S.D.	3.207	S.D.	2.033	S.D.	1.037	S.D.	2.900
Min.	11.184	Min.	15.094	Min.	14.607	Min.	12.200
Max.	19.946	Max.	20.959	Max.	17.581	Max.	20.156

Table 24.7 and Table 24.8: CO_2 Summary Statistics for Movie 2 in Blue Chair and Black Chair

Summary Statistics for CO2 Movie 2 Blue Chair							
All Subjects							
Mean				2.9174			
S.D.				0.7764			
Min				1.7567			
Max				4.6323			
All Females				All Males			
Mean		2.9381		Mean		2.8952	
S.D.		0.8099		S.D.		0.7668	
Min.		1.7567		Min.		1.8111	
Max.		4.6323		Max.		4.1962	
18-35		36-55		18-35		36-55	
Mean	3.1021	Mean	2.7274	Mean	2.7986	Mean	3.0056
S.D.	0.6216	S.D.	1.0162	S.D.	0.7281	S.D.	0.8526
Min.	2.3183	Min.	1.7567	Min.	2.0011	Min.	1.8111
Max.	4.0282	Max.	4.6323	Max.	3.8138	Max.	4.1962

Summary Statistics for CO2 Movie 2 Black Chair							
All Subjects							
Mean				2.863			
S.D.				0.818			
Min				1.735			
Max				5.209			
All Females				All Males			
Mean		1.7587		Mean		2.7927	
S.D.		1.6326		S.D.		0.6976	
Min.		0.1702		Min.		1.7352	
Max.		5.2092		Max.		4.3692	
18-35		36-55		18-35		36-55	
Mean	2.9586	Mean	0.2161	Mean	2.6291	Mean	2.9797
S.D.	1.1377	S.D.	0.0420	S.D.	0.6096	S.D.	0.7908
Min.	1.8060	Min.	0.1702	Min.	1.7352	Min.	1.9607
Max.	5.2092	Max.	0.2798	Max.	3.4608	Max.	4.3692

Table 24.9 and Table 24.10: O2Summary Statistics for Movie 2 in Blue Chair and Black Chair

Summary Statistics for O2 Movie 2 Blue Chair							
All Subjects							
Mean				3.479			
S.D.				0.676			
Min				2.304			
Max				5.412			
All Females				All Males			
Mean		3.547		Mean		3.407	
S.D.		0.545		S.D.		0.806	
Min.		2.780		Min.		2.304	
Max.		4.739		Max.		5.412	
18-35		36-55		18-35		36-55	
Mean	3.756	Mean	3.278	Mean	3.454	Mean	3.353
S.D.	0.583	S.D.	0.373	S.D.	1.010	S.D.	0.565
Min.	2.781	Min.	2.780	Min.	2.304	Min.	2.596
Max.	4.739	Max.	3.857	Max.	5.412	Max.	4.174

Summary Statistics for O2 Movie 2 Black Chair							
All Subjects							
Mean				3.464			
S.D.				0.730			
Min				2.273			
Max				5.333			
All Females				All Males			
Mean		3.563		Mean		3.360	
S.D.		0.752		S.D.		0.717	
Min.		2.536		Min.		2.273	
Max.		5.333		Max.		5.208	
18-35		36-55		18-35		36-55	
Mean	3.675	Mean	3.419	Mean	3.407	Mean	3.305
S.D.	0.928	S.D.	0.470	S.D.	0.915	S.D.	0.463
Min.	2.536	Min.	2.816	Min.	2.273	Min.	2.711
Max.	5.333	Max.	4.224	Max.	5.208	Max.	3.911

Table 24.11 and Table 24.12: TV Summary Statistics for Movie 2 in Blue Chair and Black Chair

Summary Statistics for Vt Movie 2 Blue Chair							
All Subjects							
Mean				0.621			
S.D.				0.169			
Min				0.355			
Max				1.152			
All Females				All Males			
Mean		0.534		Mean		0.713	
S.D.		0.111		S.D.		0.174	
Min.		0.355		Min.		0.525	
Max.		0.749		Max.		1.152	
18-35		36-55		18-35		36-55	
Mean	0.555	Mean	0.507	Mean	0.727	Mean	0.697
S.D.	0.134	S.D.	0.071	S.D.	0.191	S.D.	0.166
Min.	0.355	Min.	0.395	Min.	0.595	Min.	0.525
Max.	0.749	Max.	0.595	Max.	1.152	Max.	1.004

Summary Statistics for Vt Movie 2 Black Chair							
All Subjects							
Mean				0.622			
S.D.				0.158			
Min				0.385			
Max				1.118			
All Females				All Males			
Mean		0.575		Mean		0.671	
S.D.		0.161		S.D.		0.142	
Min.		0.385		Min.		0.558	
Max.		0.960		Max.		1.118	
18-35		36-55		18-35		36-55	
Mean	0.603	Mean	0.539	Mean	0.633	Mean	0.715
S.D.	0.184	S.D.	0.129	S.D.	0.049	S.D.	0.201
Min.	0.385	Min.	0.408	Min.	0.575	Min.	0.558
Max.	0.960	Max.	0.787	Max.	0.708	Max.	1.118

25 Appendix P: Summary Statistics of Typing 2 Task

Table 25.1 and Table 25.2: HR Summary Statistics for Typing 2 in Blue Chair and Black Chair

Summary Statistics for HR Typing 2 Blue Chair							
All Subjects							
Mean				74.207			
S.D.				10.502			
Min				54.358			
Max				96.048			
All Females				All Males			
Mean		75.681		Mean		72.635	
S.D.		10.888		S.D.		10.207	
Min.		55.500		Min.		54.358	
Max.		96.048		Max.		95.190	
18-35		36-55		18-35		36-55	
Mean	76.144	Mean	75.086	Mean	71.035	Mean	74.463
S.D.	9.600	S.D.	13.144	S.D.	9.078	S.D.	11.816
Min.	55.500	Min.	61.623	Min.	54.358	Min.	60.184
Max.	88.217	Max.	96.048	Max.	80.174	Max.	95.190

Summary Statistics for HR Typing 2 Black Chair							
All Subjects							
Mean				78.710			
S.D.				12.683			
Min				48.612			
Max				98.738			
All Females				All Males			
Mean		78.461		Mean		78.976	
S.D.		12.975		S.D.		12.813	
Min.		48.612		Min.		58.442	
Max.		96.682		Max.		98.738	
18-35		36-55		18-35		36-55	
Mean	78.992	Mean	77.777	Mean	77.058	Mean	81.167
S.D.	9.955	S.D.	16.965	S.D.	11.970	S.D.	14.333
Min.	61.593	Min.	48.612	Min.	58.442	Min.	59.932
Max.	95.574	Max.	96.682	Max.	98.738	Max.	98.338

Table 25.3 and Table 25.4: RER Summary Statistics for Typing 2 in Blue Chair and Black Chair

Summary Statistics for RER Typing 2 Blue Chair							
All Subjects							
Mean				0.812			
S.D.				0.066			
Min				0.575			
Max				0.937			
All Females				All Males			
Mean		0.801		Mean		0.823	
S.D.		0.079		S.D.		0.048	
Min.		0.575		Min.		0.693	
Max.		0.937		Max.		0.885	
18-35		36-55		18-35		36-55	
Mean	0.798	Mean	0.805	Mean	0.813	Mean	0.833
S.D.	0.098	S.D.	0.052	S.D.	0.056	S.D.	0.040
Min.	0.575	Min.	0.752	Min.	0.693	Min.	0.760
Max.	0.937	Max.	0.882	Max.	0.873	Max.	0.885

Summary Statistics for RER Typing 2 Black Chair							
All Subjects							
Mean				0.810			
S.D.				0.064			
Min				0.629			
Max				0.911			
All Females				All Males			
Mean		0.798		Mean		0.821	
S.D.		0.073		S.D.		0.053	
Min.		0.629		Min.		0.662	
Max.		0.911		Max.		0.888	
18-35		36-55		18-35		36-55	
Mean	0.804	Mean	0.790	Mean	0.797	Mean	0.848
S.D.	0.065	S.D.	0.087	S.D.	0.061	S.D.	0.022
Min.	0.681	Min.	0.629	Min.	0.662	Min.	0.824
Max.	0.911	Max.	0.890	Max.	0.862	Max.	0.888

Table 25.5 and Table 25.6: RR Summary Statistics for Typing 2 in Blue Chair and Black Chair

Summary Statistics for RR Typing 2 Blue Chair							
All Subjects							
Mean				18.807			
S.D.				3.093			
Min				11.113			
Max				28.328			
All Females				All Males			
Mean		19.769		Mean		17.782	
S.D.		3.024		S.D.		2.919	
Min.		15.983		Min.		11.113	
Max.		28.328		Max.		22.965	
18-35		36-55		18-35		36-55	
Mean	19.624	Mean	19.954	Mean	16.186	Mean	19.606
S.D.	3.846	S.D.	1.749	S.D.	2.479	S.D.	2.331
Min.	15.983	Min.	17.983	Min.	11.113	Min.	16.594
Max.	28.328	Max.	22.593	Max.	19.636	Max.	22.965

Summary Statistics for RR Typing 2 Black Chair							
All Subjects							
Mean				19.209			
S.D.				2.440			
Min				14.417			
Max				23.482			
All Females				All Males			
Mean		19.935		Mean		18.522	
S.D.		2.186		S.D.		2.556	
Min.		15.971		Min.		14.417	
Max.		23.482		Max.		23.411	
18-35		36-55		18-35		36-55	
Mean	19.812	Mean	20.094	Mean	16.985	Mean	20.280
S.D.	2.322	S.D.	2.169	S.D.	1.800	S.D.	2.170
Min.	16.738	Min.	15.971	Min.	14.417	Min.	16.202
Max.	23.482	Max.	21.951	Max.	19.777	Max.	23.411

Table 25.7 and Table 25.8: CO2 Summary Statistics for Typing 2 in Blue Chair and Black Chair

Summary Statistics for CO2 Typing 2 Blue Chair							
All Subjects							
Mean				3.1442			
S.D.				0.9684			
Min				1.8951			
Max				5.5052			
All Females				All Males			
Mean		3.1299		Mean		3.1595	
S.D.		1.0228		S.D.		0.9423	
Min.		1.8951		Min.		1.9135	
Max.		5.5052		Max.		5.0489	
18-35		36-55		18-35		36-55	
Mean	3.1946	Mean	3.0466	Mean	3.1382	Mean	3.1838
S.D.	0.8265	S.D.	1.3001	S.D.	0.9791	S.D.	0.9759
Min.	2.2974	Min.	1.8951	Min.	1.9135	Min.	2.2064
Max.	4.6768	Max.	5.5052	Max.	4.5116	Max.	5.0489

Summary Statistics for CO2 Typing 2 Black Chair							
All Subjects							
Mean				3.1275			
S.D.				0.9429			
Min				1.9099			
Max				5.8506			
All Females				All Males			
Mean		3.1308		Mean		3.1370	
S.D.		0.9945		S.D.		0.9194	
Min.		1.9099		Min.		1.9310	
Max.		5.8506		Max.		5.0877	
18-35		36-55		18-35		36-55	
Mean	3.2157	Mean	3.0215	Mean	3.0869	Mean	3.1943
S.D.	0.7038	S.D.	1.3370	S.D.	0.9099	S.D.	0.9997
Min.	1.9099	Min.	2.0215	Min.	1.9310	Min.	2.1294
Max.	4.4622	Max.	5.8506	Max.	4.3214	Max.	5.0877

Table 25.9 and Table 25.10: O2 Summary Statistics for Typing 2 in Blue Chair and Black Chair

Summary Statistics for O2 Typing 2 Blue Chair							
All Subjects							
Mean				3.748			
S.D.				0.858			
Min				2.543			
Max				6.417			
All Females				All Males			
Mean		3.716		Mean		3.781	
S.D.		0.733		S.D.		1.001	
Min.		2.543		Min.		2.609	
Max.		5.000		Max.		6.417	
18-35		36-55		18-35		36-55	
Mean	3.875	Mean	3.513	Mean	3.979	Mean	3.555
S.D.	0.921	S.D.	0.355	S.D.	1.284	S.D.	0.549
Min.	2.543	Min.	3.036	Min.	2.609	Min.	2.690
Max.	5.000	Max.	4.000	Max.	6.417	Max.	4.115

Summary Statistics for O2 Typing 2 Black Chair							
All Subjects							
Mean				3.793			
S.D.				0.762			
Min				2.571			
Max				5.296			
All Females				All Males			
Mean		3.818		Mean		3.797	
S.D.		0.644		S.D.		0.894	
Min.		3.122		Min.		2.571	
Max.		5.296		Max.		5.262	
18-35		36-55		18-35		36-55	
Mean	4.000	Mean	3.584	Mean	4.003	Mean	3.561
S.D.	0.761	S.D.	0.388	S.D.	1.115	S.D.	0.539
Min.	3.122	Min.	3.161	Min.	2.571	Min.	2.820
Max.	5.296	Max.	4.108	Max.	5.262	Max.	4.245

Table 25.11 and Table 25.12: TV Summary Statistics for Typing 2 in Blue Chair and Black Chair

Summary Statistics for Vt Typing 2 Blue Chair							
All Subjects							
Mean				0.615			
S.D.				0.151			
Min				0.374			
Max				1.107			
All Females				All Males			
Mean		0.517		Mean		0.719	
S.D.		0.091		S.D.		0.133	
Min.		0.374		Min.		0.565	
Max.		0.707		Max.		1.107	
18-35		36-55		18-35		36-55	
Mean	0.522	Mean	0.511	Mean	0.735	Mean	0.700
S.D.	0.110	S.D.	0.067	S.D.	0.173	S.D.	0.075
Min.	0.374	Min.	0.419	Min.	0.565	Min.	0.618
Max.	0.707	Max.	0.599	Max.	1.107	Max.	0.817

Summary Statistics for Vt Typing 2 Black Chair							
All Subjects							
Mean				0.599			
S.D.				0.126			
Min				0.376			
Max				0.891			
All Females				All Males			
Mean		0.512		Mean		0.683	
S.D.		0.092		S.D.		0.093	
Min.		0.376		Min.		0.561	
Max.		0.685		Max.		0.891	
18-35		36-55		18-35		36-55	
Mean	0.515	Mean	0.510	Mean	0.685	Mean	0.681
S.D.	0.106	S.D.	0.079	S.D.	0.100	S.D.	0.092
Min.	0.376	Min.	0.442	Min.	0.564	Min.	0.561
Max.	0.685	Max.	0.663	Max.	0.891	Max.	0.815

26 Appendix Q: Summary Statistics of Table 2 Task

Table 26.1 and Table 26.2: HR Summary Statistics for Table 2 in Blue Chair and Black Chair

Summary Statistics for HR Table 2 Blue Chair							
All Subjects							
Mean				73.923			
S.D.				9.725			
Min				56.640			
Max				95.333			
All Females				All Males			
Mean		75.513		Mean		72.228	
S.D.		10.062		S.D.		9.392	
Min.		56.640		Min.		57.082	
Max.		90.591		Max.		95.333	
18-35		36-55		18-35		36-55	
Mean	76.142	Mean	74.704	Mean	70.934	Mean	73.707
S.D.	8.899	S.D.	12.091	S.D.	7.971	S.D.	11.265
Min.	56.640	Min.	61.891	Min.	57.082	Min.	62.263
Max.	86.111	Max.	90.591	Max.	80.255	Max.	95.333

Summary Statistics for HR Table 2 Black Chair							
All Subjects							
Mean				79.484			
S.D.				10.914			
Min				59.979			
Max				101.671			
All Females				All Males			
Mean		78.916		Mean		80.089	
S.D.		10.806		S.D.		11.375	
Min.		64.132		Min.		59.979	
Max.		101.671		Max.		98.213	
18-35		36-55		18-35		36-55	
Mean	78.680	Mean	79.219	Mean	77.591	Mean	82.945
S.D.	8.654	S.D.	13.852	S.D.	10.874	S.D.	12.088
Min.	66.527	Min.	64.132	Min.	59.979	Min.	62.968
Max.	95.186	Max.	101.671	Max.	98.213	Max.	93.206

Table 26.3 and Table 26.4: RER Summary Statistics for Table 2 in Blue Chair and Black Chair

Summary Statistics for RER Table 2 Blue Chair							
All Subjects							
Mean				0.810			
S.D.				0.063			
Min				0.533			
Max				0.891			
All Females				All Males			
Mean		0.791		Mean		0.829	
S.D.		0.079		S.D.		0.032	
Min.		0.533		Min.		0.783	
Max.		0.891		Max.		0.886	
18-35		36-55		18-35		36-55	
Mean	0.786	Mean	0.797	Mean	0.821	Mean	0.838
S.D.	0.103	S.D.	0.040	S.D.	0.031	S.D.	0.032
Min.	0.533	Min.	0.744	Min.	0.783	Min.	0.792
Max.	0.891	Max.	0.848	Max.	0.862	Max.	0.886

Summary Statistics for RER Table 2 Black Chair							
All Subjects							
Mean				0.806			
S.D.				0.064			
Min				0.608			
Max				0.900			
All Females				All Males			
Mean		0.797		Mean		0.817	
S.D.		0.072		S.D.		0.055	
Min.		0.608		Min.		0.649	
Max.		0.900		Max.		0.876	
18-35		36-55		18-35		36-55	
Mean	0.805	Mean	0.786	Mean	0.796	Mean	0.841
S.D.	0.058	S.D.	0.091	S.D.	0.071	S.D.	0.008
Min.	0.720	Min.	0.608	Min.	0.649	Min.	0.832
Max.	0.900	Max.	0.887	Max.	0.876	Max.	0.855

Table 26.5 and Table 26.6: RR Summary Statistics for Table 2 in Blue Chair and Black Chair

Summary Statistics for RR Table 2 Blue Chair								Summary Statistics for RR Table 2 Black Chair							
All Subjects								All Subjects							
Mean				18.574				Mean				19.107			
S.D.				3.200				S.D.				2.658			
Min				9.044				Min				14.116			
Max				26.856				Max				24.474			
All Females				All Males				All Females				All Males			
Mean		19.458		Mean		17.632		Mean		19.496		Mean		18.693	
S.D.		3.116		S.D.		3.114		S.D.		3.033		S.D.		2.219	
Min.		16.182		Min.		9.044		Min.		14.116		Min.		15.822	
Max.		26.856		Max.		21.190		Max.		24.474		Max.		22.147	
18-35		36-55		18-35		36-55		18-35		36-55		18-35		36-55	
Mean	18.905	Mean	20.168	Mean	15.827	Mean	19.694	Mean	18.781	Mean	20.415	Mean	17.368	Mean	20.206
S.D.	3.596	S.D.	2.447	S.D.	3.151	S.D.	1.321	S.D.	3.250	S.D.	2.676	S.D.	1.430	S.D.	2.024
Min.	16.182	Min.	16.772	Min.	9.044	Min.	17.402	Min.	14.116	Min.	15.875	Min.	15.921	Min.	15.822
Max.	26.856	Max.	23.225	Max.	19.505	Max.	21.190	Max.	24.474	Max.	23.275	Max.	20.372	Max.	22.147

Table 26.7 and Table 26.8: CO2 Summary Statistics for Table 2 in Blue Chair and Black Chair

Summary Statistics for CO2 Table 2 Blue Chair							
All Subjects							
Mean				3.049			
S.D.				0.958			
Min				1.700			
Max				5.747			
All Females				All Males			
Mean		3.0503		Mean		3.049	
S.D.		1.0339		S.D.		0.906	
Min.		1.8851		Min.		1.700	
Max.		5.7467		Max.		4.617	
18-35		36-55		18-35		36-55	
Mean	3.1354	Mean	2.9408	Mean	2.9491	Mean	3.1625
S.D.	0.7826	S.D.	1.3531	S.D.	0.9971	S.D.	0.8534
Min.	2.0776	Min.	1.8851	Min.	1.6995	Min.	2.2136
Max.	4.5145	Max.	5.7467	Max.	4.3129	Max.	4.6170

Summary Statistics for CO2 Table 2 Black Chair							
All Subjects							
Mean				3.175			
S.D.				0.950			
Min				1.823			
Max				6.248			
All Females				All Males			
Mean		3.1723		Mean		3.1780	
S.D.		1.0866		S.D.		0.8185	
Min.		1.8234		Min.		1.9984	
Max.		6.2481		Max.		4.6477	
18-35		36-55		18-35		36-55	
Mean	3.1919	Mean	3.1472	Mean	3.0498	Mean	3.3246
S.D.	0.7712	S.D.	1.4688	S.D.	0.9275	S.D.	0.7159
Min.	1.8234	Min.	1.9801	Min.	1.9984	Min.	2.2366
Max.	4.5367	Max.	6.2481	Max.	4.6477	Max.	4.5686

Table 26.9 and Table 26.10: O2 Summary Statistics for Table 2 in Blue Chair and Black Chair

Summary Statistics for O2 Table 2 Blue Chair								Summary Statistics for O2 Table 2 Black Chair							
All Subjects								All Subjects							
Mean				3.641				Mean				3.844			
S.D.				0.738				S.D.				0.693			
Min				2.596				Min				2.480			
Max				4.949				Max				5.234			
All Females				All Males				All Females				All Males			
Mean		3.694		Mean		3.585		Mean		3.861		Mean		3.825	
S.D.		0.729		S.D.		0.769		S.D.		0.617		S.D.		0.789	
Min.		2.639		Min.		2.596		Min.		3.149		Min.		2.480	
Max.		4.949		Max.		4.800		Max.		5.121		Max.		5.234	
18-35		36-55		18-35		36-55		18-35		36-55		18-35		36-55	
Mean	3.885	Mean	3.447	Mean	3.612	Mean	3.553	Mean	3.953	Mean	3.743	Mean	3.939	Mean	3.695
S.D.	0.871	S.D.	0.438	S.D.	0.959	S.D.	0.551	S.D.	0.766	S.D.	0.375	S.D.	1.036	S.D.	0.402
Min.	2.639	Min.	3.022	Min.	2.596	Min.	2.661	Min.	3.149	Min.	3.305	Min.	2.480	Min.	3.000
Max.	4.949	Max.	4.111	Max.	4.800	Max.	4.294	Max.	5.121	Max.	4.309	Max.	5.234	Max.	4.226

Table 26.11 and Table 26.12: TV Summary Statistics for Table 2 in Blue Chair and Black Chair

Summary Statistics for Vt Table 2 Blue Chair							
All Subjects							
Mean				0.617			
S.D.				0.137			
Min				0.380			
Max				1.007			
All Females				All Males			
Mean		0.525		Mean		0.716	
S.D.		0.086		S.D.		0.110	
Min.		0.380		Min.		0.593	
Max.		0.684		Max.		1.007	
18-35		36-55		18-35		36-55	
Mean	0.544	Mean	0.500	Mean	0.719	Mean	0.713
S.D.	0.104	S.D.	0.054	S.D.	0.136	S.D.	0.083
Min.	0.380	Min.	0.420	Min.	0.593	Min.	0.598
Max.	0.684	Max.	0.560	Max.	1.007	Max.	0.833

