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# The effects of singing on blood pressure in classically trained singers

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THE EFFECTS OF SINGING ON BLOOD PRESSURE  
IN CLASSICALLY TRAINED SINGERS

A Monograph

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Doctor of Musical Arts

In

The School of Music

by  
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B.M., Delta State University, 1992  
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May 2002

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## DEDICATION

To Mom and Pop: Thank you for the blind faith in your support for me. I am the person I am today because of you. I am a reflection of you. I could not have accomplished my goals without you and your love. Thank you.

To a special group of friends, my chosen family: Mark, Karen, Shelly, Gabrielle, Susan, and Betty. Thank you for your words of advice, for the laughs, for everything. You make my life more complete.

To Stephen Austin: You were the inspiration for this paper. Thank you for sharing your love for the science behind the human voice and for giving that spark to me, opening a door that can never be closed. Thank you.

To Lori Bade: Thank you for not giving up on me. Your guidance and understanding will guide me through the difficult and wonderful times ahead. I will never forget you.

To Mary Lenn: My mentor, friend, companion. You were able to see in me what others could not. This is the greatest gift anyone has shared with me. I only hope that one day I will be given the ability to see that glimmer in a student's soul and to share with them the love and passion for music and life that you have opened to me. Thank you.

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## ABSTRACT

Blood pressure readings were taken in four normotensive, classically trained singers of varying age and experience. The results show changes during the systolic and diastolic phases of blood pressure measurements while singing. While systolic blood pressure changes were individualized and random, diastolic blood pressure changes generally showed a direct correlation to changes in intrathoracic pressure. Additional research using a larger subject base involving normotensive, hypertensive, and hypotensive populations is warranted.

## CHAPTER ONE

### INTRODUCTION

The introduction of noninvasive methods of measuring blood pressure has created an abundance of research concerning physical activity and its effect on blood pressure. Singing is an activity with physiological implications. Within reasonable time, many or all aspects of human physiology while singing may be examined. It is the purpose of this study to examine possible effects on blood pressure while singing in the Western classical tradition.

As teachers of singing, our goal should be a complete understanding of the way our vocal instrument works. Blood pressure is a measurement that applies to all students. Accordingly, it is important that a teacher of singing have a significant knowledge of possible high or low blood pressure levels and their effects on singing. To this end, there are three physical states which the author has observed while teaching that could be blood pressure related. Those three are: 1.) jugular venous distention or protruding veins in the singer's neck; 2.) facial flushing or red skin blotches appearing; and 3.) dizziness while singing.

Empirical analysis could lead one to believe that these events are blood pressure related. For instance, thoracic pressures created during the singing process could produce increased levels of pressure within the cardiovascular system and jugular venous distention could occur. Brown reports that "by closing the mouth and nose and making a forcible expiratory effort that it tended to inflate

the eustachian tube and to increase the intrathoracic pressure and thus to check the return flow of blood which is manifested by engorged veins in the neck.”<sup>1</sup>

Facial flushing or red splotches could possibly be explained as blood “rushing” to the skin’s surface. It has been shown that when one is frightened and facial flushing occurs that, “red splotches are caused by irregular blood flow to the outer layers of your skin by adrenaline.”<sup>2</sup> Changes in blood pressure created by singing could contribute to blood flow irregularities.

While characteristic dizziness during a voice lesson could be associated with hyper-oxygenation, it is possible dizziness is caused by changes in blood pressure created when singing. “Dizziness is your body’s way of telling you that something isn’t right. In about 90% of cases, it’s a common trigger such as medication, mild anemia, or low blood pressure.”<sup>3</sup> If dizziness or syncope (fainting) occurs during a voice lesson, a teacher of singing needs to be aware of all the implications and be able to respond appropriately. Should a student be unaware of existing blood pressure problems, his or her teacher could be the first link to understanding a serious health issue.

This monograph will provide information regarding aspects of blood pressure including the following: 1.) a historical overview of blood pressure, 2.) definitions of the three types of blood pressure; 3.) how blood pressure is measured; 4.) the components involved in both the circulatory cycle and the

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<sup>1</sup> Brown, Oren, “The Valsalva Maneuver and Other Phenomena.” <http://www.nyst.org/valsalva.htm> (7 Jan 2002).

<sup>2</sup> Whatley, Randall P., (2000) <http://www.cypressmedia.net/pages/article8.htm> (7 Jan 2002).

<sup>3</sup> Linda Mooney, “Is Your Dizzy Spell Dangerous?” *Prevention*, 52 (2000): p. 142.



cardiovascular system; and 5.) controllable and uncontrollable affects on blood pressures.

As a way of learning about the study of early anatomy, the author has incorporated information in this chapter on the early writers of anatomy. Early writings show that the Paleolithic bowman (c. 700,000 BC) knew the location of the heart, allowing them to kill their prey. Evidence of this anatomical knowledge exists in detailed pictures on the walls of their caves where the bowman drew pictures of his victim with arrows piercing the animal in the region of the heart.<sup>4</sup>

Additional early recordings of anatomical observations are found in the writings of Alcmaeon (ca. 535-unknown BC), an Italian anatomist and the first to practice dissections on animals.<sup>5</sup> Aristotle of Stagira (384-322 BC) furthered Alcmaeon's work by dissecting animals that had been strangled, allowing the vessels to be visible.<sup>6</sup> Knowledge gleaned from Aristotle's studies is considered to be the first accurate description of blood vessels and the circulatory system.<sup>7</sup> An important discovery was made by Empedocles of Acragas (495-435 BC), Italian anatomist, who first to suggested that the heart was the center of the vascular system and that blood, *pneuma*, "was equivalent to both soul and mind," thus furthering the wide belief of a generation of anatomists that human blood was related to a person's soul.<sup>8</sup>

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<sup>4</sup> Singer, Charles. *A Short History of Anatomy and Physiology from the Greeks to Harvey*, 3-4.

<sup>5</sup> *Ibid.*, 9.

<sup>6</sup> Fulton, John F. *Selected Readings in the History of Physiology*. (Springfield, IL: Thomas Books, 1966), 25.

<sup>7</sup> Fulton, John F. *Selected Readings in the History of Physiology*. (Springfield, IL: Thomas Books, 1966), 26.

<sup>8</sup> Singer, Charles. *A Short History of Anatomy and Physiology from the Greeks to Harvey*, 9-10.

The Greek physician Hippocrates (c. 460 BC- ca 370 BC) has long been considered the founder of medicine<sup>9</sup> and was credited with being the first to accurately discuss the function of the heart's valves. Hippocrates described the valves as "bellows" which are "independently inflating and collapsing."<sup>10</sup> Herophilus of Chalcedon (335-280 BC) described the physiology of and differences between veins (which send oxygen poor blood to the heart) and arteries (which send oxygen rich blood to body tissues,) basing his findings on his discovery of the thickness of the walls of each vessel.<sup>11</sup> Erasistratus of Chios (ca. 304-ca. 250 BC), Greek physiologist and "Father of Physiology,"<sup>12</sup> studied the action of the semilunar valves and the tricuspid valves, discovering that the valves work so that flow can only move in one direction.<sup>13</sup>

Many discoveries and theories existed in the impending years. It is only with William Harvey (1578-1657), British physician and physiologist, that we first have a more thorough understanding of the physiology of the circulatory system.<sup>14</sup> Harvey stated in his book *An Anatomical Dissertation on the Movement of the Heart and Blood in Animals* accurate theories describing the

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<sup>9</sup> Pease, Jr., Roger W., ed., *Merriam-Webster's Medical Desk Dictionary* (Springfield: Merriam-Webster Inc., 1993), 297.

<sup>10</sup> Fulton, John F. *Selected Readings in the History of Physiology*, 35.

<sup>11</sup> Fulton, John F. *Selected Readings in the History of Physiology*, 27.

<sup>12</sup> Singer, Charles. *A Short History of Anatomy and Physiology from the Greeks to Harvey*, 31.

<sup>13</sup> Fulton, John F. *Selected Readings in the History of Physiology*, 27-28.

<sup>14</sup> Fulton, John F. *Selected Readings in the History of Physiology*, 32.

circulatory system in modern terms.<sup>15</sup> Much of his terminology is still in use in 20<sup>th</sup> Century textbooks.<sup>16</sup>

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<sup>15</sup> Singer, Charles. *A Short History of Anatomy and Physiology from the Greeks to Harvey*, 174.

<sup>16</sup> Fulton, John F. *Selected Readings in the History of Physiology*, 49.

## CHAPTER TWO

### THE CIRCULATORY SYSTEM

The circulatory system is composed of the heart, lungs, and blood vessels and has two main functions: 1.) to deliver oxygen-rich blood to all body tissues and 2.) to carry waste gases from the tissues of the body to the lungs to be exhaled from the body.

The heart, a major player in the circulatory system, is “a hollow muscular organ of vertebrate animals that by its rhythmic contraction acts as a force pump maintaining the circulation of the blood.”<sup>17</sup> The heart provides the impetus for blood circulation in the body.<sup>18</sup> The heart is located within the thorax and is enclosed in the pericardial membrane.

