INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.
Biomechanical analysis of double bassists' performance postures

Horvath, Kathleen Ann, Ph.D.
The Ohio State University, 1994

Copyright ©1994 by Horvath, Kathleen Ann. All rights reserved.
BIOMECHANICAL ANALYSIS OF DOUBLE BASSISTS' PERFORMANCE POSTURES

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

Kathleen A. Horvath, B. M., M. A.

* * * * *

The Ohio State University
1994

Dissertation Committee: Patricia J. Flowers
                              David Butler
                              Robert Gillespie
                              Paul Robinson

Approved by: Patricia J. Flowers
Advisor, School of Music
To My Parents:
Arthur A. and
Margaret C. Horvath
ACKNOWLEDGMENTS

I wish to express my sincere appreciation to the members of my committee for their support and patience throughout this process. I wish to thank my advisor Dr. Patricia Flowers for her confidence, guidance, and belief in this project. I would also like to acknowledge the support I received from the Biomechanics Department for the use of equipment and resources. To Kermit Davis for his assistance as my interobserver, and to Dr. William Marras for methodological support. I would also like to thank my family, friends, and SAI sisters for their caring. Finally, I wish to thank my parents for their unending encouragement and support.
VITA

10 January 1963 ............ Born - Youngstown, Ohio.

1986 ......................... B. M. in Music Education from the Eastman School of Music in Rochester, New York.


1987 - 1990 ................... Orchestra Director, New Bedford High School in New Bedford, Massachusetts.

1990 - 1992 ................... Graduate Teaching Associate, at The Ohio State University.


1992 - 1994 ................... Graduate Teaching Associate in Double Bass and Director of the Pre-College Strings Program at The Ohio State University.

FIELDS OF STUDY

Major Field: Music
Minor Field: Biomechanics
# TABLE OF CONTENTS

ACKNOWLEDGMENTS ........................................ iii
VITA .................................................................. iv
LIST OF TABLES .............................................. vi
LIST OF FIGURES ............................................ ix

CHAPTER

I. INTRODUCTION ............................................ 1
   Pedagogical Practice .................................. 4
   The Double Bass ....................................... 8
   Biomechanics .......................................... 13
   Statement of the Problem ......................... 17
   Need for the Project ................................. 18
   Purpose of the Project ............................... 19

II. RELATED LITERATURE ................................. 20
   Double Bass Related Literature ................. 21
   Instructional Literature ......................... 21
   Pedagogical Literature ............................ 24
Arts Medicine Research 31
Incidence and Prevention Research 37
Pedagogy, Technique, and Instruction Research 42
Postural Research 45

III. METHOD 50
Performance Posture Theory and Evaluative Criteria 50
Posture Theory 50
Evaluative Criteria 66
Experimental Procedure 67
Part 1: Measurement 68
Part 2: Video Observation 69
Part 3: Survey Information 73
Part 4: Evaluation 74
Limitations of the Study 75

IV. RESULTS 76
Survey Results 76
Anthropomorphic Measurements 79
Instrument Measurements 80
# LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basic Survey Information</td>
<td>134</td>
</tr>
<tr>
<td>2. Double Bass Postural Information A</td>
<td>135</td>
</tr>
<tr>
<td>3. Double Bass Postural Information B</td>
<td>136</td>
</tr>
<tr>
<td>4. Double Bass Postural Information C</td>
<td>137</td>
</tr>
<tr>
<td>5. Anthropomorphic Measurements</td>
<td>138</td>
</tr>
<tr>
<td>6. Double Bass Measurements</td>
<td>139</td>
</tr>
<tr>
<td>7. Interobserver Agreement</td>
<td>141</td>
</tr>
<tr>
<td>8. &quot;I&quot; Beam Results</td>
<td>143</td>
</tr>
<tr>
<td>9. Vertical Orientation of the Torso Results</td>
<td>144</td>
</tr>
<tr>
<td>10. Coxal Joint Results</td>
<td>145</td>
</tr>
<tr>
<td>11. Head Over Shoulders Results</td>
<td>146</td>
</tr>
<tr>
<td>12. Left Arm Orientation Results</td>
<td>147</td>
</tr>
<tr>
<td>13. Right Arm Orientation Results</td>
<td>148</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURES</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. &quot;I&quot; Beam on Body</td>
<td>52</td>
</tr>
<tr>
<td>2. Pelvis as Inferior Cross Section of &quot;I&quot; Beam</td>
<td>53</td>
</tr>
<tr>
<td>3. Ischial Tuberosites as base of &quot;I&quot; Beam</td>
<td>54</td>
</tr>
<tr>
<td>4. Pectoral Girdle as Superior Cross Section of &quot;I&quot; Beam</td>
<td>55</td>
</tr>
<tr>
<td>5. Spinal Column as Vertical Element of &quot;I&quot; Beam</td>
<td>56</td>
</tr>
<tr>
<td>6. Coxal Joint at Hip</td>
<td>59</td>
</tr>
<tr>
<td>7. Bending from the Coxal Joint</td>
<td>60</td>
</tr>
<tr>
<td>8. Facets Interlock for Support</td>
<td>61</td>
</tr>
<tr>
<td>9. Lumbar Vertebrae Designed for Compressive Weight Bearing</td>
<td>62</td>
</tr>
<tr>
<td>10. Head as an Extension if the &quot;I&quot; Beam</td>
<td>63</td>
</tr>
<tr>
<td>11. Left Arm Orientation</td>
<td>65</td>
</tr>
<tr>
<td>12. Right Arm Orientation</td>
<td>66</td>
</tr>
</tbody>
</table>
13. Left Arm Orientation in the Lower Positions 70
14. Left Arm Orientation in Middle Positions 71
15. Left Arm in Orientation in Upper Positions 71
16. Video Observation Camera Angles 73
CHAPTER I
INTRODUCTION

The interaction between the performing musician and the instrument is very complex. There are many elements that interact simultaneously: the discipline of the mind to move the hands, the emotional relationship between the instrumentalist and the music, what the performing musician is communicating through the music, and the physical ramifications of such actions.

The act of musical performance on any instrument demands a thorough knowledge of the music, the mechanics of the instrument, performance technique, and a facile understanding of the interaction between these components. As a musician begins a performance decisions are made about how to play through a particular passage and subtle adjustments must be made simultaneously. The slightest error needs to be detected and corrected while the performance continues.

The act of performing on a musical instrument can be defined as skilled work. Grandjean (1988) defines skilled jobs as requiring precise motion of the hands and fingers and
1. Quick and accurate regulation of muscular contraction
2. Co-ordination of the movements of the individual muscles
3. Precision of movements
4. Concentration
5. Visual control

He continues that "it is clear that to perform a delicate movement with speed and precision calls for a whole series of sensory nerve impulses, followed by motor directives from the brain." (Grandjean, 1988, p. 115)

The process of acquiring this high degree of skill is a matter of imprinting these necessary muscular movements into the brain so that they leave the realm of conscious control and become a reflex action. (Grandjean, 1988, p. 115) The process of training such skill for musical endeavor takes many years because the physical and mental actions are very complex. In industry, progress has been made to train individuals for these jobs, and teach them to function at a high skill level with maximum efficiency and low risk of injury. In the performing arts, the process of analyzing musical skills for risk of injury and maximum efficiency is just beginning. The inherent problem is that musical training is a highly complex individual process of
sensory mapping and muscular imprinting. This, coupled with the extensive time required to develop the muscular, cognitive, and synthesis skills, makes the process very difficult to monitor.

The results of the International Congress of Symphony and Opera Musicians (ICSOM) survey (1988) reveal a startling number of performance related injuries. The Survey revealed that 76% of the 2212 musicians in the sample had at least one medical problem that was severe enough to affect performance. (Fishbein, 1988, p. 8) It is also very important to note that because the acquisition of these highly specialized musical skills is a combination of muscular, musical, and work load elements, it was suggested that these individual elements be defined and analyzed to determine risk factors and how they interact.

The ICSOM survey brought to the attention of the medical community the individuality of these performance related physical problems and informed the musical community about the enormity of the problem. The results indicate problems on several different levels. Because the training of a musician is such a long complex process, the cause or causes of these performance injuries have not yet been defined. There are issues of teaching practice, pedagogy, and workload, all of which need to be analyzed for their role in performance injuries. Music medicine is still working to determine how these various elements interact and assess their risk potential.
Pedagogical Practice

Current pedagogical practice does not involve a complete discussion and analysis of the role of physical aspects of performance. For the total health of the musician it is necessary to redefine the concept of pedagogy to include the broader aspect of the interaction of the body with the instrument as well as the specific technical information. Pedagogy should therefore be a system that teaches the necessary skills by including all of the elements of performance.

Traditionally, arts instruction has been thought of as kinesthetic or aesthetic in nature. While it is true that musical instruction exhibits kinesthetic elements, musical performance by its nature is the fusion of the aesthetic within the discipline of refined motion in space and time.

In music we have defined this disciplined motion in space and time as technique. Technique is a compilation of skills required for performance, but it must also be thought of in terms of physical motion as well. This technique must be developed by a process that involves understanding what is required musically and learning to articulate these musical elements in the least taxing manner to the body. Most musicians who are committed to their performance develop their own individual technique that meets the demands of their performance environment. These
musicians generally are not at risk for injury because they have the adaptive skills of analysis and evaluation. Whenever a physical problem begins to develop, these musicians are able to analyze the technique and alter a specific element or elements to compensate. However, there are many musicians who have not been instructed in these skills and their risk of performance injury is much higher.

The pedagogy should include basic instruction about the body as it relates to a specific performing environment so that instrumentalists can develop the analytic skills needed to evaluate their own technical performance and determine if adjustments are required. Technique, or the physical act of performance, cannot be thoroughly discussed without including basic anatomy and physiology, and an investigation of the role of the body in the music making process. In the case of a vocalist, the body is the instrument and the performance technique is developed around this understanding. Instrumentalists need to be aware of the role of the body in the performance technique.

Most important to the instruction of a vocalist is the training of the mind to know how the body works. Vocalists study in great detail the physical vocal structure, and how this mechanism interacts with performance technique. Instruction on training and care of the vocal mechanism are as important as the musical training itself. Instrumentalists need to investigate more fully the physical interaction between performance
technique and the musculature. Instrumental musicians are rarely given instruction in this area.

For a musician to become highly skilled the training process must involve several interrelated topics. These topics are:

1. Basic anatomy and physiology
2. Principles of human movement
3. Musical knowledge
4. Specific technical information
5. The relationship between technique and the body
6. Principles of safe training

These pedagogical topics are important for all instrumentalists, but according to the ICSOM Survey information these are more critical for performers of string instruments. The performers of string instruments had the highest rate of musculoskeletal problems than any other instrument group. (Middlestadt, 1989, p.44) Within the group of string instruments the largest string instrument, the double bass, had a higher prevalence of low back problems than any other instrument group. There was also evidence to suggest that women were more adversely affected by the size of the instrument than men. (Middlestadt, 1989, p. 44) The double bass, because of its size, requires more physical motion, and will stress the body in a
more physical way so the pedagogy must reflect this difference. Currently, the written published pedagogy does not include comprehensive information on the relationship between the body and the instrument.

Like all the other string instruments the double bass does have pedagogical writings. But, since the instrument is still evolving, and new developments are being made in technique, it is much harder to find standardization. In addition, much of the available pedagogical literature is based only on the author's experience. That in itself in not negative except it is not research based and many of the standard elements of technique employed by one individual do not necessarily meet the needs of others.

It is largely the responsibility of the instructor to research the available pedagogy and draw from each source the elements that each individual student would benefit from. But, not every beginning instrumentalist has access to an instructor. Unfortunately, there are areas of imprecision in the present double bass pedagogy that are reflective of a philosophy of independence, and the lack of a standard practice leaves many instrumentalists with inadequate information.

Current pedagogical writings emphasize the technique rather than the body that produces the technique. The act of musical performance is a highly specialized physical and mental process that demands more than just a rudimentary
understanding of the mind, body, and music connection. The pedagogy at times seems to be a list of instructions rather than a description of the process whereby these technical elements are produced and musically executed.

The execution of a simple détaché bow stroke on the D string, for example, is the result of many complex intellectual and muscular actions. Unfortunately, the manner in which this information is often introduced to a beginning student belies the existence of muscles. The musical sounds are a direct result of trained muscle movements. It is important information for the bassist to know how, and where, a motion is produced.

The arts and artistic endeavors are separate from the scientific realm. However, in the case of the double bassist, the integration of the musical art and movement science is necessary for good performance technique and health maintenance.

The Double Bass

The double bass is the most unique and individual of all the string instruments. The details of its construction, pedagogy, technique, and use are not as well researched and developed as the rest of the string family. Historically, the double bass has never had standardized dimensions. The modern double bass is a synthesis of the Viola da gamba and the Viola da braccio as it
evolved throughout history (Sachs, 1940, p. 297). Forerunners of the modern double bass have had as few as three strings and as many as six. (Stanton, 1965, p. 16)

The shape and size of the body can vary according to the individual maker's design, and each instrument a maker produces may not be the same. A luthier makes decisions as the instrument is being built that will determine the slope of the shoulders, the depth of the ribs, the length of the body, the swell of the top, and whether to make the back round or flat. These decisions are generally made on the basis of available materials and labor cost, rather than artistic taste. However, the only true measure of an instrument's size is its vibrating string length.

The modern double bass, although not completely standardized, has more identifiable dimensions. The body length of a full sized orchestral double bass is approximately 110 cm with a vibrating string length of approximately 101 to 112 cm. Shoulder width and depth are not specifically prescribed, but generally have to do with the overall shape of the instrument. The "violin-shaped" basses have the largest shoulders because the top bouts are the same size as the lower bouts. Most instrumentalists favor the "viol da gamba-shaped" instruments, because the shoulders are appreciably smaller than the lower bouts, which permits easier access to the upper positions.

The contemporary double bass possesses fairly standardized dimensions, because modern instruments are
patterned after one of few well known instruments such as those built by Amati, or Testore. The instruments of today have adjustable bridges which permit moving the string up or down depending on weather conditions. The strings of today are much thinner and stronger, which permits them to placed closer together on the fingerboard and therefore, require less effort to play. The body size of a double bass has never been prescribed. Even today the factors of cost and finishing time dictate the dimensions of the instrument.