Summary Statistics for Vt Table 2 Black Chair							
All Subjects							
Mean				0.611			
S.D.				0.121			
Min				0.387			
Max				0.829			
All Females				All Males			
Mean		0.544		Mean		0.681	
S.D.		0.118		S.D.		0.079	
Min.		0.387		Min.		0.555	
Max.		0.804		Max.		0.829	
18-35		36-55		18-35		36-55	
Mean	0.560	Mean	0.524	Mean	0.669	Mean	0.695
S.D.	0.145	S.D.	0.078	S.D.	0.077	S.D.	0.086
Min.	0.387	Min.	0.447	Min.	0.590	Min.	0.555
Max.	0.804	Max.	0.673	Max.	0.829	Max.	0.810

27 Appendix R: Summary Statistics of Internet 2 Task

Table 27.1 and Table 27.2: HR Summary Statistics for Internet 2 in Blue Chair and Black Chair

Summary Statistics for HR Internet 2 Blue Chair							
All Subjects							
Mean				72.883			
S.D.				9.340			
Min				54.039			
Max				94.442			
All Females				All Males			
Mean		74.547		Mean		71.108	
S.D.		8.839		S.D.		9.833	
Min.		58.531		Min.		54.039	
Max.		90.097		Max.		94.442	
18-35		36-55		18-35		36-55	
Mean	74.716	Mean	74.329	Mean	69.397	Mean	73.064
S.D.	7.489	S.D.	10.975	S.D.	8.680	S.D.	11.374
Min.	58.531	Min.	62.791	Min.	54.039	Min.	60.886
Max.	85.511	Max.	90.097	Max.	79.733	Max.	94.442

Summary Statistics for HR Internet 2 Black Chair							
All Subjects							
Mean				77.086			
S.D.				11.182			
Min				53.714			
Max				98.100			
All Females				All Males			
Mean		77.157		Mean		77.010	
S.D.		10.154		S.D.		12.549	
Min.		65.039		Min.		53.714	
Max.		98.100		Max.		96.553	
18-35		36-55		18-35		36-55	
Mean	76.207	Mean	78.379	Mean	75.064	Mean	79.235
S.D.	8.813	S.D.	12.293	S.D.	12.692	S.D.	12.988
Min.	65.039	Min.	65.727	Min.	53.714	Min.	60.049
Max.	93.350	Max.	98.100	Max.	96.553	Max.	95.014

Table 27.3 and Table 27.4: RER Summary Statistics for Internet 2 in Blue Chair and Black Chair

Summary Statistics for RER Internet 2 Blue Chair							
All Subjects							
Mean				0.801			
S.D.				0.058			
Min				0.590			
Max				0.887			
All Females				All Males			
Mean		0.787		Mean		0.817	
S.D.		0.071		S.D.		0.035	
Min.		0.590		Min.		0.751	
Max.		0.887		Max.		0.885	
18-35		36-55		18-35		36-55	
Mean	0.791	Mean	0.781	Mean	0.808	Mean	0.827
S.D.	0.084	S.D.	0.055	S.D.	0.029	S.D.	0.042
Min.	0.590	Min.	0.707	Min.	0.751	Min.	0.760
Max.	0.887	Max.	0.855	Max.	0.836	Max.	0.885

Summary Statistics for RER Internet 2 Black Chair							
All Subjects							
Mean				0.795			
S.D.				0.066			
Min				0.582			
Max				0.910			
All Females				All Males			
Mean		0.785		Mean		0.807	
S.D.		0.080		S.D.		0.048	
Min.		0.582		Min.		0.666	
Max.		0.910		Max.		0.859	
18-35		36-55		18-35		36-55	
Mean	0.793	Mean	0.775	Mean	0.788	Mean	0.828
S.D.	0.071	S.D.	0.095	S.D.	0.059	S.D.	0.016
Min.	0.676	Min.	0.582	Min.	0.666	Min.	0.814
Max.	0.910	Max.	0.882	Max.	0.855	Max.	0.859

Table 27.5 and Table 27.6: RR Summary Statistics for Internet 2 in Blue Chair and Black Chair

Summary Statistics for RR Internet 2 Blue Chair							
All Subjects							
Mean				17.504			
S.D.				2.946			
Min				9.754			
Max				23.381			
All Females				All Males			
Mean		17.784		Mean		17.205	
S.D.		2.779		S.D.		3.183	
Min.		14.376		Min.		9.754	
Max.		23.381		Max.		22.965	
18-35		36-55		18-35		36-55	
Mean	17.287	Mean	18.424	Mean	15.669	Mean	18.959
S.D.	2.943	S.D.	2.629	S.D.	3.061	S.D.	2.444
Min.	14.376	Min.	15.234	Min.	9.754	Min.	15.409
Max.	23.381	Max.	21.464	Max.	20.047	Max.	22.965

Summary Statistics for RR Internet 2 Black Chair							
All Subjects							
Mean				18.019			
S.D.				2.587			
Min				14.093			
Max				24.069			
All Females				All Males			
Mean		17.914		Mean		18.132	
S.D.		2.668		S.D.		2.587	
Min.		14.093		Min.		14.230	
Max.		22.137		Max.		24.069	
18-35		36-55		18-35		36-55	
Mean	17.505	Mean	18.439	Mean	16.754	Mean	19.707
S.D.	2.731	S.D.	2.698	S.D.	1.877	S.D.	2.466
Min.	14.093	Min.	14.259	Min.	14.230	Min.	15.772
Max.	22.137	Max.	22.066	Max.	20.131	Max.	24.069

Table 27.7 and Table 27.8: CO_2 Summary Statistics for Internet 2 in Blue Chair and Black Chair

Summary Statistics for CO2 Internet 2 Blue Chair							
All Subjects							
Mean				3.189			
S.D.				1.009			
Min				1.830			
Max				5.933			
All Females				All Males			
Mean		3.2009		Mean		3.1759	
S.D.		1.0833		S.D.		0.9620	
Min.		2.0038		Min.		1.8299	
Max.		5.9328		Max.		5.0489	
18-35		36-55		18-35		36-55	
Mean	3.2635	Mean	3.1205	Mean	3.1363	Mean	3.2211
S.D.	0.8647	S.D.	1.3870	S.D.	1.0227	S.D.	0.9669
Min.	2.1168	Min.	2.0038	Min.	1.8299	Min.	2.2783
Max.	5.0572	Max.	5.9328	Max.	4.5619	Max.	5.0489

Summary Statistics for CO2 Internet 2 Black Chair							
All Subjects							
Mean				3.144			
S.D.				0.921			
Min				1.882			
Max				5.492			
All Females				All Males			
Mean		3.1472		Mean		3.1398	
S.D.		0.9587		S.D.		0.9129	
Min.		1.8822		Min.		2.0164	
Max.		5.4920		Max.		4.9041	
18-35		36-55		18-35		36-55	
Mean	3.2101	Mean	3.0664	Mean	3.0972	Mean	3.1885
S.D.	0.7957	S.D.	1.2001	S.D.	0.9214	S.D.	0.9740
Min.	1.8822	Min.	1.9995	Min.	2.0164	Min.	2.1025
Max.	4.4367	Max.	5.4920	Max.	4.4965	Max.	4.9041

Table 27.9 and Table 27.10: O2 Summary Statistics for Internet 2 in Blue Chair and Black Chair

Summary Statistics for O2 Internet 2 Blue Chair							
All Subjects							
Mean				3.851			
S.D.				0.751			
Min				2.689			
Max				5.667			
All Females				All Males			
Mean		3.887		Mean		3.813	
S.D.		0.610		S.D.		0.898	
Min.		3.000		Min.		2.689	
Max.		4.743		Max.		5.667	
18-35		36-55		18-35		36-55	
Mean	3.994	Mean	3.750	Mean	3.953	Mean	3.652
S.D.	0.694	S.D.	0.498	S.D.	1.144	S.D.	0.545
Min.	3.000	Min.	3.204	Min.	2.689	Min.	2.759
Max.	4.743	Max.	4.350	Max.	5.667	Max.	4.260

Summary Statistics for O2 Internet 2 Black Chair							
All Subjects							
Mean				3.867			
S.D.				0.767			
Min				2.661			
Max				5.447			
All Females				All Males			
Mean		3.879		Mean		3.854	
S.D.		0.672		S.D.		0.882	
Min.		3.067		Min.		2.661	
Max.		5.197		Max.		5.447	
18-35		36-55		18-35		36-55	
Mean	4.005	Mean	3.717	Mean	4.067	Mean	3.611
S.D.	0.841	S.D.	0.361	S.D.	1.074	S.D.	0.584
Min.	3.067	Min.	3.333	Min.	2.667	Min.	2.661
Max.	5.197	Max.	4.273	Max.	5.447	Max.	4.196

Table 27.11 and Table 27.12: TV Summary Statistics for Internet 2 in Blue Chair and Black Chair

Summary Statistics for Vt Internet 2 Blue Chair								Summary Statistics for Vt Internet 2 Black Chair							
All Subjects								All Subjects							
Mean				0.659				Mean				0.639			
S.D.				0.142				S.D.				0.114			
Min				0.394				Min				0.415			
Max				1.056				Max				0.860			
All Females				All Males				All Females				All Males			
Mean		0.584		Mean		0.740		Mean		0.579		Mean		0.702	
S.D.		0.126		S.D.		0.113		S.D.		0.115		S.D.		0.073	
Min.		0.394		Min.		0.611		Min.		0.415		Min.		0.569	
Max.		0.806		Max.		1.056		Max.		0.860		Max.		0.836	
18-35		36-55		18-35		36-55		18-35		36-55		18-35		36-55	
Mean	0.598	Mean	0.565	Mean	0.751	Mean	0.727	Mean	0.597	Mean	0.556	Mean	0.702	Mean	0.702
S.D.	0.149	S.D.	0.098	S.D.	0.148	S.D.	0.061	S.D.	0.143	S.D.	0.068	S.D.	0.063	S.D.	0.088
Min.	0.394	Min.	0.431	Min.	0.611	Min.	0.656	Min.	0.415	Min.	0.464	Min.	0.632	Min.	0.569
Max.	0.806	Max.	0.726	Max.	1.056	Max.	0.817	Max.	0.860	Max.	0.672	Max.	0.836	Max.	0.810

28 Appendix S: Subjective Assessment – Blue Chair

Table 28.1: Blue Chair Subjective Data

Participant	Ease of Use	Comfort	Overall Evaluation	Back of Seat Comfort	Chair tilts too far	Chair Tilts too Little	Front of Seat Uncomfortable
F01	3	4	3	4	1	5	4
F04	3	5	4	3	2	2	3
F06	10	10	10	5	1	1	5
F08	7	7	7	4	1	2	4
F09	9	9	8	5	1	1	5
F11	7	8	8.5	4	1	1	4
F12	7	9	8	4	3	2	4
F13	5	5	5	3	2	1	4
F14	7	4	4	3	1	1	3
F02	9	9	9	5	1	1	5
F03	7	9	9	5	2	2	5
F05	10	9	9	5	2	2	5
F07	7	6	7	4	2	3	4
F10	4	8	8	5	1	1	5
F15	9	9	9	5	2	1	5
F16	5	8	8	4	2	2	4
M01	8	10	10	5	1	1	5
M02	3	7	7	2	1	1	2
M06	7	6	7	3	2	4	3
M07	4	7	6	4	2	4	4
M08	5	8	7	5	3	4	5
M10	7	9	9	4	2	2	4
M11	6	5	7	3	4	2	3
M12	3	9	7	5	3	3	5
M03	8	8	9	5	1	1	4
M04	7	7	7	5	2	2	5
M05	10	10	10	5	4	1	5
M09	9	10	9	5	1	3	5
M13	3	8	7	4	2	2	4
M14	7	7	7	4	2	2	4
M15	9	9	8	4	1	1	5
Mean	**6.61**	**7.71**	**7.53**	**4.23**	**1.81**	**1.97**	**4.26**
Median	**7.00**	**8.00**	**8.00**	**4.00**	**2.00**	**2.00**	**4.00**
Std. Dev	2.28	1.77	1.76	0.84	0.87	1.11	0.82
Minimum	3.00	4.00	3.00	2.00	1.00	1.00	2.00
Maximum	10.00	10.00	10.00	5.00	4.00	5.00	5.00

29 Appendix T: Subjective Assessment – Black Chair

Table 29.1: Black chair Subjective Data

	Ease of Use	Comfort	Overall Evaluation	Back of Seat Comfort	Chair tilts too far	Chair Tilts to Little	Front of Seat Uncomfortable
F01	8	8	8	5	1	1	5
F04	7	6	6	4	2	2	2
F06	8	10	9	5	1	1	5
F08	9	9	9	3	1	2	4
F09	9	8	8	4	1	1	4
F11	7	6	7	3.4	2	3	4
F12	7	7	8	4	2	3	4
F13	8	9	8	4	1	1	3
F14	10	6	8	3	1	1	4
F02	10	10	10	5	1	1	5
F03	8	6	9	4	2	3	4
F05	7	7	7	2	2	1	2
F07	4	5	4	4	3	3	3
F10	8	9	9	4	1	3	4
F15	5	4	3	3	1	4	3
F16	7	5	6	3	3	3	4
M01	5	4	2	3	1	1	4
M02	3	4	4	3	1	1	3
M06	3	8	7	4	2	1	4
M07	9	10	8	4	2	3	3
M08	5	6	6	4	5	1	3
M10	7	6	7	4	4	1	2
M11	8	9	8	5	1	1	4
M12	8	5	6	3	2	2	3
M03	7	6	7	5	2	2	5
M04	9	6	7	2	2	2	2
M05	8	6	7	4	4	1	3
M09	8	8	6	4	2	3	4
M13	4	7	6	4	4	1	4
M14	8	8	8	4	1	2	4
M15	8	8	9	4	2	2	4
Mean	**7.16**	**6.97**	**7.00**	**3.79**	**1.94**	**1.84**	**3.61**
Median	**8.00**	**7.00**	**7.00**	**4.00**	**2.00**	**2.00**	**4.00**
Std. Dev	1.88	1.80	1.84	0.79	1.09	0.93	0.88
Minimum	3.00	4.00	2.00	2.00	1.00	1.00	2.00
Maximum	10.00	10.00	10.00	5.00	5.00	4.00	5.00