The heart is divided into four sections; the left and right atrium and the left and right ventricle (see Figure 2.1). Blood travels through the superior vena cava or the inferior vena cava to enter the heart. Oxygen depleted blood flows into the right atrium, a holding chamber. When the next rhythmic contraction occurs, the blood is forced out of the right atrium, through the tricuspid valve, and into the right ventricle. Blood then travels into the pulmonary artery on the way to the lungs. While in the lungs, waste gas in the red blood cells is exchanged for oxygen. Blood returns to the heart by way of the pulmonary veins and enters the left atrium. During the next rhythmic contraction, the heart muscle forces the blood through the mitral valve into the left ventricle. The left ventricle pushes

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<sup>17</sup> Pease, Jr., Roger W., ed., *Merriam-Webster's Medical Desk Dictionary* (Springfield: Merriam-Webster Inc., 1993), p. 535.

<sup>18</sup> McArdle, William D., Frank I. Katch, and Victor L. Katch. *Exercise Physiology: Energy, Nutrition, and Human Performance*. (Philadelphia: Lea and Febiger, 1985), p. 243.

blood through the aortic valve into the aorta where it is sent to the tissues of the body. This description completes one cycle of the circulatory system, all being pumped by the heart.<sup>19</sup>

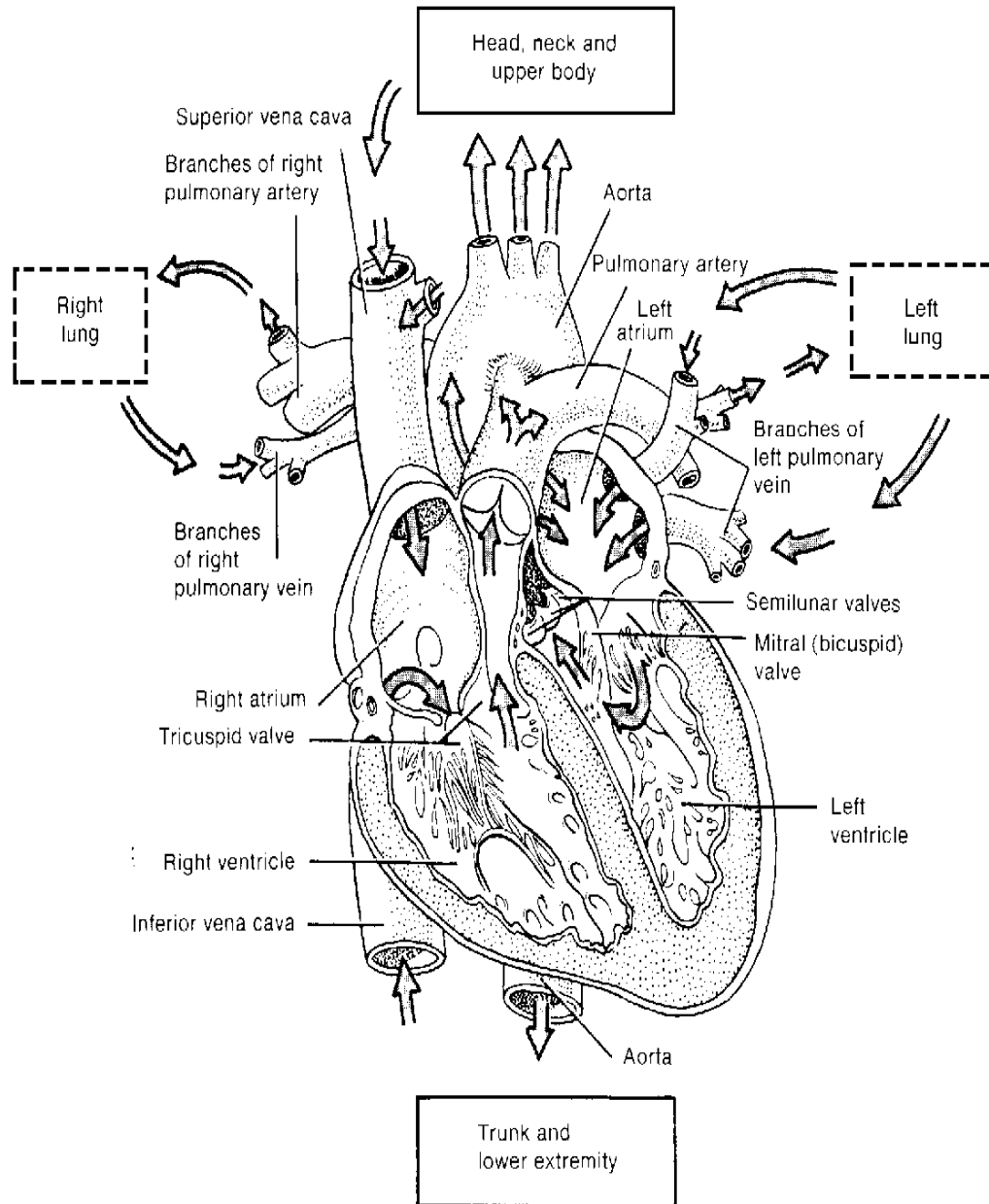


Figure 2.1  
The heart<sup>20</sup>

<sup>19</sup> American Heart Association, *Guide to Heart Attack: Treatment, Recovery, and Prevention*, 18-19.

The pericardium is a closed sac surrounding the heart that assists in keeping the heart in place within the chest cavity<sup>21</sup> and is a membrane that “provides a barrier to inflammation, a lubricant for the perpetually beating organ, and may equalize gravitational forces across myocardial walls.”<sup>22</sup> The outermost layer of the heart is called the epicardium. The myocardium is the muscular wall of the heart and the endocardium is the thin smooth membrane forming the interior surface of the heart.<sup>23</sup>

The “two compound saccular organs that constitute the basic respiratory organ of air breathing vertebrates, that normally occupy the entire lateral parts of the thorax are known as the lungs.”<sup>24</sup> Each day, one inhales and exhales approximately 10,000 liters of air a day.<sup>25</sup> The body draws in air through the nostrils or mouth and into the trachea, or windpipe, which is a tube shaped by rings of cartilage. The trachea divides into two tubes (bronchi) that carry the air into the lungs. The bronchi further divide into three lower bronchi, bronchioles and alveoli. Thin-walled blood vessels (capillaries) are wrapped around the alveoli. The walls of these capillaries are thin enough that air easily can slip through, thus allowing air in the alveoli to seep into the capillaries. Oxygen rich

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<sup>20</sup> McArdle, William D., Frank I. Katch, and Victor L. Katch. *Exercise Physiology: Energy, Nutrition, and Human Performance*, 245.

<sup>21</sup> American Heart Association, *Guide to Heart Attack: Treatment, Recovery, and Prevention*, 20.

<sup>22</sup> Hammond, H. Kirk, Francis C. White, and Valmik Bhargava. “Heart Size and Maximal Cardiac Output are Limited by the Pericardium.” *American Journal of Physiology*, Vol. 263 (Dec 1992): H4675.

<sup>23</sup> American Heart Association, *Guide to Heart Attack: Treatment, Recovery, and Prevention*, 20.

<sup>24</sup> Pease, Jr., Roger W., ed., *Merriam-Webster’s Medical Desk Dictionary*, 397.

<sup>25</sup> Proctor, Donald F. *Breathing, Speech, and Song*. (New York: Springer-Verlag Wien, 1980), 1.

blood is carried by the capillaries to the tissues of the body.<sup>26</sup> “Blood is the fluid that circulates in the heart, arteries, capillaries, and veins of a vertebrate animal carrying nourishment and oxygen to and bringing away waste products from all parts of the body.”<sup>27</sup>

The cardiac cycle is the interval of time needed for blood to circulate through the cardiovascular system. There are nine phases to one cardiac cycle during which the heart contracts (phases I-III) and relaxes (IV-IX).<sup>28</sup>

- I. Isovolumic contraction (0.05 seconds) Onset of ventricular systole and pressure is rising in the atrium (first sound of heart beat occurs).
- II. Maximum ejection (0.09 sec.) The semilunar valves open.
- III. Reduced ejection (0.13) Pressures rise to the highest point in atrium.
- IV. Protodiastole (0.04 sec.) Onset of ventricular diastole and pressure drops.
- V. Isovolumic relaxation (0.08 sec.) Valves close.
- VI. Rapid inflow (0.11 sec.) Valve opens allowing blood into ventricle. Ventricle pressure begins to increase.
- VII. Diastasis (0.19 sec.) Pressure increases in atrium and ventricle.
- VIII. Atrial systole (0.11 sec.) Ending of ventricular diastole.
- IX. End of cycle.<sup>29</sup>

In 1733, Stephen Hales, an English priest, was the first to measure blood pressure. “He inserted a long glass tube into the artery of a horse’s neck, and found that the blood reached a height of eight feet in the tube.” Hales also noticed that when the horse would struggle, the blood in the tube elevated.<sup>30</sup>

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<sup>26</sup> Zemlin, Willard. *Speech and Hearing Science: Anatomy and Physiology*, 35-39.