In addition to the lack of standardization of the double bass, it is the only stringed instrument that has two distinctly different bow constructions and corresponding techniques. The French bow" developed from the violin bow of François Tourte and it is essentially a larger version of the same. It was not well received at first because it was decided that it could not exploit the full potential of the instrument; however, the Paris Conservatory decided to let it pass until a better design could be introduced. (Stanton, 1965, p. 21) The second of the two bows, the German bow, is held underhand with the thumb on top of the stick. It is this bow that was the most prevalent until the mid-nineteenth century. Pedagogical thought of the eighteenth and nineteenth centuries regarded this bow as superior, because the player was able to exert great downward pressure on the string and gain power of execution. (Stanton, 1965, p. 20)
The performance population is divided among the modern musical community. Both bows have substantial pedagogy associated with them so instruction in either style would be informed. Today, bow choice depends on several factors such as comfort, availability, and teacher recommendation. In addition, there has never been any conclusive evidence that either style of bow and corresponding technique is superior. Bow choice, like many other aspects of double bass performance technique, is an individual decision based on performance taste and muscular comfort. There are still many bassists who have a definite preference and teach to that preference.

The lack of standardization of the instrument also leads to a variety of performance postures. It is the only instrument where both standing and sitting postures are acceptable for performance. In addition, each of these postures can have a great deal of variety. Performers who sit, can choose to use a high stool and place one foot on a rung and the other on the floor, or employ a low stool that permits both feet to rest on the floor. For those performers who choose to stand, there are any number of positions or postures employed. Some use the left leg behind the instrument to stabilize it; others may use a stand or some other mechanism to support the instrument; while others find an individual posture that satisfies their physical requirements. This individuality is a positive aspect for the performer, but presumes that all instrumentalists will analyze their posture
and develop a performance position that is efficient; however, this may not always be the case.

Even the details of mechanics such as the shape and use of the left hand, and position system are different depending on the school of technique. The traditional German school advocates a 1-2(3)-4 hand shape with a half step between 1 and 2, and 2 and 4 where the third finger acts to support 4 until it is used in thumb position. The Italian and French schools use a 1-(2)3-4 system where there is a half step between 1 and 3, and 3 and 4, where the second finger acts to support the third finger. Each hand frame system has a substantial methodology and instruction materials, and either system a bassist chooses is a matter of personal preference or teacher recommendation.

The division of the fingerboard into separate positions is another area where there are several accepted systems, each with its own pedagogy and supporting instructional materials. The orchestral tradition and the public school-oriented heterogeneous string class methods in the United States tend to favor the German school of technique by Franz Simandl. However, there are many examples of professional performers who use other systems or a combination of systems with success.

The lack of standardization of all aspects of double bass performance presents a unique problem in terms of defining a uniform technique. To a large extent, many elements of performance technique need to be developed on an individual
basis because each performer is very different. Therefore, it may not be necessary to develop a uniform technique but rather develop core elements which all bassists can employ and customize to meet their own individual needs.

One way to approach this new concept is to look at how the body moves, define how is used in musical performance, and then combine these elements with the specific aspects of double bass technique. In industry, the use of biomechanics and ergonomics has proven very helpful in bringing body motion principles and specific skilled work elements together.

Biomechanics

Biomechanics is a science that involves employing the laws of physics and engineering to describe the motions of the body and the forces that are exerted on it during activity. The study of biomechanics has revealed that many musculoskeletal disorders are the result of exceeding the body's limitations. (Chaffin, 1991, p. 1) "Occupational biomechanics can be defined as the study of the physical interaction of workers with their tools, machines, and materials so as to enhance the worker's performance while minimizing the risk of musculoskeletal disorders." (Chaffin, 1991, p. 2)

In the study of music, the tool is the instrument, the music itself is the material, and the work environment is the practice
room, rehearsal hall, or performance space. The application of the principles of biomechanics have lead to more realistic definition of what kind of work can be expected from the body. Industry has come to realize how important creating a safe work environment is to production and employee well being. The performing arts community is just beginning to integrate these concepts into all facets of artistic endeavor.

Critical to the success of biomechanical analysis is the development of a system of data gathering that will provide all the necessary information. In industry, a biomechanics expert will come to the work environment and specifically design the data gathering system to analyze against biomechanical models. Like music, the beginning of this process in industry involved creating new models.

Biomechanical analysis has typically relied on specific measures or scientific disciplines to develop an evaluative model. One such science is anthropometry. "Anthropometry is the empirical science that attempts to define reliable physical measures of a person's size and form for anthropological comparison." (Chaffin, 1991. p. 6) Many work space designs are a resulting product of this kind of data. Currently, the industry has defined over 300 different human size and form variables that have been statistically tabulated for use in job analysis. (Chaffin, 1991, p. 6)
In addition, biomechanics makes use of other measures like mechanical work-capacity evaluation by analyzing factors such as age, fitness, gender, and genetics. This kind of information is used to determine a worker's physical capacity to perform certain tasks in the work environment. (Chaffin, 1991, p. 6)

Another form of gathering biomechanical information is through the use of computer analysis. Such techniques of bioinstrumentation include:

1. Kinematic measurement
2. Electromyographic analysis

Kinematic measurement is movement is analyzed for efficiency. Electromyographic analysis detects the electrical impulses generated in a muscle or muscle group to show that percentage of muscle energy required for a specific task. Multidirectional force transducers deal with the effect of different forces when exerted simultaneously on one structure.

Industry now has an entire system of acquiring data for biomechanical analysis. The present model involves creating teams that represent all aspects of production personnel. These teams analyze a work environment, evaluate for potential risk, and implement change if needed. Many times a minor change in operating procedure, or updating materials handling procedures
is all that is necessary. There are also cases when evaluation requires extensive retooling or retraining. What is important about this process is that it is ongoing, and that the goal is to create the safest work environment possible.

This team concept could easily be adapted for use particularly in an educational environment. A school of music environment is similar in many ways. An instrumentalist receives instruction from many individuals. The private instructor gives the student individual technical and musical information, the ensemble director gives information pertaining to the group dynamic involved with musical endeavor, and other instructors provide information about general musicianship away from the instrument itself. Just as in industry, all of these individuals are related in that they are simultaneously involved with training a student for future employment.

Musical instruction is so rich in tradition that many would argue that change is not necessary. Biomechanical information could be addressed in any number of musical situations. Instructors of sightsinging could give rudimentary instruction in basic vocal production by discussing the anatomy of the vocal mechanism. Conducting instruction could include a presentation of information that explains how the conducting motion originates in the upper back, and is transmitted to the muscles in the arm. Methods or pedagogy classes taught on the various instruments could include basic anatomy and physiology as it
relates to efficiently producing musical sound on that instrument.

The training of a musician, like the production of an industrial product, is the result of many elements coming together. Therefore in the training of musicians, a more global concept needs to be developed that reflects the entire body of musical knowledge rather than just the technique of performance practice.

Statement of the Problem

It well known that there are physical risks involved in the process of music making. The data indicate that string players are more at risk for musculoskeletal injury than other instrument groups. Within the group of string players, double bassists show the highest prevalence of low back disorders. These disorders, if left unaddressed, have the potential to permanently disable a performing musician. Through the application of biomechanical models, it is possible to analyze pedagogy, performance technique, instruction methods, and work schedules to evaluate risk factors, successfully implementing change and thereby decreasing or eliminating serious performance injury.
Need for the Project

The training of a musician, unlike that of a skilled industrial laborer or craftsman, is a process that begins long before the time of employment. Usually the process begins in childhood, culminating in a performance degree and or a professional performance career. Musculoskeletal injury should not be an outcome of intense musical instruction, but the evidence from the ICSOM Survey and other research reveals that injury is all too common.

The most critical time of instruction is the first few years because it is during this time that many of the basic muscle motions are programmed in the brain. These technical performance skills require disciplined training of specific reflexes, so that they occur without conscious control. If the technique imprinted in the brain does not reflect a thorough knowledge of human mechanics, it is incongruous with safe body motion, therefore, making the risk of performance injury great.

A systematic analysis and comparison of body mechanics and instrumental technique will result in the creation of pedagogy which will meet the needs of the body and the instrument.
Purpose of the Project

The purpose of this project is to:

1. Investigate how the body is designed to work.
2. Define the necessary body motion elements that apply to the musical work environment.
3. Apply these physical movement parameters to the performance technique of the double bass.
4. Investigate the relationship between the body and the instrument by looking at the most fundamental aspect of technique, the performance posture.
5. Develop and define postural elements based on the study of biomechanics that are necessary for a physically appropriate body posture during double bass performance.
6. Apply this evaluative criteria to double bassists in several different performing environments.
7. Evaluate these performance postures for risk of injury.
CHAPTER II
RELATED LITERATURE

Embarking on research that relates double bass performance and biomechanics requires a comprehensive literature search in several different areas. Traditionally, an interdisciplinary study requires that several content areas be analyzed and related to one another through common elements. Although these two areas may appear unrelated at first, the physical act of performance lends itself very easily to biomechanical analysis because both share the concept of skilled work.

To deal specifically with double bass performance issues, it was necessary to develop a relationship between the performance practice of the instrument and biomechanics by reviewing current and historical instructional and pedagogical literature. The relationship between the body and its interaction with performance technique is unique. Therefore, to assess the role of injury, treatment, and prevention in the performing community it was necessary to review arts medicine literature as well.
Instructional Literature

Instructional literature can be defined as texts of exercises or studies designed to teach the bassist the elements of performance technique.

In double bass instruction there are approximately five methods which comprise standard performance practice. These books are:

1. *New Method for the Double Bass* by Franz Simandl, representing the German school of technique
2. *Enseignement Complet pour la Contrebasse* by Edouard Nanny, representing the French school of technique
3. *Nuove Metodo* by Isaia Billé, representing the Italian school of technique
4. *Nagybogoiskola* by Lajos Montag, representing the Hungarian school of technique
5. *Novelle Technique De La Contrabasse* by François Rabbath, representing the New French school of technique
In many regards these books are markedly diverse. Of the five methods, there are three different hand frame systems: one system favoring the 1-2(3)-4 hand shape; another system employing a 1-(2)3-4 hand shape; and still another advocating a 1-2(3)-4 shape frame with the use of pivots and extensions. A "pivot" uses the thumb as an axis of rotation, allowing the fingers to retain the same frame and move a half step in either direction on the fingerboard. An "extension" actually changes the shape of the hand frame by altering the intervals between the fingers, enabling more pitches to be included in one position. Among the five methods, there are also several different position systems and two different bow holds.

In one specific area all five books are similar: there is little information about the interaction between the body and the instrument. When posture is introduced or discussed, it usually consists of the author explaining the posture that he finds comfortable. The Simandl and Rabbath books are the only texts which contain photographs. However, there is very little accompanying explanatory text to provide comprehensive information.

In addition to the standard methods, an analysis was made of several other instructional texts to ascertain if these materials provided any other relevant information on performance postures. The texts analyzed were:
2. *The Double Bass* by A. C. White
5. *All For Strings* by Gerald Anderson and Robert Frost
6. *String Builder* by Samuel Applebaum
7. *A Tune A Day* by C. Paul Herfurth
8. *Elementary Double Bass Method* by Oscar Zimmerman
9. *The String Musician* by Alfred d'Auberge
10. *I Like to Play the Bass* by Samuel Flor
12. *Young Strings in Action* by Sheila Johnson

Of these texts, 13 of them include some postural information of some kind. The Bottesini method (1982) did not include any text at all. Of these 13, there is only one point of agreement: the double bass needs to lean into the body. There were a variety of postures either graphically rendered by line drawings or photographs, but two texts had no illustrated reference at all. All but one described the standing posture only
and the Watson bass method (1938) included a short description of the seated posture.

The average amount of space provided for postural information was about one paragraph, with the exception of Gary Karr's method (1987) which spent two pages of the introduction on body posture and the concept of body interaction with the instrument. These included pictures from more than one angle with a child as a model, but only in the standing position. In addition, the series of two volumes by Karr (1987) shows pictures of body posture throughout both books as new positions and techniques are introduced.

Still another feature of the methods is that many of the illustrations or pictures included actually present postural disorders rather than provide a correct postural reference. It is also worthwhile to note that the quality of these pictures does not lend itself to clear imaging of body posture.

**Pedagogical Literature**

While the methods described above represent current performance technique on the instrument, there are several other texts which have been written on the pedagogical principles of double bass performance and teaching. These texts are important because they are not exercise books but are texts that contain the body of pedagogical writing about the aspects of performance
technique, teaching, and the history of the instrument. These include:

1. *The String (Double) Bass* by David H. Stanton
3. *The Contemporary Contrabass* by Bertrum Türetzky
4. *Teaching the String Bass* by Theron R. McClure
5. *Principles of Contrabass Playing* by Douglas Gardali
7. *Fundamentals of Double Bass Playing* by Barry Green
8. *Advanced Techniques of Double Bass Playing* by Barry Green
9. *Creative Bass Technique* by Henry Portnoi

Each one of these texts has contributed greatly to the pedagogical information on double bass performance and teaching. The first two texts by Stanton (1965), and Benfield and Dean (1973) provide very good information on instrument history, elements of instrument construction, and many aspects of technique; however, the postural information is scant and not very precise. For basic pedagogical history and an overview of the different philosophies of technique, these two books have extensive bibliographies and are excellent resources. In terms of
posture, both texts advocate placing the left leg behind the instrument for stability, and it is clear by the texts that the standing posture is much preferred. Unfortunately, the photographs included are not good postural models.

The Turetzky (1974) text is dedicated to the performance aspects of contemporary music, but does not mention body posture at all. It is surprising that he did not discuss it in his section dedicated to the performance demands of contemporary music, since the physical demands in this genre are very extensive, especially in the area of thumb position, which is not always required in orchestral literature. This text does provide some very good information about the technical aspects of many contemporary pieces, but many of these technical elements could have been more fully illuminated had he chosen to undertake a discussion about the relationship between the body and the instrument in the context of the demands of contemporary music.

McClure's (1961) material represents the oldest text in this group, and although it provides some very good information about the Simandl school of technique, it lacks specific information about posture. There was a small 3 page section dedicated to the posture of the double bassist and it summarized the two schools of thought regarding sitting or standing, and the employment of French or German bow. At the end of this section, he concludes that "the needs of the right and left arms for freedom of action in doing their specialized tasks should
determine the posture of the bass player at his instrument." (McClure, 1961, p. 2)

Girdali (1980) presents more postural information than the texts previously discussed. Many of his technical explanations throughout the method are accompanied by a postural discussion. Finally, he has several pages dedicated to postural information as the last section of his book. While many of Girdali's concepts for body position and motion while performing are very good, there are no photographs or illustrations to graphically exemplify optimum posture. Although this information is basically sound, it is not specific enough to be useful.