30 Appendix: U Regression Analysis Graphs

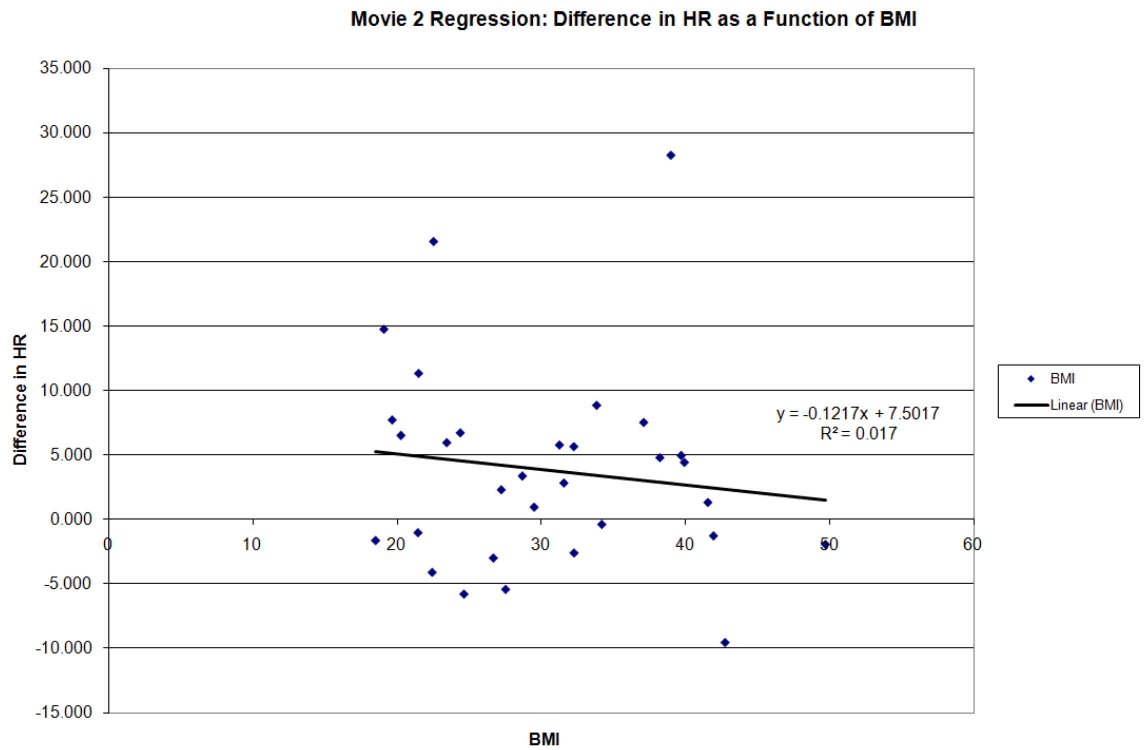

Figure 30.1: Regression HR vs. BMI (Movie 2) All Data

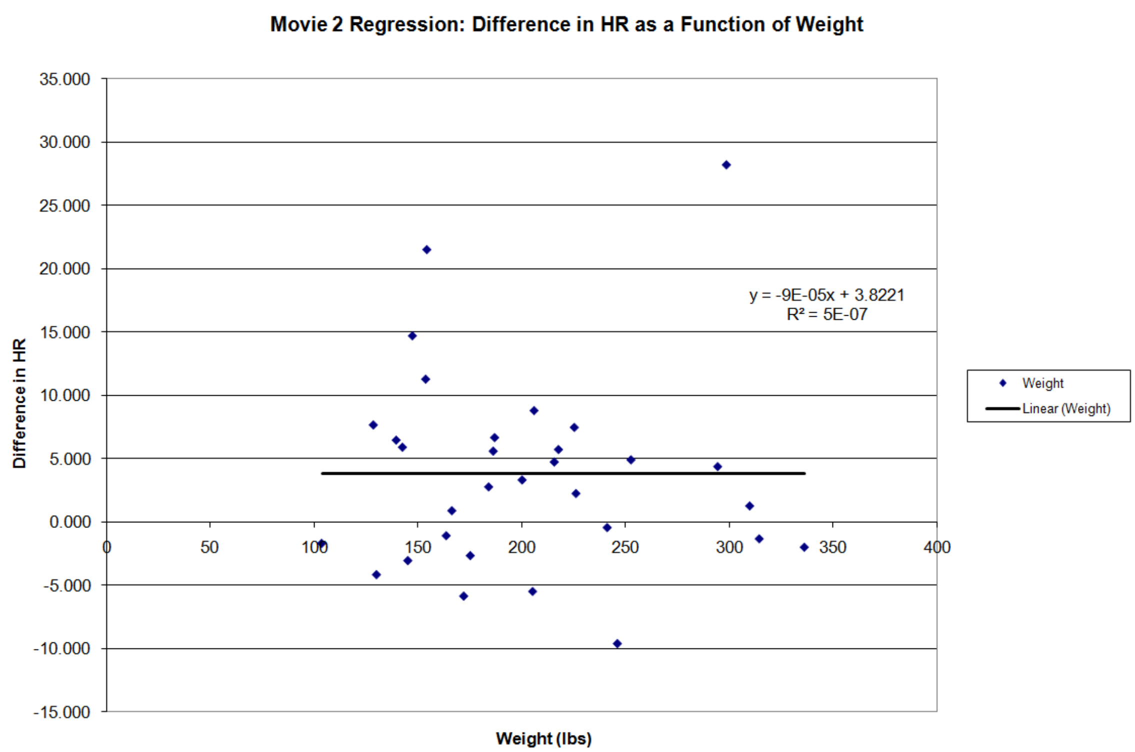

Figure 30.2: Regression HR vs. Weight (Movie 2) All Data

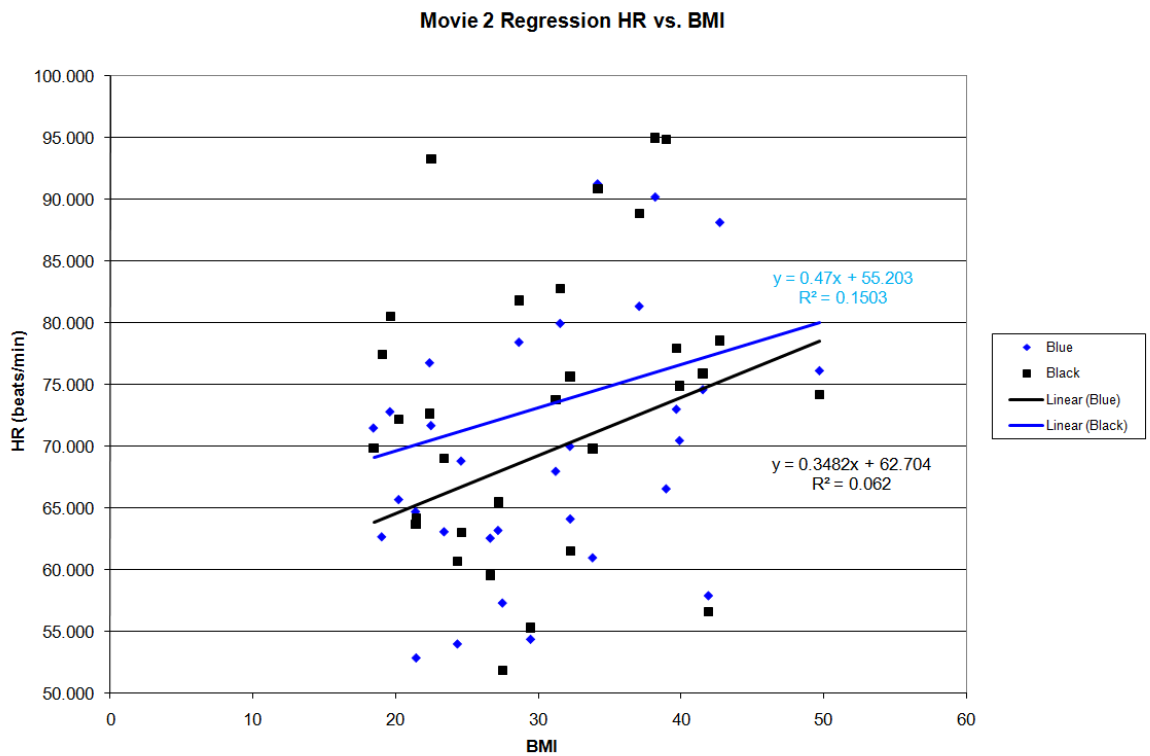

Figure 30.3: Regression HR vs. BMI (Movie 2) by Chair

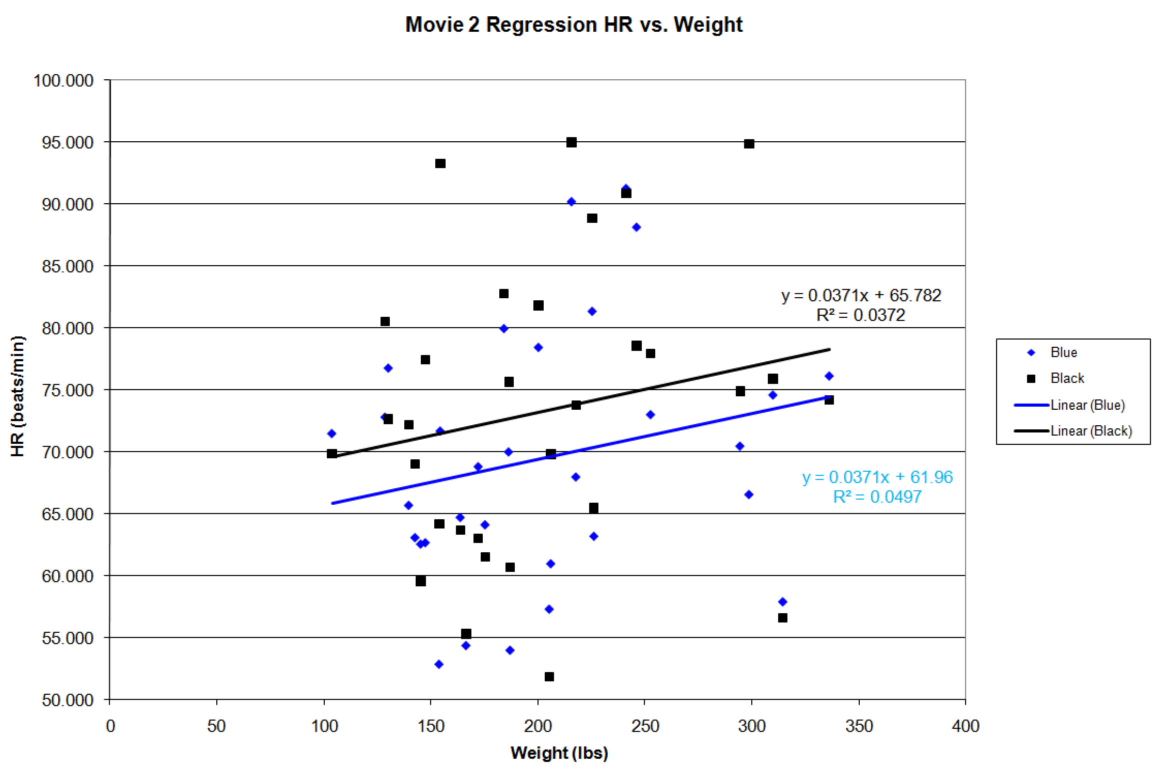

Figure 30.4: Regression HR vs. Weight (Movie 2) by Chair

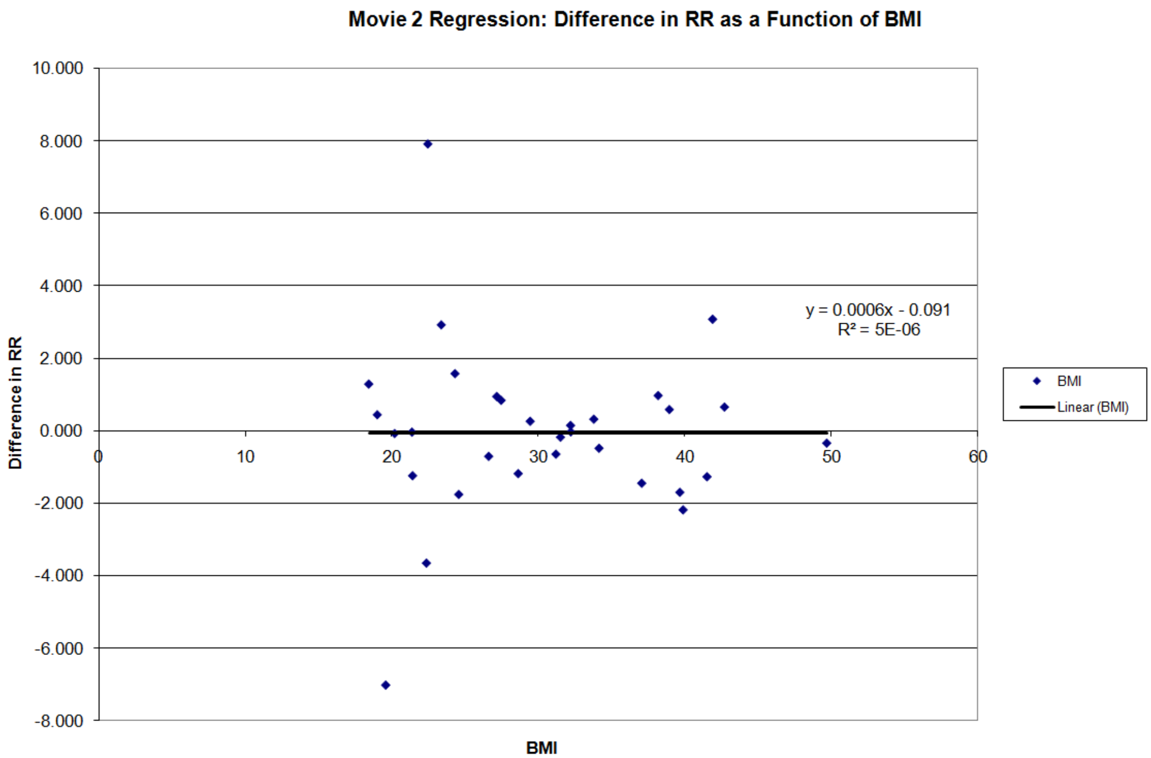

Figure 30.5: Regression RR vs. BMI (Movie 2) All Data

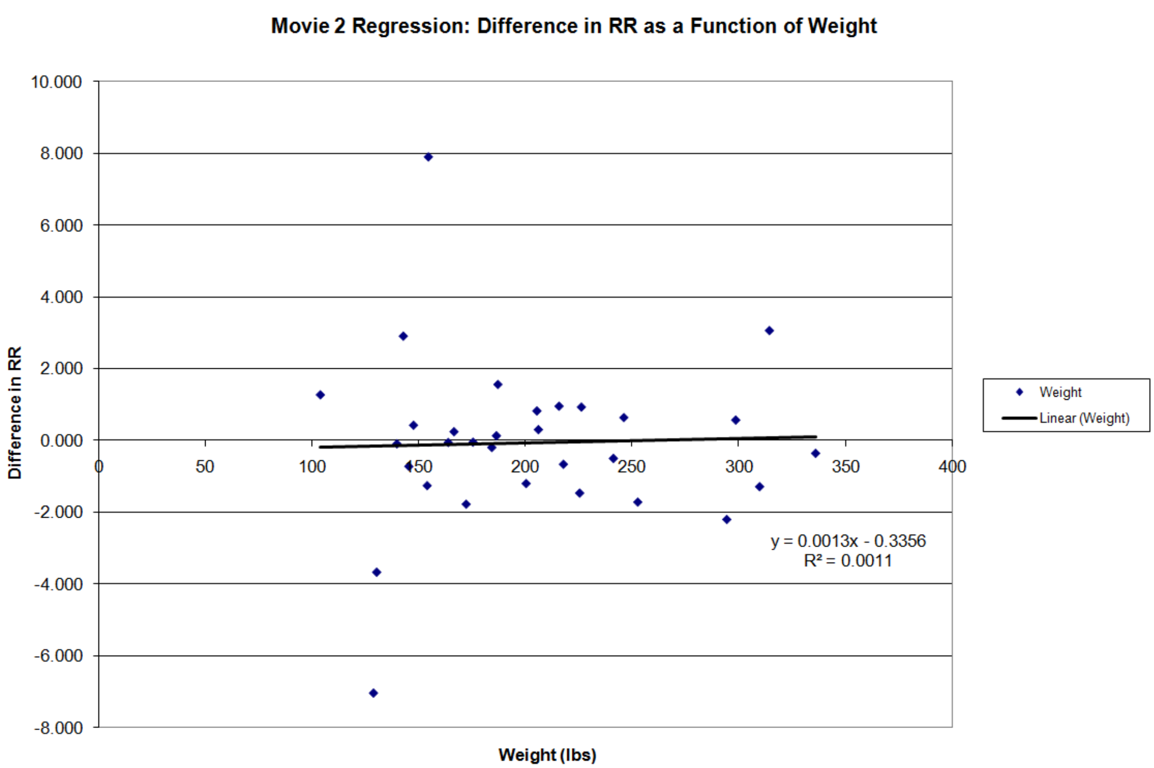

Figure 30.6: Regression RR vs. Weight (Movie 2) All Data

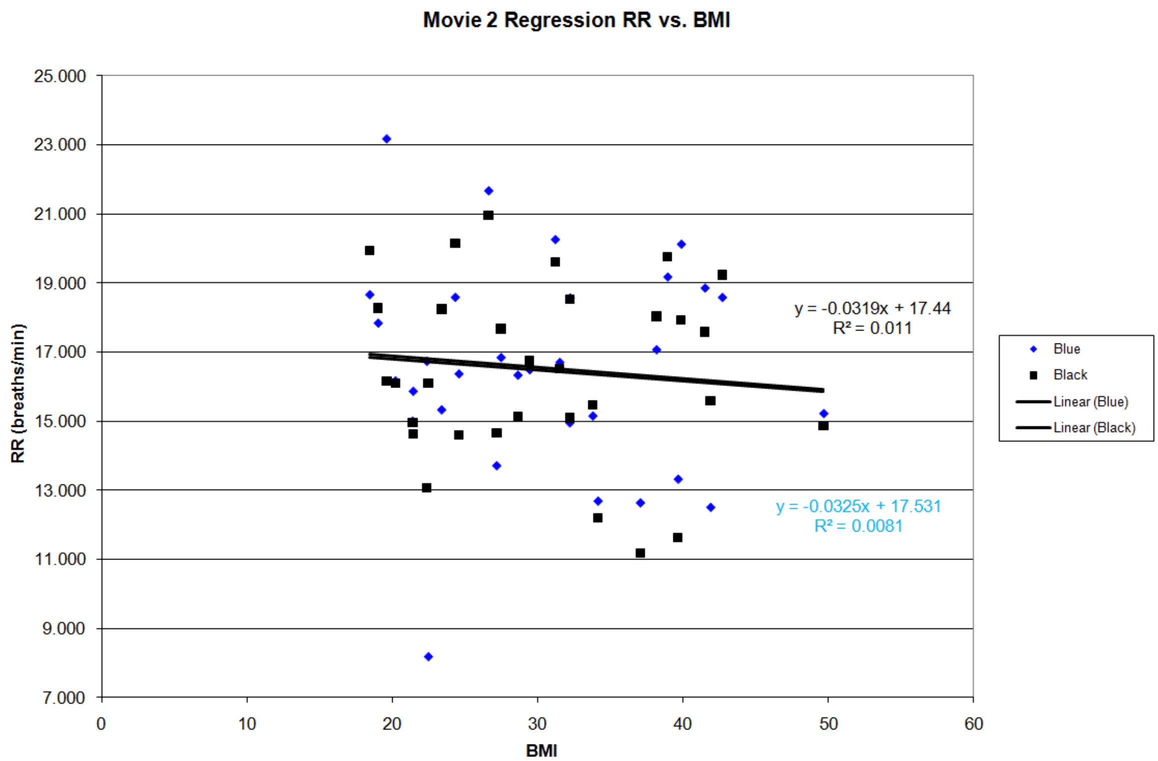

Figure 30.7: Regression RR vs. BMI (Movie 2) by Chair

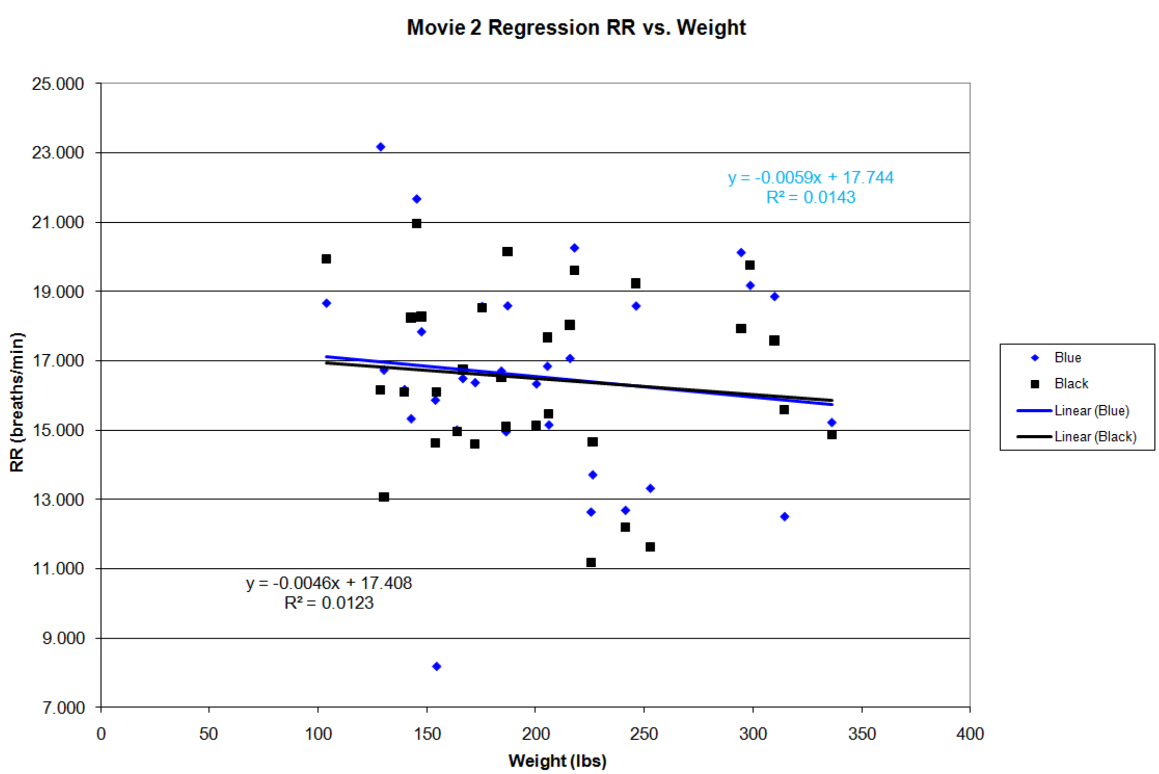

Figure 30.8: Regression RR vs. Weight (Movie 2) by Chair

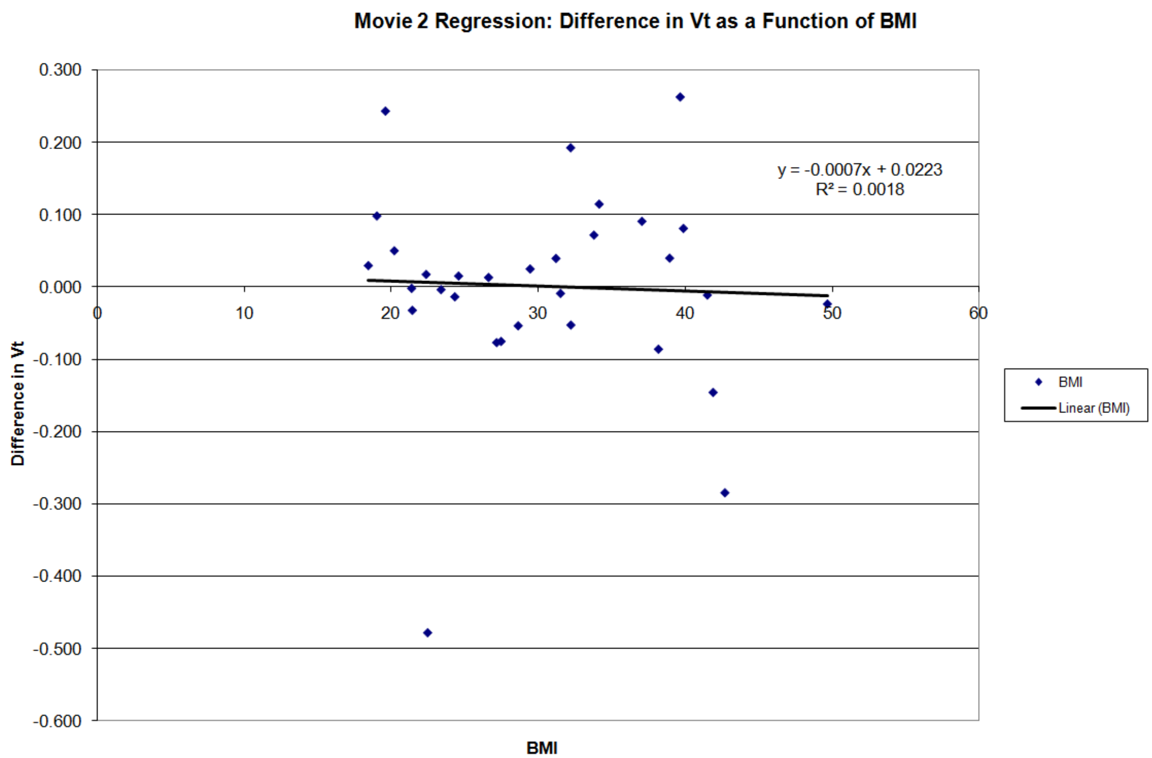

Figure 30.9: Regression TV vs. BMI (Movie 2) All Data

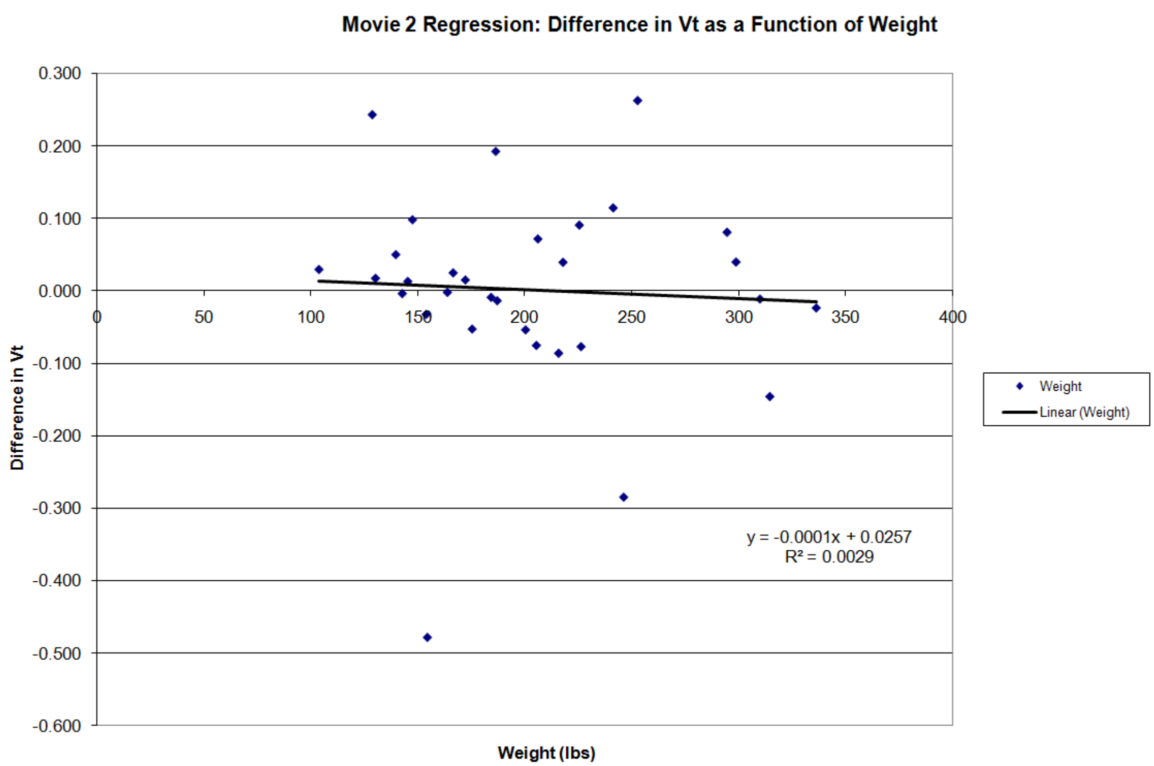

Figure 30.10: Regression TV vs. Weight (Movie 2) All Data

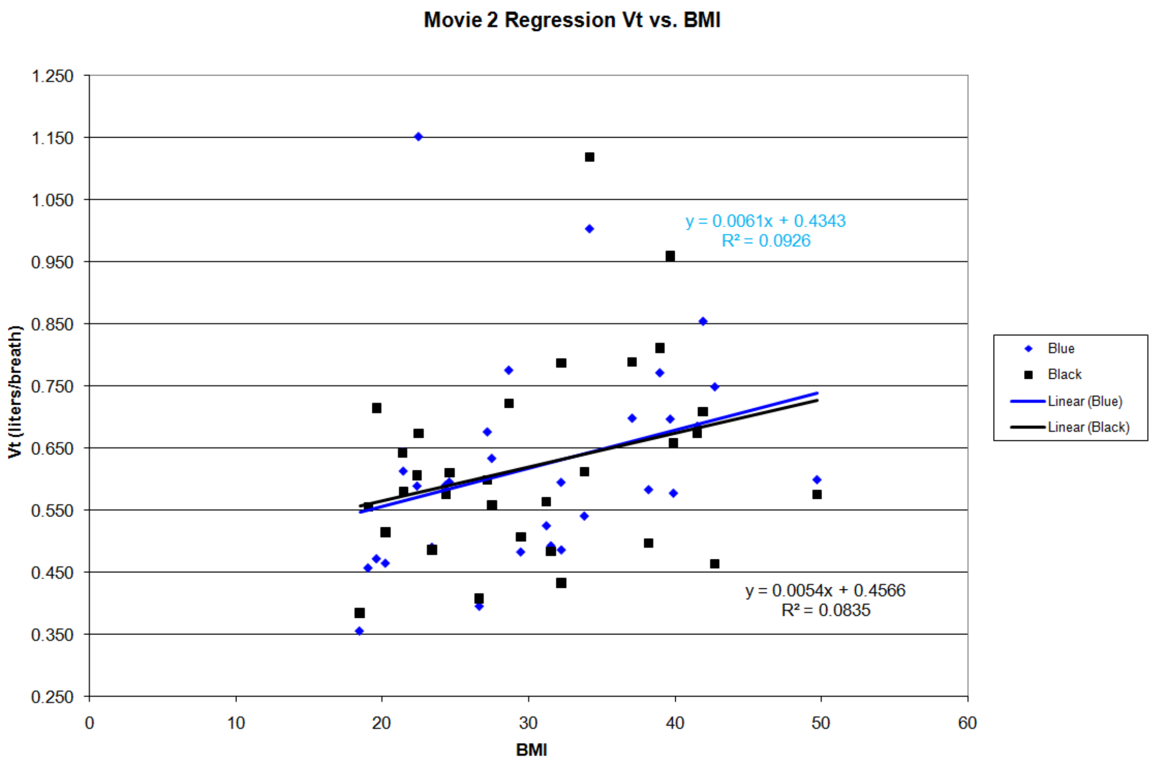

Figure 30.11: Regression TV vs. BMI (Movie 2) by Chair

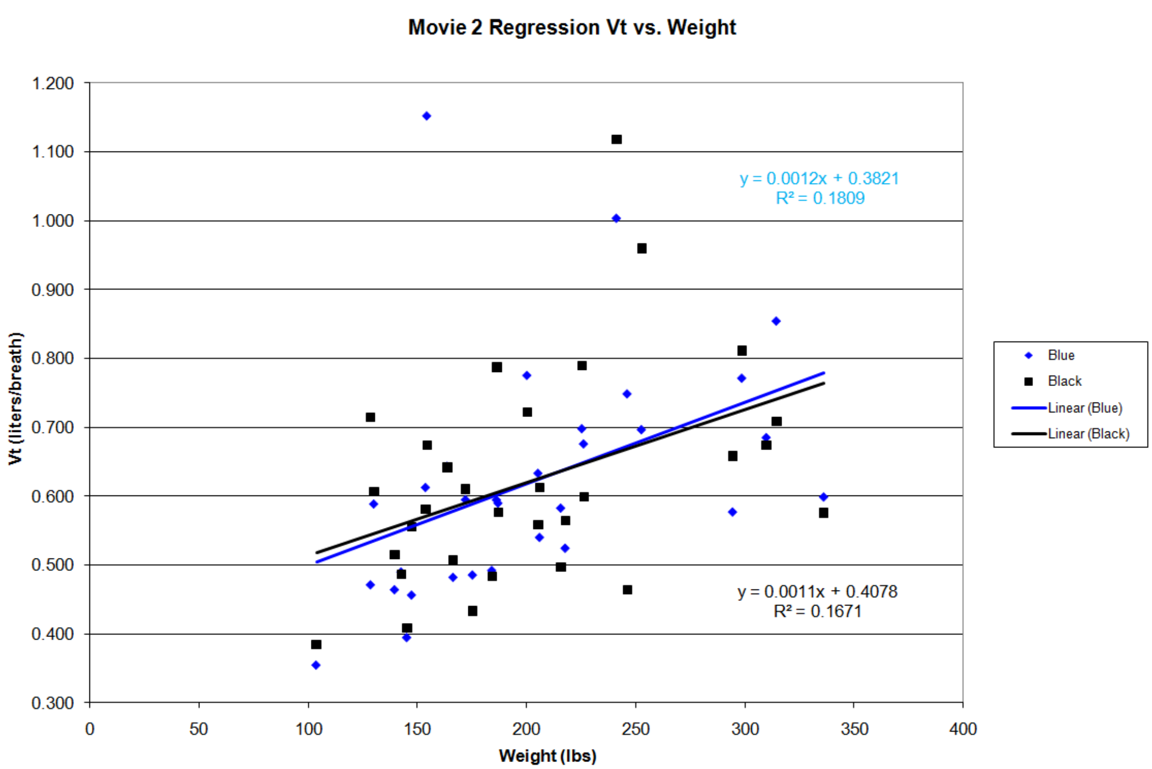

Figure 30.12: Regression TV vs. Weight (Movie 2) by Chair

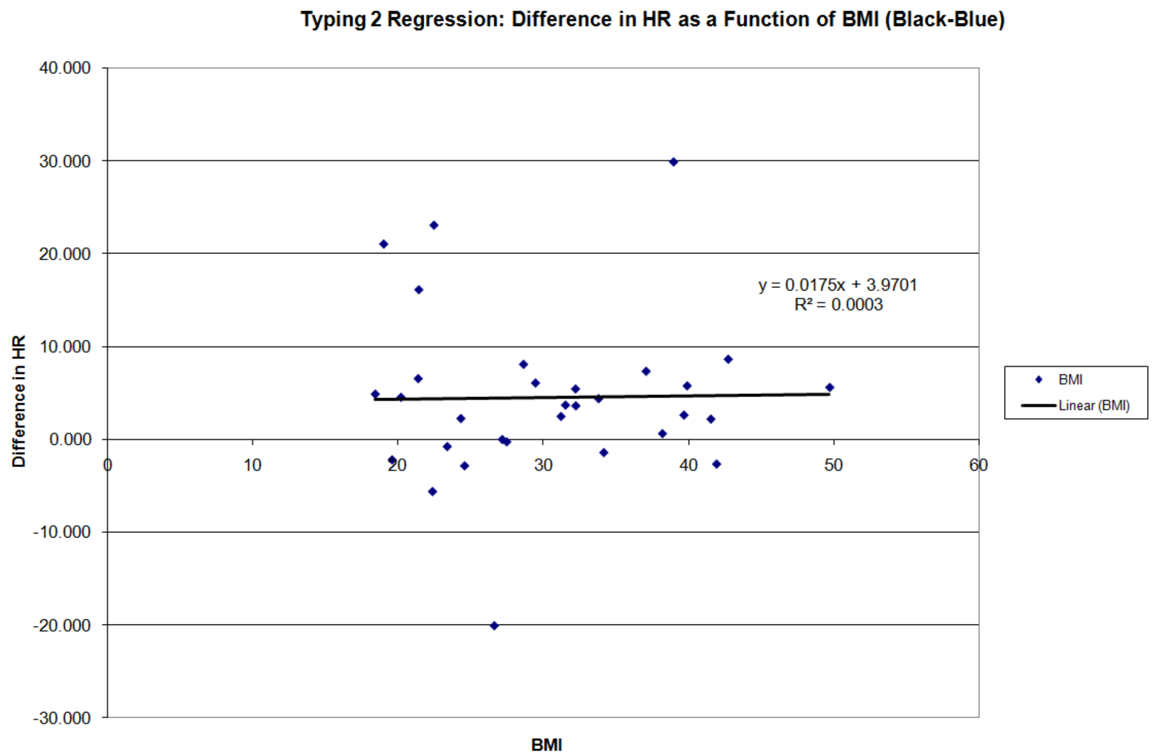

Figure 30.13: Regression HR vs. BMI (Typing 2) All Data

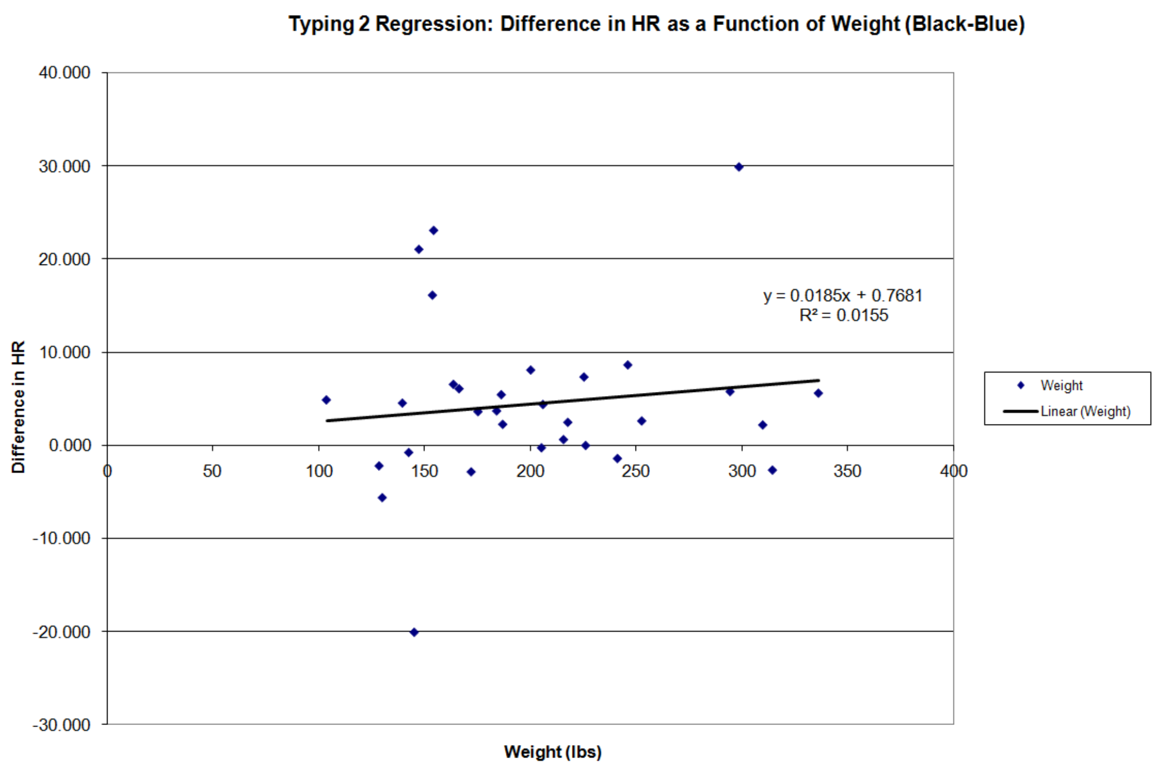

Figure 30.14: Regression HR vs. Weight (Typing 2) All Data