<sup>27</sup> Pease, Jr., Roger W., ed., *Merriam-Webster’s Medical Desk Dictionary*, 81.

<sup>28</sup> Katz, Arnold M. *Physiology of the Heart*. (New York: Raven Press Books, Ltd., 1977), 20.

<sup>29</sup> *Ibid.*, 20-23.

<sup>30</sup> Pickering, Thomas. *Good News About High Blood Pressure* (New York: Fireside, 1997), 27-28.

Modern measurements of blood pressures within the circulatory system are made of the contraction phase (systole) and the relaxation phase (diastole). Blood pressures are measured in millimeters of mercury (mm Hg) by an instrument called a sphygmomanometer through a cuff which is placed and inflated around the upper arm. A stethoscope diaphragm is placed over the brachial artery in the bend of the elbow. The inflated cuff will briefly stop blood flow in the artery. As pressure of the inflation is slowly released, one listens through the stethoscope to the flow of blood as it returns to the artery. The onset of sound (turbulence and then a heartbeat) marks the systolic blood pressure and the cessation of sound (heartbeat) marks the diastolic blood pressure.<sup>31</sup>

The American Heart Association released new standards in 1997 (see Table 2.1) with reference to average blood pressures. "Normal values of mean arterial pressure varies widely but usually ranges between 77-97 mm Hg."<sup>32</sup>

One in five Americans is hypertensive (high blood pressure) with only 31.6 percent of those affected having knowledge of the problem. High blood pressure is generally only a concern when it exists for long periods of time.<sup>33</sup>

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<sup>31</sup> American Heart Association, *Guide to Heart Attack: Treatment, Recovery, and Prevention*, 27.

<sup>32</sup> Gouvea, Glauber. "Cardiovascular Physiology." N.D.  
<http://www.medstudents.com.br/basic/cardfs/cardfs5.htm> (12 Jan 02).

<sup>33</sup> Pickering, Thomas. *Good News About High Blood Pressure* (New York: Fireside, 1997), 27.



Table 2.1  
Classifications of blood pressures<sup>34</sup>

Category	Systolic (mm Hg)	Diastolic (mm Hg)
Optimal	< 120	<80
Normal	<130	<85
High Normal	130-139	85-89
Hypertension (Stage 1)	140-159	90-99
Hypertension (Stage 2)	160-179	100-109
Hypertension (Stage 3)	180 +	110 +

Long periods of high blood pressure can cause three serious health concerns. First, one can rupture a vein or artery if pressure within the vessel reaches excessive levels.<sup>35</sup> Second, high blood pressure accelerates the deposit of cholesterol plaque (atheroma), which eventually leads to blocked arteries, causing heart failure.<sup>36</sup> Third, high blood pressure forces the heart to work above normal function, thus causing the heart to enlarge. The heart muscle can outgrow the blood supply rendering it more susceptible to the effects of atheroma.<sup>37</sup>

Factors that can contribute to hypertension can be placed in two categories: 1.) uncontrollable risk factors and 2.) controllable risk factors.

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<sup>34</sup> Rose, Verna L. "National Heart, Lung, and Blood Institute Releases New Guidelines for the Treatment of Hypertension." *American Family Physician*. (Vol. 57, No. 2 (15 Jan 1998): p. 362, Ebscohost Database, <http://www.epnet.com/ehost/magnolia/login.html>.)

<sup>35</sup> Kennewick General Hospital, "KGH Performs First TIPS Procedure." (14 Feb 2000) <http://www.kennewickgeneral.com/news/2-14-00.html> (11 July 2001).

<sup>36</sup> Pickering, Thomas. *Good News About High Blood Pressure* (New York: Fireside, 1997), 32-33.

Elements within each category are numerous and only the most prevalent factors will be discussed.

It is important that one understand the most common uncontrollable factors regulating blood pressure. African Americans are almost twice as likely to have hypertension than Caucasians. People with a family history of high blood pressure are more likely to acquire hypertension. Age also plays a role in hypertension. As age increases, so do the risks of hypertension. Most often hypertension occurs in people over 35 and men seem to develop it most often between the age 35 and 50. Women tend to develop hypertension after menopause. People that have diabetes, gout, or kidney disease have a higher chance of being hypertensive.<sup>38</sup>

Controllable factors that affect blood pressure are equally important to know and recognize. Diet is perhaps the easiest controllable factor that can be altered. It has been shown that vegetarians have lower blood pressure, less heart disease, and less cancer than non-vegetarians.<sup>39</sup> Salt has been shown to affect blood pressure. However, new controversial evidence suggests that a high salt diet may not directly affect blood pressure.<sup>40</sup> Consuming alcohol raises

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<sup>37</sup> Pickering, Thomas. *Good News About High Blood Pressure* (New York: Fireside, 1997), 32-33.

<sup>38</sup> American Heart Association. "High Blood Pressure Statistics." (2000) [http://www.americanheart.org/Heart\\_and\\_Stroke\\_A\\_Z\\_Guide/hbps.html](http://www.americanheart.org/Heart_and_Stroke_A_Z_Guide/hbps.html) (06 Jun 01).

<sup>39</sup> Pickering, Thomas. *Good News About High Blood Pressure* (New York: Fireside, 1997), 85.

<sup>40</sup> Pickering, Thomas. *Good News About High Blood Pressure* (New York: Fireside, 1997), 63.

blood pressure approximately one mm Hg for each additional drink. In spite of this, moderate drinkers have less heart disease than non-drinkers.<sup>41</sup>

Smoking and caffeine produces temporary changes in the constriction of blood vessels and limits blood flow.<sup>42</sup> Studies show that obesity, changes in body weight over time, and sedentary lifestyle contribute to high blood pressure.<sup>43</sup> “For every ten pounds you put on (or lose), your blood pressure is likely to go up (or down) by five mm Hg.”<sup>44</sup> Stress has been shown to increase heart rate and blood pressure.<sup>45</sup>

Hypotension is defined as a condition in which one’s blood pressure is abnormally low.<sup>46</sup> Hypotension is more difficult to diagnose than hypertension because borderline low pressure for one person could be considered normal for another. Hypotension is almost always not severe and is usually associated with underlying medical conditions such as shock, excessive bleeding, or kidney disease.<sup>47</sup>

A student that is hypotensive or hypertensive may be taking medications. A teacher of singing should be aware of the side effects associated with medications that treat abnormal blood pressures. Hypertension is typically

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<sup>41</sup> Pickering, Thomas. *Good News About High Blood Pressure* (New York: Fireside, 1997), 112.

<sup>42</sup> American Heart Association, *American Heart Association Guide to Heart Attack Treatment*. (New York: Random House, Inc., 1996), 204.

<sup>43</sup> American Heart Association. “High Blood Pressure Statistics.” (2000) [http://www.americanheart.org/Heart\\_and\\_Stroke\\_A\\_Z\\_Guide/hbps.html](http://www.americanheart.org/Heart_and_Stroke_A_Z_Guide/hbps.html) (06 Jun 01).

<sup>44</sup> Pickering, Thomas. *Good News About High Blood Pressure* (New York: Fireside, 1997), 95.

<sup>45</sup> American Heart Association. *American Heart Association Guide to Heart Attack Treatment*. (New York: Random House, Inc., 1996), 250.

<sup>46</sup> Pease, Jr., Roger W., ed., *Merriam-Webster’s Medical Desk Dictionary* (Springfield: Merriam-Webster Inc., 1993), 320.

treated with diuretics, beta blockers, alpha blockers, angiotensin converting enzyme inhibitors (ACE inhibitors), calcium-channel blockers, or vasodilators.<sup>48</sup>

“Almost all of the current antihypertensive agents have some degree of parasympathomimetic effect and thus dry mucous membranes of the upper respiratory tract.”<sup>49</sup>

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<sup>47</sup> WebMD, “Hypotension.” (2001) <http://my.webmd.com/content/article/3608.1124> (06 Jun 2001).

<sup>48</sup> Pickering, Thomas. *Good News About High Blood Pressure* (New York: Fireside, 1997), 252-262.

<sup>49</sup> Sataloff, Robert Thayer. *Vocal Health and Pedagogy* (San Diego: Singular Publishing Group, Inc., 1998), 227.

## CHAPTER THREE

### THORACIC PRESSURES AND BLOOD PRESSURE

Exercise, a common physiological event, can elicit cardiovascular changes not found at rest.<sup>50</sup> There are three types of muscular contraction that are involved with exercise: 1.) isometric (static); 2.) isotonic (dynamic); and 3.) resistive (combination of isometric and isotonic).<sup>51</sup> Isometric exercise is muscular contraction without movement. These straining type exercises create a greater increase in blood flow due to compression on the peripheral arterial system.<sup>52</sup> An example of isometric exercise is bench pressing weights without incorporating the Valsalva maneuver. The Valsalva maneuver is forced expiration on a closed glottis and is primarily used to expel objects from the body. Antonio Maria Valsalva (1666-1723), Italian anatomist, discussed the maneuver in his book *De aure humana* and the maneuver was used as a technique for expelling pus from the middle ear.<sup>53</sup> Isotonic exercise, or exercise involving muscular contraction resulting in movement, “primarily provides a volume load to the left ventricle, and the cardiovascular response is proportional to the size of the muscle mass and the intensity of the exercise.”<sup>54</sup> An example of isometric exercise is lifting free weights. Resistive exercise combines both isometric and

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<sup>50</sup> American Heart Association, “Exercise Standards.” (1995)  
<http://www.americanheart.org/Scientific/statements/1995/029530.html> (7 Dec 2000).