Of all the material examined in this section, Morton's (1991) text is the most thorough. This text provides the most detailed information on many aspects of technique, including posture. In addition, the annotated bibliography is the only one of its kind to provide an overview of literature about the double bass. In terms of postural information, this text distinguishes itself from others in this category because not only does he spend the entire first chapter on posture -- including anatomical drawings of the hand and a listing of movement terminology -- but, he continues to discuss the postural elements as they relate to specific aspects of double bass performance technique.

Morton advocates a seated posture on a 26-inch stool, enabling the bassist to have both feet on the floor permitting the torso to be vertical without rotation so that both arms can be
free to move around the instrument. This discussion of posture is very detailed with multiple photographs from many different angles. Rather than a discussion of different postural theories, it is an extensive explanation of Morton's own performance technique. Although it has some excellent components, is carefully presented and reinforced by pedagogical information, his concepts cannot unilaterally be accepted by all bassists because his posture is designed to meet his individual needs and may not meet the needs of others.

The texts written by Barry Green in 1971 and 1976 contain good pedagogical information. While there are extensive discussions of all elements of beginning and advanced performance techniques. This text represents Green's personal insight on the aspects of double bass performance technique, and therefore he does not include a list of references. Like Morton's (1991) text, the postural information contained within is based on Green's own performance posture. He does include some information on both standing and sitting with photographs from multiple angles, but all defined from his own performance posture.

The text by Portnoi (1978) gives some detailed technical information, and clearly represents Portnoi's understanding of technique. This book systematically defines the performance technique of its author, who had a very successful career in the Boston Symphony Orchestra. The postural information contained
in the text describes a standing posture with the left leg behind the instrument for support. There are no photographs contained in the text of the whole body, only isolated shots of the arms, hands, or parts of the torso. After the initial postural information is presented, Portnoi does not return to the topic until he briefly discusses the position of the arms in thumb position.

The conclusion drawn from the analysis of both the double bass instructional methods and pedagogical texts is that the aspect of posture is very individual. This may demonstrate an unspoken philosophy in which posture is a matter of discussion between instructor and student. The critical aspect of this omission is that not every double bassist has a teacher who can assist with the process of developing an individual posture. For the public school heterogeneous string class student, more information must be provided in written or photograph form to compensate for the lack of individual instruction.

Further, the analysis of the pedagogical literature reveals a basic imprecise vocabulary utilized to describe posture and postural elements. Frequently, the terms "correct", "natural", "favorable", and "balanced" are used without definition. While it is clear that the authors of these texts have a particular concept in mind, it is not always conveyed in the pedagogical discussion. A majority of the texts advocated standing rather than sitting, because it is believed a standing posture enables the performer
to be more mobile. When a seated posture is described, it is in favor of the orchestral musician who endures long rehearsals and that this posture may help to reduce fatigue.

Analysis of these texts points to one central element of double bass technique: posture is an individual determination and there is no universal or accepted standard. It is not clear if the relationship between the body and the instrument is not included because these authors assume it is already understood, or it is not considered to be central to performance technique. The assumption may be that because it is such an individual element and because definite standard information unavailable, it should be discussed between teacher and student in the context of a lesson. However, for the student to decide the best posture it is necessary to be exposed to more than just one approach to allow thorough decision making.

Traditionally, pedagogues present the aspects of technique as they understand it, and although many of the elements discussed are important, they may not be directly applicable to other bassists' individual needs. The specific elements of body posture must be defined so that they can be interpreted to fit a specific situation.
The interdisciplinary field of music medicine is still relatively new. In arts medicine, the Performing Arts Medicine Association (PAMA) coordinates the reporting of research, and in 1986, began a journal entitled *Medical Problems of Performing Artists* the premier publication for arts medicine research.

It is difficult to clearly represent the breadth of knowledge currently available in this area, because it is a complicated process to locate all relevant information. Goode, in an article entitled "Identification, Retrieval, and Analysis of Arts Medicine Literature" (1991), describes the difficulties of obtaining arts medicine literature. He cites several reasons for these difficulties: first, the interdisciplinary nature of artistic endeavors; second, the lack of "arts medicine" key word identifiers on databases; third, the lack of consistent terminology to be adequately catalogued; and finally, the absence of a standardized arts medicine vehicle to bring these issues to the attention of the greater scientific and musical community.

Goode points out that much of the information needed could be found in other sources besides MPPA provided that a large enough search was conducted and many different areas explored. Information pertinent to the rehabilitation of dancers, for example, could be gleaned from sports medicine journals. Locating information in the arts medicine field requires
extensive bibliographic and research skills, as well as a large medical knowledge base. While knowledge of medical resources and terminology is essential for the physician, it is a formidable obstacle for the musician attempting to execute interdisciplinary research.

In order to understand issues and limitations of arts medicine research, *Medical Problems of Performing Artists Journal* (MPPA), volumes 2, 1987 (the second year of its existence) through volume 7, 1992 were subjected to a thorough examination. The resulting content analysis focuses on three elements: first, confirmation of completed research; second, establishing trends in arts medicine research; and third, isolating specific research related to the investigation of double bass performance postures undertaken in this study.

There are 209 articles contained in Volumes 2-7 and for the purposes of this analysis, they were divided into categories by percentile. Of the 209 articles, 84% deal with performance related problems and the remaining 16% are editorials, or articles of an historical or interdisciplinary nature relating arts medicine literature to other fields. Of the 84%, 176 articles, dealing with performance related problems, a total of 38 or 13% examine the performance problems of dancers. The remaining 148 articles, deal with performance problems of musicians. These 148 articles fall into seven categories by percentile. These categories are:
1. Performance anxiety and related performance stress problems, including research on beta blockers. This constitutes 13% of the total number of articles.

2. Overuse injuries, a broad category including Cumulative Trauma Syndrome, inflammation, hand trauma, and other "overuse" syndromes. This constitutes 10% of the total number of articles.

3. Survey results. This category includes analysis of extensive surveys done by the International Conference of Symphony and Opera Musicians (ICSOM), as well as smaller studies done by individual physicians or groups. This information illustrates the prevalence of occupational disorders in the musical performance community and bring these problems to the attention of both the medical and musical communities. This information represents 8% of the total number of articles.

4. Voice related problems. This category studies on vocal disease, constituting 7% of the total number of articles.

5. Case Studies. This category represents the research analyzing specific medical problems and follows subjects through diagnosis, treatment, and return to the initial work environment. Rare or complicated cases where medical information is scant are investigated, also. These articles represent 7% of the total number of medical disorder-related studies.

6. Treatment. These articles suggest ways to treat certain problems or report successful treatment programs. These articles constitute 6% of the total number of articles.
7. Prevention. These articles suggest ways to prevent medical problems, much that are based on surveys and case studies already presented. Some represent follow-up information or are designed as a series to bring to light new research on preventing specific medical problems. These articles constitute 5% of the total number of articles.

The remaining 28% fall into categories that represent extensive information, but not as much research has been published. These include topics such as hypermobility (2%), hearing disorders (2%), postural research (3%), occupational cramps (4%), and technical assistance devices (3%).

Analysis of these articles yields several conclusions. First, the discipline of arts medicine is still in a developmental stage. The amount of articles that present survey alone information is revealing because it indicates that the arts community is in the process of assessing the prevalence of occupational disorders and actively gathering information on successful treatment programs.

Like many other areas of study, current data suggest that accurate reporting is relatively new. In the past, a medical problem could result in a symphony orchestra musician losing employment; therefore, many pertinent medical problems went unreported and unresearched. It has been the task of the performing arts community, in cooperation with management and the medical profession, to create a language and a supportive
environment where musicians could disclose this information and receive treatment without sacrificing job security. In this regard, the analysis clearly shows that considerable progress has been made in the area of arts medicine, and further, suggests that this process will continue to yield more accurate data on occupational disorders, treatment, and prevention.

Secondly, because the area of arts medicine is still establishing definitions and parameters, a variety of conditions falling into the "overuse" category, due to insufficient research and the inability to substantiate any other conclusion. Many of these disorders are unique and have not appeared in medical literature before. Clearly, as a result of continuing research some of these ailments may be described in greater detail. At present, the music medicine area is still in the process of establishing prevalence rates, assessing occupational risks, identifying specific medical conditions, and determining effective treatment of these conditions.

A third conclusion to be drawn from this content analysis is that few of the research articles indicate a successful treatment program. Since arts medicine is still in the process of assessing the incidence of occupational disorders, treatment and or prevention programs are based largely on supposition, or on the treatment of only one specific case. While this information is helpful, only a few cases have been identified and successfully treated, therefore, broad recommendations about how musicians,
the performing arts community, and music medicine specialists can improve treatment is difficult. There are a few examples in the literature of early prevention programs, but the conclusive results of this specific research are not yet available. Currently, performing arts medicine research traces the occupational disorder from its symptoms to its cause, rather than how to design it out of the environment.

Fourth, the incidence rate of occupational disorder among professional performing musicians is serious. According to the ICSOM survey which surveyed 2,212 musicians in orchestras throughout the United States, 82% reported experiencing a medical problem and 76% reported that this medical problem severely affected their performance. This statistic alone indicates the necessity for performing arts medicine research. A distinguishing factor of performing arts medicine and one that separates it from other occupational is the element of performance anxiety. From the analysis of the MPPA Journal, the largest number of articles in any one category involved performance anxiety.

Performance anxiety is a catalyst for most non-musculoskeletal problems. The ICSOM survey identifies two problem classifications: musculoskeletal and non-musculoskeletal disorders. The area of musculoskeletal problems primarily addresses disorders of the upper body, including the shoulders, lower back, neck, and hands. The non-
musculoskeletal area is confined to performance anxiety and its associated physiological symptoms and psychological stress.

The implications for research are many. A career in the performing arts does distinguish itself from industrial employment in the respect that performance anxiety is a key element in injury statistics. Ordinarily, a performance job requires specific skills which, in most cases, takes years of preparation to develop. Consequently, it is unrealistic, in a performance environment, to change a person's job description to compensate for a debilitating injury.

The physical ramifications for a high standard of performance accuracy are great in the performing arts. Not only is the competition for jobs keen, but until recently, musicians have not had any organized professional association to assist in defining acceptable working conditions. With the assistance of organizations like the ICSOM, the musician now has help in negotiating fair schedules, establishing workers compensation claim procedures, and the management of job security issues. These efforts are working to assess the risk factors and develop safer work environments for the performing arts occupations.

Incidence and Prevention Research

The ICSOM survey (1988) was the first survey designed to give an overview of performance related occupational disorders.
The sample was large enough at 2212 musicians for the results to be considered very relevant, and the findings suggest that the incidence rate of medical problems for performing musicians is high. The results also reveal that the current system of diagnosis, treatment, research, and prevention is not designed to deal with the specific needs of the performing arts community.

The data has been further analyzed to investigate specific populations within the performance community. One such analysis was done by Middlestadt and Fishbein (1989). Its purpose was to more thoroughly examine the impact of musculoskeletal problems on the 378 string players who participated in the ICSOM survey. The results indicate that 66% of the string instrument performers had severe musculoskeletal problems as compared with 48% of the woodwind players and 32% of the brass players. The overall performance problem percentages for string instrumentalists by gender were 72% for women and 62% for men indicating that women may be at greater risk.

This analysis also revealed that string players are most likely to have problems in the shoulder, neck, and lower back, with the incidence in the left arm and hand more prevalent than the right. In particular, double bassists reported a higher incidence rate of severe low back problems. The Middlestadt and Fishbein (1989) study also revealed that there was not enough data to accurately determine the prevalence rate of severe
disorders among female bassists, because only 22 female bassists participated in the study. However, the results are clear in one element: male double bass players are more vulnerable to low back problems than any other instrumentalists, by group or gender. This suggests that the postural element of technique may be a contributing factor in determining risk for injury. In addition, the results indicate that as the size of the instrument increases, so does the vulnerability of the female musician to hand and wrist injuries. However, at present, this information is not been adequately investigated for female double bassists.

The results of this analysis indicate a need for more research. There is strong evidence to suggest that there are considerable differences in the prevalence of severe musculoskeletal problems as a result of musculature location, instrument size, and gender. At present, the data concerning the causes for these differences has been identified variously as instrumental technique, general health status, performance anxiety, and size of the instrument.

Larsson et al (1993), in a study examining the impact of musculoskeletal problems on a specific population of musicians, also suggests that string players had a much higher incidence of injury than other instrumental groups. This study specifically isolates the features of hypermobility or joint laxity on the health of a specific performance population, and the results
indicate that intensive repetitive motion seemed to be the cause. Another prominent finding of this study was that most of the current research has focused on upper extremity problems and, although they are still the most frequent areas for injury, this study also records problems in other anatomic regions such as the low back and lower extremities. This study also suggests that more women experience performance related injuries than men.

Smith (1992) identifies the same trends as the other studies, but finds no difference between young or more experienced players, concluding that risk factors do not seem to be linked to age. In fact, younger musicians had the same or higher incidence rates of injury. This evidence contradicts some of the other research suggesting that "overuse" injuries are cumulative. Lippmann (1991) suggests that the term "overuse" is simply "overused". Certain diseases, such as carpal tunnel syndrome are cumulative trauma disorders, but others are not. He makes the case that playing an instrument negatively affects the body in a way that is similar to athletic exercise. He explains that when a musician pushes the tissues past the point of fatigue an injury will occur, but, he attempts to look at the problem on a number of levels to determine the underlying cause. His conclusion is that the application of the term "overuse" does not encompass the entire problem because it generally implies a
treatment of rest rather than address the malfunction of mind or technique that may have caused the initial injury.

These studies are compelling because of the ramifications they have for the music educator. Two studies, by Fry, Ross and Rutherford (1988), and Lockwood (1988), both suggest that the incidence rate of performance injury is more substantial than initially considered. Lockwood describes a higher rate of medical problems among females (68%) than males (47%). This study also suggests that the large string instruments have a much higher incidence rate at 78%. This study is important in its description of the prominent role of the music educator in preventing performance injury, because the subjects in the study based many of their habits on the instruction they had received in public or private schools. Lockwood predicts it may be possible to anticipate future student's risk factors, and describes the importance of teaching a "pain free" pedagogy.

Another relevant study done by Newmark and Salmon (1990), explores the performance related complaints of amateur musicians. This study attempts to look at the problems associated with non-professionals and draw correlations with the ICSOM survey. This study suggests that performance problems are similar between professional and amateur musicians, supported by the fact that instruction did not seem to make any protective effect on the percentage of subjects who experienced performance related injury.
One factor common to all of the studies reviewed is the need for further research. At this point it can be concluded that there are risk factors involved in musical performance, but as of yet, treatment is generally experimental and prevention programs are rare. One exception is an interdisciplinary program at the Trøndelag Musikkonservatorium (TMK) in Trondheim, Norway. Spaulding (1988), in an article entitled "Before Pathology: Prevention for Performing Artists," describes this landmark program.