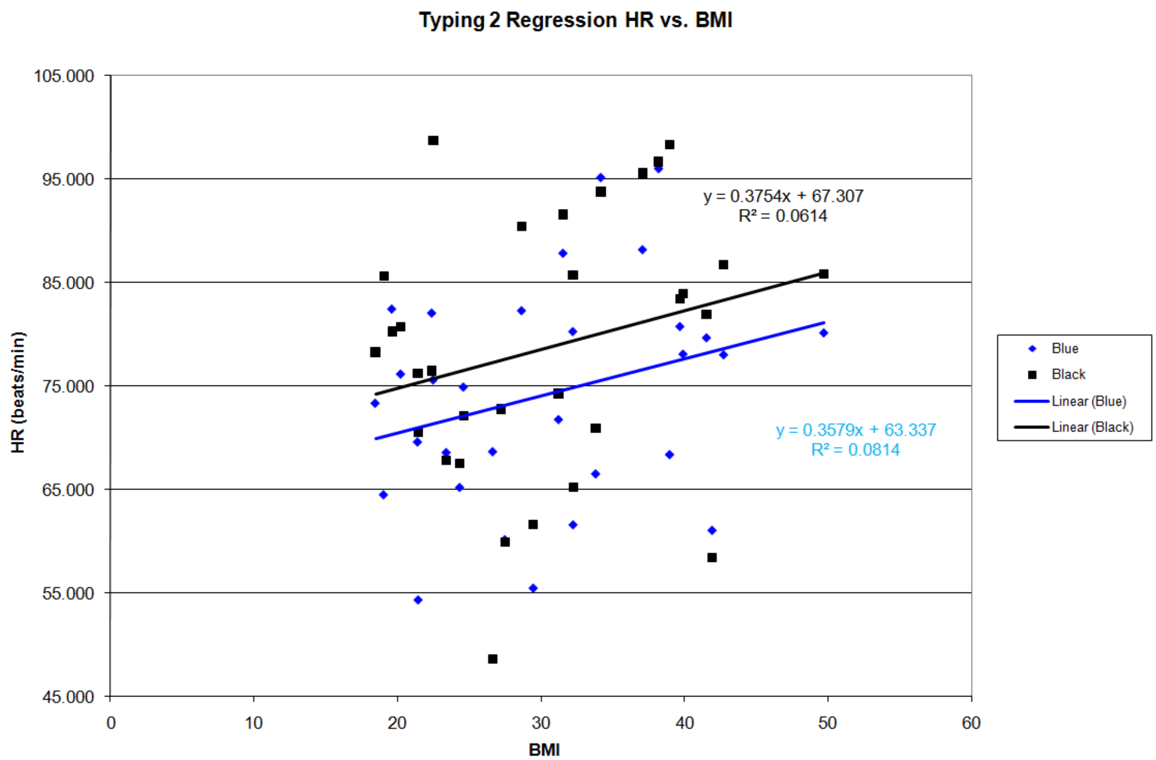

Figure 30.15: Regression HR vs. BMI (Typing 2) by Chair

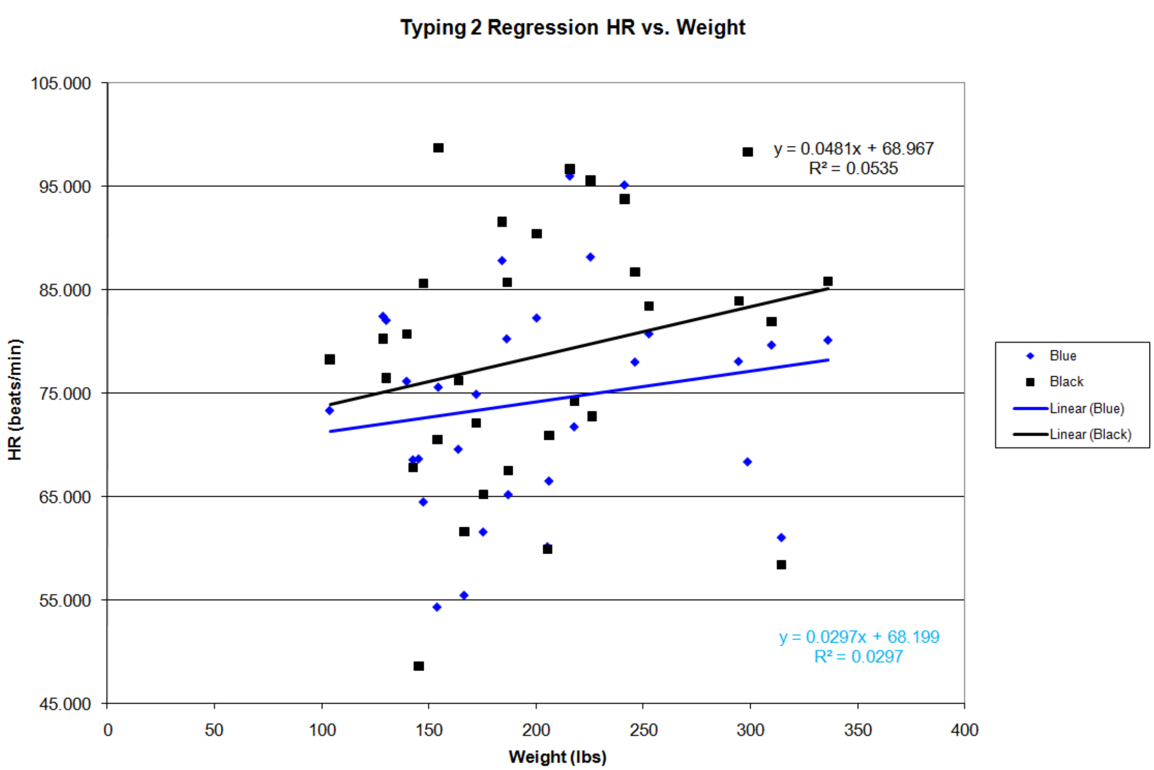

Figure 30.16: Regression HR vs. Weight (Typing 2) by Chair

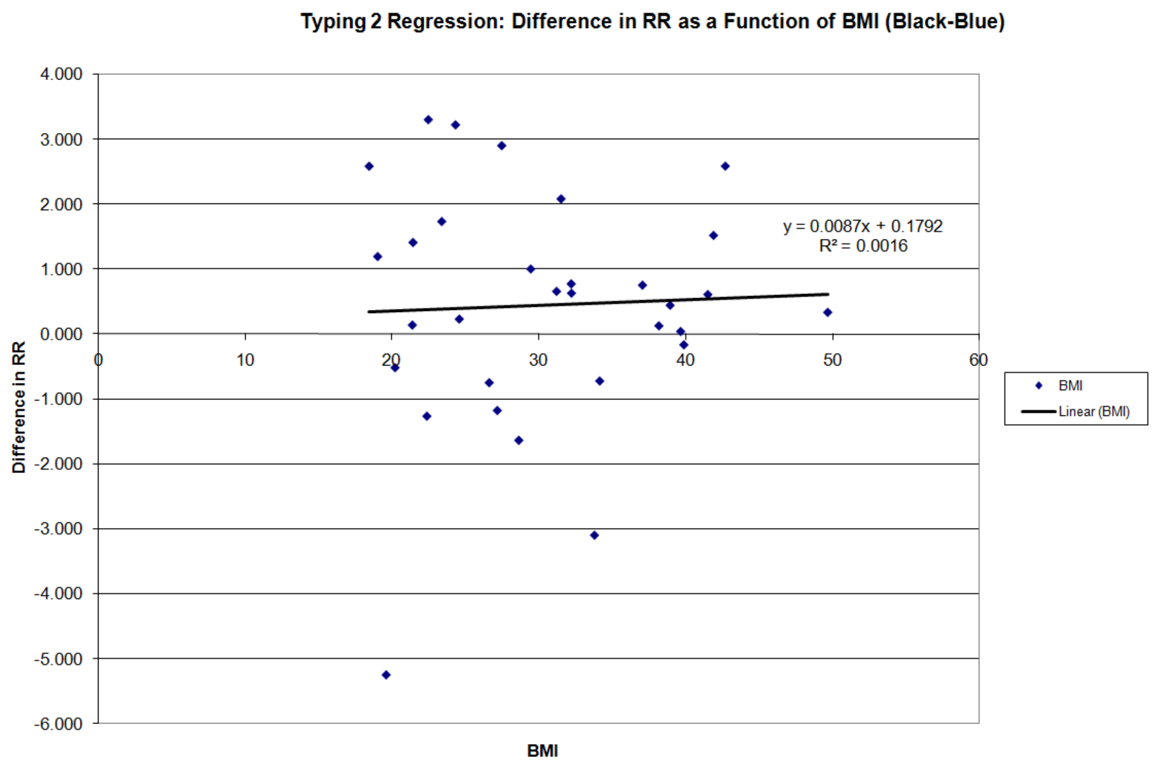

Figure 30.17: Regression RR vs. BMI (Typing 2) All Data

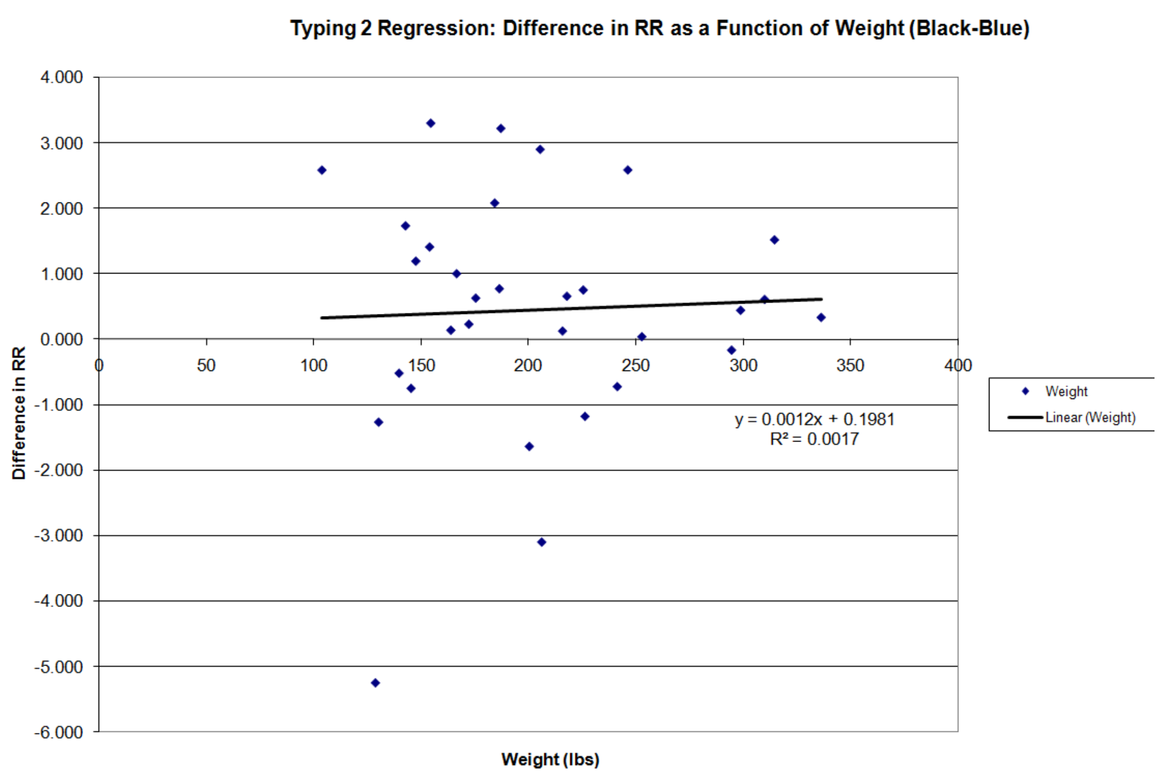

Figure 30.18: Regression RR vs. Weight (Typing 2) All Data

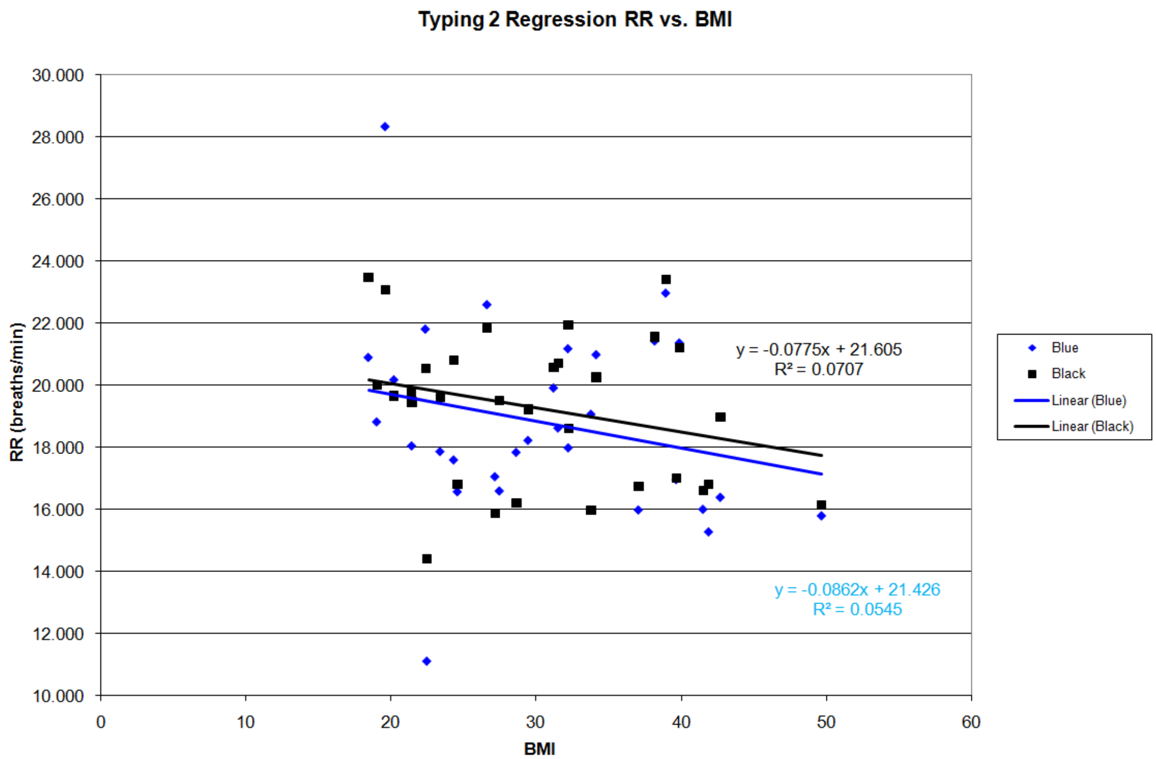

Figure 30.19: Regression RR vs. BMI (Typing 2) by Chair

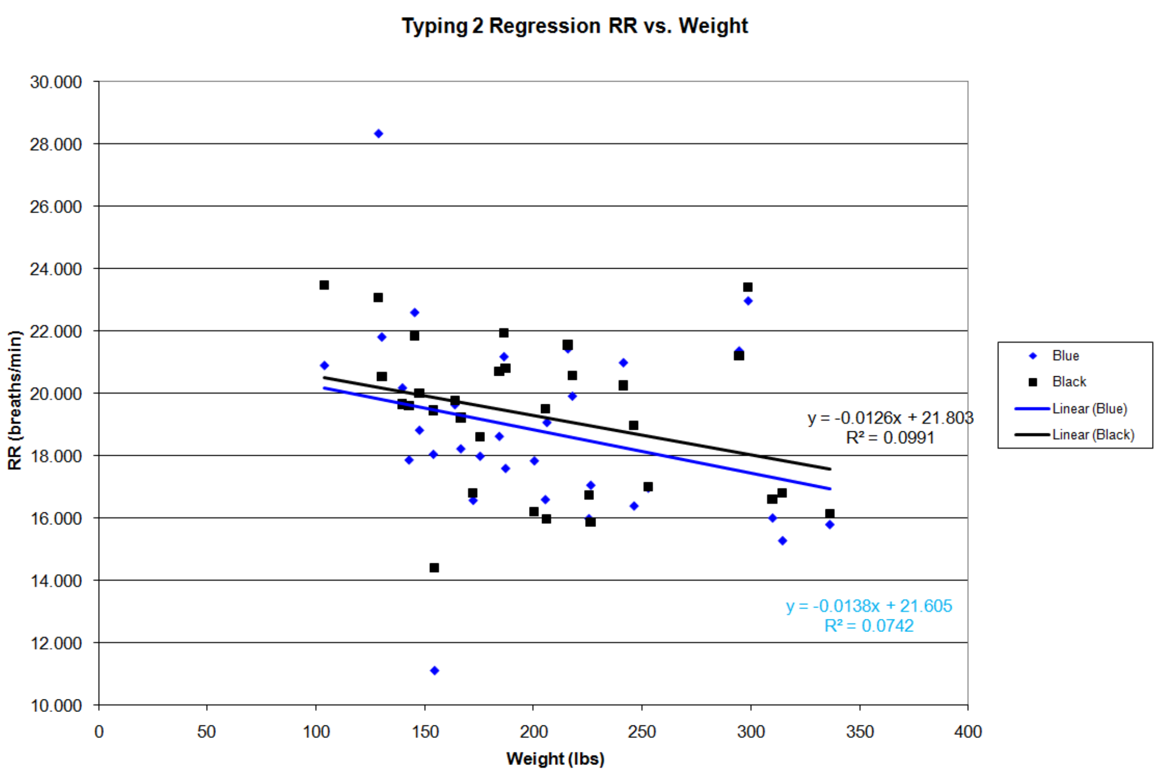

Figure 30.20: Regression RR vs. Weight (Typing 2) by Chair

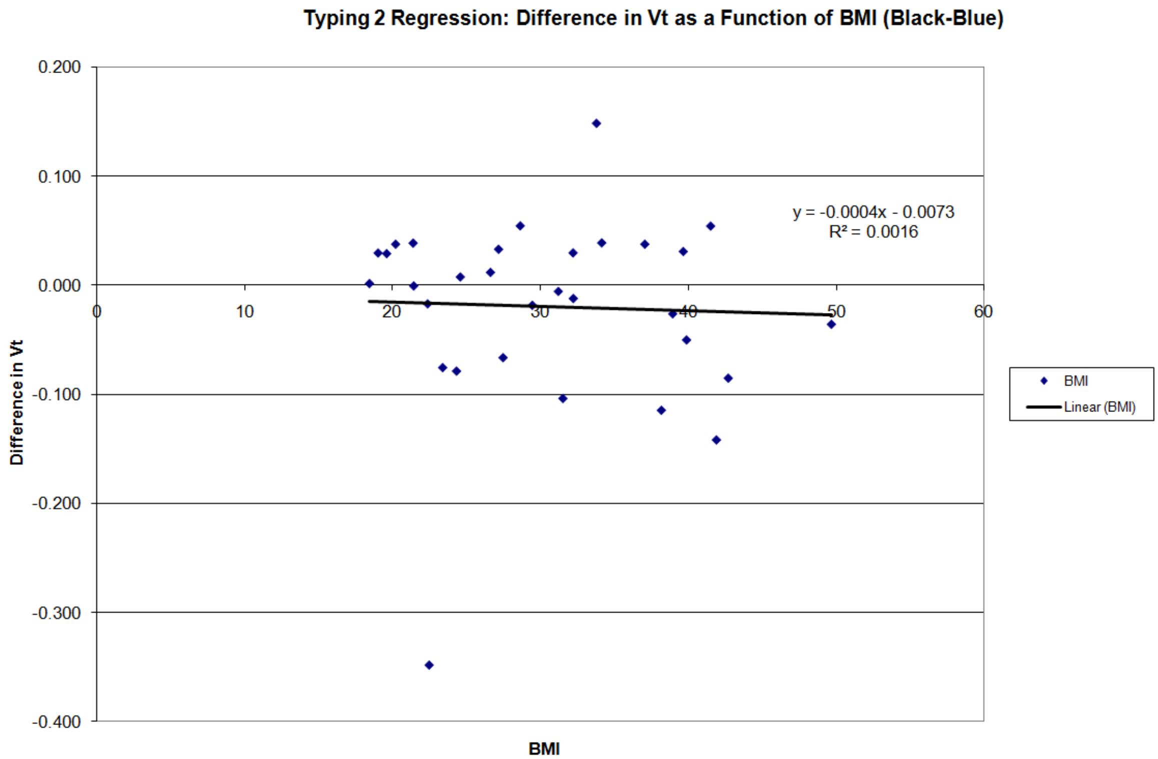

Figure 30.21: Regression TV vs. BMI (Typing 2) All Data

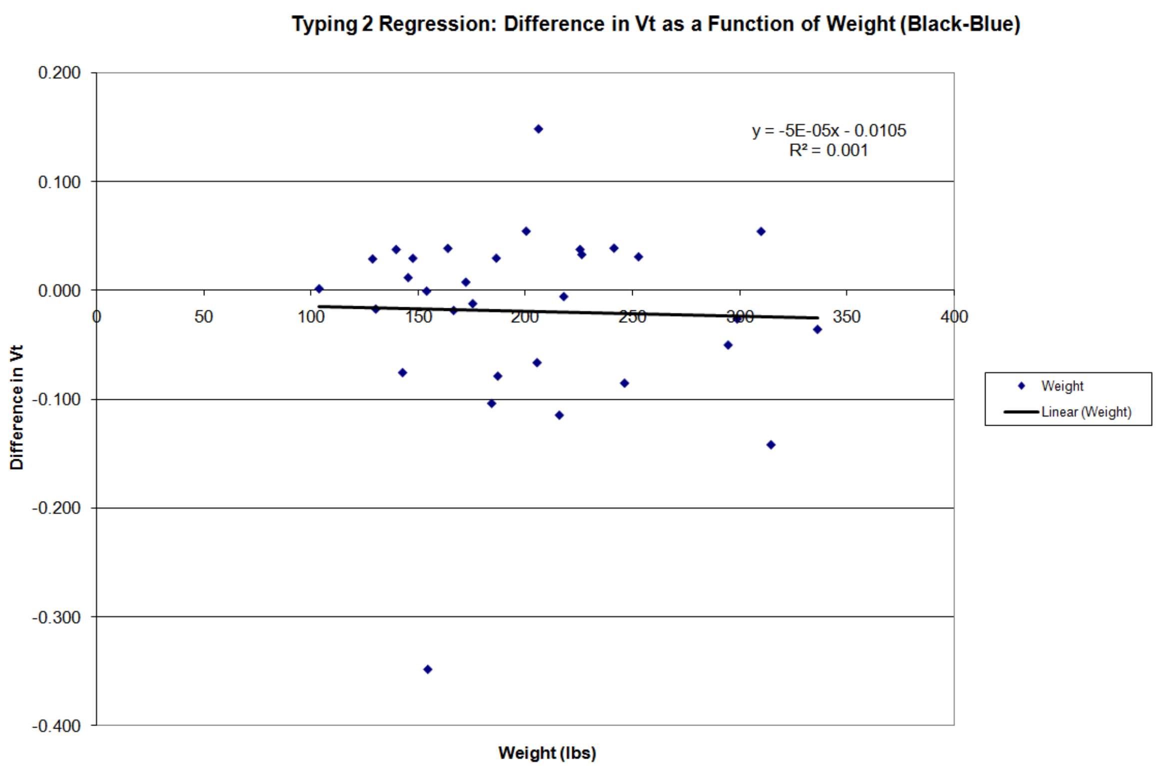

Figure 30.22: Regression TV vs. Weight (Typing 2) All Data

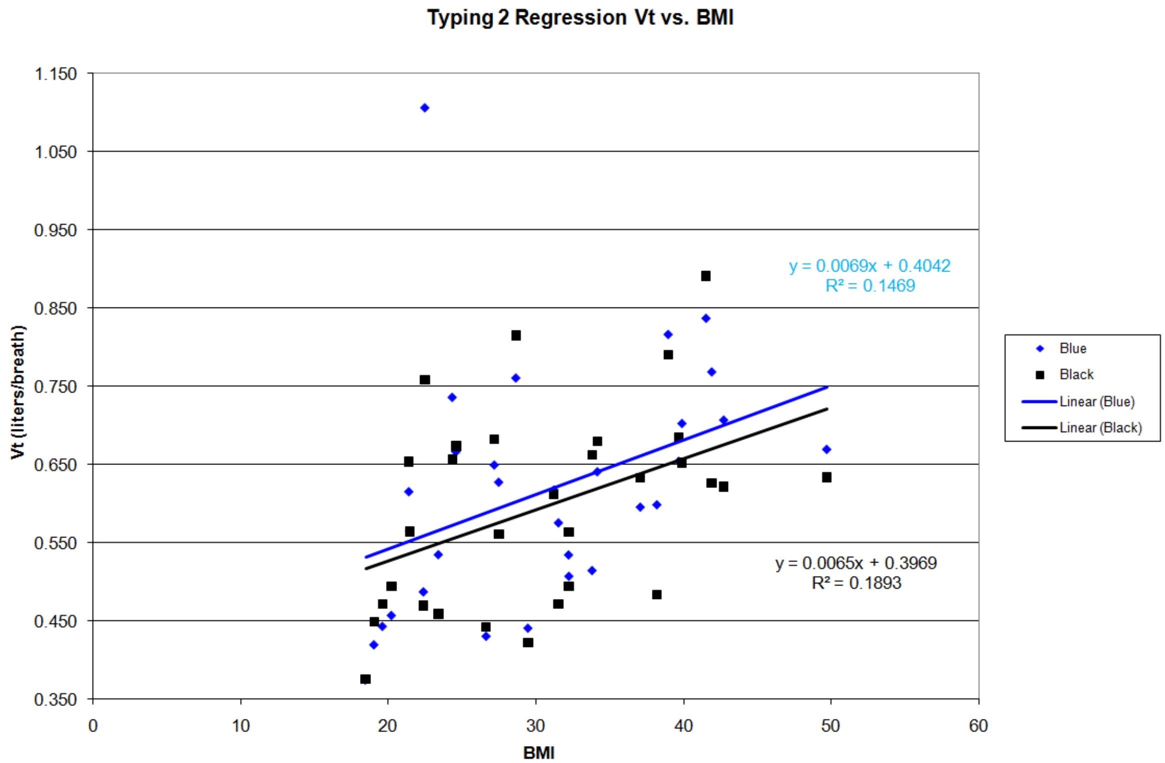

Figure 30.23: Regression TV vs. BMI (Typing 2) by Chair

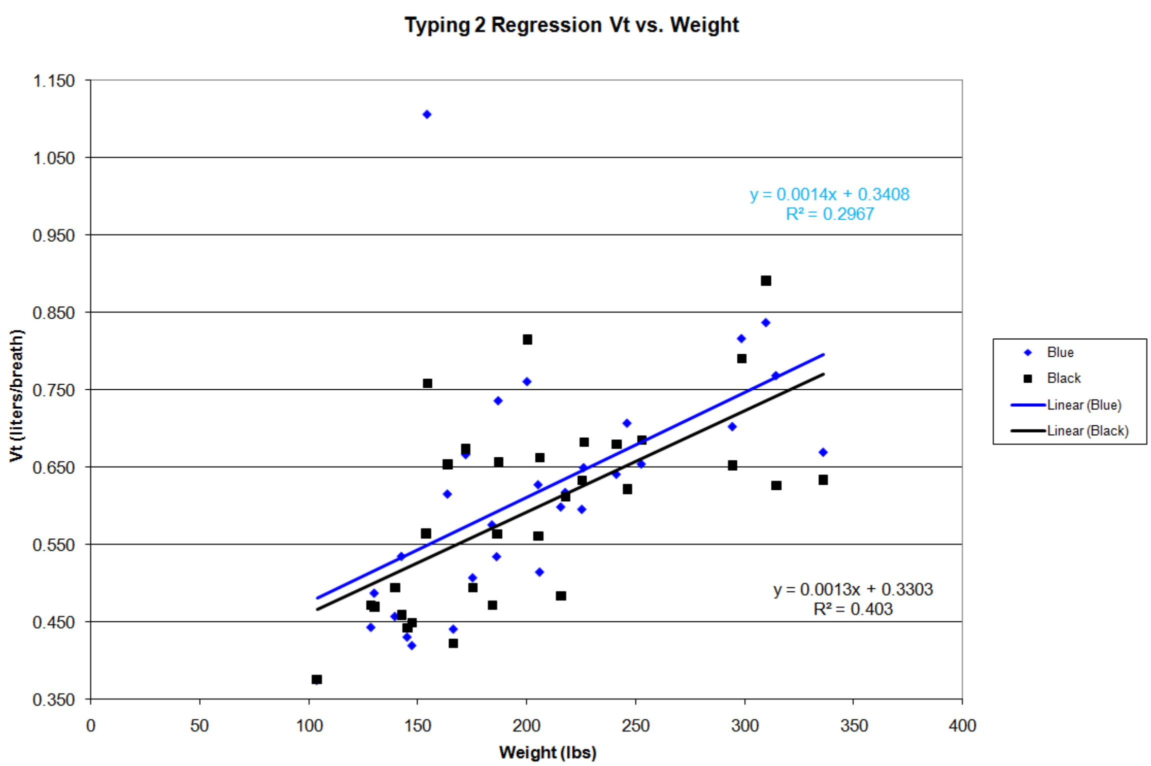

Figure 30.24: Regression TV vs. Weight (Typing 2) by Chair

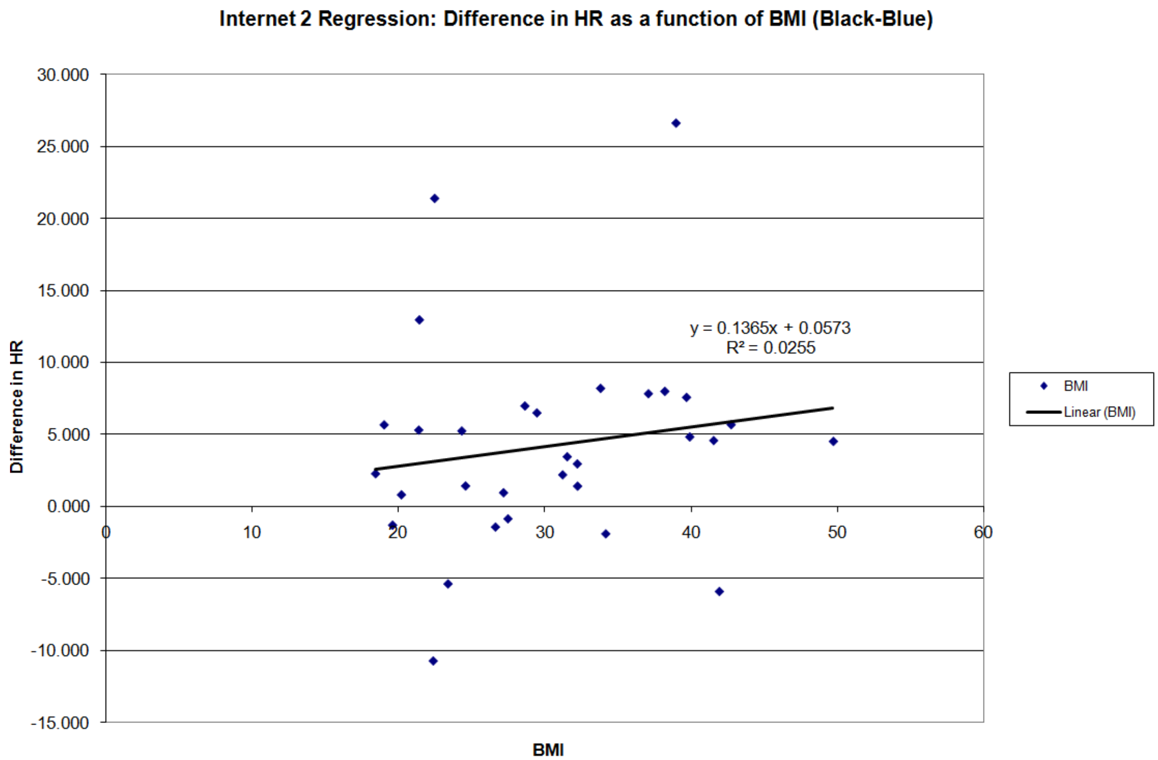

Figure 30.25: Regression HR vs. BMI (Internet 2) All Data

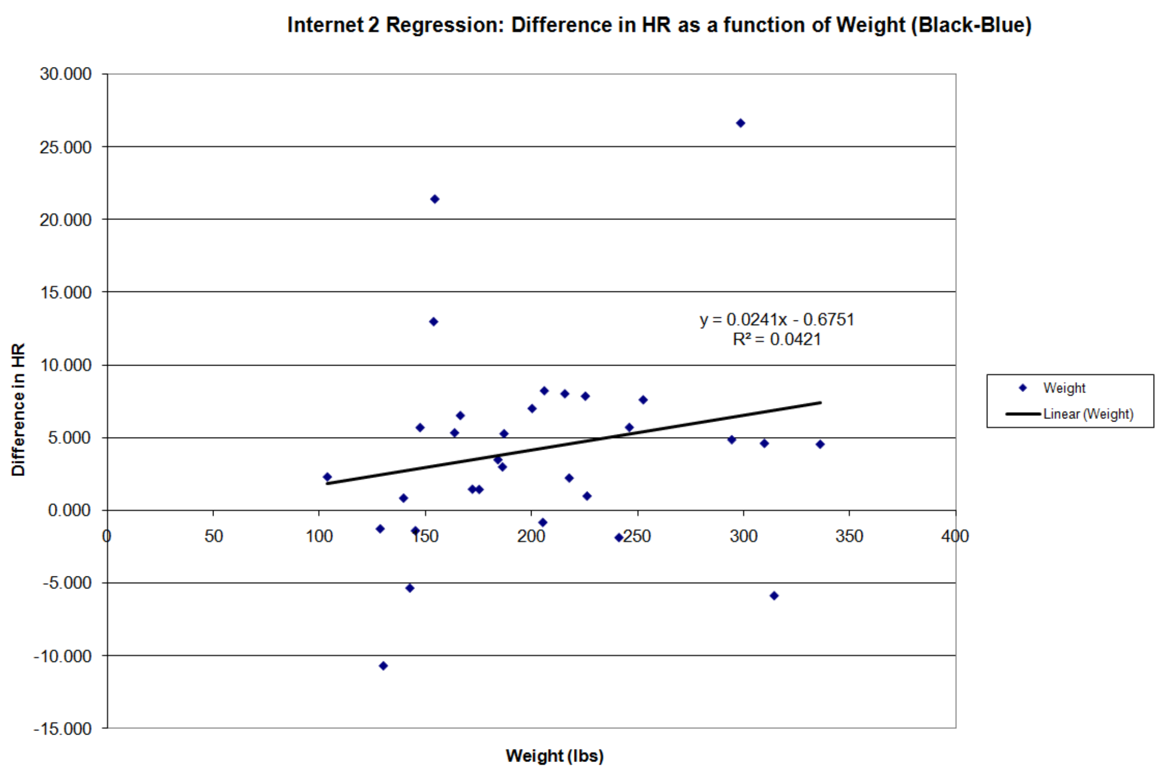

Figure 30.26: Regression HR vs. Weight (Internet 2) All Data

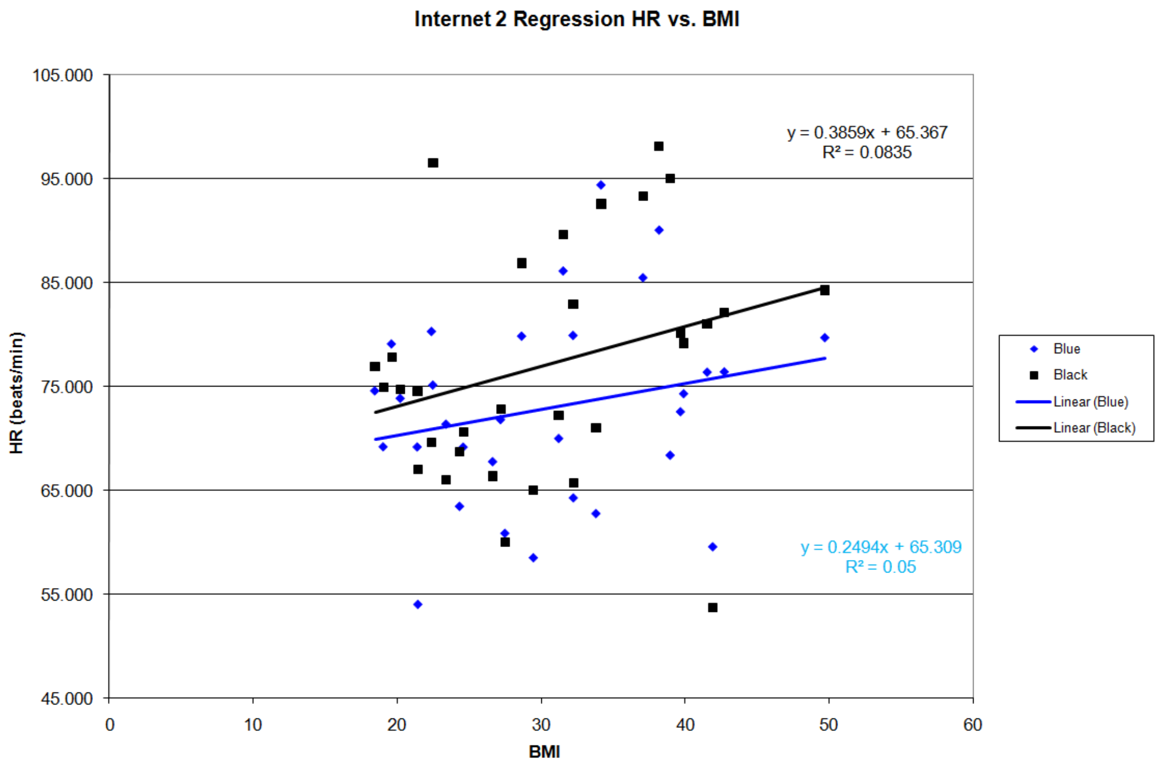

Figure 30.27: Regression HR vs. BMI (Internet 2) by chair

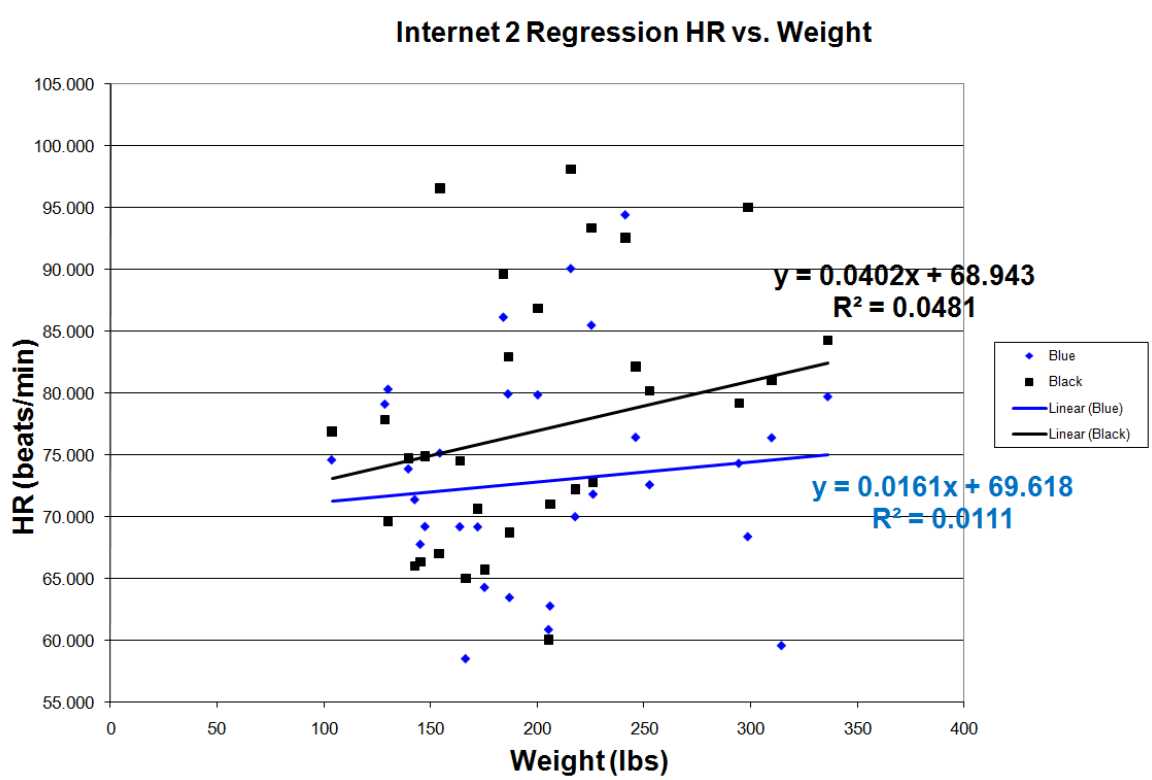

Figure 30.28: Regression HR vs. Weight (Internet 2) by chair