<sup>51</sup> American Heart Association, “Exercise Standards.” (1995)  
<http://www.americanheart.org/Scientific/statements/1995/029530.html> (7 Dec 2000).

<sup>52</sup> McArdle, William D., Frank I. Katch, and Victor L. Katch, *Exercise Physiology: Energy, Nutrition, and Human Performance*, 251.

<sup>53</sup> Gibson, Neil. “The CARE-EF1 Study: Protocol for Assessing the Accuracy of a Bedside Approach to Estimating the Left Ventricular Ejection Fraction.” (2000)  
<http://www.carestudy.com/CareStudy/EF1/Intro.asp> (06 Jan 2001).

<sup>54</sup> American Heart Association, “Exercise Standards.” (1995)  
<http://www.americanheart.org/Scientific/statements/1995/029530.html> (7 Dec 2000).

isotonic muscle contraction that involves the Valsalva maneuver. An example of resistive exercise is bench pressing with maximum voluntary contraction. In a study led by McArdle, systolic and diastolic pressures were measured during isometric, isotonic, and resistive exercise. See Table 3.1. Isometric bench pressing was measured at 25, 50, 75, and 100% of the maximum voluntary contraction (MVC). Isotonic exercise was measured during 25% and 50% of free weight lifting. Resistive exercise was measured during all out bench pressing, both slow and fast, involving both isometric and isotonic muscle contraction. The results displayed in Table 3.1 clearly demonstrate a significant increase in both systolic and diastolic pressures during all phases of exercise.

Table 3.1<sup>55</sup>

Comparison of peak systolic and diastolic blood pressure during isometric, isotonic, and resistive exercise measured at a percentage of maximum voluntary contraction (MVC).

Condition	Isometric (% MVC)				Isotonic (% MVC)		Resistive	
	25	50	75	100	25	50	Slow	Fast
Peak Systolic	172	179	200	225	169	232	237	245
Peak Diastolic	106	116	135	156	104	154	101	160

Blood pressure has been shown to increase significantly during the playing of the horn,<sup>56</sup> trumpet,<sup>57</sup> and bagpipes.<sup>58</sup> Each instrument requires

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<sup>55</sup> McArdle, William D., Frank I. Katch, and Victor L. Katch, *Exercise Physiology: Energy, Nutrition, and Human Performance*, 253.

<sup>56</sup> Dimsdale, Joel E. "French Horn Hypertension." *The New England Journal of Medicine* Vol. 333, No. 5 (3 Aug 1995), online database, <http://www.nejm.org/content/1995/0333/0005/0326.asp>.

<sup>57</sup> Hunsaker, Leigh Anne and Darhyl Ramsey. "Cardiac Dynamics in Marching Band Trumpet Players." *Medical Problems of Performing Artists* Vol. 13, No. 2 (01 Jun 1998), 75.

increases in thoracic pressures during playing. Additionally, trumpet playing was shown to create “arrhythmias associated with the Valsalva maneuver.”<sup>59</sup> These changes consisted of “arrhythmias, including T wave changes, premature atrial and ventricular contractions, interpolated ventricular contractions, ventricular escape beats, right bundle branch block, and sinus arrhythmia.”<sup>60</sup> Episodic blood pressure elevations during horn playing may or may not have clinical relevance. But “brass players’ folklore suggests an increased incidence of [eye] hemorrhages, retinal detachments, and cerebrovascular accidents.”<sup>61</sup>

Heart rate and blood pressure increase during talking. Systolic blood pressure showed an increase of nine mm Hg/maximum difference from quiet baseline and diastolic blood pressure elevated seven mm Hg/maximum difference from quiet baseline.<sup>62</sup> Additionally, when subjects were asked to read passages with text that could create anxieties, blood pressure showed an increase.<sup>63</sup> Higher measurements in blood pressure were discovered in rapid speech, as compared to normal speech rates. However, researches attribute

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<sup>58</sup> Barr, Deborah, Lee Van Dusen, Steve Ess, and Julie Plezbert. “Physiological Assessment of Bagpipers: A Preliminary Study of Cardiopulmonary Parameters.” *Medical Problems of Performing Artists* Vol.15, No. 2 (Jun 2000), 51-52.

<sup>59</sup> Hunsaker, Leigh Anne and Darhyl Ramsey. “Cardiac Dynamics in Marching Band Trumpet Players.” *Medical Problems of Performing Artists* Vol. 13, No. 2 (01 Jun 1998), 78.

<sup>60</sup> Hunsaker, Leigh Anne and Darhyl Ramsey. “Cardiac Dynamics in Marching Band Trumpet Players.” *Medical Problems of Performing Artists* Vol. 13, No. 2 (01 Jun 1998), 76.

<sup>61</sup> Gordon, Laura. “French Horn Playing Causes Blood Pressure to Rise.” (03 Aug 1995) [http://www.hornplanet.com/hornpage/museum/articles/blood\\_pressure.html](http://www.hornplanet.com/hornpage/museum/articles/blood_pressure.html) (08 Jan 2000).

<sup>62</sup> Lynch, James J., Sue Ann Thomas, Jack M. Long, Kenneth L. Malinow, Grace Chickadonz, and Aaron Honori Katcher. “Human Speech and Blood Pressure.” *The Journal of Nervous and Mental Disease* Vol. 168, No. 9 (1980), 526-527.

<sup>63</sup> Lynch, James J., Sue Ann Thomas, Jack M. Long, Kenneth L. Malinow, Grace Chickadonz, and Aaron Honori Katcher. “Human Speech and Blood Pressure.” *The Journal of Nervous and Mental Disease* Vol. 168, No. 9 (1980), 526-527.

changes to the increase of stress involved with the anxiety of having to speak in front of a crowd, not to any physiological changes.<sup>64</sup>

The Valsalva maneuver has shown to possess additional physiological implications. A normotensive patient arrived at the emergency room with “a sensation of crackling under the skin.” An examination of the torso region showed pockets of air trapped under the patients’ skin. Prior to being admitted to the hospital, the patient inflated twenty balloons in the duration of an hour. Thoracic pressures created during balloon blowing are consistent with those found during the Valsalva maneuver. In this case, thoracic pressures caused the alveoli to rupture, allowing air to leak towards the body’s surface, forming the air pockets. Pockets of trapped air under the skin have also occurred in saxophone players.<sup>65</sup>

Valsalva maneuvers can cause exertional headaches or syncope (fainting). “Straining or a Valsalva type maneuver precipitates the acute onset of severe throbbing pain, usually occipital, for a few seconds to a minute. The headache then settles to a dull ache.”<sup>66</sup> During the Valsalva maneuver, heart rate and stroke volume show a rise in cardiac output. Muscular activity facilitates and sustains venous return to the heart. After releasing the Valsalva maneuver, “without the muscular activity to increase venous return, cardiac filling may decrease dramatically because of the reduction in left ventricular end-diastolic

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<sup>64</sup> Friedman, Erika, Sue A. Thomas, Denise Kulick-Ciuffo, James J. Lynch, and Masazumi Suginoara. “The Effects of Normal and Rapid Speech on Blood Pressure.” *Psychosomatic Medicine* Vol. 44, No. 6 (Dec 1982), 545.

<sup>65</sup> Mirsky, Steve. “Body Blow.” *Scientific American* Vol. 276, No. 3, (Mar 1997) 25.

<sup>66</sup> McCrory, Paul. “Recognizing Exercise Related Headache.” *The Physician and Sports Medicine* Vol. 25, No. 2 (Feb 1997), <http://www.physsportsmed.com/issues/1997/02feb/mccrory.htm>.



volume and stroke volume.<sup>67</sup> This sudden drop in blood pressure can cause syncope.

The normal blood pressure response to the Valsalva maneuver is divided into four phases:

- Phase I      Onset of Valsalva; immediate increase in blood pressure, heart rate slows.
- Phase II      Gradual decrease in blood pressure, increase in heart rate.
- Phase III      Valsalva released; Further drop in blood pressure, additional rise in heart rate.
- Phase IV      A rapid rise in blood pressure above the baseline, heart rate decreases (overshoot).<sup>68</sup>

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<sup>67</sup> O'Connor, Francis and Ralph G. Oriscello. "Exercise Related Syncope in the Young Athlete: Reassurance, Restriction, or Referral?" *American Family Physician* Vol. 60, No. 7 (01 Nov 1999) 2001-2009.

<sup>68</sup> Henbest, Heath and Jon Baker. "Valsalva Device." (07 Apr 1998) [http://www.vubme.vuse.vanderbilt.edu/King/bme272\\_273/Projects97\\_98/group11/valsalva.html](http://www.vubme.vuse.vanderbilt.edu/King/bme272_273/Projects97_98/group11/valsalva.html) (06 Jan 2001).