In this program, all undergraduate students are required to take a series of classes to teach them about the interaction of the body and their instrument. The students take classes in functional anatomy and physiology as related to performance on their instrument. They also learn about nutrition and rest, and then learn to analyze their individual habits and determine their own risk. So far, the program has been successful in teaching students to better identify their own personal risk factors, but not enough time has passed to determine if this will effect current occupational injury statistics.

Pedagogy, Technique, and Instruction Research

An added component to the development of occupational disorders is the factor of longevity. The risk factors may be present long before a musician enters the professional
performance environment, and unlike some industrial jobs which can be learned in a few weeks, many musicians are in training for as many as 15 years in preparation for a professional career. The most substantive problem or problems may have started in the first years of performance preparation and develop into something debilitating. At present, we have no mechanism to evaluate the physical process by which musicians develop their performance skills. In athletics, we refer to "form" to describe how an athlete moves; in music, we refer to it as "technique." In addition, music lacks the specific vocabulary to describe movement apart from performance technique.

Technique refers to the specific skills, or physical motions required to execute a musical passage. Throughout history there have been many schools of technique in every instrumental and vocal discipline. Since music is a profession deeply rooted in historical tradition, it is often difficult to trace why specific things are done. Palac (1992) analyzes pedagogical literature in terms of the principles of human movement and she concludes that an understanding of human movement is essential to the development of a sound technique. She also points out that many pedagogues have studied performance technique, but may not have background in the mechanics of human movement. Like many aesthetic activities, music is an art form that has been passed down from generation to generation without the advantage of scientific evaluation.
Biomechanics can provide useful information to help prevent occupational disorders in musicians. The task of arts medicine is to investigate current performance practice and relate it to the principles of body movement known from biomechanical research. Once the two areas begin to interact, arts medicine may be able to integrate these biomechanical principles into technical practice and prevent or change current occupational risk factors.

Analysis of research literature reveals few studies relating biomechanics and performance. Lee states that "piano pedagogues have dealt with student's hand ergonomics in developing piano technique for two centuries and yet little has been accomplished in understanding the relationships between the individual's hand ergonomics and particular skill development" (Lee, 1990, p. 72). Today, after considerable investigation, the performing arts community is listening and supporting ergonomic and medical research by applying it to pedagogical practices.

This investigation yields some interesting results, because it shows that the hand ergonomic variables are task specific. Given this information, all technical exercises cannot be useful for all people, but, because much of performance training is the same for everyone, each musician may not get enough instruction for their individual physical needs. In the discussion section of his study, Lee describes this as "uncharted" territory in the
music world, and suggests that more research of this type is required to make decisions about the acquisition of skills and pedagogical practice.

Postural Research

Specific research designed to obtain information about the interaction of the body with the musical instrument made up only 3% of the studies in the content analysis. This information, though scant, is relevant to the study of pedagogy. Until recently, electromyographic (EMG) analysis -- the electronic measurement of exerted muscle force -- was not frequently used in performing arts medicine research because it was not accepted as an evaluative tool. However, EMG analysis has been used and shown to be an effective tool for evaluating muscular involvement in the performance process.

One of the first studies to use electromyography was designed by Philipson et al (1990) to assess the muscle activity in a group of violinists. This study indicates that quantitative electromyographic analysis is an effective tool to measure muscle activity, and when results of the two groups of violinists were compared, it was shown that the group with pain used considerably more muscle force as compared to the group without pain.
Another study using electromyographic analysis was designed to determine if shoulder rests were useful in assisting violinists to support the instrument and obtain the most relaxed performance posture. Levy et al (1992) found that a shoulder rest does have a prominent effect on the muscles of the upper body that support the violin and use of a shoulder rest may decrease the risk of a musculoskeletal injury. In pedagogy, the instrument position and relative body posture are important factors to the development of a good performance technique.

Several studies focus on the performance postures of musicians and the problems associated with them. Rene Cailliet (1990) describes the abnormal performing postures assumed by musicians and the corresponding physical problems caused by such postures. This study is important because it attempts to identify specific postural elements and bridge the gap between ergonomics and performance.

Dr. Cailliet (1990) identifies the primary problem of postural research as ignorance, and points out the necessity of investigating more fully the relationship between ergonomics and music as one possible avenue to assist the musician in relieving pain and avoiding permanent injury. Her study examines the support the back must have to allow the body to execute the complex physical motions of performance, then analyzes actual performance postures, indicating abnormalities and their effect on the body over years of performance. Her conclusion was that
much more research needs to be done to analyze the interaction of the entire torso region and the motions required to perform on specific instruments. Because each instrument places very different demands on the body, she suggests that each should be evaluated individually since pain is usually chronic rather than acute. Caillet also points out that posture and movement are related to musculoskeletal issues. However, they are often a reflection of a musician's self concept and may be central to the musician's emotional connection to the music, and therefore, posture is much more than a mechanical process.

At present, postural research is not as clearly defined as other kinds of performance research because it is still often subjective and standardized reliable evaluative procedures have not been developed. Without X-rays it is very difficult to see the internal structure of the body and analysis must be made by trained observers to generate relevant results.

One research study that investigated postural alignment in musicians, Blanken et al (1991), suggests that the lack of a standardized evaluative tool to accurately assess postural characteristics is largely responsible for its absence in the training of musicians and dancers. Blanken suggests that postural examination is necessary for proper physical functioning and should be included in the training sequence for musicians and dancers.
Evaluative methods for postural research include filming, observation, X-ray, and comparison. One study employing the comparison method was done by Eijsden-Besseling et al (1993) which compared the postures of musicians to medical students. The results indicate that many of the musculoskeletal complaints of musicians can be attributed to the performance posture.

This study utilizes two groups of subjects for comparison: group 1, comprised of students, and group 2, of medical students. Both groups were evaluated in the erect or standing posture, and then the music students were evaluated with their respective instruments in a performance situation. A comparison reveals little difference between the two groups in the erect or standing posture with both groups demonstrating very poor posture overall. For the group of musicians, the most notable posture disorders were observed during performance. Many of the music students participating in this study were given occupational or ergonomic suggestions to assist them in alleviating their postural problems. In the sample, the group of instrumentalists with the highest frequency of postural disorders were string players. It was also concluded that many of the postural problems could be reduced or eliminated with ergonomic instruction and advice.

Another study of importance was done by Newmark and Rybock (1990), with an individual case study involving a double
bassist who had cervical disc herniation. The significance of this investigation was that the performance posture of the individual was responsible for the acceleration of a disc lesion that might have gone undiagnosed. This case study supports research that asserts that stressful performance postures can make other conditions worse.

Postural analysis specific to the double bass is scant and only one such study was identified. Allan Dennis (1984) investigated the muscular effect of supporting the double bass in three different postures. These postures are defined as: the bass standing method, the student standing method, and the sitting method. In this study, students from several of the United States' most prestigious music schools perform the "recitative" from Ludwig van Beethoven's Symphony No. 9, with evaluation made by audio recording and electromyographic analysis. The results of this study reveal that there is no considerable difference in muscle tension or performance quality between the three postures.

It is clear from the lack of general, pedagogical, and performance oriented research on the double bass that additional information is required to make sound pedagogical decisions about the postural characteristics of the double bassist.
CHAPTER III

METHOD AND PROCEDURE

Performance Posture Theory and Evaluative Criteria

Posture Theory

The first step used to develop a design for this study was to construct an operational theory by defining the parameters of an acceptable double bass performance posture and establishing a criteria for evaluation. An extensive analysis of pedagogical material, arts medicine research, and related information was executed to identify and isolate those postural elements that comprise an acceptable performance posture. This analysis yielded a new postural concept based on the architectural concept of "framing".

In modern skyscraper construction, "I" beams are welded together to make a frame that supports the building. The walls comprise a barrier from the outside environment and actually support no weight. This is analogous to the body, with the skeletal system providing a frame that supports the body while
the skin provides a barrier protecting the musculature and internal organs.

This theory, based on the "I" (Figure 1) beam concept can be more clearly expressed in terms of support for the body when it is in a performance posture. The principle structures of the skeletal system form an "I" beam: the inferior, or lower, "cross section" of the "I" (Figure 2) is the base of the pelvis at the ischial tuberosites comprising the weight bearing structure while seated. In level sitting, weight is equally distributed upon these two structures and the pelvis is level, in turn providing the spine with a vertically straight alignment. (Figure 3)

The superior, or top, "cross section" of the "I" beam (Figure 4) is the pectoral girdle at the acromioclavicular, or shoulder joint, providing the body with support required for bilateral motion of the arms.

The vertical element of the "I" beam is the spinal column. The spinal column, classified as axial skeleton, is the primary supportive structure of the body and permits movement in several planes. (Figure 5) It is important to note that this concept is from the frontal or coronal plane of the body only. The spine viewed from the side or median plane is not straight and is not designed to be. The "I" beam theory places emphasis is on support of the spine at the pelvic level with a shoulder line parallel to the floor. In addition, the "I" beam can be supported either standing or sitting.
Figure 1
"I" Beam on the Body
Figure 2
Pelvis as Inferior Cross Section of "I" Beam
Figure 3
Ischial Tuberosites as base of "I" Beam
Figure 4
Pectoral Girdle as Superior Cross Section of "I" Beam
Figure 5
Spinal Column as Vertical Element of "I" Beam
Of equal importance is the realization that muscles work at their greatest potential in a "length strength" relationship. In general terms, the longer a muscle is the stronger it is. When a double bassist assumes a performance posture, both arms are required to execute different tasks and many muscles in the torso are required to initiate these complex and specific motions. The double bass, a large instrument, requires large physical motions of the arms and if the muscles are long these motions will be efficient.

Muscles work together in pairs. One muscle, or muscle group, is responsible for flexion, which is defined as movement involving the bending of a joint whereby the angle between the bones is diminished (Chaffin, 1991) while another muscle, or group of muscles, is responsible for extension which is defined as movement back to the resting position of the joint. For each specific technical element there are numerous muscle motions involved.

If the "I" beam retains its integrity as a structure, then the torso is supported, and the arms are fully mobile and capable of executing musical "work" without undue stress on the lower back or shoulders. Further, although the spine is flexible, there is no joint within the "I" beam structure.

The joint that provides forward motion of the shoulders is actually at the hip or coxal joint. (Figures 6 and 7) The structural foundation of this concept is that when the spine is
properly supported on the ischial tuberosites, the facets of each individual vertebrae interlock to provide a strong bony frame. (Figure 8) Weight bearing by the spine is cumulative, therefore, the more inferiorly positioned the vertebrae, the more actual weight is being borne.

The lumbar vertebrae are much larger and are designed to bear greater forces of compression than the cervical or thoracic vertebral structures. (Figure 9) However, they obviously cannot bear this force exclusively. (Nordin, 1989, p. 183) When the spine is improperly supported, the bony facets do not interlock, requiring the vertebral discs to bear all of the compressive stress. Over time and with age, abnormal postures or excessive load handling can cause the discs to break down and the potential for serious injury is increased. In biomechanics, this concept of weight support is referred to as the "load path".

The load path most desirable for the spine is when the facet joints interlock for support. (Figure 8) In a static position, the load path would remain constant: however, when motion is added shear forces are produced that can stress spinal joints and the supportive muscles. It is at this point that the performer is at risk for injury. A shear force is a force applied parallel to the surface of a structure which causes angular deformation. (Chaffin, 1991) A study by Anderson et al that measured intradisc pressure suggests that keeping the torso in a
Coxal Joint at Hip

Figure 6
more erect or vertical position is the best orientation for the spine when dealing with heavy loads.

Once the spine is supported, other structures are supported as well. The head "sits" on the shoulders, not leaning forward or backward, and should be thought of as an extension of the "I" beam. (Figure 10) Although for the purposes of this experiment we primarily deal with the torso, it is important to note that the spine supports the base of the cranium at a point directly behind the mandible. It is critical that the head be considered an essential part of the "I" beam.
Figure 8
Facets Interlock for Support
Figure 9
Lumbar Vertebrae
Designed for Compressive Weight Bearing
Figure 10
Head as an Extension of the "I" Beam
The shoulders and arms comprise the second set of elements within the "I" beam. When the spine is properly supported at the pelvic region the shoulders form a linear structure which is relatively parallel to the floor. This concept of "level" shoulders is important because many of the muscles needed to make the upper arms move are located in the upper area of the trunk. In particular, a muscle like the deltoid is used to raise the arm is connected to both the arm bone and the upper torso.

With the shoulders level and straight, the arms are free to move around the instrument. The only biomechanical factor influencing the orientation of the arms is the position of the wrists. The wrists should be in a straight line with the arms if possible. For the left arm, the forearm and wrist should be thought of as one linear unit. The upper left arm positions itself relative to the alignment of the forearm, wrist, and hand. (Figure 11.) The right arm follows the same concept of forearm, wrist, and hand alignment, with the upper arm adjusting to the placement of the bow on the instrument. (Figure 12.)

The orientation of the wrist is a critical technical element for the double bassist. Since most of the supporting ligaments for hand motion pass within the diminutive carpal tunnel, it is important that the wrists remain straight so that the ligaments, tendons, and nerves are not constricted. Industry has redesigned tools, workstations, and materials operating
It is the reoccurring trauma to those structures that pass through the carpal tunnel which results in what has been known as carpal tunnel syndrome (CTS). The greater the deviation from a straight wrist the higher the potential for injury.
Evaluative Criteria

The operational theory now developed, it is necessary to establish criteria for evaluating double bass performance postures. The six essential elements which comprise the evaluative criteria are:
1. "I" beam structure with proper pelvis support (sitting or standing position)

2. Vertical orientation of the torso, with shoulders square to the hips (no rotation)

3. Bending from the hip or coxal joint when moving the shoulders forward

4. Head remaining over the shoulders (extension of the "I" beam), not extending forward or back or to the sides

5. Left arm orientation based on forearm, wrist, and hand straight alignment

6. Right upper arm orientation based on forearm, wrist, and hand straight alignment and angle required to put the bow on the string

**Experimental Procedure**

Bassist from the greater Columbus (OH) metropolitan area and the Double Bass Symposium III at the University of Georgia, in Athens, Georgia comprised the pool of subjects used for this project. The experiment consisted of three parts:

Part 1: Measurement of instrument and specific anthropomorphic segments

Part 2: Video Observation

Part 3: Survey of basic information
Part 1. Measurement

This section consisted of measuring the subject and the instrument. The recorded measurements of the body and body segments were taken with anthropometers and expressed in centimeters. All subjects were measured fully clothed with shoes because these are present on the body during performance. Generally, anthropomorphic data is gathered with minimum clothing, but in order to obtain an accurate set of body dimensions during performance attire becomes an important factor. Anthropomorphic measurements employed were:

1. Shoulder width
2. Upper arm segment
3. Lower arm to wrist segment
4. Hand length (from wrist to middle finger)
5. Hand breadth (across the base hand knuckles)
6. Buttock to knee (Sitting Thigh)
7. Lower leg segment
8. Shoulders to top of head
9. Total height

Anthropomorphic measurements are most accurate when taken at bony landmarks of the body, and the guidelines
established by Webb and Associates (1978), were employed in this study.