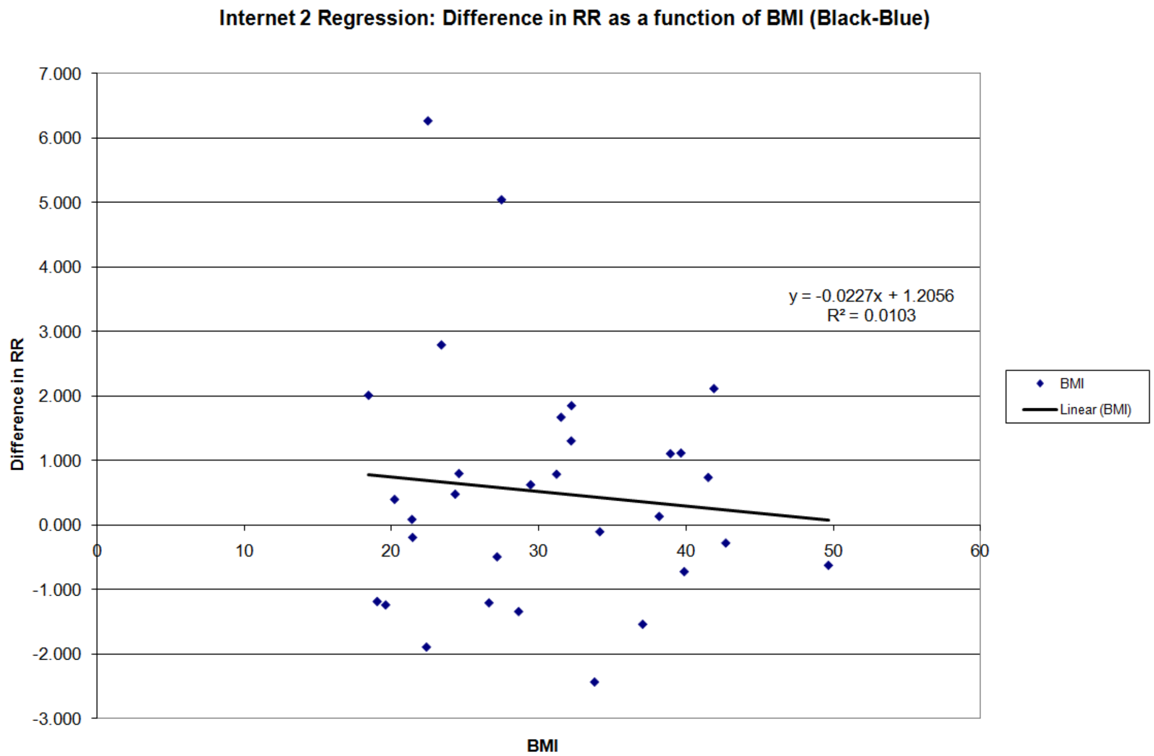

Figure 30.29: Regression RR vs. BMI (Internet 2) All Data

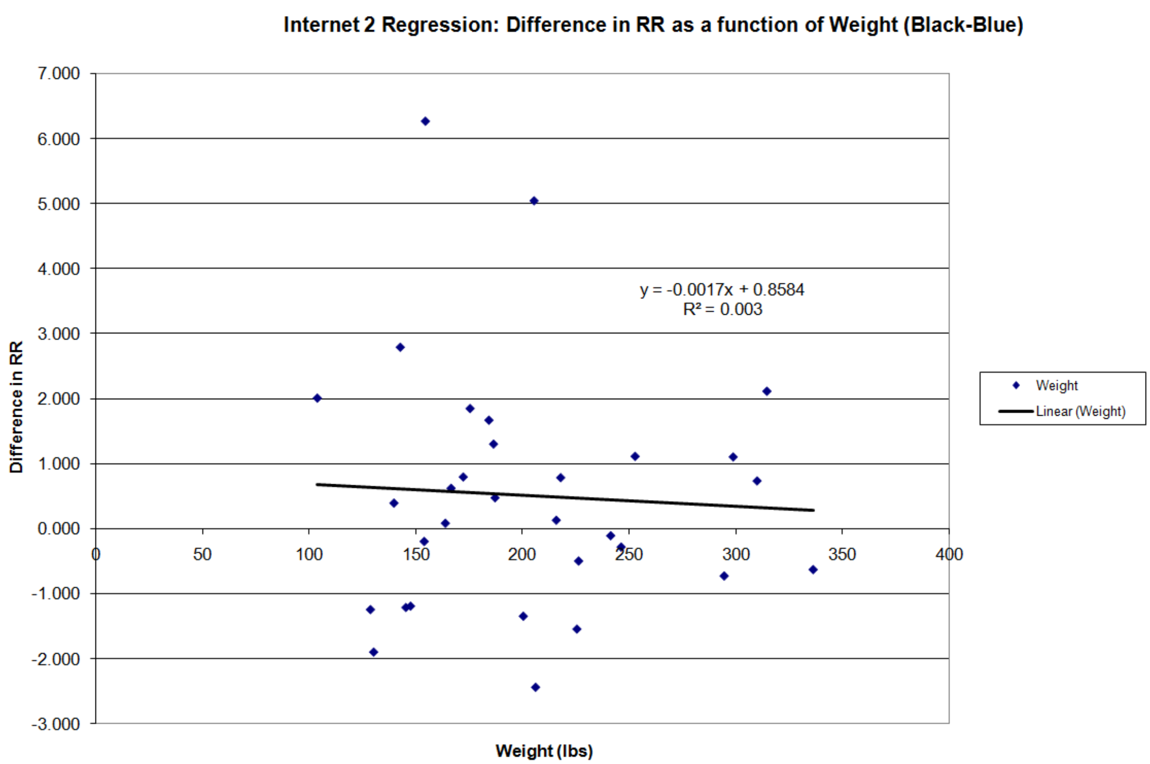

Figure 30.30: Regression RR vs. Weight (Internet 2) All Data

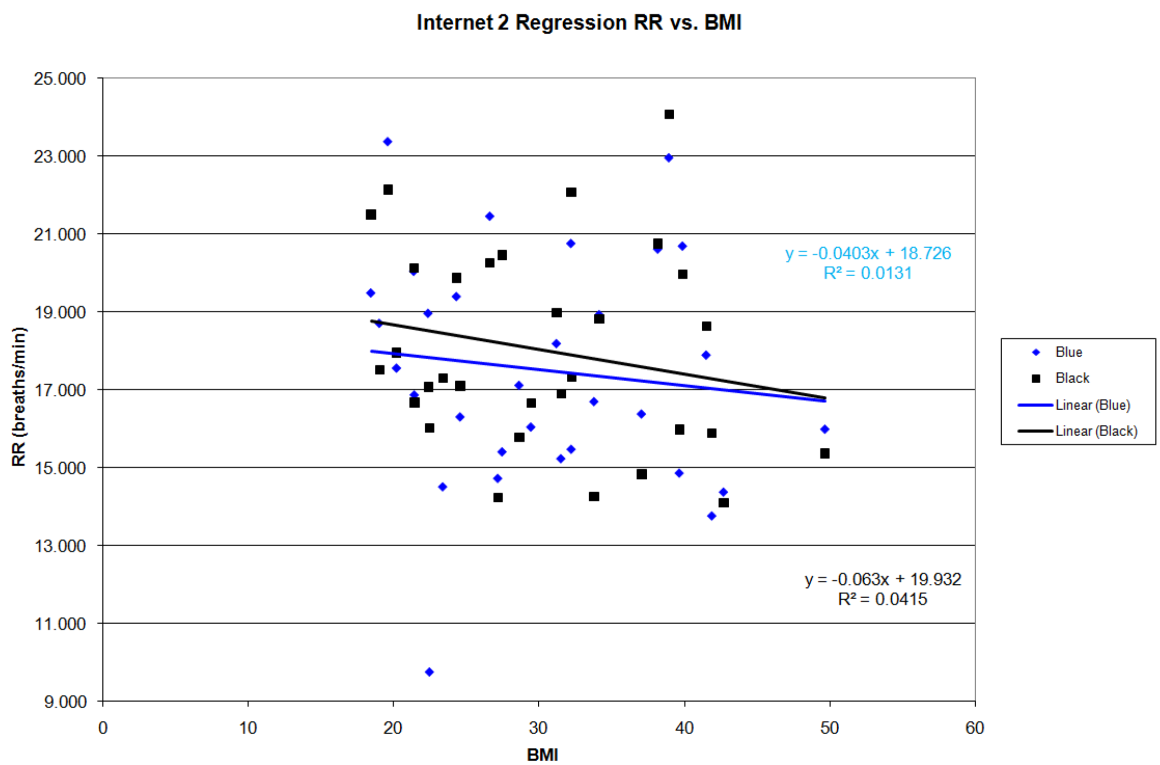

Figure 30.31: Regression RR vs. BMI (Internet 2) by chair

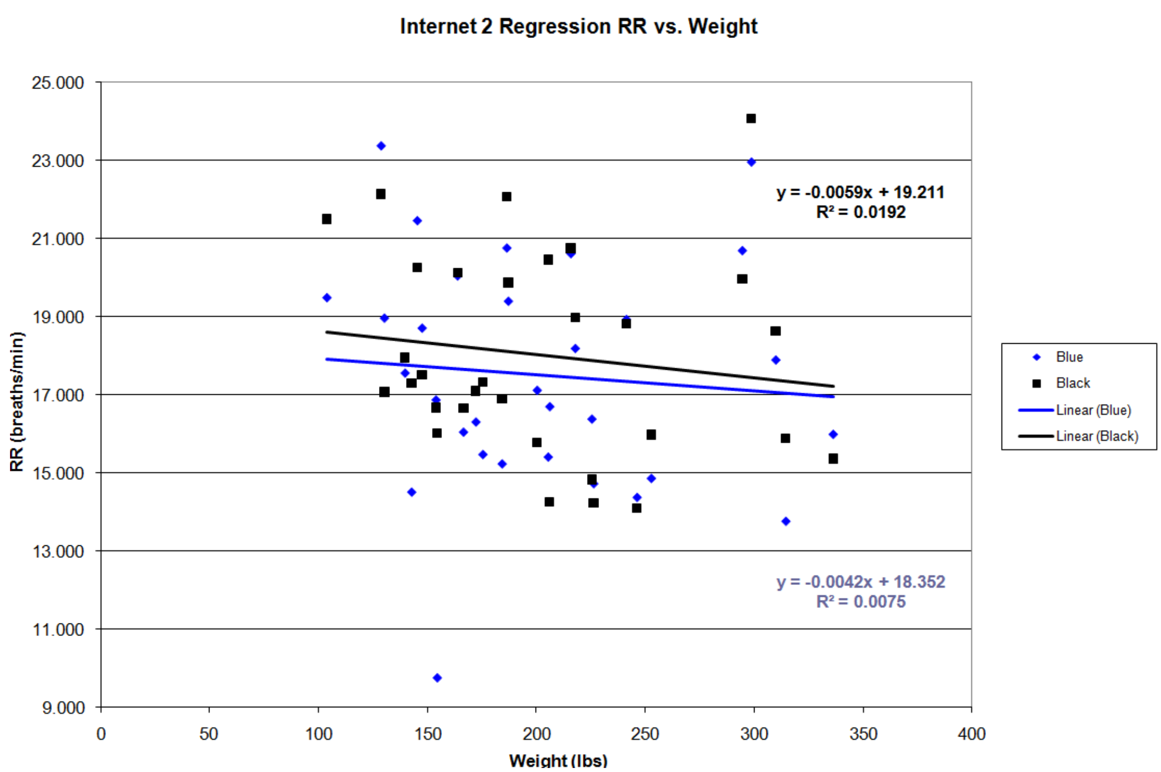

Figure 30.32: Regression RR vs. Weight (Internet 2) by chair

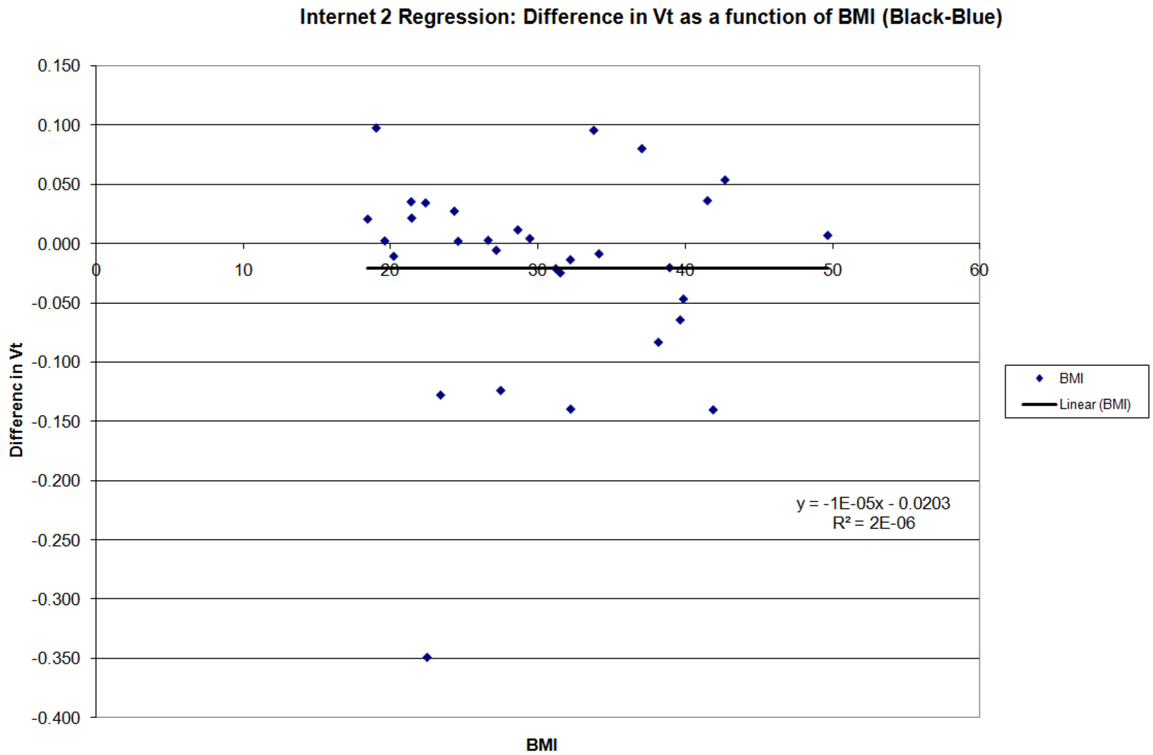

Figure 30.33: Regression TV vs. BMI (Internet 2) All Data

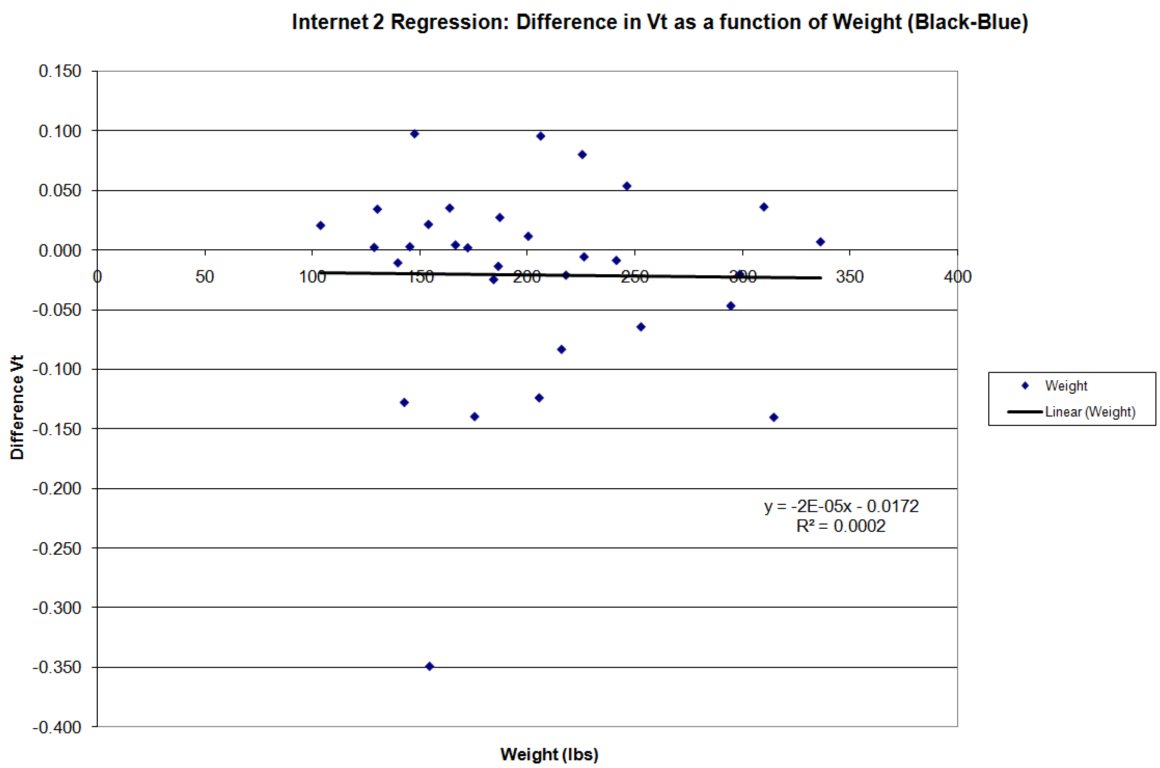

Figure 30.34: Regression TV vs. Weight (Internet 2) All Data

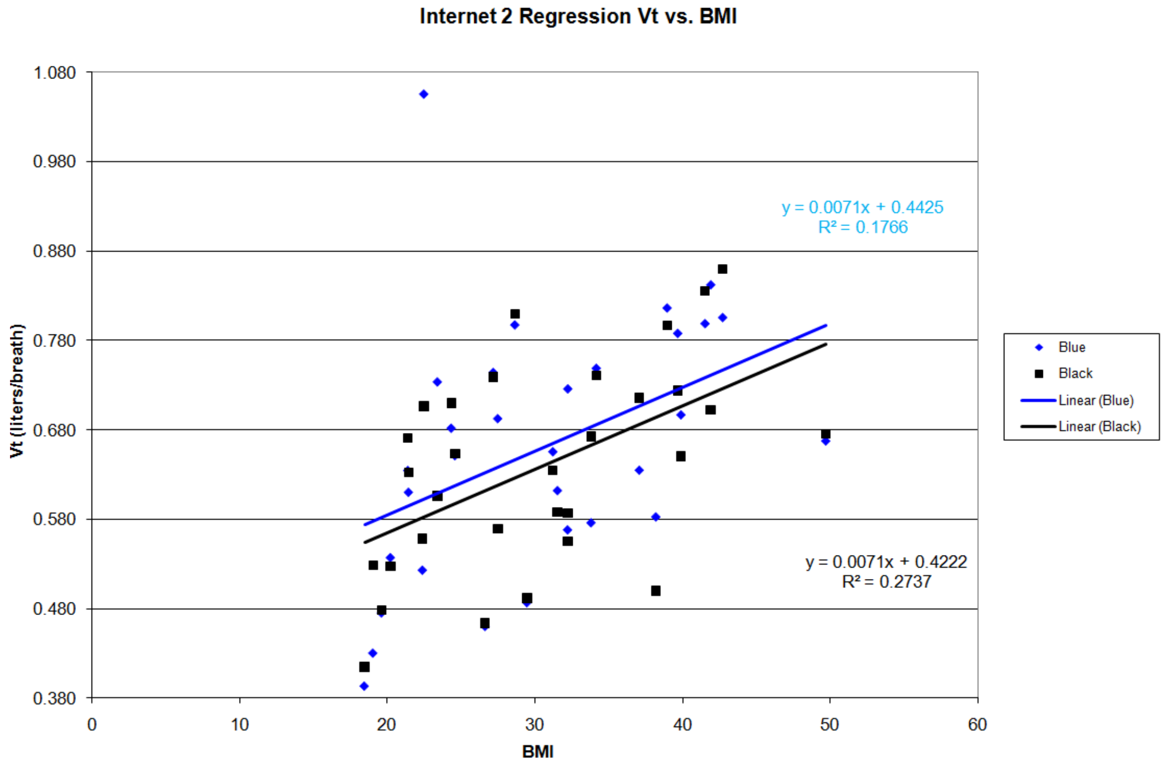

Figure 30.35: Regression TV vs. BMI (Internet 2) by chair

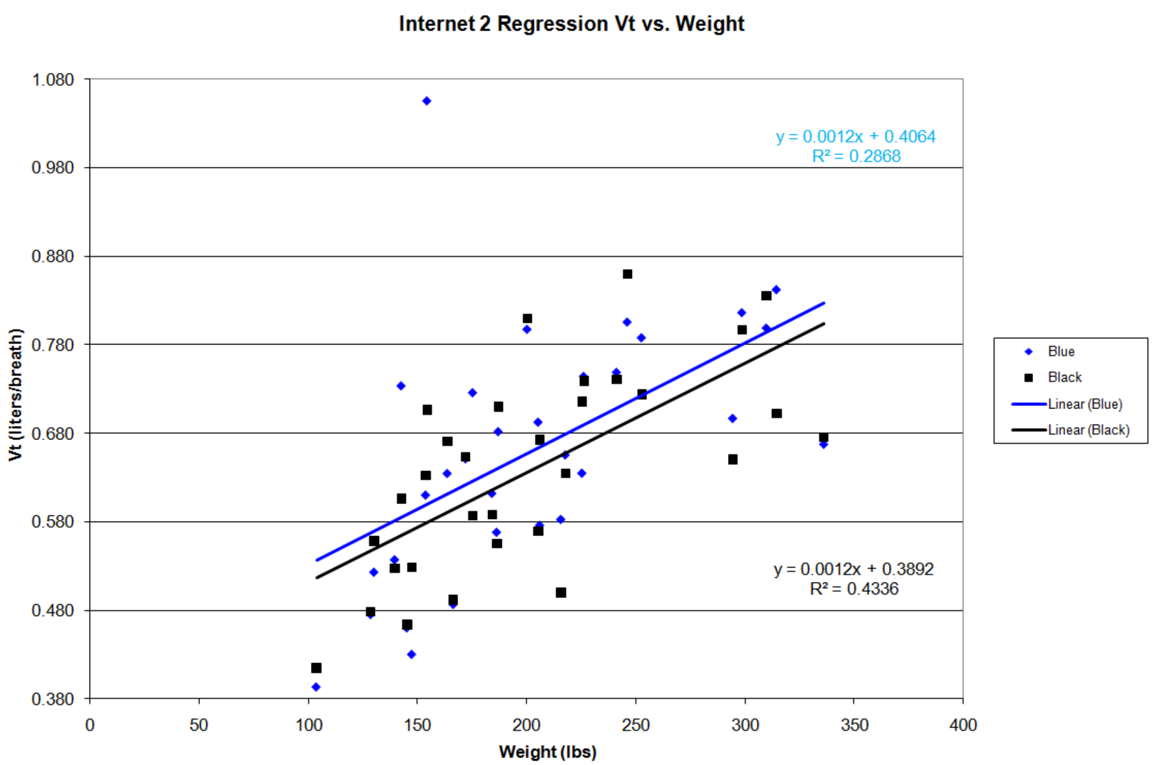

Figure 30.36: Regression TV vs. Weight (Internet 2) by chair

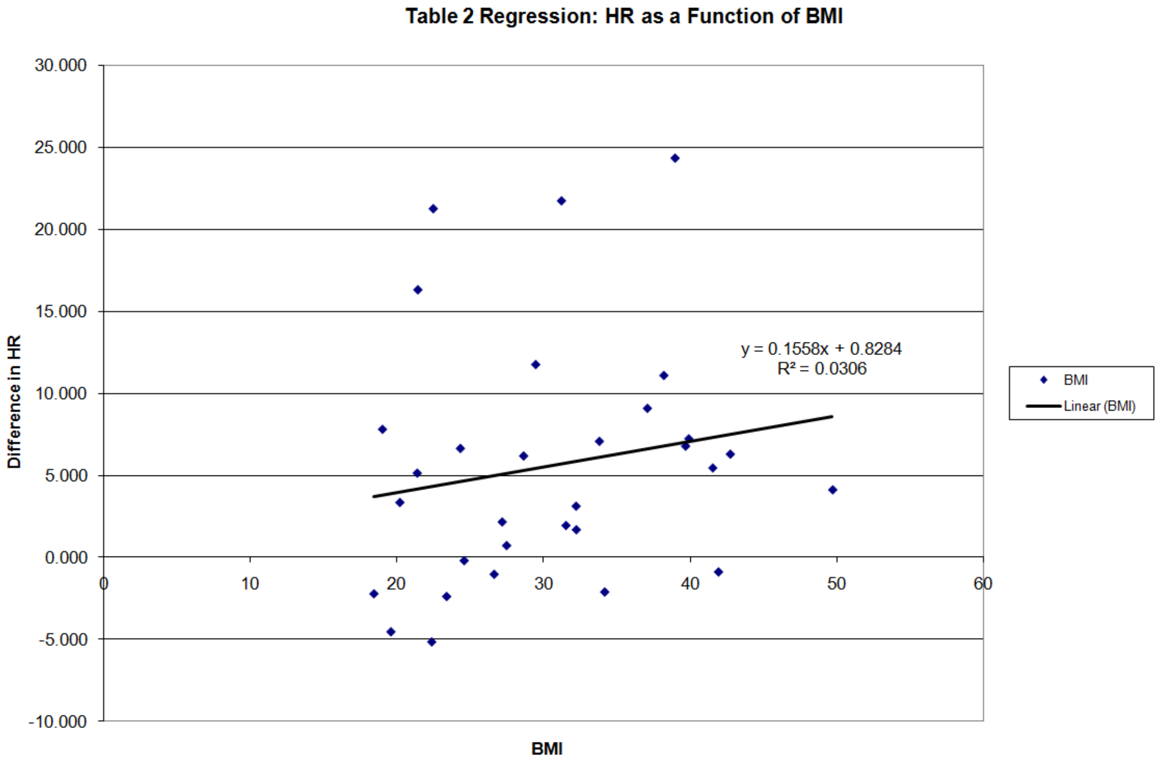

Figure 30.37: Regression HR vs. BMI (Table 2) All Data

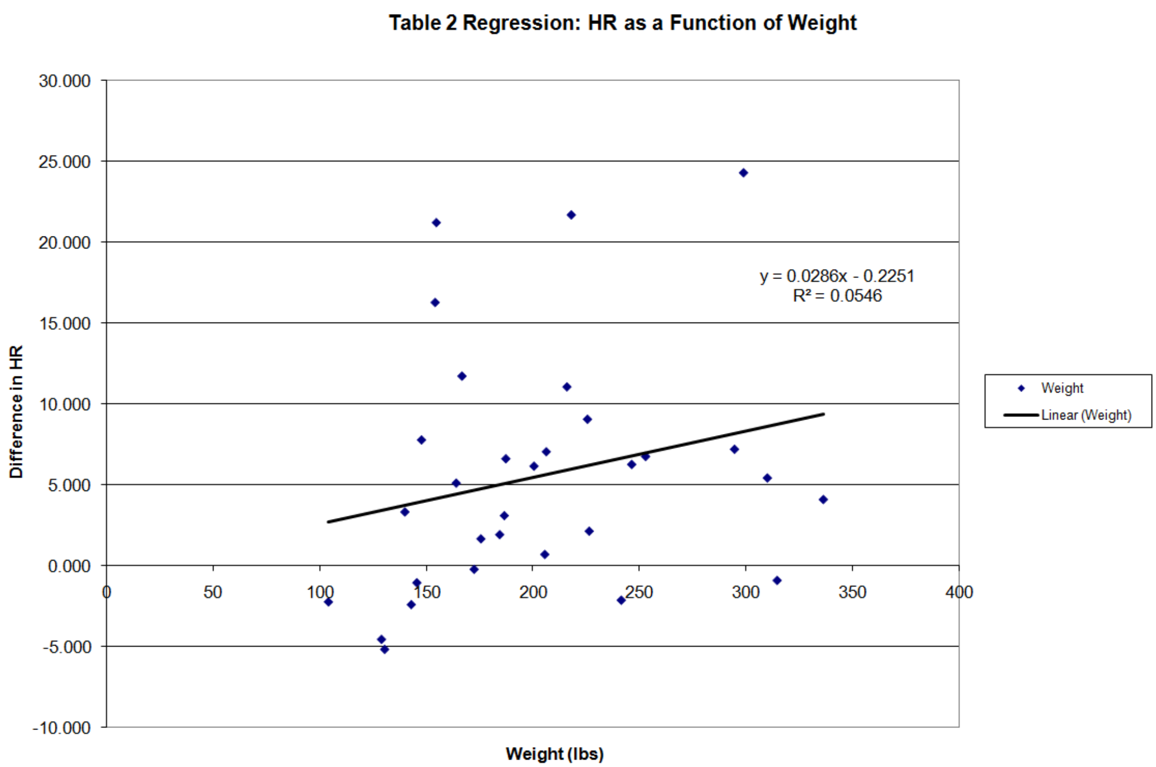

Figure 30.38: Regression HR vs. Weight (Table 2) All Data

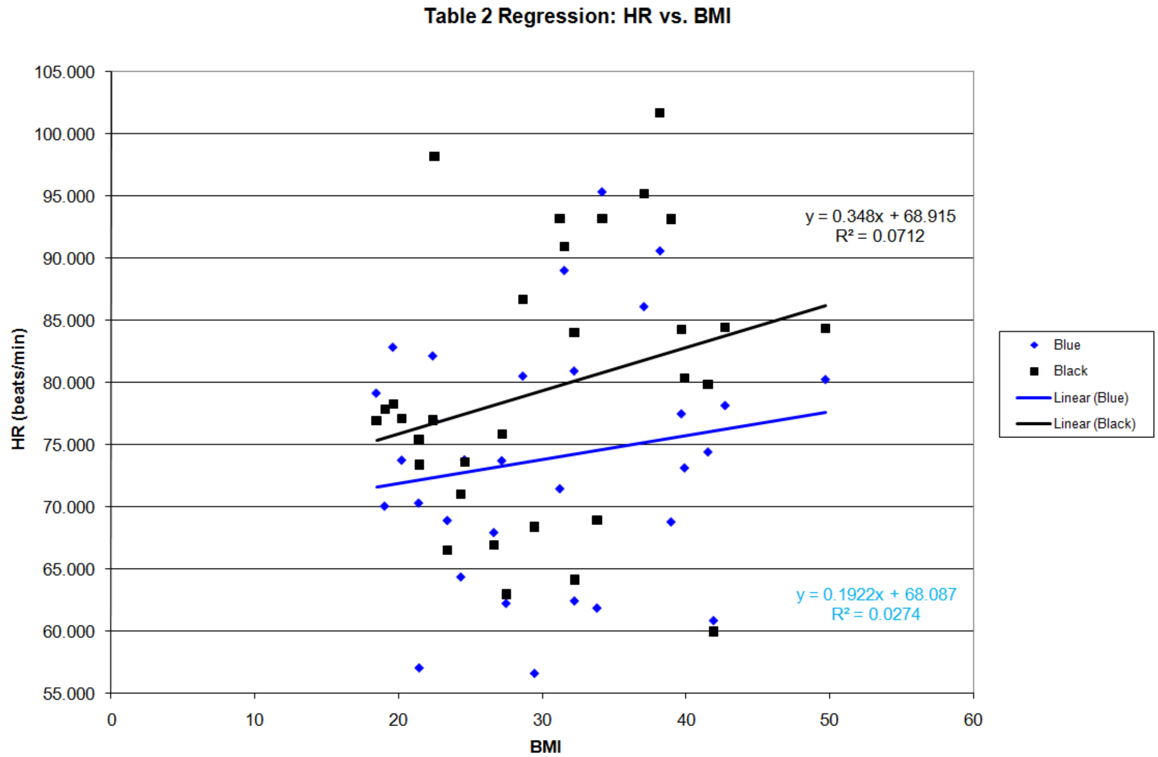

Figure 30.39: Regression HR vs. BMI (Table 2) by chair

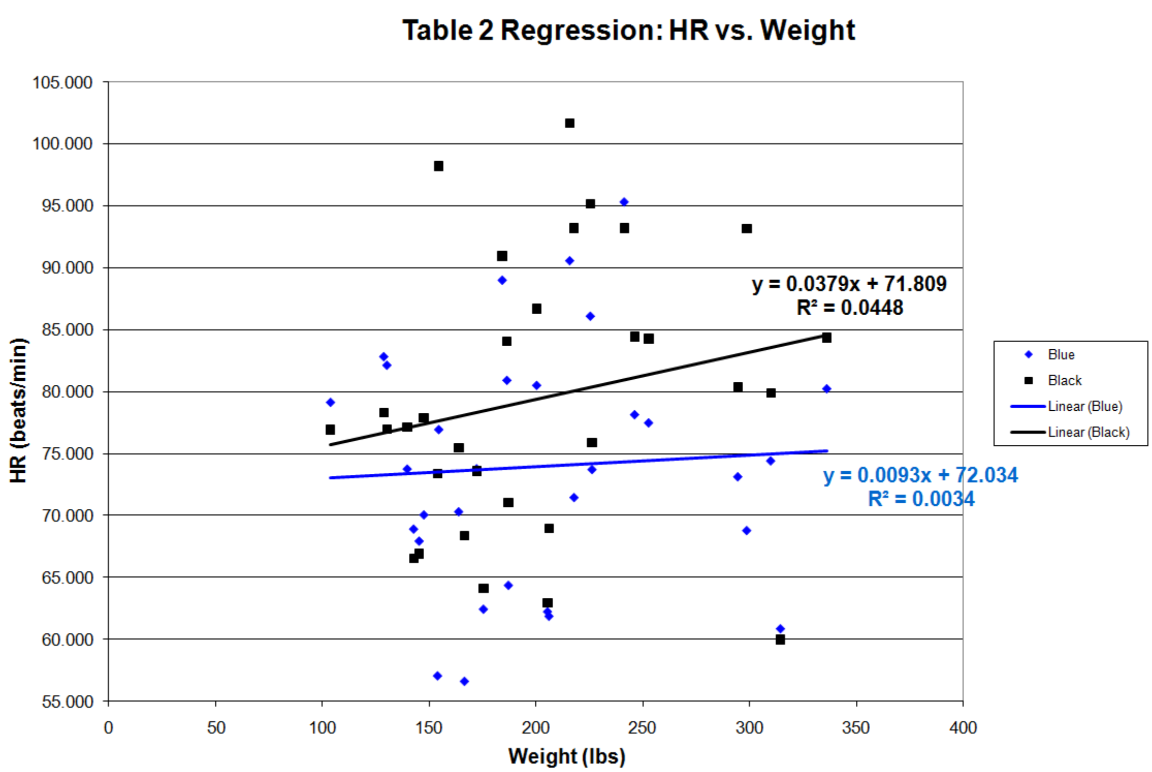

Figure 30.40: Regression HR vs. Weight (Table 2) by chair

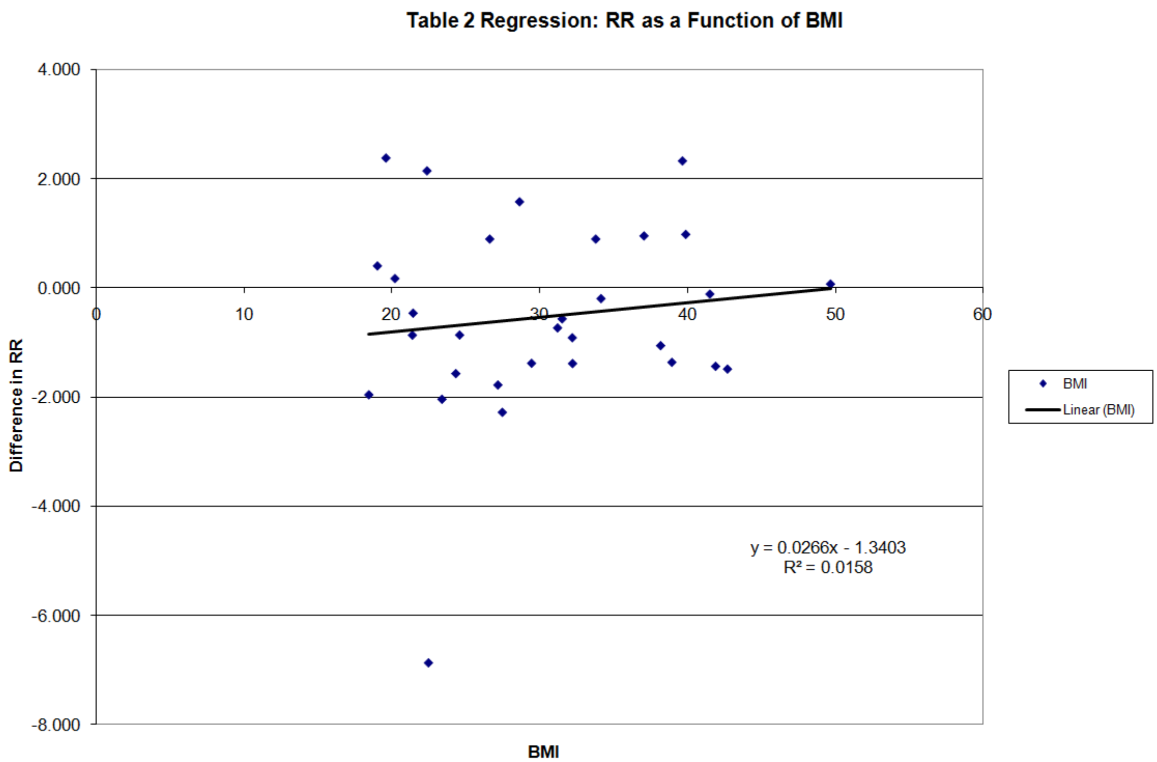

Figure 30.41: Regression RR vs. BMI (Table 2) All Data

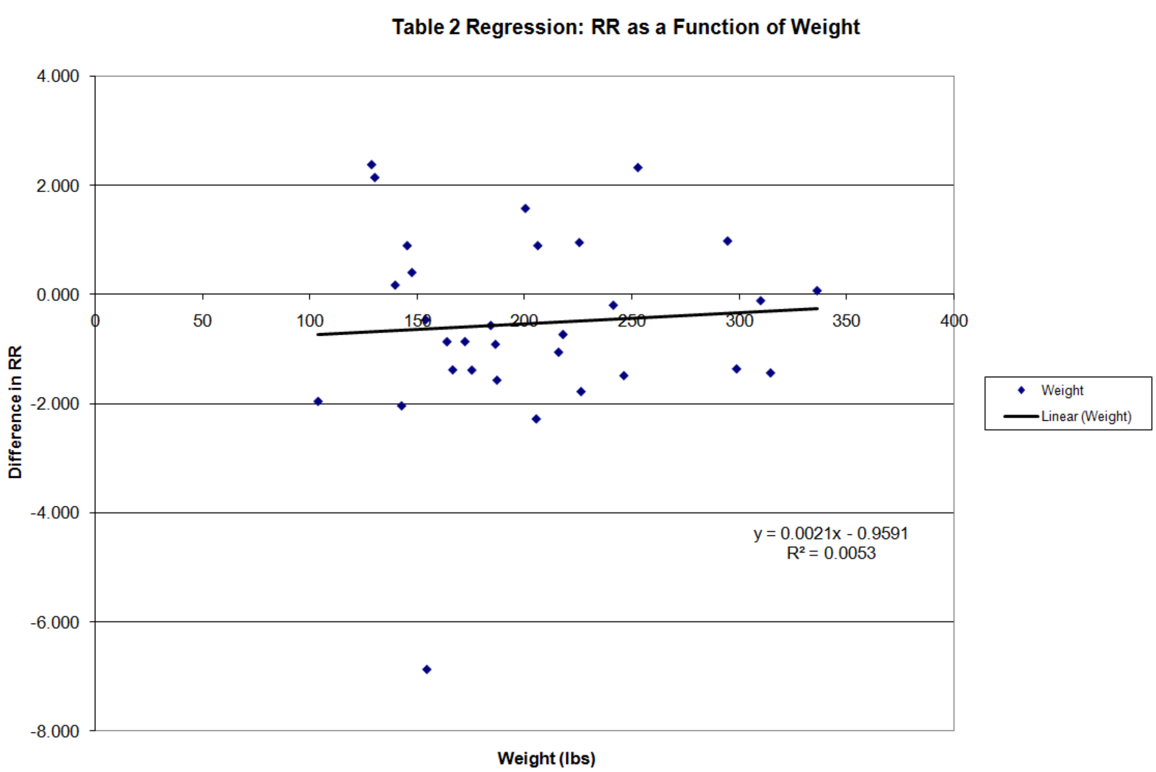

Figure 30.42: Regression RR vs. Weight (Table 2) All Data