## CHAPTER FOUR

### MATERIALS AND METHODS

Four classically trained singers were selected by researcher. C.G. was thirty-three years of age, pursuing a Bachelor degree in music education, had one year applied vocal training, and extensive volunteer choral experience. A.M. was thirty-two years of age, pursuing a Master degree in vocal performance, and had five years of applied vocal training. D.W. was nineteen years of age, pursuing a Bachelor degree in vocal performance, had one year of vocal training, and junior high and high school choral experience. R.N. was twenty-two years of age, was pursuing a Bachelor degree in music education, and had two years of applied vocal training. C.G., A.M., and D.W. were female, while R.N. was male.

The procedure was described to the subject. If the subject was compliant, the procedure began. The subject was asked a series of questions to gather information (see Appendix A). When all questions were answered satisfactorily, the subject was asked to sign a consent form (see Appendix B) and the procedure began.

Blood pressure was taken five separate times for each treatment. Five readings were taken. A waiting period of at least one minute occurred between each measurement. Blood pressure was taken at rest and was measured during the following treatments:

1. The subject was asked to sustain his/her perception of a low note on an [a] vowel
  - a. at his/her perception of *pianissimo*

- b. at his/her perception of *mezzo forte*
  - c. at his/her perception of *fortissimo*
2. The subject was asked to sustain their perception of a high note on an [a] vowel
- a. at his/her perception of *pianissimo*
  - b. at his/her perception of *mezzo forte*
  - c. at his/her perception of *fortissimo*
3. The subject was asked to exhale for a duration that could allow an accurate blood pressure reading

Blood pressures were measured by a sphygmomanometer, an inflated cuff, and a stethoscope. The sphygmomanometer was calibrated by comparing it to a recently sphygmomanometer, which had been calibrated by a qualified health professional seven days prior. The cuff was placed over the brachial artery in the right arm and inflated. Measurements were taken as the inflation of the cuff was released. Blood pressures were measured in millimeters of mercury (mm Hg.) The subjects stood with their right arm placed on a grand piano, near the level of the subject's heart to give a more accurate reading. A sound pressure level meter, Radio Shack, Cat. No. 33-2055, was placed on a tripod at a distance of twenty four inches from the subject. The subject initiated a tone and was instructed to maintain the same decibel level through each individual measurement. Total duration of the experiment was approximately forty-five minutes per subject.

Table 4.1 illustrates the results for D.W. One-way repeated measures analysis of variance (ANOVA) showed that the differences in mean values among the treatment groups were greater than would be expected by chance ( $p < 0.001$  for systolic and  $p < 0.001$  for diastolic). Systolic pressures during singing in subject D.W. showed an increase in all cases except Low note, *ff* and breathing than from at rest. Diastolic pressures showed an increase in all treatments, except breathing than from at rest. Mean arterial pressure showed an increase in each treatment than from at rest. An expected increase in sound pressure level was found as the treatments became louder and higher. Chart 4.1 shows the trends of blood pressures in D.W.

Table 4.2 shows the results for A.M. One-way repeated measures analysis of variance (ANOVA) showed that the differences in mean values among the treatment groups were greater than would be expected by chance ( $p < 0.001$  for systolic and  $p < 0.001$  for diastolic). Systolic blood pressures in A.M. were lower in all treatments except high note *ff* than from at rest. Diastolic pressures were higher in all treatments as compared to at rest. Mean arterial pressures were higher in all treatments than from at rest except low note, *mf*. Sound pressure levels increased as pitch and loudness increased. Chart 4.2 shows the trends of A.M.

Table 4.1

Average measurements of D.W. Systolic, diastolic, and mean arterial pressures were measured in millimeters of mercury. Sound pressure levels are shown in decibels. Changes in systolic and diastolic as compared to at rest are shown in millimeters of mercury.

Treatment		Systolic	Diastolic	Mean	Decibels	Systolic Difference from Rest	Diastolic Difference from Rest
Rest		119.4	79.6	93	N/A	0.0	0.0
Low Note	pp	120.2	80.4	94	65	+0.8	+0.8
	mf	120.0	81.4	95	75	+0.6	+1.8
	ff	119.2	80.8	94	84	-0.2	+1.2
High Note	pp	128.4	85.6	100	83	+9.0	+6.0
	mf	125.6	82.4	97	95	+6.2	+2.8
	ff	133.0	88.4	104	105	+13.6	+8.8
Breathing		115.6	84.4	95	N/A	-3.8	+4.6

(p < 0.001) (p < 0.001)

Table 4.2

Average measurements of A.M. Systolic, diastolic, and mean arterial pressures were measured in millimeters of mercury. Sound pressure levels are shown in decibels. Changes in systolic and diastolic as compared to at rest are shown in millimeters of mercury.

Treatment		Systolic	Diastolic	Mean	Decibels	Systolic Difference from Rest	Diastolic Difference from Rest
Rest		107.2	81.4	90	N/A	0.0	0.0
Low Note	pp	100.0	87.8	92	63	-7.2	+6.4
	mf	99.8	82.8	89	83	-7.4	+1.4
	ff	106.4	88.2	95	95	-0.8	+6.8
High Note	pp	103.6	90.0	95	86	-3.6	+8.6
	mf	101.2	89.6	94	95	-6.0	+8.2
	ff	110.2	92.0	98	100	+3.0	+10.6
Breathing		95.2	83.2	87	N/A	-12.0	+1.8

(p <0.001)                      (p < 0.001)

Table 4.3 shows the results for R.N. One-way repeated measures analysis of variance (ANOVA) showed that the differences in mean values among the treatment groups were greater than would be expected by chance ( $p < 0.589$  for systolic and  $p < 0.001$  for diastolic). Systolic pressures showed a decrease in each treatment than from at rest. Diastolic pressures showed an increase in each treatment as compared to rest, except during breathing. Mean arterial pressure showed an increase through all treatments except breathing. Sound pressure levels showed an increase as pitch and loudness increased.

Table 4.3

Average measurements of R.N. Systolic, diastolic, and mean arterial pressures were measured in millimeters of mercury. Sound pressure levels are shown in decibels. Changes in systolic and diastolic as compared to at rest are shown in millimeters of mercury.

Treatment		Systolic	Diastolic	Mean	Decibels	Systolic Difference from Rest	Diastolic Difference from Rest
Rest		113.6	79.6	91	N/A	0.0	0.0
Low Note	pp	108.4	80.4	90	63	-5.2	+0.8
	mf	112.4	81.4	92	73	-1.2	+1.8
	ff	106.2	80.8	90	82	-7.4	+1.2
High Note	pp	106.8	85.6	93	73	-6.8	+6.0
	mf	107.6	82.4	91	76	-6.0	+2.8
	ff	112.8	88.4	94	85	-0.8	+8.8
Breathing		102.4	76.2	85	N/A	-11.2	-3.4

(p < 0.589)      (p < 0.001)

Table 4.4 shows the results for C.G. One-way repeated measures analysis of variance (ANOVA) showed that the differences in mean values among the treatment groups were greater than would be expected by chance (p < 0.149 for systolic and p < 0.001 for diastolic). Systolic pressures showed a decrease in low note treatments, but showed an increase during high note treatments than from at rest. Diastolic pressures showed an increase in all treatments as compared to at rest. Mean arterial pressure showed an increase

in all treatments as compared to at rest. Sound pressure levels showed an increase as pitch and loudness increases.

Table 4.4

Average measurements of C.G.. Systolic, diastolic, and mean arterial pressures were measured in millimeters of mercury. Sound pressure levels are shown in decibels. Changes in systolic and diastolic as compared to at rest are shown in millimeters of mercury.