The measurements of the instrument were taken with a tape measure and expressed in centimeters. The instrument measurements recorded were:

1. Overall body length (down the center line of the instrument)
2. Shoulder width at the widest point
3. Neck length (from nut to shoulder)
4. Endpin height used by performer
5. Vibrating string length
6. Depth of ribs at shoulder
7. Depth of ribs at bridge
8. Width of lower bout
9. Depth of lower bout

Additionally, it was noted if the instrument has a flat or round back, and possesses a taper of the upper back.

**Part 2. Video Observation**

All subjects were to play 4 sets of 2 scales each in half notes with a metronome set at quarter equals 72. The four sets facilitated filming the subjects from 4 distinct camera angles. These scales were chosen because they exploit the largest area of the fingerboard. The scales are:
These scales, F and D major 2 octaves, require starting in first or half position and move through the middle positions (III and IV), and culminate in the thumb position region of the neck. The motion required to articulate these scales is to bend at the coxal joint. It is critical that as the left hand and arm moves around the shoulder of the instrument the alignment of the wrist remains constant. (Figures 13, 14, and 15)

Figure 13
Left Arm Orientation in the Lower Positions
Figure 14
Left Arm Orientation in Middle Positions

Figure 15
Left Arm Orientation in Upper Positions
The 4 different camera angles were designed to show the torso, the bow arm and hand (right), and the left arm and hand. The subjects were instructed to wear form fitting clothing to permit a clear view of the torso and arms during performance. The four camera angles were:

Position 1 - **Frontal**: Camera square in front of the subject. (Figure 16.)

Position 2 - **Right Side**: Camera at a 90 degree angle to the body allowing clear view of the bow arm. (Figure 16.)

Position 3 - **Posterior**: Camera behind the subject to view the torso and shoulders. (Figure 16.)

Position 4 - **Left Side**: Camera at a 90 degree angle to body allowing a clear view of the left hand, shoulder, and elbow. (Figure 16.)

Since the camera angles could not be replicated exactly and each posture exhibited so many unique characteristics, it was impossible to get the precise physical view of each subject.
Part 3: Survey Information

Each subject completed an informational survey designed to ascertain data on the basic history of performance, musculoskeletal injuries, and other relevant information. The survey form did not include the subjects name, but a researcher assigned subject number. The names and corresponding subject numbers were be recorded separately to maintain impartiality and confidentiality in the interobserver component. (See Appendix A)
Evaluation

The operational "I" beam concept served as the criteria by which each subject was evaluated. Video tapes generated by the video observation component of the research were viewed by the researcher and a biomechanically trained observer. Each subject's posture was compared to that of the operational theory using the evaluation form. (See Appendix B) Additional data were evaluated and compared with the survey, the anthropomorphic data, and the instrument measurements. (See Appendix C)

Limitations of the Study

This experiment was designed to assess the role of the torso as the organizing element of a biomechanically sound double bass performance posture, and was therefore limited in scope. This analysis did not present conclusions regarding more advantageous postures, but biomechanical principles were applied to observed performance behaviors, including ratings that indicate agreement with the established postural criteria.

Neither the interaction between postural and technical elements, nor specific technical elements were explored in this investigation. Although, motions of the body were subjected to analysis, it was only in their relationship to posture.
Ultimately, it was the purpose of this investigation to determine if the bassist's body posture would adequately support the physical motions required for musical performance.
CHAPTER IV
RESULTS

Survey Results

Twenty-four bassists participated in this study and were filmed from 10 February to 13 March 1994. The measurement, filming, and survey took approximately 30 minutes per subject. The field of 24 participants, has an age range of 14 to 49, with a gender ratio of approximately 2:1 with 17 males to 7 females. The average years of performing experience was 6, with two subjects playing only one year and one subject playing 31 years. Fifty-four percent started instruction in the public schools, but only 29% of the participants began their musical instruction on the double bass.

The sample was divided into two categories -- student and professional performer -- with "student" being defined as an individual attending an educational institution full time, and "professional" defined as a person who makes his/her income by performing on the double bass. Students, numbering 19, made up 80% of the sample, while professional performers, numbering 5,
represent 20%. The professional category was further divided into genres: jazz, orchestra, and freelance. The freelance distinction was made because a freelance musician routinely functions in a variety of genres that may include jazz, orchestral, or other performance situations. In the student category, 1 subject (4%) is in Junior High school, 5 subjects (21%) in High School, and 13 subjects (54%) are college students. In the professional category, 2 subjects (8%) are jazz performers, 2 subjects (8%) are symphony orchestra performers, and 1 subject (4%) is a freelance performer.

A total of 13 subjects (54%) employ a seated posture exclusively while only 1 subject (4%) stands exclusively. Ten subjects (42%) indicated a combination of standing and sitting for different performance situations. Of the 13 (54%) that sit exclusively, 10 (80%) use the same stool all the time. It is interesting to note that many of the subjects who employ both postures use the seated posture for classical music and stand for jazz or solo playing. Many remarks noted on the survey sheets indicated that sitting was helpful for long rehearsals because it reduced fatigue.

Approximately 15 subjects (63%) in the sample note that they made minor alterations to their performance posture to address issues of pain, comfort, or technical control. Of these, 12 (80%) made changes to alleviate pain or increase comfort, while the remaining 3 (20%) sought a postural change to gain
more technical control over the instrument. The latter 3 (20%) indicated the change from standing to sitting assisted them in developing a more stable instrument position and improved intonation.

French bow players accounted for 19 members (79%) of the sample, German bow players accounted for 3 members (3%) of the sample, and 2 subjects indicated they (8%) use both French and German bows. The 2 subjects (8%) that use both bows provided no discriminating information regarding situational preferences for each bow. Only 2 subjects (8%) had switched from French to German bow. However, both of these individuals indicated that the change to German bow was beneficial to their overall performance technique and comfort. No one in the sample indicated a change from German to French bow.

In the sample, 4 (17%) of the participants reported a medically diagnosed postural disorder, with only 2 (50%) of these individuals changing their performance posture as a result of their diagnosed condition. Only one subject was evaluated by a medical professional in a performance posture. Of additional interest is that 9 individuals (38%) in the sample experience chronic pain during performance, 3 (12%) have pain occasionally, while 12 (50%) experience no pain at all. Of the 9 (38%) that experience chronic pain, the average length of occurrence is 2 years, with 2 subjects reporting chronic pain for 4 years. Only 3
(33%) of the subjects with chronic pain have ever consulted a physician.

Performance anxiety effects 15 (63%) individuals in the sample, but only 6 (40%) indicate it influenced their performance posture. Those reporting postural effects of performance anxiety describe the change as tension, but only 10 (67%) individuals attempted to compensate for this added muscular stress. However, no specific methods of tension reduction were illuminated by these individuals.

Anthropomorphic Measurements

The sample provided a diverse cross section of body measurements. The average height of the sample was 178.25 cm (5'8") with the smallest individual being 164.3 cm (5'3"), and the tallest individual being 188.3 cm (6'1"). The width of the shoulders ranged from 29.1 cm (11.4 in.) to 43.6 cm (17.1 in.) with an average of 35.5 cm (14 in.). Upper arm segments ranged from 23.1 cm (9 in.) to 34.5 cm (13.6 in.) with an average of 29.9 cm (11.8 in.). Lower arm segments ranged from 21.9 cm (8.6 in) to 30.6 cm (12 in), with the average at 26.7 cm (10.5 in). Hand length figures ranged from 16.7 cm (6.6 in) to 20.4 cm (8 in), with an average of 18.8 cm (7.4 in). In the hand breadth category, the measurements ranged from 7.2 cm (2.8 in) to 9.1 cm (3.6 in) with an average of 8.3 cm (3.2 in). "Sitting thigh" length varied
from 53.3 cm (20.9 in) to 65.7 cm (25.9 in) with an average of 60.6 cm (23.9 in). Lower leg measurements ranged from 50.4 cm (19.8 in) to 63.3 cm (24.9 in) with an average of 56.7 cm (22.3 in.).

Instrument Measurements

Of the 24 instruments played by the subjects in the study, there were few common dimensions, with each instrument demonstrating particularly individual characteristics. The commercially produced instruments had similar measurements, but the hand carved instruments were markedly different. In the sample, the range of instrument body length varied from 108 cm (42.5 in) to 119 cm (46.9 in) with an average of 110.7 cm (43.6 in). The shoulder width ranged from 48 cm (18.9 in) to 54 cm (21.3 in) at the widest part of the upper bout. Only three basses, 13% of the sample, had no taper at the upper bout. The remaining 21 (87%) instruments had a taper of the upper bout which ranged from 1 cm (.39 in) to 4 cm (1.6 in). Neck lengths varied from 40.5 cm (15.9 in) to 49.4 cm (19.4 in) and the vibrating string length ranged from 103 cm (40.6 in) to 112 cm (44.1 in).

Of the subjects that use stools, the height ranged from 67 cm (26.4 in) to 77.6 cm (30.6 in). The lowest stool contained no rungs because the subject placed both feet on the floor. There
was only one participant, subject 18 in the sample, that had this posture. Another participant, subject 16, altered the configuration of the stool by cutting two legs of the stool about 1/2 to 3/4 of an inch. This resulted in a performance posture which was angled forward giving this subject a more comfortable position. It should be noted that subject 16 used the largest instrument measured in this study, with an overall body length of 119 cm (46.9 in) and a vibrating string length of 112 cm (44.1 in). This subject is a female with an overall height of 170.5 cm (67.1 in). The other stools measured all had even legs.

Interobserver Agreement

The six postural elements previously discussed in "Performance Posture Theory and Evaluative Criteria," were evaluated by two observers who viewed the videotaped performances and determined whether or not each subject met the criteria established for the given elements. (See Appendix D) Observer A was the researcher, and observer B was a doctoral student in Biomechanics.

Interobserver agreement was determined by dividing the number of agreed responses by the total number of observations. There was 96% interobserver agreement for elements 1 ("I" beam structure), 2 (vertical orientation of the torso), 4 (head over shoulders), 5 (left arm alignment with forearm), and 6 (right
arm alignment with forearm). There was 100% interobserver agreement for element 3, bending from the coxal joint.

Individual Analysis by Subject

The videotaped performances were analyzed by the two independent observers for agreement with or deviations from the established postural criteria. Appendix E provides a summary of these evaluations.

To properly evaluate the sample, several terms were employed as descriptors to ensure consistency in the analytic procedure. This vocabulary was drawn from medical terminology and describes musculoskeletal motion in relation to the planes of the body in space.

If the "I" structure lacks integrity it can be defined as "not balanced" or "misaligned." In the sample, there were several subjects who leaned to one side or the other and this was duly noted in the individual evaluation section. The second element, vertical orientation of the torso, was based on the shoulders positioned parallel with the pelvis and the floor. Any rotation of the shoulders which changed that relationship was noted in the evaluation.

The head position should be perpendicular to the shoulders and any deviation from that posture was recorded. The term "anterior" refers to a forward position of the head wherein the
mandible is thrust into a position directly superior to the sternum. In this position, the cervical vertebrae no longer approximate a 90° degree angle with the pectoral girdle. The term "posterior" refers to the opposite of "anterior", wherein the head is retracted into a position that locates the head superior to the shoulders.

The wrist, forearm, base hand knuckles, and finger alignment orientation was based on keeping the wrist in the most consistent linear position to the forearm as possible. When this position is achieved, it is defined as the "neutral position". When the forearm is parallel to the floor in the neutral position it can move in four different directions.

"Flexion" as it is used in the following categories refers to movement of the palm up or down in relation to the forearm. If the palm moves down so that the surface of the hand is facing toward the body, this is defined as "palmer flexion." If the palm raises from the neutral position so that the knuckles are higher than the forearm, this is defined as "dorsiflexion."

The other two directions in which the wrist can move are "ulnar" or "radial deviated" positions. The terms "deviated" or "deviation" refer to the motions of the wrist that move it to the right and left side of the forearm. If the forearm is in the neutral position parallel to the floor, "ulnar deviation" is when the wrist moves to the left or first finger side (palm still parallel to the floor) of the hand. "Radial deviation" is the
opposite where the wrist bends to the right side or the small finger of the hand. Of the four directions the wrist can move, it is only possible to move in two directions simultaneously. For the purposes of this evaluation there was no discussion of "supination" and "pronation" which refers to the twisting of the forearm.

Individual Postural Analysis

**Subject: 1**  
**Age:** 16  
**Sex:** Female  
**Years Performing:** 6  
**Status:** High School Student  
**Bow:** French  
**Posture:** Both Stand and Sit  
**Posture Problems:** None  
**Postural Analysis:** Forward rotation of the right shoulder, and anterior position of the head. Ulnar deviation of both wrists.

**Subject: 2**  
**Age:** 17  
**Sex:** Male  
**Years Performing:** 6  
**Status:** High School Student  
**Bow:** French  
**Posture:** Sit Only (not same stool)  
**Posture Problems:** Spinal misalignment; some minor adjustments in performance posture made by private instructor have greatly effected playing comfort.  
**Postural Analysis:** Subject has a very pronounced rotation in the torso to favor the right or bow arm and leans to
the left. The double bass is positioned into the abdomen in such a way as to prevent bending from the coxal joint. Ulnar deviation in both wrists.

**Subject: 3**  
**Age:** 16  
**Sex:** Male  
**Years Performing:** 5  
**Status:** High School Student  
**Bow:** French  
**Posture:** Stand/Sit (not same stool)  
**Posture Problems:** None  
**Postural Analysis:** Rotation of shoulders to right side. Tall individual exhibits no bending at coxal joint; stretches by bending the upper back to reach into thumb position. Anterior position of the head relative to the torso and ulnar deviation of the right wrist.