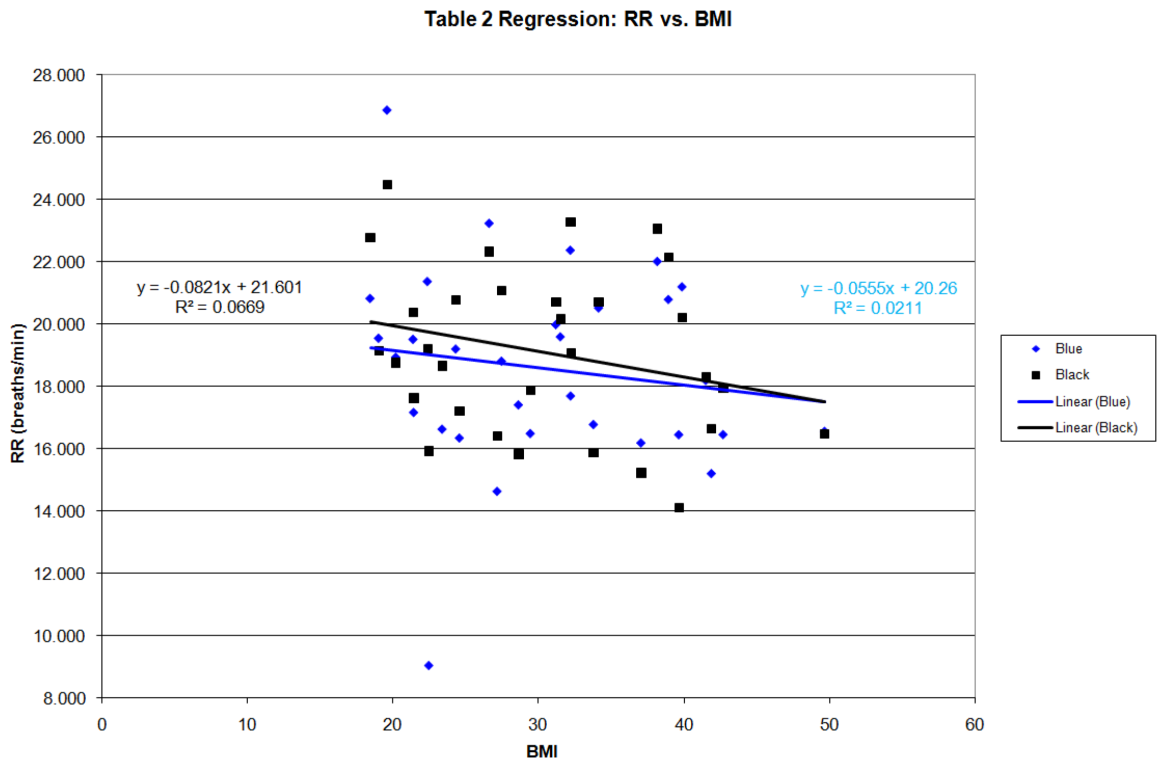

Figure 30.43: Regression RR vs. BMI (Table 2) by chair

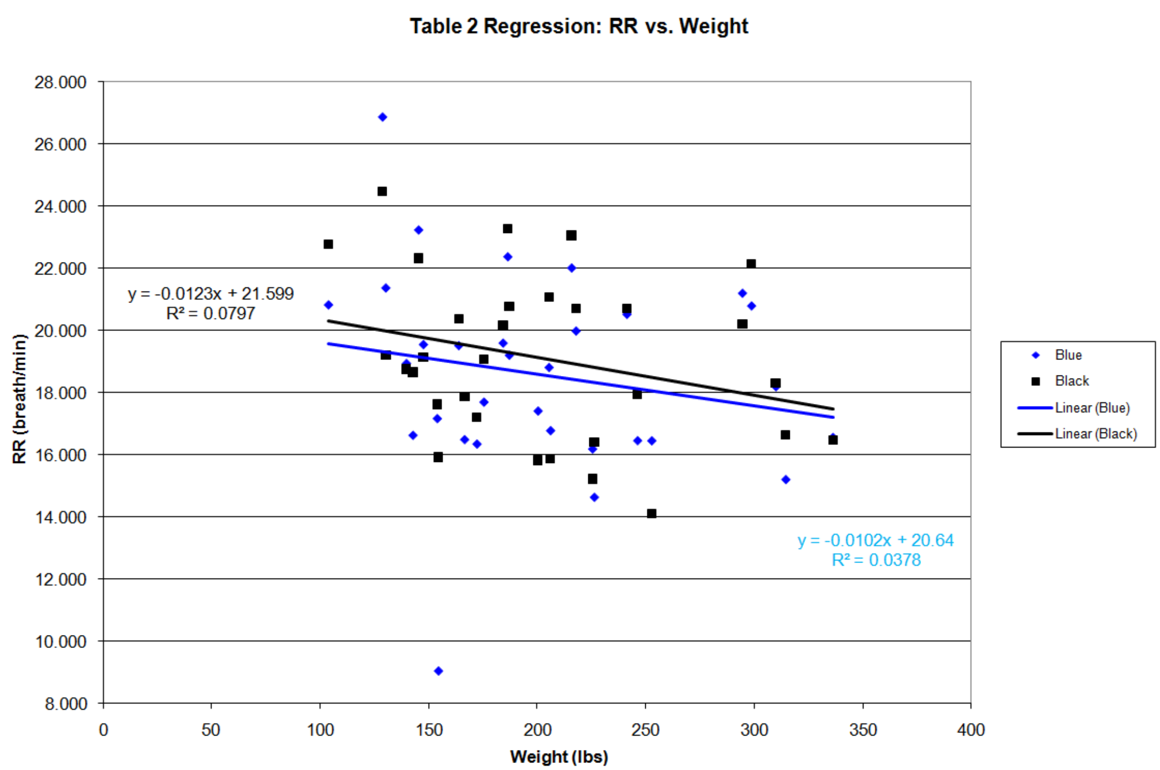

Figure 30.44: Regression RR vs. Weight (Table 2) by chair

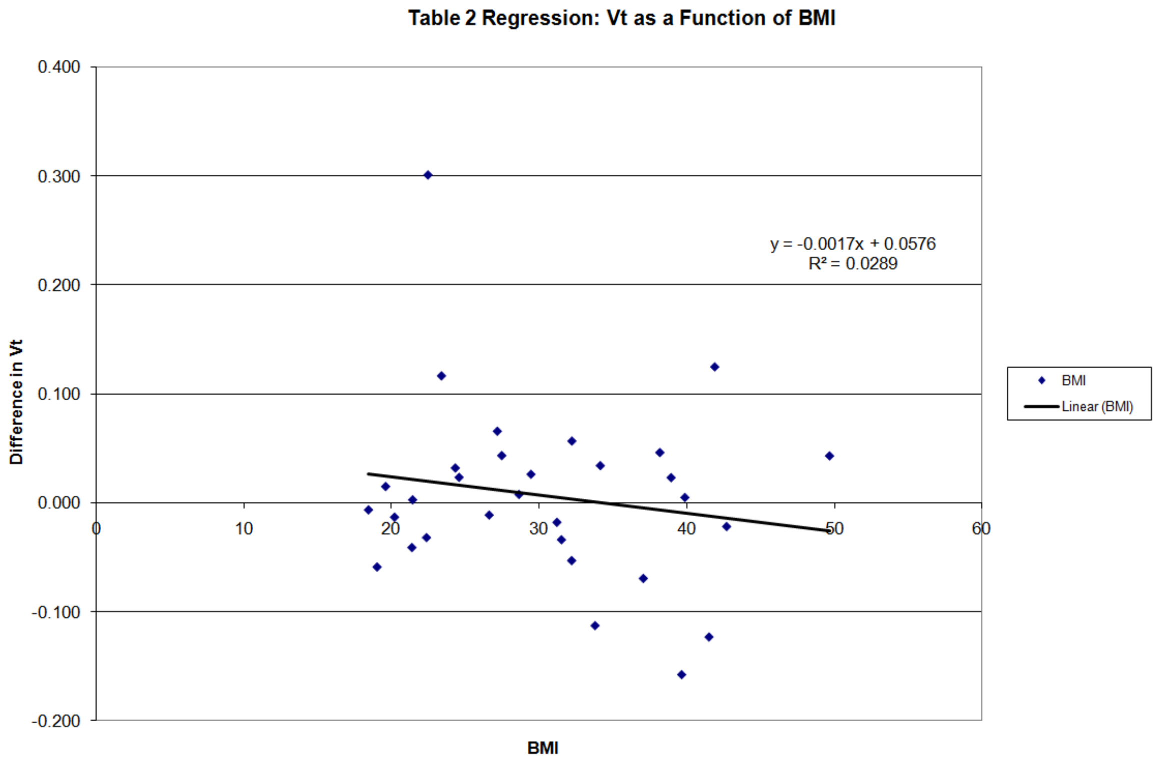

Figure 30.45: Regression TV vs. BMI (Table 2) All Data

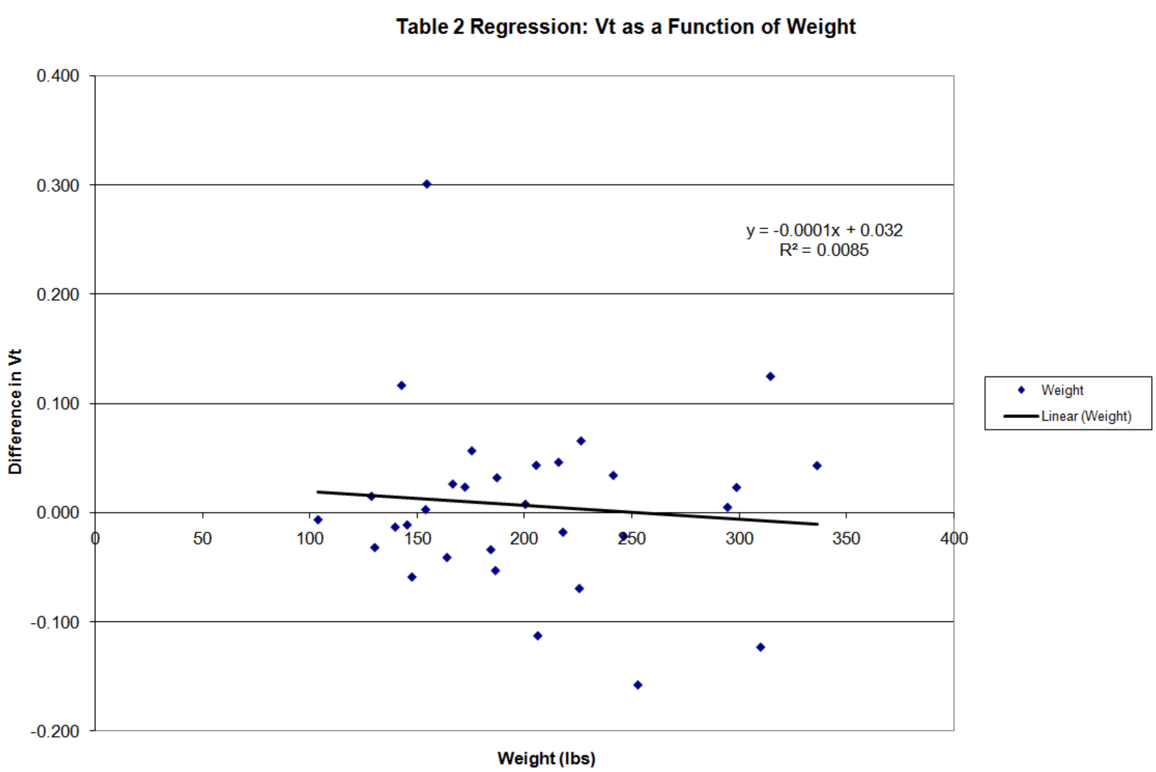

Figure 30.46: Regression TV vs. Weight (Table 2) All Data

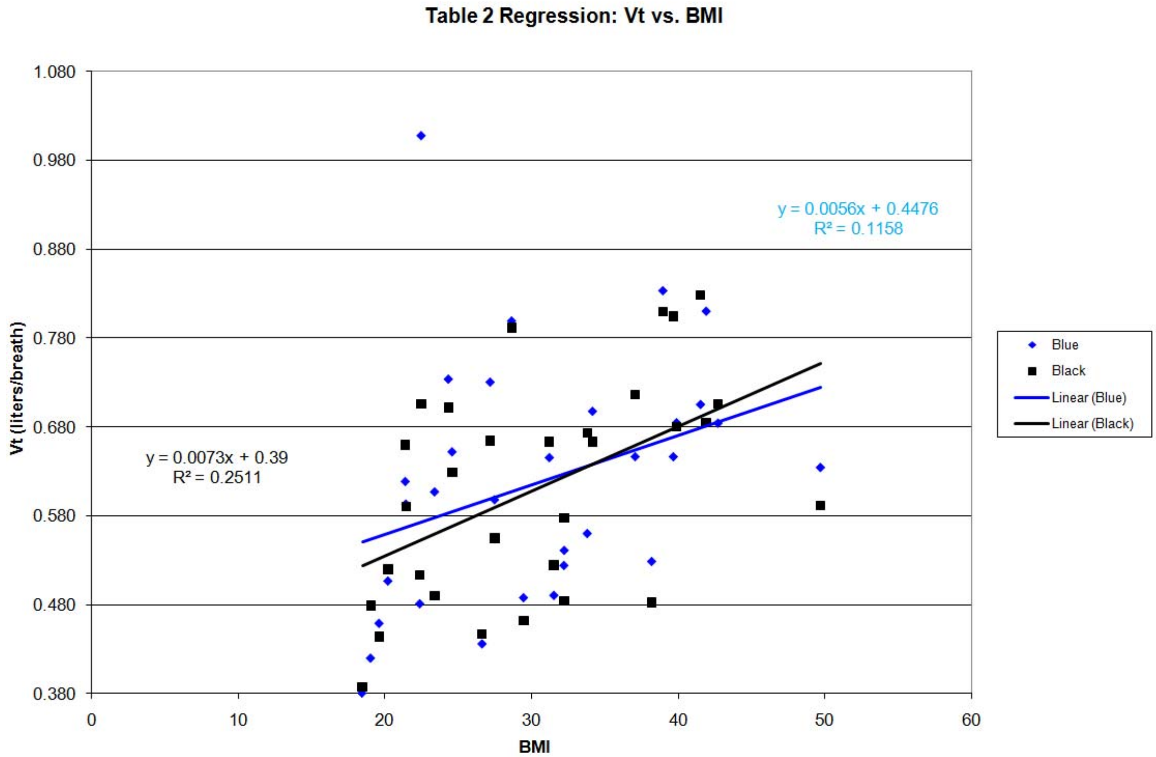

Figure 30.47: Regression TV vs. BMI (Table 2) by Chair

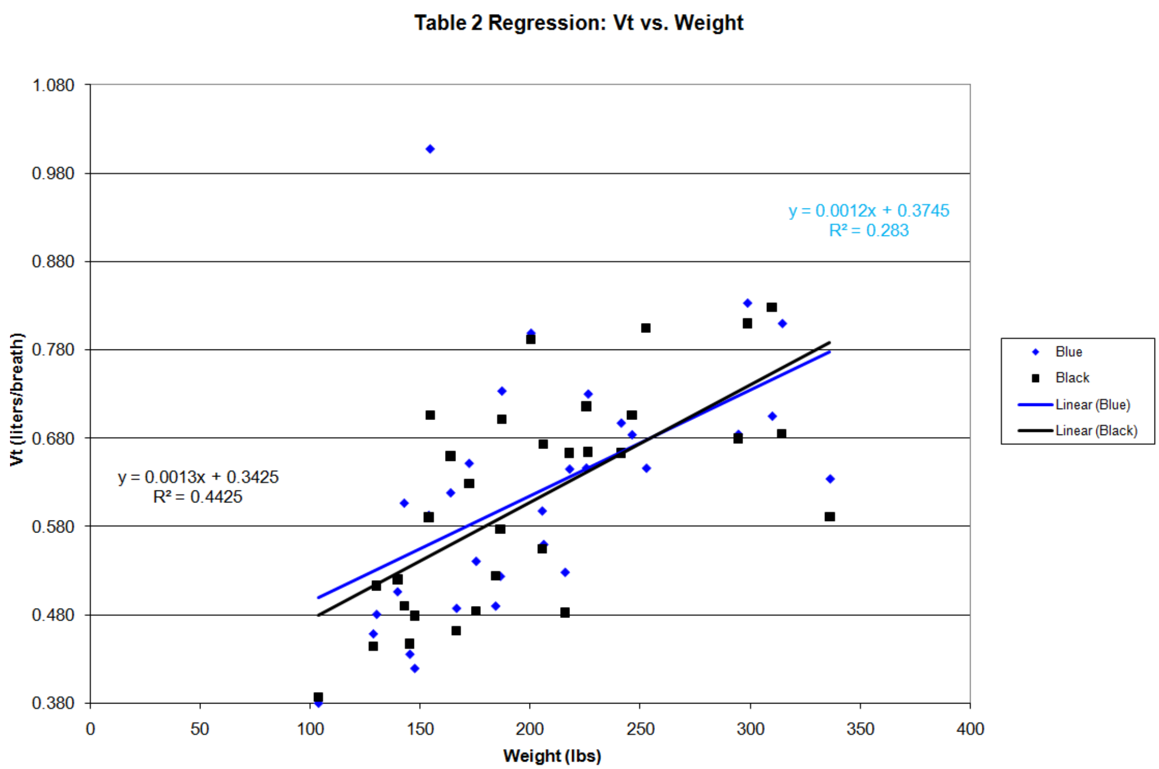

Figure 30.48: Regression TV vs. Weight (Table 2) by chair

31 Appendix V: Required Number of Subjects Calculation

Prior to the beginning of this study, calculations were done to determine the minimum number of participants needed to maintain 80% statistical power. There will also be a few extra subjects added in case some of the data cannot be used. This process is an iterative one. This a priori calculation was based on respiratory data taken from an article by Sarang et al. published in 2006. An initial "guess" at the sample size is entered in to the following equations, and the resulting phi squared value and the v_2 value, in conjunction with an operating characteristic curve, is used to determine the value of β (type II error). The statistical power is then the value of 1-β. A sample calculation, as well as a table containing the iterations, for the factor of chair for women only follows.