Treatment		Systolic	Diastolic	Mean	Decibels	Systolic Difference from Rest	Diastolic Difference from Rest
Rest		101.4	72.0	82	N/A	0.0	0.0
Low Note	pp	104.8	81.8	90	55	+3.4	+9.8
	mf	104.2	86.4	93	65	+2.8	+14.4
	ff	107.6	86.0	93	77	+6.2	+14.0
High Note	pp	101.2	88.4	93	73	-0.2	+16.4
	mf	103.0	89.0	94	90	+1.6	+17.0
	ff	100.8	84.2	90	97	-0.6	+12.2
Breathing		99.8	80.6	87	N/A	-1.6	+8.6

(p < 0.149)      (p < 0.001)



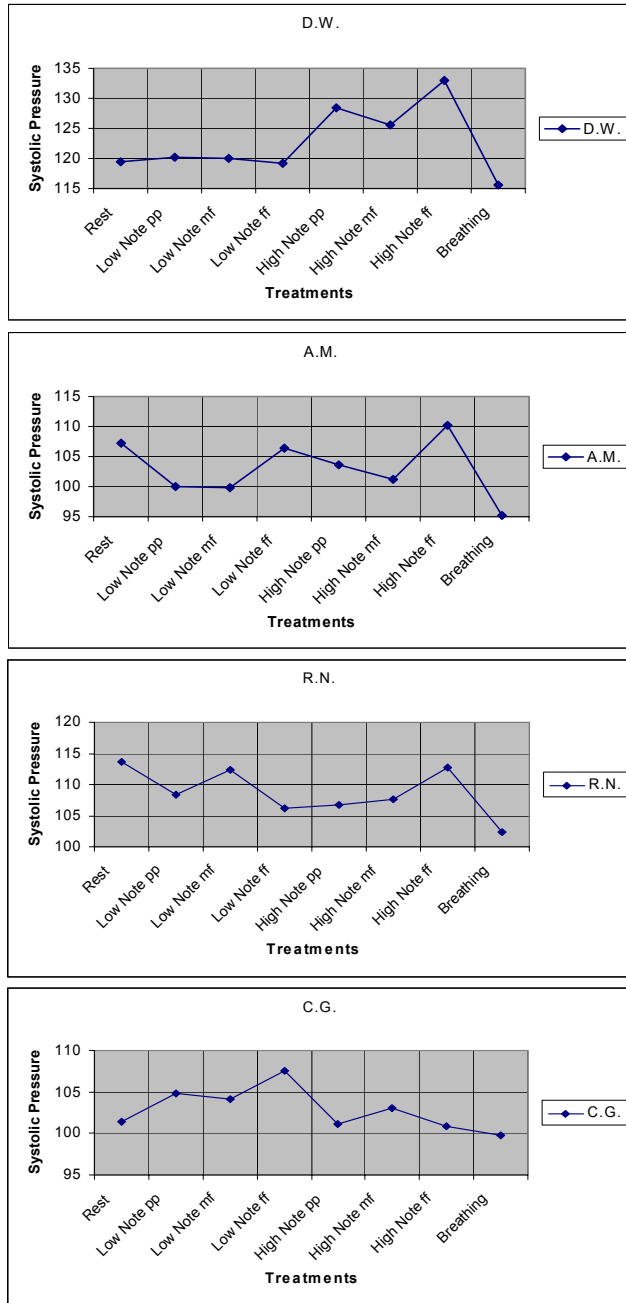


Figure 4.1  
Systolic pressures expressed in millimeters of mercury (mm Hg) on Y axis and Treatments on X axis.

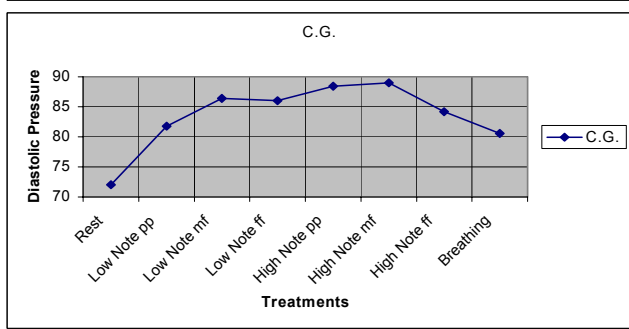
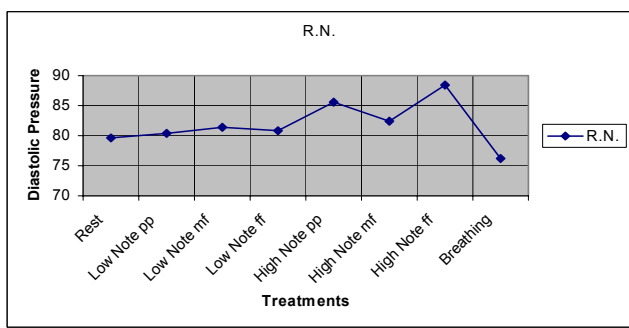
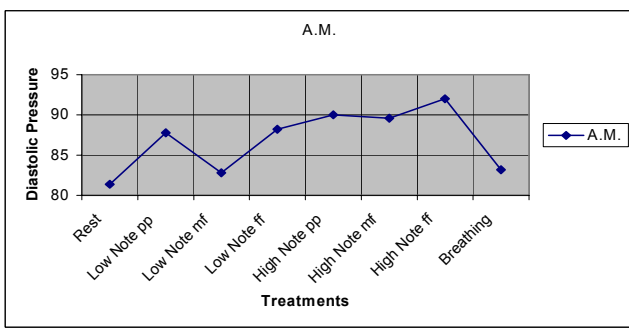
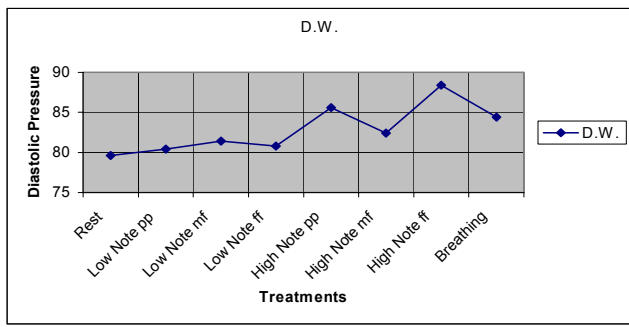


Chart 4.2  
 Diastolic pressures expressed in millimeters of mercury (mm Hg) on Y axis and Treatments on X axis.

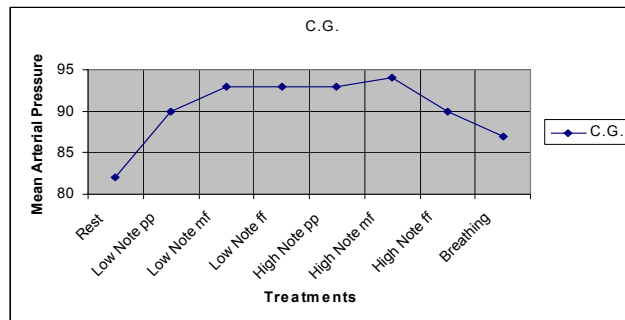
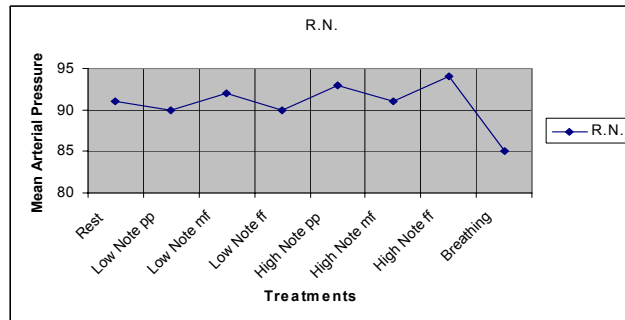
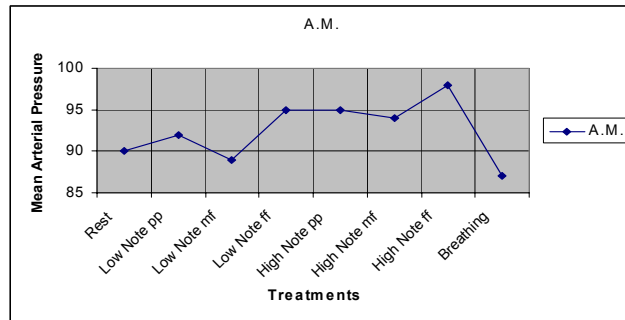
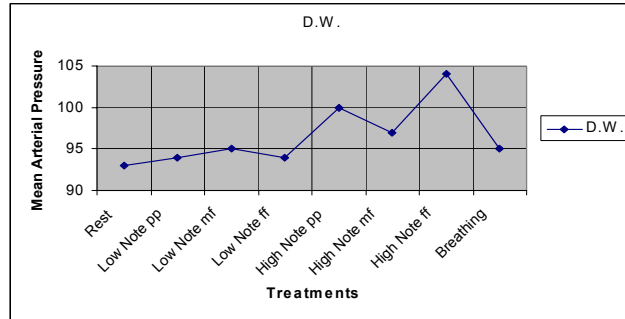


Chart 4.3  
 Mean arterial pressures expressed in millimeters of mercury (mm Hg) on Y axis and Treatments on X axis.

Figure 4.1 illustrates the trends in systolic blood pressure of all four subjects. Similarities between subjects were random, demonstrating that systolic blood pressure does change during singing, but the variations are individual. For all subjects, blood pressure decreased between the treatment high note *ff* and breathing. While there are minor differences between subjects, Figure 4.2 (diastolic blood pressure) and Figure 4.3 (mean arterial pressure) establishes a strong trend towards an increase in blood pressures in all treatments as decibels and assumed intrathoracic pressure increase.

A group of classically trained singers had blood pressure measured while singing. In addition, sound pressure levels were measured. The purpose of this study was to determine if singing had any effect on blood pressure in classically trained singers. The heart is located in the central region of the thorax, near the cardiac impression of the lung. When the thorax and lungs expand during inspiration, air pressure in the lungs, subglottal or intrathoracic pressure, increases. Subglottal pressure in normal speech averages six cm of H<sub>2</sub>O, soft to medium loudness can create subglottal pressures as high as fifteen cm of H<sub>2</sub>O, and loud singing can create pressures between twenty and thirty cm of H<sub>2</sub>O. Thus, an increase in subglottal pressure has a direct correlation with an increase in loudness (decibels).<sup>69</sup> As shown in chapter 3, intrathoracic pressures associated with the Valsalva maneuver and playing a wind instrument create an increase in blood pressure. Singing follows the same principle of increased

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<sup>69</sup> Sundberg, 1987.

thoracic pressure as instrument playing. Thus, one could consider that thoracic pressures may cause changes in blood pressure during singing.