**Subject: 4**  
**Age:** 14  
**Sex:** Female  
**Years Performing:** 2.5  
**Status:** Junior High Student  
**Bow:** French  
**Posture:** Sit (Always same stool)  
**Posture Problems:** None  
**Postural Analysis:** Rotation of the torso to the right side. Radial deviation of the right wrist.

**Subject: 5**  
**Age:** 49  
**Sex:** Male  
**Years Performing:** 31  
**Status:** Professional/Symphony  
**Bow:** French  
**Posture:** Sit (not the same stool)
Posture Problems: Yes, diagnosed with arthritis of the spine in the neck region (cervical kyphosis). Treatment included medication and physical therapy. This condition did not alter the subject's performance posture. 

Postural Analysis: Subject's performance posture met all of the evaluative criteria except for a severe anterior positioning of the head which is consistent with the medical diagnosis.

Subject: 6  Age: 20  Sex: Female
Years Performing: 2  Status: College Student
Bow: French  Posture: Sit (always same stool)
Posture Problems: None, but has some pain and numbness in the legs during extended rehearsals and is currently working with her instructor to find a more comfortable posture for long rehearsals.

Postural Analysis: Rotation of the shoulders to the right for the right arm motion. Ulnar deviation of both wrists.

Subject: 7  Age: 19  Sex: Male
Years Performing: 6  Status: College Student
Bow: French  Posture: Sit (always same stool)
Posture Problems: None, but has altered position for additional comfort during extended rehearsals.
Postural Analysis: Slight rotation of the torso at the shoulder to the right side to favor bow arm. Left wrist exhibits slight palmer deviation and ulnar flexion. Right wrist demonstrates nearly consistent ulnar deviation.

Subject: 8  
Age: 21  Sex: Male  
Years Performing: 10  Status: College Student  
Bow: French  Posture: Sit (always same stool)  
Posture Problems: None, but has altered posture for a more stable instrument position.  
Postural Analysis: Not balanced on pelvis, leans to the right. Slight rotation of the torso to the right, with head in an anterior position. Both wrists are in the ulnar deviated position throughout the prescribed tasks.

Subject: 9  
Age: 23  Sex: Male  
Years Performing: 2.5  Status: College Student  
Bow: French  Posture: Sit (Always same stool)  
Posture Problems: None, but has changed posture from standing to sitting to avoid back pain, fatigue, and assist with ease of playing. Saw a medical professional for pain and was given strengthening and stretching exercises.  
Postural Analysis: This subject did not meet any of the evaluative criteria established. The pelvis is not supported because the right ischial tuberosite is not on
the stool. The torso is rotated to the right side and the bass is pressed into the abdomen so bending at the coxal joint is not possible. The head is extended forward from the spine. The left wrist is not stable and tended to be dorsiflexed more in the upper positions. The right wrist is almost always in ulnar deviation and moves from neutral to palmer flexion.

Subject: 10      Age: 20      Sex: Male
Years Performing: 2      Status: College Student
Bow: French      Posture: Stand/Sit (same stool)
Posture Problems: None, but has some pain in left arm during performance.
Postural Analysis: Slight rotation of the spine which makes the left shoulder higher. Makes large position shifts the coxal joint, but smaller shifts tend to come from bending the upper back. The head is in an anterior orientation and both wrists are in the ulnar deviated position.

Subject: 11      Age: 20      Sex: Male
Years Performing: 10      Status: College Student
Bow: French      Posture: Sit (Always same stool)
Posture Problems: None, but changed posture from standing to sitting for better control of the instrument.
Postural Analysis: Shoulders are rounded forward and held at an uneven height. Rotation of the shoulders to the right. Does not bend at coxal joint, but bends from the upper back. Head leans to the right side (lateral). Both wrists have ulnar deviation tendencies.

Subject: 12  
Age: 19  
Sex: Female  
Years Performing: 1  
Status: College Student  
Bow: French  
Posture: Sit (not same stool)  
Posture Problems: Diagnosed with weak back muscles as the cause of chronic back pain: treated with strengthening exercises.

Postural Analysis: The head exhibits an anterior position throughout the task. The left wrist demonstrates palmer flexion and occasionally ulnar deviation. The right wrist exhibits ulnar deviation with some palmer flexion.

Subject: 13  
Age: 18  
Sex: Male  
Years Performing: 5  
Status: College Student  
Bow: French  
Posture: Sit/Stand (not same stool)  
Posture Problems: None  
Postural Analysis: This subject does not have the weight balanced because he is leaning on one leg. The shoulders are rotated to the right with some minor bending of the upper back. The left wrist demonstrates palmer flexion
most of the time. The right wrist is extremely stiff, exhibiting negligible wrist motion during the bow stroke.

**Subject:** 14  
**Age:** 41  
**Sex:** Male  
**Years Performing:** 17  
**Status:** Professional/Jazz  
**Bow:** German  
**Posture:** Stand/Sit (same stool)  
**Posture Problems:** None, but this subject has been diagnosed with and treated for carpal tunnel syndrome.  
**Postural Analysis:** The wrist orientation for both arms is in palmer flexion.

**Subject:** 15  
**Age:** 22  
**Sex:** Male  
**Years Performing:** 4  
**Status:** College Student  
**Bow:** French  
**Posture:** Sit (Always same stool)  
**Posture Problems:** None, but he has made some minor postural changes for greater comfort while performing.  
**Postural Analysis:** Instrument position does not permit bending at the coxal joint. Slight anterior positioning of the head. The left wrist is in palmer flexion in lower positions and in ulnar deviation in thumb position. The right wrist is in ulnar deviation throughout the prescribed tasks.

**Subject:** 16  
**Age:** 29  
**Sex:** Female  
**Years Performing:** 17  
**Status:** Professional/Freelance
**Bow:** German  
**Posture:** Sit (Always same stool)  
**Posture Problems:** None, but has switched from standing to sitting because of low back pain, and from French to German bow to avoid right arm pain.  
**Postural Analysis:** Slight rotation of the shoulders to the right. Left wrist is in palmer flexion in thumb position and right wrist is in palmer flexion throughout the task.

**Subject:** 17  
**Age:** 21  
**Sex:** Male  
**Years Performing:** 5  
**Status:** College Student  
**Bow:** French  
**Posture:** Stand/Sit (same stool)  
**Posture Problems:** None, but some upper back pain.  
**Postural Analysis:** Rotation of shoulders to the right side with shifting motion into the upper positions from the upper back not the coxal joint. The left wrist tends to exhibit palmer flexion and the right wrist is consistently in ulnar deviation with incidence of palmer flexion as well.

**Subject:** 18  
**Age:** 33  
**Sex:** Male  
**Years Performing:** 23  
**Status:** Professional/Orchestra  
**Bow:** German  
**Posture:** Sit (Always same stool)  
**Posture Problems:** Mild scoliosis and fused low back vertebrae. Changed posture from standing to sitting on a low stool to keep both feet on the floor.
Postural Analysis: Minimal forward rotation of the right shoulder and anterior position of the head with the chin pulled down toward the sternum. Left wrist demonstrated some ulnar deviation in thumb position and some radial deviation in the lower positions. The right wrist consistently demonstrates palmer flexion.

Subject: 19  Age: 19  Sex: Male
Years Performing: 4  Status: College Student
Bow: French/German  Posture: Stand/Sit (same stool)
Posture Problems: None
Postural Analysis: Right shoulder is slightly lower than the left. Rotation of the shoulder to the right side and anterior positioning of the head. Left wrist demonstrates palmer flexion in thumb position and ulnar deviation in lower positions. Right wrist consistently demonstrates palmer flexion.

Subject: 20  Age: 30  Sex: Female
Years Performing: 1  Status: College Student
Bow: French  Posture: Stand/Sit (same stool)
Posture Problems: None diagnosed, but this individual has hypermobile joints including the pelvis and shoulders which creates a pronounced "slouch." She experiences
numbness of the left shoulder and has altered her position to alleviate this condition.

**Postural Analysis:** Slight forward rotation of the shoulders to the right side. Head moves into an anterior posture in thumb position. The left wrist demonstrates slight palmer flexion in the lower positions with pronounced flexion in thumb position.

**Subject:** 21  
**Age:** 18  
**Sex:** Female  
**Years Performing:** 9  
**Status:** High School Student  
**Bow:** French  
**Posture:** Stand  
**Posture Problems:** None, but she has made some minor changes in her posture to accommodate proper placement of the bow on the string. Occasionally, she experiences pain in her right foot.

**Postural Analysis:** Slight forward rotation of the right shoulder. The left wrist demonstrates ulnar deviation in thumb position and palmer flexion in the lower positions. The right wrist alternates between states of ulnar and radial deviation.

**Subject:** 22  
**Age:** 28  
**Sex:** Male  
**Years Performing:** 5  
**Status:** College Student  
**Bow:** French  
**Posture:** Stand and Sit (same stool)
Posture Problems: None, although some minor changes have been made in his performance posture to provide more comfort. He still experiences some pain in the middle back when playing in thumb position.

Postural Analysis: Slight forward rotation of the shoulders and anterior positioning of the head. Left wrist demonstrates palmer flexion and ulnar deviation throughout. Right wrist demonstrates ulnar deviation throughout the bow stroke, with arm weight leaning on the first finger.

Subject: 23  Age: 18  Sex: Male
Years Performing: 8.5  Status: High School Student
Bow: French  Posture: Sit (Always same stool)
Posture Problems: None, but has changed posture to facilitate more comfort in thumb position.
Postural Analysis: Slight forward rotation of the right shoulder and anterior positioning of the head. Slight ulnar deviation of the right wrist with alternating states of ulnar and radial deviation during bow stroke.

Subject: 24  Age: 41  Sex: Male
Years Performing: 20  Status: Professional/Jazz
Bow: German  Posture: Stand/Sit (not same stool)
Posture Problems: None
Postural Analysis: Slight rotation of the shoulders to the right side. The bending motion originates from the upper back with accompanying minimal anterior positioning of the head. The left wrist demonstrates ulnar deviation in thumb position. The right wrist is ulnarly deviated throughout the entire bow stroke.

Summary of Individual Postural Analysis

Of the 24 subjects who participated in this study, 7 (29%) did not meet the first postural criteria of the "I" frame. For element 2, vertical orientation of the torso, there were 19 (79%) who did not meet the established criteria. Of this group, 17 (89%) demonstrated a forward rotation of the right shoulder.

For postural element 3, bending from the coxal joint, 8 individuals (33%), all male, did not meet the established criteria. Of these 8 subjects, half of them positioned their instrument into the abdomen so it is not possible to bend from the hip or coxal joint. The remainder played with rounded shoulders, and in general, did not move the lower torso during performance.

The analysis of element 4, head over the shoulders, revealed that 18 subjects (75%) had an extended position. Of that group, 17 subjects (94%) favored the anterior position while one subject (6%), displaced the head to the right shoulder in a lateral posture.
Postural elements 5 and 6 deal with the orientation of the wrists, and in both of these categories 21 subjects (88%) did not meet the established criteria. For left arm orientation, 9 subjects (43%) demonstrated ulnar deviation throughout the entire task, while only 5 subjects (24%) demonstrated ulnar deviation in thumb position only. In this same group, 7 subjects (33%) demonstrated palmer flexion throughout the task, while only 4 subjects (19%) demonstrated palmer flexion in the thumb position. Of this same group, 5 subjects (24%) had two simultaneously occurring abnormal postures with the most common result being ulnar deviation and palmer flexion.

In the right arm orientation category, 21 subjects (88%) did not meet the established criteria. The most common posture problem was ulnar deviation, and 15 subjects (71%) demonstrated this position. The palmer flexion posture was demonstrated by 8 (38%) subjects in this group, while radial deviation was demonstrated in only 3 (14%) subjects of this group. There were 7 (33%) subjects in the sample who demonstrated two of these postures simultaneously.
CHAPTER V
DISCUSSION

The results of the postural analysis yield extremely relevant information. First, posture is a very individual element in the life of a performer. The size of the instrument, the size and proportion of the body, comfort level, and ease of execution are all factors which contribute to the performance posture. Many of the subjects indicated in their surveys that minor alterations were made in their performance posture to accommodate comfort, suggesting that posture was a process of making the body interact with the instrument in the most comfortable position without sacrificing technical precision. But, it also suggests that these performers were not inclined to analyze their posture unless they were in discomfort.

The second conclusion drawn from this experiment is that postural analysis was not generally an element of the performer's awareness. If the performer was not in pain, there was no motivation to experiment with other postural orientations. In fact, the lack of personal experimentation with posture is very revealing, because overall, the sample
demonstrated poor posture with, and without the instrument. Further, subjects with the best posture also had the most performance experience. Suggesting that those who have played the longest must accommodate for comfort and technical precision.

In addition, the lack of concern for postural elements indicates that current pedagogy fails to address these issues in more than a cursory manner. Since posture is such an individual factor of performance technique, the development of an individually appropriate performance posture is largely the responsibility of the musician. Following this progression it is likely that the less experienced performers have not yet encountered a performance situation requiring a postural adjustment.

The small number of women in the sample is consistent with percentages from other research, but there is a need for additional data to determine the relevance of body size. The ICSOM survey discussed in the "Review of Literature", indicates a higher incidence rate of certain physical problems in females, but the data from this investigation does not demonstrate consistency with that finding due to the small sample size.
Survey Information

The information provided by the survey is extensive. It is particularly relevant that 17 subjects (71%) did not begin musical instruction on the double bass. This can be interpreted variously as a lack of interest at the time of instruction, or the inability to locate an appropriately sized instrument, in the case of a child. In addition, only 13 subjects (54%) began instruction in the public schools. Three subjects who began musical instruction in the public schools had a string teacher who played the double bass, while the remainder had string teachers that primarily played the violin. Almost half of the sample, 11 subjects (45.8%), began musical instruction in some other environment.

The sample clearly indicated a preference for a seated posture with a total of 13 subjects (54%) using the seated posture exclusively. An analysis of these responses on the survey showed that many of the performers had adopted this posture for technical reasons. This posture is in many ways more stable, because when the same stool is used the performer will always approach the instrument with the same physical orientation. Those performers who stand often have to adjust endpin height or modify their posture to accommodate different heel heights, stage configuration, and similar variables.
A large portion of the sample adopted both the performance posture and the style of bow from their instructors. In addition, 15 subjects (63%) indicated they were basically satisfied with the comfort and technical elements of their own performance posture, while 9 subjects (38%) indicated they were not satisfied and had made major alterations.

The responses indicating postural change are important because they reveal that this element of technique has received little analysis. The only reason cited for change was pain, suggesting that ergonomic principles may not have been addressed during instruction. For those that had made major postural changes, a majority of them were changes from standing to sitting.