$$\text{For factor A (chair)}: \ \phi^2 = \frac{nbD^2}{2a\sigma^2}$$

$$\text{For factor B (gender)}: \ \phi^2 = \frac{naD^2}{2b\sigma^2}$$

$$a = \text{levels in factor A}$$

$$\text{b} = \text{levels in factor B}$$

$$a = 2$$

$$b = 2$$

$$n = 15$$

$$\sigma = 2.5$$

$$D = 1.5$$

$$For \text{ factor A}: \phi^2 = \frac{15 * 2 * 1.5^2}{2 * 2 * 2.5^2}$$

$$\phi^2 = 2.7$$

$$\phi = 1.64$$

$$v_2 = ab(n-1)$$

$$v_2 = 2 * 2 * (15-1)$$

$$v_2 = 56$$

$$\beta = 0.37$$

$$Power = 0.63$$

Figure 31.1: Sample Calculation for Sample Size

The following table shows the iterative process that takes place to determine the minimum number of participants.

Table 31.1: Iterations to find Minimum Number of Participants

n	v_2	Φ^2	Φ	β	Power
15	56	2.7	1.64	0.3	70%
20	76	3.6	1.9	0.22	78%
23	88	4.14	2.03	0.2	80%
25	96	4.5	2.12	0.18	82%

The number of participant taken for the study was 31; this was to accommodate any faulty data.

The results of the study showed that the chair with the upwardly tapered backrest had no significant impact on the respiratory rate or the tidal volume of the participants. However, a significant difference was detected in heart rate between the chairs tested. Since the number of participants was not derived from heart rate data, it was necessary to check the statistical power of these results after the analysis. The following figures outline the statistical power the heart rate results hold for men and women individually.