The evidence in this study appears to suggest that singing in the Western classical tradition does have an effect on blood pressure. Changes in systolic pressure occurred. However, changes were individualized. Diastolic and mean arterial pressure generally showed a direct correlation to thoracic pressure.

While measurements were taken within a controlled environment, it may be possible that the order of treatments and the clinical nature of the experiment may have affected the results. Therefore, additional research using a larger subject base involving normotensive, hypertensive, and hypotensive populations is warranted.

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APPENDIX A  
QUESTIONNAIRE

Question one was asked to ascertain each subject's expertise in singing. Questions two through eleven were asked to ensure normotensive blood pressures. Names have been withheld to maintain the identification of each subject.

## QUESTIONNAIRE

Name: C.G.

Age: 33

Sex: Female

1. Please state your experience as a singer: pursuing a Bachelor degree in music education, had one year applied vocal training, and extensive volunteer choral experience.
2. Have you ever had or been told that you have high/low blood pressure?  
No.
3. Is there a history of high/low blood pressure in your family? If yes, who?  
None.
4. Are you anemic or have you ever been told you are anemic? No.
5. Are you currently taking any medication? Appetite suppressant-Dexatrim.
6. When did you last eat? Forty-five minutes.
7. Have you exercised today? If so, explain. No.
8. How often do you exercise? Explain. Three to five times a week; stationary bicycle and aerobics.
9. How long have you been awake? Seven and one half hours.
10. Are you currently experiencing menstruation? If so, when did your cycle begin? Yes, began 5 Nov 1995 (two days into period, day of experiment.)
11. Do you have any current medical conditions that are affecting your health?  
No.

## QUESTIONNAIRE

Name: R.N.

Age: 22

Sex: Male

1. Please state your experience as a singer: pursuing a Bachelor degree in music education, and had two years of applied vocal training.
2. Have you ever had or been told that you have high/low blood pressure?  
No.
3. Is there a history of high/low blood pressure in your family? If yes, who?  
None.
4. Are you anemic or have you ever been told you are anemic? No.
5. Are you currently taking any medication? None.
6. When did you last eat? Previous evening.
7. Have you exercised today? If so, explain. No.
8. How often do you exercise? Explain. Couple of times a week; push ups, set-ups, and walking.
9. How long have you been awake? Six hours.
10. Are you currently experiencing menstruation? If so, when did your cycle begin? N/A
11. Do you have any current medical conditions that are affecting your health?  
No.

## QUESTIONNAIRE

Name: A.M.

Age: 32

Sex: Female

1. Please state your experience as a singer: pursuing a Master degree in vocal performance, and had five years of applied vocal training.
2. Have you ever had or been told that you have high/low blood pressure?  
No.
3. Is there a history of high/low blood pressure in your family? If yes, who?  
None.
4. Are you anemic or have you ever been told you are anemic? No.
5. Are you currently taking any medication? None.
6. When did you last eat? Four hours.
7. Have you exercised today? If so, explain. No.
8. How often do you exercise? Explain. Occasionally; walking.
9. How long have you been awake? Four and one half hours.
10. Are you currently experiencing menstruation? If so, when did your cycle begin? N/A
11. Do you have any current medical conditions that are affecting your health?  
No.

## QUESTIONNAIRE

Name: D.W.

Age: 19

Sex: Female

1. Please state your experience as a singer: pursuing a Bachelor degree in vocal performance, had one year of vocal training, and junior high and high school choral experience.
2. Have you ever had or been told that you have high/low blood pressure?  
Yes, fluctuates high and low, but nothing chronic.
3. Is there a history of high/low blood pressure in your family? If yes, who?  
Yes, mother, grandmother, father.
4. Are you anemic or have you ever been told you are anemic? No.
5. Are you currently taking any medication? None.
6. When did you last eat? Two and one half hours.
7. Have you exercised today? If so, explain. No.
8. How often do you exercise? Explain. Everyday; swimming or walking.
9. How long have you been awake? Three hours.
10. Are you currently experiencing menstruation? If so, when did your cycle begin? N/A
11. Do you have any current medical conditions that are affecting your health?  
Hypoglycemia controlled by diet.

APPENDIX B  
CONSENT FORM

Appendix B contains the consent form signed by each subject. Signatures have been withheld to maintain the identification of each subject.

## CONSENT FORM

My signature, on this sheet, by which I volunteer to participate in the experiment

“The Effects of Singing on Blood Pressure in Classically Trained Singers”

conducted by Kimberly Broadwater, M.M. indicates that I understand that all subjects in the project are volunteers, that I can withdraw at any time from the experiment, that I have been or will be informed as to the nature of the experiment, that the data I provide will be anonymous and my identity will not be revealed without my permission, and that my performance in this experiment may be used for additional approved projects. Finally, I shall be given an opportunity to ask questions prior to the start of the experiment and after my participation is complete.

C.G. (Subject name withheld)

Subject's Signature

7 Nov 1995

Date

## CONSENT FORM

My signature, on this sheet, by which I volunteer to participate in the experiment

“The Effects of Singing on Blood Pressure in Classically Trained Singers”

conducted by Kimberly Broadwater, M.M. indicates that I understand that all subjects in the project are volunteers, that I can withdraw at any time from the experiment, that I have been or will be informed as to the nature of the experiment, that the data I provide will be anonymous and my identity will not be revealed without my permission, and that my performance in this experiment may be used for additional approved projects. Finally, I shall be given an opportunity to ask questions prior to the start of the experiment and after my participation is complete.

R.N. (Subject name withheld)

Subject's Signature

10 Nov 1995

Date



## CONSENT FORM

My signature, on this sheet, by which I volunteer to participate in the experiment

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A.M. (Subject name withheld)

Subject's Signature

7 Nov 1995

Date

## CONSENT FORM

My signature, on this sheet, by which I volunteer to participate in the experiment

“The Effects of Singing on Blood Pressure in Classically Trained Singers”

conducted by Kimberly Broadwater, M.M. indicates that I understand that all subjects in the project are volunteers, that I can withdraw at any time from the experiment, that I have been or will be informed as to the nature of the experiment, that the data I provide will be anonymous and my identity will not be revealed without my permission, and that my performance in this experiment may be used for additional approved projects. Finally, I shall be given an opportunity to ask questions prior to the start of the experiment and after my participation is complete.

D.W. (Subject name withheld)

Subject's Signature

7 Nov 1995

Date

## APPENDIX C

### STATISTICAL ANALYSIS FOR INDIVIDUALS

Appendix C contains statistical analysis for individual subjects and their treatments. Subject, blood pressure type, and the analysis of data are shown.

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Subject: A.M.

Blood Pressure Type: Systolic

<b>Treatment</b>	<b>Mean</b>	<b>Standard Deviation</b>
At Rest	110.800	6.8132
Low pp	108.680	7.4988
Low mf	109.800	7.9057
Low ff	109.880	5.4351
High pp	110.000	10.8074
High mf	110.200	9.8529
High ff	114.520	11.7581

The differences in the mean values among treatment groups are not great enough to exclude the possibility that the difference is just due to random sampling variation. There is not a statistically significant difference ( $P=0.250.$ )

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Subject: A.M.

Blood Pressure Type: Diastolic

<b>Treatment</b>	<b>Mean</b>	<b>Standard Deviation</b>
At Rest	79.280	4.3327
Low pp	82.760	3.1856
Low mf	85.720	4.5047
Low ff	88.200	7.6433
High pp	90.360	7.2476
High mf	90.120	6.1443
High ff	93.600	8.3150

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Subject: R.N.

Blood Pressure Type: Systolic

<b>Treatment</b>	<b>Mean</b>	<b>Standard Deviation</b>
At Rest	113.600	5.1769
Low pp	108.400	4.3359
Low mf	112.400	7.1274
Low ff	106.200	11.0995
High pp	106.800	6.0992
High mf	107.600	8.4143
High ff	112.800	10.4738

The differences in the mean values among treatment groups are not great enough to exclude the possibility that the difference is just due to random sampling variation. There is not a statistically significant difference ( $P=0.589$ .)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Subject: R.N.

Blood Pressure Type: Diastolic

<b>Treatment</b>	<b>Mean</b>	<b>Standard Deviation</b>
At Rest	79.600	1.6733
Low pp	80.400	2.1909
Low mf	81.400	2.6077
Low ff	80.800	1.7889
High pp	85.600	1.6733
High mf	82.400	2.5100
High ff	88.400	3.5777

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Subject: C.G.