Based on the generally poor posture of the sample, it was surprising that only 4 subjects (17%) have medically diagnosed postural problems. Of those, only 1 subject indicated that the medical diagnosis resulted in a performance posture alteration. An additional subject indicated that the medical professional who diagnosed his postural disorder demonstrated no concern for the interaction of his professional performance career and his medical condition.

The number of subjects who experience chronic pain is startling. Nine subjects (38%) have played in constant pain for an average of 2 years, while 3 subjects (12%) have played in pain periodically. This information is revealing because only 3
subjects have consulted a medical professional. Subject 20 indicates that pain was present in performance on the electric bass for 4 years, and for the length of performance on the double bass, while subject 21 has performed in pain for 5 years and neither individual has consulted a medical professional. Many bassists obviously accept pain as a consequence of performance.

Comparison of the body and instrument measurements indicated there is no correlation between body size and instrument. The proportions of the body do not influence instrument choice, demonstrated by the largest instrument in the study being played by a female. The variation of instrument dimensions lends credence to the necessity of defining postural characteristics rather than advocating a specific posture.

Discussion by Postural Element

Element 1: "I" Beam Orientation

The results for element 1, the "I" orientation, showed that most of the sample had a good postural base for support of the spine. This is perhaps the single most important postural element, because the orientation of the torso provides the support for the whole body throughout a musical task.

The body is designed for work based on the linear alignment of the spine at the facet joints and because weight bearing has a
cumulative compressive effect on the spine, proper alignment of the spine is necessary to distribute the weight safely. The body compensates for this weight distribution through two skeletal controls. First, the curvature of the spinal column itself serves to distribute weight down to the pelvic area (lumbar vertebrae) of the body; and second, the shape and size of the individual vertebrae and invertebral discs are modified in the lumbar spine to compensate for the compressive force of weight bearing.

The spine is designed to support a great amount of weight, provided that the spine is properly positioned. When the posture of the individual does not permit the spine to line up correctly, the load path changes and can place excessive compressive weight on an area of the body that was not designed to bear such loads. (Nordin, 1980, p. 192) The spine is designed to bear weight at the facet joints with the invertebral discs acting to distribute the weight uniformly. (Nordin, 1980, p. 185) These discs are intended to cushion the spinal column for movement, but are not designed to bear the entire compressive weight of the body.

The new research on invertebral discs indicates that discs are more fragile than previously believed. An invertebral disc is a fibrous mass with a gelatinous core, and receives its nutrients by absorption through a surrounding membrane. When the disc sustains considerable trauma, it develops a small tear, which as it repairs itself creates scar tissue that does not permit
nutrients to pass through, resulting in marked deterioration over time. Most cumulative back injuries are a result of this kind of disintegration, many times with little symptomatic warning. Because there are no nerves in a disc, thus no feeling, an injury may not be detected until the damage is extensive and untreatable. It is critical that the risk of developing these kind of debilitating cumulative injuries be reduced.

About one third of the sample did not meet the "I" beam criteria, with most of the deviations being uneven shoulders or a lack of a solid pelvic base. With proper support of the pelvic area, most of these problems could be eliminated. Sitting on a stool with one leg on a rung and one leg on the floor dictates that part of the posterior section will not be in contact with the stool therefore, care must be taken to support the pelvis on the stool.

There were several subjects whose posture demonstrated risk for cumulative injury to the lumbar spine, and unless there are substantial alterations in the performance posture, serious problems may eventually develop

**Element 2: Vertical Orientation of the Torso**

The results of the postural analysis for element 2, vertical orientation of the spine, were quite revealing. Since 21 subjects (88%) of this group demonstrated a forward rotation of the right
shoulder, it indicates a prevailing technical concept rather than a postural issue. The only reason a performer would adopt a shoulder forward posture is to facilitate bringing the bow arm closer to the string so that more weight can be applied to the string. From a technical standpoint, weight and sound have a parallel relationship wherein more weight equals more sound. Although the older, more experienced players demonstrated this rotated posture, the degree to which they rotate is generally much less than that of the inexperienced players.

This rotated torso posture places excessive stress on the back muscles because it takes a great deal of muscular energy to support the body itself before the musician ever plays a note. This posture creates additional tension in the upper back muscles. This rotated posture may be the result of the combination of the weight sound technical relationship or from the ulnar deviation tendency of the right wrist. When the wrist is in the ulnar deviated posture, the arm, in a sense, becomes shorter and may require the torso to rotate to keep weight on the string. In addition, the ulnar deviated wrist posture does not transfer energy as efficiently to the hand.

**Element 3: Coxal Joint**

About a third of the subject sample (33%) exhibited pronounced deficiencies in this area. It should be noted that no
females were included in this group. Of the group that did not meet established criteria, half demonstrated efficient technique, but the instrument was thrust into the abdomen so that forward motion from the coxal joint was impossible. The remainder of this group were tall males who are accustomed to stretching to reach upper position rather than bending at the hip. There may be a correlation between the center of gravity in the male physique and awareness of a joint. The male pelvis is taller and thinner than the female pelvis and coupled with height raises the center of gravity above the coxal joint. Additionally, many of the males who did not bend at the hip or coxal joint, demonstrated rigidity and loss of range of motion in the hip area.

**Element 4: Head over Shoulders**

Analysis of element 4 revealed that 18 subjects (75%) of the sample did not meet the established criteria. Of this group, 17 subjects (94%) favored an anterior posture, which has been shown to place undue stress on the cervical vertebrae, causing compression and misalignment. This in turn changes the load path and stresses the invertebral discs in the cervical spine and does not allow the lumbar spine to correctly bear the weight of the torso. In addition, this deviated posture constricts the windpipe, reducing oxygen intake which results in rapid muscle fatigue and, ultimately oxygen debt.
Elements 5 and 6: Arm Orientation

The most critical issue in arm orientation is the position of the wrists relative to the arms. For both wrists, 21 subjects (88%) did not meet the established criteria. The overwhelming number of deviated positions indicates a lack of coherent information on the gravity of this posture on the health of the musculature. It is almost impossible to do any activity without bending the wrists, but there are ways to eliminate excessive deviation. The research on carpal tunnel syndrome suggests that it is the deviated posture, in combination with compressive force, that leads to tissue breakdown; and because the carpal tunnel aperture is so small, it is imperative that this compressive stress be eliminated.

It is no surprise that a majority of the sample had ulnar deviation of the right wrist because much of traditional pedagogy for the French bow favors a "pronated" position, and this follows from the concept that the French bow is merely a larger version of the violin bow, therefore, the wrist position will be similar to that of the violinist. Unfortunately, this comparison is inconsistent with the activity required by the arm to produce good tone on an instrument that is not supported on the shoulder, but sits on the floor. For the violinist, the arm is held up so that the bow can reach the violin while the bassist
lowers the arm, reducing the bend at the elbow to reach the string.

The solution to this excessively deviated wrist posture clearly lies in the pedagogy. There is little information presented regarding the balance between the weight force of the arm and the movement directives of the hand. The bow hold must balance the hand so that the base hand knuckles are parallel with the bow stick, and the thumb must assume a position relative to the center of the hand so that weight from the arm can be evenly distributed among the digits. When a deviated posture is assumed, the weight force requires a "clamping" of the thumb to stabilize the hand, resulting in fixation, rigidity and a loss of range of motion.

The results for the left wrist orientation were similar in that they also point to a deficiency in the pedagogy. Generally, the left hand is discussed in pedagogical literature as if it were not attached to the arm at all. Movement of the hand in a shifting motion, for example, has very little to do with the hand itself. The motion that moves the hand for the shift comes from the back. The hand is the actual contact point of the body on the instrument, but it is the upper back and shoulders that do the work. Often, in pedagogical literature, the shift is discussed as a motion that begins in the hand rather than in the back.

Clearly, the issue here is the position of the upper arm. If the upper arm moves ahead of the shoulder line, the hand is
thrust past the fingerboard so the only way the hand can meet the fingerboard is to bend at the wrist. If the upper arm remains in a straight line with the shoulders, the wrist can assume a straight alignment with the forearm. Biomechanically speaking, the arms function as levers. Lever arms derive their greatest strength from a straight orientation. Each bend in a lever arm represents a loss of efficiency and wasted motion. Additionally, keeping the upper arm in line with the shoulders gives the body much more strength by allowing those muscles to remain in an elongated state. Unfortunately, when the upper arm is in line with the shoulders, it feels to the performer as though the body is too far away from the instrument.

The sample demonstrated extremely high risk wrist behaviors, and unless these bassists eliminate the force resulting from excessive deviation, many may sustain serious injury.

Summary of Results

The 6 postural criteria used to evaluate double bassists' performance postures was developed after an extensive analysis of pedagogical material, arts medicine research, and related information revealed no biomechanically accurate information that would adequately instruct a bassist in developing an acceptable performance posture. Coupled with the high incidence
of low back injuries, it was necessary to develop an experimental procedure that would isolate the function of the torso in establishing a mechanically efficient body posture.

A biomechanical model was developed that would first identify and isolate those postural elements that comprise an acceptable performance posture in terms of the physical motions required of double bass performance technique, and define those elements in technical terms. This biomechanical analysis yielded a new postural concept, the "I" beam theory, based on the architectural concept of "framing."

This theory identifies an "I" beam on the body wherein the pelvis forms the inferior cross section of the "I", the spinal column comprises the vertical section, and the shoulders form the superior cross section of the "I" structure. (See Figure 1, Page 52) Of paramount importance is that the torso remain in a vertical alignment so that the compressive force of weight bearing and movement of the arms be appropriately transferred to the lumbar vertebrae. This "I" beam structure with vertical alignment, when properly articulated on the body, creates the appropriate support for bilateral motion of the arms which is the basis of double bass performance technique.

The remaining 4 postural elements are results of this "I" beam and vertical configuration of the torso. Element 3, bending at the coxal joint, refers to the place on the body where the actual joint is located. The coxal joint, located where the legs
meet the torso, is where the forward motion of the trunk begins. The spine is very flexible by design, but does not contain an actual joint possible of gross movement.

Element 4, head over the shoulders, incorporates the head as an extension of the vertical element of the "I" beam. The head "sits" on the shoulders and should follow the motion of the torso.

Elements 5 and 6, describe the relationship of the arms and wrists to the body. Both wrists should follow the straight line of the forearms. This orientation is critical because most of the ligaments and tendons that support hand movement must pass through the carpal tunnel in the wrist, and they function best when not constricted by excessive wrist deviation. The greater the deviation from a straight wrist the higher the potential for injury.

These 6 elements comprise the operational postural theory and serve as criteria used to evaluate the double bassist's performance posture. The six essential elements which comprise the evaluative criteria are:

1. "I" beam structure with proper pelvis support (sitting or standing position)
2. Vertical orientation of the torso, with shoulders square to the hips (no rotation)
3. Bending from the hip or coxal joint when moving the shoulders forward
4. Head remaining over the shoulders (extension of the "I" beam), not extending forward or back or to the sides

5. Left arm orientation based on forearm, wrist, and hand straight alignment

6. Right upper arm orientation based on forearm, wrist, and hand straight alignment and angle required to put the bow on the string

The Experimental Procedure consisted of three parts. Part 1 involved measuring the instrument and the subject. Instrument measurements were taken with a measuring tape and expressed in centimeters. Anthropomorphic, body segment, measurements were taken with anthropometers following the guidelines established by Webb and Associates (1978). It is important to note that the subjects were measured fully clothed and with shoes because this is similar to performance attire.

Part 2 of the Experimental Procedure involved filming each subject while performing 4 sets of 2 two octave scales from 4 distinct camera angles. The two scales chosen were F and D major because they exploit the largest amount of fingerboard area.

Part 3 required that each subject complete an informational survey designed to ascertain data on basic performance history, musculoskeletal injury, and other relevant information.
The videotaped performances were evaluated using the operational "I" beam concept by two observers. Observer one was the researcher and observer two was a biomechanically trained individual. Each subject's posture was compared to that of the operational theory using an evaluation form. (See Appendix B)

Twenty-four bassists participated in this study with an age range of 14 to 49 with 17 males and 7 females. For analysis the subjects were divided into two groups by performance experience. These two groups were student and professional. Students numbered 19 (80%) and professionals numbered 5 (20%).

Results of the specific postural evaluations revealed that few subjects met any of the postural criteria. The following is a list of the results by element.

1. **"I" Beam**: 7 Subjects (29%) did not meet criteria

2. **Vertical Orientation**: 19 Subjects (79%) did not meet criteria

3. **Coxal Joint**: 8 Subjects (33%) did not meet criteria

4. **Head over Shoulders**: 18 Subjects (75%) did not meet criteria

5. **Left Arm Orientation**: 21 Subjects (88%) did not meet criteria

6. **Right Arm Orientation**: 21 Subjects (88%) did not meet criteria
The results of this investigation suggest that there is no correlation between body and instrument size. There are a large number of subjects who routinely play in pain and have not consulted with a medical professional. In addition, the excessive deviation of the wrists could be interpreted as a very serious problem. More research needs to be done to learn more about the relationship between wrist deviation and pedagogical practice. This analysis indicates that postural issues are not adequately addressed in double bass performance pedagogy.

Conclusion

It is clear from the analysis that the most severe problems involve the wrists, with features of the left arm and wrist of particular interest. A majority of the sample demonstrated consistent ulnar deviation of the wrist, indicating that the hand was organized around the first finger instead of the fourth. The hand should be organized on the fingerboard by accommodating the needs of the fourth and shortest finger. The other longer fingers will bend as necessary to establish the hand frame. By organizing the hand around the first finger an added "twist" or "pronation" of the wrist places the palm in the wrong direction for shifts into the upper positions, and stresses the fourth finger by making it stretch uncomfortably.
Current pedagogy for the double bass advocates a slightly "pronated" or "twisted" right wrist for the French bow, which when employed to an extreme, causes severe ulnar deviation. The essential biomechanical problem here is that the weight of the arm is centered on the right first finger, requiring the hand to become rigid in order to support the first finger. This ultimately can create a "clamp" effect in the hand, resulting in cramping or fixation of the first finger and cessation of movement.

Another interesting observation in regard to the prominent number of the sample with the left wrist in consistent palmer flexion. This is an indication that the left arm lever is extending past the fingerboard. If the left upper arm were kept in the same line as the shoulders this problem could be eliminated.

Of additional concern is the large number of subjects who hold their heads in an anterior posture to the shoulders, creating two biomechanical problems. First, it places stress on the lower cervical spine by compressing these vertebrae to make the forward motion possible. Secondly, it constricts the breathing mechanism. When a performer executes a passage that requires a considerable physical motion, the muscles may go into oxygen debt because air intake has been reduced.