$$\text{For factor A (chair)}: \ \phi^2 = \frac{nbD^2}{2a\sigma^2}$$

$$\text{For factor B (gender)}: \ \phi^2 = \frac{naD^2}{2b\sigma^2}$$

$$a = \text{levels in factor A}$$

$$\text{b} = \text{levels in factor B}$$

$$a = 2$$

$$b = 2$$

$$n = 15$$

$$\sigma = 6$$

$$D = 4$$

$$For \text{ factor A}: \phi^2 = \frac{15 * 2 * 4^2}{2 * 2 * 6^2}$$

$$\phi^2 = 3.3$$

$$\phi = 1.83$$

$$v_2 = ab(n-1)$$

$$v_2 = 2 * 2 * (15-1)$$

$$v_2 = 56$$

$$\beta = 0.28$$

$$Power = 0.72$$

Figure 31.2: Sample Calculation for Sample Size

$$\text{For factor A (chair)}: \ \phi^2 = \frac{nbD^2}{2a\sigma^2}$$

$$\text{For factor B (gender)}: \ \phi^2 = \frac{naD^2}{2b\sigma^2}$$

$$a = \text{levels in factor A}$$
$$\text{b} = \text{levels in factor B}$$
$$a = 2$$
$$b = 2$$
$$n = 15$$
$$\sigma = 9$$
$$D = 6$$

$$For\ \text{factor A}: \phi^2 = \frac{15*2*6^2}{2*2*9^2}$$

$$\phi^2 = 3.33$$
$$\phi = 1.83$$
$$\nu_2 = ab(n-1)$$
$$\nu_2 = 2*2*(15-1)$$
$$\nu_2 = 56$$
$$\beta = 0.28$$
$$Power = 0.72$$

Figure 31.3: Sample Calculation for Sample Size

These results show that the statistical power of the analyses is only 72%, not reaching the required 80%. This is most likely due to the fact that the population of participants was split in half for this analysis. If there had been a greater number of male and female participants the statistical power would be closer to or surpass the 80% threshold.