Blood Pressure Type: Systolic

<b>Treatment</b>	<b>Mean</b>	<b>Standard Deviation</b>
At Rest	101.400	5.0794
Low pp	104.800	3.0332
Low mf	104.200	3.7683
Low ff	107.600	6.9498
High pp	101.200	3.7014
High mf	103.000	1.4142
High ff	100.800	2.6833

The differences in the mean values among treatment groups are not great enough to exclude the possibility that the difference is just due to random sampling variation. There is not a statistically significant difference ( $P=0.149.$ )



## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Subject: C.G.

Blood Pressure Type: Diastolic

<b>Treatment</b>	<b>Mean</b>	<b>Standard Deviation</b>
At Rest	72.000	3.0822
Low pp	81.800	2.0494
Low mf	86.400	3.5071
Low ff	86.000	5.4772
High pp	88.400	3.9115
High mf	89.000	4.1833
High ff	84.200	2.4900

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Subject: D.W.

Blood Pressure Type: Systolic

<b>Treatment</b>	<b>Mean</b>	<b>Standard Deviation</b>
At Rest	119.400	2.9665
Low pp	120.200	5.4498
Low mf	120.000	1.4142
Low ff	119.200	3.6332
High pp	128.400	3.2094
High mf	125.600	3.2863
High ff	133.000	6.0828

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Subject: D.W.

Blood Pressure Type: Diastolic

<b>Treatment</b>	<b>Mean</b>	<b>Standard Deviation</b>
At Rest	83.400	2.3022
Low pp	83.800	3.8987
Low mf	93.000	2.7386
Low ff	101.000	2.2361
High pp	102.800	5.0200
High mf	99.600	0.8944
High ff	105.400	4.5607

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

## APPENDIX D

### STATISTICAL ANALYSIS ALL SUBJECTS

Appendix D contains statistical analysis for all subjects and their treatments. Treatment, blood pressure type, and the analysis of data are shown.

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: At rest

Blood Pressure Type: Systolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	113.600	5.1769
C.G.	101.400	5.0794
A.M.	107.200	3.8987
D.W.	119.400	2.9665

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

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## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: At rest

Blood Pressure Type: Diastolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	79.600	1.6733
C.G.	72.000	3.0822
A.M.	81.400	2.6077
D.W.	83.400	2.3022

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: Low note pp

Blood Pressure Type: Systolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	108.400	4.3359
C.G.	104.800	3.0332
A.M.	100.000	1.4142
D.W.	120.200	5.4498

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

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## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: Low note pp

Blood Pressure Type: Diastolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	80.400	2.1909
C.G.	81.800	2.0494
A.M.	87.800	1.7889
D.W.	83.800	3.8987

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.005$ .)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: Low note mf

Blood Pressure Type: Systolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	112.400	7.1274
C.G.	104.200	3.7683
A.M.	99.800	2.8636
D.W.	120.000	1.4142

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference (P<0.001.)

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## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: Low note mf

Blood Pressure Type: Diastolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	81.400	2.6077
C.G.	86.400	3.5071
A.M.	82.800	2.1679
D.W.	93.000	2.7386

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference (P<0.001.)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: Low note ff

Blood Pressure Type: Systolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	106.200	11.0995
C.G.	107.600	6.9498
A.M.	106.400	4.0988
D.W.	119.200	3.6332

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.041$ .)

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## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: Low note ff

Blood Pressure Type: Diastolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	80.800	1.7889
C.G.	86.000	5.4772
A.M.	88.200	2.0494
D.W.	101.000	2.2361

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)



## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: High note pp

Blood Pressure Type: Systolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	106.800	6.0992
C.G.	101.200	3.7014
A.M.	103.600	5.1769
D.W.	128.400	3.2094

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

---

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: High note pp

Blood Pressure Type: Diastolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	85.600	1.6733
C.G.	88.400	3.9115
A.M.	90.000	3.8079
D.W.	102.800	5.0200

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: High note mf

Blood Pressure Type: Systolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	107.600	8.4143
C.G.	103.000	1.4142
A.M.	101.200	1.0954
D.W.	125.600	3.2863

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

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## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: High note mf

Blood Pressure Type: Diastolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	82.400	2.5100
C.G.	89.000	4.1833
A.M.	89.600	5.3666
D.W.	99.600	0.8944

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: High note ff

Blood Pressure Type: Systolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	112.800	10.4738
C.G.	100.800	2.6833
A.M.	110.200	4.8166
D.W.	133.000	6.0828

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

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## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: High note ff

Blood Pressure Type: Diastolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	88.400	3.5777
C.G.	84.200	2.4900
A.M.	92.000	4.9497
D.W.	105.400	4.5607

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: Breathing

Blood Pressure Type: Systolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	102.400	8.2946
C.G.	99.800	6.4962
A.M.	95.200	2.1679
D.W.	115.600	6.2290

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.001$ .)

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## ONE WAY REPEATED MEASURES ANALYSIS OF VARIANCE

Treatment: Breathing

Blood Pressure Type: Diastolic

<b>Subject</b>	<b>Mean Blood Pressure</b>	<b>Standard Deviation</b>
R.N.	76.200	3.8987
C.G.	80.600	2.6077
A.M.	83.200	1.6432
D.W.	84.400	3.8471

The differences in the mean values among treatment groups are greater than would be expected by chance. There is a statistically significant difference ( $P < 0.002$ .)

## APPENDIX E

### INDIVIDUAL DATA

Appendix E shows individual records of data collected directly from each subject.

<b>Subject</b>	<b>R.N.</b>										
	Systolic Blood Pressure					Diastolic Blood Pressure					Sound Pressure Level in Decibels
Rest	108	110	112	120	118	78	80	80	78	82	N/A
Low note pp	110	114	104	110	104	80	80	84	78	80	63
Low note mf	112	102	114	112	122	80	82	78	82	85	73
Low note ff	100	105	92	120	114	82	82	82	80	78	82
High note pp	102	116	110	102	104	84	86	84	88	86	73
High note mf	102	110	120	108	98	80	85	82	85	80	76
High note ff	115	125	120	102	102	90	90	90	82	90	85
Breathing	102	110	90	100	110	78	70	75	78	80	N/A

Subject	C.G.										Sound Pressure Level in Decibels
	Systolic Blood Pressure					Diastolic Blood Pressure					
Rest	104	102	108	98	95	75	75	72	68	70	N/A
Low note pp	108	104	108	102	102	80	85	80	82	82	55
Low note mf	110	105	104	102	100	85	82	90	90	85	65
Low note ff	104	104	105	120	105	80	80	90	90	90	77
High note pp	102	95	105	102	102	88	85	95	86	88	73
High note mf	102	105	102	102	104	85	95	85	90	90	90
High note ff	102	102	98	104	98	82	84	88	82	85	97
Breathing	100	110	98	92	99	85	80	80	78	80	N/A

Subject	A.M.										Sound Pressure Level in Decibels
	Systolic Blood Pressure					Diastolic Blood Pressure					
Rest	102	104	110	110	110	82	80	85	82	78	N/A
Low note pp	102	100	100	98	100	88	88	90	88	85	63
Low note mf	102	102	100	95	100	85	80	85	82	82	83
Low note ff	110	108	110	102	102	90	88	85	90	88	95
High note pp	110	100	102	108	98	92	90	88	95	85	86
High note mf	100	102	102	100	102	80	92	92	92	92	95
High note ff	108	118	110	105	110	92	98	95	85	90	100
Breathing	98	95	95	96	92	85	85	82	82	82	N/A



<b>Subject</b>	<b>D.W.</b>										
	Systolic Blood Pressure					Diastolic Blood Pressure					Sound Pressure Level in Decibels
Rest	120	115	122	122	118	82	80	85	85	85	N/A
Low note pp	118	125	116	127	115	82	85	82	90	80	65
Low note mf	120	120	118	122	120	90	90	95	95	95	75
Low note ff	118	125	119	119	115	100	100	100	105	100	84
High note pp	130	125	130	132	125	102	108	98	108	98	83
High note mf	128	122	124	130	124	98	100	100	100	100	95
High note ff	132	130	125	140	138	102	110	105	100	110	105
Breathing	122	120	110	108	118	90	82	80	86	84	N/A

## VITA

Kimberly Broadwater serves as the Coordinator of Choral Activities and Instructor of Music in the Department of Music at Delta State University, and as Assistant Technical Director of the Bologna Performing Arts Center in Cleveland, Mississippi. She is the director of Delta Singers, an auditioned choral ensemble. Ms. Broadwater maintains a studio of private voice students.

As a researcher, Ms. Broadwater maintains an active pursuit of new data and historical information. Among Ms. Broadwater's accomplishments includes a presentation "The Effects of Singing on Blood Pressure in Classically Trained Singers" at the 26th Annual Care of the Professional Voice Symposium in Philadelphia. Future projects in research include "The Pedagogical Teachings of Eugene Feuchtinger, " alternate methods used in the voice studio, including technology and distance education, and environmental vs. biological effects on acoustics of the speaking/singing voice.

A native of Cleveland, Mississippi, Ms. Broadwater received the Bachelor of Music degree in vocal performance from Delta State University, the Master of Music degree in vocal performance from Louisiana State University, and is completing the degree of Doctor of Musical Arts in vocal performance with an emphasis in voice science at Louisiana State University.