All of the postural elements defined as "biomechanically sound" deal only with the physical aspect of performance. Dr. Cailliet (1990) points out that the emotional element also interacts with the physical elements. Body posture is often a
sign of an individual's overall self concept. However, it is arguable that many of the postural abnormalities identified in the sample result from an instrumentalist's innate desire to achieve proximity to the instrument. The intuitive motivation is laudable, but the biomechanical result is without justification. The forward rotation of the right shoulder puts the player in closer contact with the string, and the generally held assumption is that this position provides more power and control. In actuality, the opposite is true. As a result, the player compensates by adding more weight and, therefore, more tension.

In biomechanical terms, the best posture maintains elongation of the muscles to give maximum strength and efficiency. The inherent problem is that it does not "feel right" to the instrumentalist. To complicate the issue further, technique is often separated into elements so far removed from normal motion, it becomes difficult for the bassist to achieve a kinesthetic sense of these motions because they have no experiential reference.

Ultimately, the postural issue must be addressed by the pedagogy. It is the sole responsibility of the player to be aware of the body and the signals it sends. The current mode of operation for instruction is mechanistic and task specific, and nullifies the intrinsic worth of a holistic approach. By identifying 6 postural elements that all bassists can employ for a basic performance posture they are afforded the opportunity to
develop an individual posture that permits them freedom of movement, increased comfort, and reduced risk of musculoskeletal injury.

Suggestions for Further Study

This investigation revealed some very important findings about the interaction of the body with the instrument. But, it is only the first step. It is clear that the pedagogy does not reflect a clear understanding of the relationship between the musculature and performance technique. Inherent in this investigation is that it is limited in scope. To adequately ascertain the role of performance posture in the total health of the musician, it would be interesting to follow some of the sample throughout the next ten years of their performance careers to see if physical problems develop.

It would also be revealing to study these postures with electromyographic analysis. It would show the extent of muscle involvement to assume the posture and that data could be compared with the muscle involvement for actual performance. In addition, this type of analysis could be employed to determine the muscular difference, if any, for the two bow styles.

The interaction of the body with the instrument could be further investigated if the actual instrument was redesigned to meet the biomechanical requirements of the body. Traditionally,
the design of the instrument has been largely determined by tradition rather than the physical requirements of the body. A new instrument could be developed around the biomechanical needs of the body. The instrument and its performers could be studied to determine if this new design would assist the musculature in the execution of performance technique.

This study does point out that there is a general lack of information on performance posture and suggests that much more research is required to make informed conclusions about a biomechanically sound performance technique.
REFERENCES


APPENDIX A
INFORMATION SHEETS
DOUBLE BASS POSTURAL STUDY INFORMATION SHEET

Part 1: Measurement  (Subject No: _____ )

A. Body Measurements:

1. Shoulder Breadth (biacromial): ____________
2. Upper Arm Segment: ________________
3. Lower Arm to Wrist Segment: __________
4. Hand Length: __________
5. Hand Breadth: __________
6. Buttock-Knee length: ________________
7. Lower Leg Segment: ________________
8. Shoulders to top of Head: ______________
9. Total Height: ________________

B. Instrument Measurements:

1. Overall Body Length (Down the center line of the instrument): ________________
2. Shoulder Width at the widest point: ________________
3. Neck length (From nut to shoulder): ________________
4. Endpin height used by performer: ________________
5. Vibrating String Length: ________________
6. Depth of Ribs at Shoulder: ________________
7. Depth of Ribs at Bridge: ________________
8. Width of Lower Bout: ________________
9. Depth of Lower Bout: ________________
10. Stool Height (if seated posture): ________________
   ___ Round Back  ___ Flat Back
Taper of upper bout to neck: ________________
Part 2: Video Observation

All subjects will be asked to play a series of 3 scales and be filmed from 3 positions. These 3 scales will use all positions on the fingerboard. These scales are:

- F Major (2 Octaves)
- D Major (2 Octaves)
- Rear View (3)
- Right Side (2)
- Bassist
- Left Side (4)
- Front View (1)

**Position 1 - Frontal:** This places the camera square in front of the subject.

F ____ / D ____

**Position 2 - Right Side:** This places the camera at a 90 degree angle to the body allowing clear view of the bow arm. F ____ / D ____

**Position 3 - Rear:** This places the camera behind the subject to see the torso and shoulders. F ____ / D ____

**Position 4 - Left Side:** This places the camera at a 90 degree angle to body allowing a clear view of the left hand, shoulder, and elbow. F ____ / D ____
Part 3: Survey Information (Subject No. ___)

Age _____  Sex: ____ Female (Check ____ Male  

Years Playing the instrument ______

How many years have you studied Double Bass ______

Did you begin double bass instruction in the public schools? ___

If Yes, what instrument did your first instructor play?

________________________________________________________________________

Did you begin musical study on the Double Bass? ______

If Not, what instrument did you begin with? ______________

Do you:  ____ Stand  ____ Sit  ____ Both

If you checked Both, when do you stand and when do you sit?

________________________________________________________________________

If you sit, do you use the same stool? ______________

Have you altered your posture from standing to sitting or vice versa? ______

If yes, why? ____________________________

________________________________________________________________________

Do you use:  ____ French Bow  ____ German Bow

Have you always used the same bow? __________

If Not, why did you switch? ____________________________

________________________________________________________________________

Did or does your teacher use the same bow as you? ________
Are You:  ____ Student ( ___ High School / ___ College)
             ___  Professional

Have you had the same posture for the length of you playing career? ______ If not, how has it changed? ______________
______________________________________________________________________________________________
______________________________________________________________________________________________
What was the reason for the postural change? _______
______________________________________________________________________________________________
______________________________________________________________________________________________
Was the change suggested by a teacher or did you decide to change yourself? _____________________________
______________________________________________________________________________________________
______________________________________________________________________________________________
Have you ever been diagnosed with a postural disorder? _____ Yes  _____ No
If yes, please list disorder and indicate treatment(s) if prescribed. _________________________________
______________________________________________________________________________________________
______________________________________________________________________________________________
If yes, did you change your performance posture? _____ How? _________________________________
______________________________________________________________________________________________
Was this postural change suggested by a medical professional?

Do you think you have a postural disorder?

___ Yes ___ No  If yes, Why?

Do you experience pain while playing?

If yes, please indicate where and under what circumstances.

How long have you played in pain?

Have you consulted a doctor?  If yes, what was the diagnosis and treatment?

Do you experience performance anxiety?  If so, does it affect your performance posture?

If yes, how have you compensated?
APPENDIX B

DOUBLE BASS POSTURE EVALUATION FORM
DOUBLE BASS POSTURE EVALUATION FORM

Subject No. _____, Observer ________________

Circle one/Comment if "No"

1. "I" STRUCTURE: "I" beam structure with proper pelvis support (sitting or standing)
   YES   NO
   COMMENTS: ____________________________________

2. VERTICAL ORIENTATION OF TORSO: "Squared" shoulders and hips, without twisting
   YES   NO
   COMMENTS: ____________________________________

3. BENDING FORWARD FROM COXAL JOINT: Bending from the coxal or "hip" joint when moving the shoulders forward
   YES   NO
   COMMENTS: ____________________________________
4. **HEAD OVER SHOULDERS:** Head remains over the shoulders, without extending forward (anterior) or backward (posterior) from the spine

   YES  NO

   COMMENTS: ____________________________________

   ________________________________________________

5. **LEFT ARM:** Orientation based on forearm to middle finger alignment. Base hand knuckles parallel to fingerboard.

   YES  NO

   COMMENTS: ____________________________________

   ________________________________________________

6. **RIGHT ARM:** Orientation based on a straight forearm, wrist and hand alignment and angle required to place the bow on the string

   YES  NO

   COMMENTS: ____________________________________

   ________________________________________________
<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Age</th>
<th>Sex</th>
<th>Years Playing</th>
<th>Years Studying</th>
<th>Number of Teachers</th>
<th>Start in School</th>
<th>Teacher's Instrument</th>
<th>Begin on Bass</th>
<th>If No, What Instrument</th>
<th>Performance Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>F</td>
<td>6.0</td>
<td>6.0</td>
<td>3</td>
<td>Yes</td>
<td>Viola</td>
<td>Yes</td>
<td>HS Student</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>M</td>
<td>6.0</td>
<td>2.0</td>
<td>3</td>
<td>Yes</td>
<td>Viola</td>
<td>Yes</td>
<td>HS Student</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>M</td>
<td>5.0</td>
<td>4.0</td>
<td>5</td>
<td>Yes</td>
<td>Violin</td>
<td>Yes</td>
<td>HS Student</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>F</td>
<td>2.5</td>
<td>1.5</td>
<td>1</td>
<td>Yes</td>
<td>Violin</td>
<td>No</td>
<td>Violin</td>
<td>JR HGH Student</td>
</tr>
<tr>
<td>5</td>
<td>49</td>
<td>M</td>
<td>31.0</td>
<td>10.0</td>
<td>5</td>
<td>No</td>
<td>Trumpet</td>
<td>No</td>
<td>Trumpet</td>
<td>Prof-Symphony</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>F</td>
<td>2.0</td>
<td>2.0</td>
<td>2</td>
<td>No</td>
<td>Trumpet</td>
<td>No</td>
<td>Trumpet</td>
<td>College Student</td>
</tr>
<tr>
<td>7</td>
<td>19</td>
<td>M</td>
<td>6.0</td>
<td>4.0</td>
<td>3</td>
<td>Yes</td>
<td>Bass</td>
<td>No</td>
<td>Saxophone</td>
<td>College Student</td>
</tr>
<tr>
<td>8</td>
<td>21</td>
<td>M</td>
<td>10.0</td>
<td>10.0</td>
<td>2</td>
<td>Yes</td>
<td>Bass</td>
<td>No</td>
<td>Piano</td>
<td>College Student</td>
</tr>
<tr>
<td>9</td>
<td>23</td>
<td>M</td>
<td>2.5</td>
<td>2.5</td>
<td>3</td>
<td>No</td>
<td>Trombone</td>
<td>No</td>
<td>Trombone</td>
<td>College Student</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>M</td>
<td>2.0</td>
<td>2.0</td>
<td>1</td>
<td>No</td>
<td>Piano</td>
<td>No</td>
<td>Piano</td>
<td>College Student</td>
</tr>
<tr>
<td>11</td>
<td>20</td>
<td>M</td>
<td>10.0</td>
<td>10.0</td>
<td>5</td>
<td>Yes</td>
<td>Trombone</td>
<td>Yes</td>
<td>Trombone</td>
<td>College Student</td>
</tr>
<tr>
<td>12</td>
<td>19</td>
<td>F</td>
<td>1.0</td>
<td>1.0</td>
<td>2</td>
<td>No</td>
<td>Clarinet</td>
<td>No</td>
<td>Clarinet</td>
<td>College Student</td>
</tr>
<tr>
<td>13</td>
<td>18</td>
<td>M</td>
<td>5.0</td>
<td>4.0</td>
<td>3</td>
<td>Yes</td>
<td>Bass</td>
<td>No</td>
<td>Cello</td>
<td>College Student</td>
</tr>
<tr>
<td>14</td>
<td>41</td>
<td>M</td>
<td>17.0</td>
<td>17.0</td>
<td>3</td>
<td>No</td>
<td>Electric Bass</td>
<td>No</td>
<td>Electric Bass</td>
<td>Prof-Jazz</td>
</tr>
<tr>
<td>15</td>
<td>22</td>
<td>M</td>
<td>4.0</td>
<td>4.0</td>
<td>1</td>
<td>No</td>
<td>Violin</td>
<td>No</td>
<td>Violin</td>
<td>College Student</td>
</tr>
<tr>
<td>16</td>
<td>29</td>
<td>F</td>
<td>17.0</td>
<td>12.0</td>
<td>6</td>
<td>Yes</td>
<td>Bass/Tuba</td>
<td>No</td>
<td>Piano</td>
<td>Prof-Freelance</td>
</tr>
<tr>
<td>17</td>
<td>21</td>
<td>M</td>
<td>5.0</td>
<td>5.0</td>
<td>3</td>
<td>No</td>
<td>Piano</td>
<td>No</td>
<td>Piano</td>
<td>College Student</td>
</tr>
<tr>
<td>18</td>
<td>33</td>
<td>M</td>
<td>23.0</td>
<td>9.0</td>
<td>6</td>
<td>Yes</td>
<td>Trombone</td>
<td>Yes</td>
<td>Trombone</td>
<td>Prof-Symphony</td>
</tr>
<tr>
<td>19</td>
<td>19</td>
<td>M</td>
<td>4.0</td>
<td>4.0</td>
<td>2</td>
<td>Yes</td>
<td>Percussion</td>
<td>No</td>
<td>Trumpet</td>
<td>College Student</td>
</tr>
<tr>
<td>20</td>
<td>30</td>
<td>F</td>
<td>1.0</td>
<td>1.0</td>
<td>2</td>
<td>No</td>
<td>Violin</td>
<td>No</td>
<td>Clarien</td>
<td>College Student</td>
</tr>
<tr>
<td>21</td>
<td>18</td>
<td>F</td>
<td>9.0</td>
<td>9.0</td>
<td>3</td>
<td>Yes</td>
<td>Violin</td>
<td>Yes</td>
<td>HS Student</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>28</td>
<td>M</td>
<td>5.0</td>
<td>5.0</td>
<td>1</td>
<td>No</td>
<td>Electric Bass</td>
<td>No</td>
<td>Electric Bass</td>
<td>College Student</td>
</tr>
<tr>
<td>23</td>
<td>18</td>
<td>M</td>
<td>8.5</td>
<td>5.5</td>
<td>2</td>
<td>Yes</td>
<td>Violin</td>
<td>Yes</td>
<td>HS Student</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>41</td>
<td>M</td>
<td>20.0</td>
<td>15.0</td>
<td>3</td>
<td>No</td>
<td>Violin</td>
<td>No</td>
<td>Clarien</td>
<td>Prof-Jazz</td>
</tr>
<tr>
<td>Subject Number</td>
<td>Stand</td>
<td>Sit</td>
<td>Both</td>
<td>Posture?</td>
<td>If Yes, Why?</td>
<td>Teacher Same?</td>
<td>French Bow</td>
<td>German Bow</td>
<td>Switch Bows?</td>
<td>Same Posture for career</td>
</tr>
<tr>
<td>---------------</td>
<td>-------</td>
<td>-----</td>
<td>------</td>
<td>----------</td>
<td>-------------</td>
<td>--------------</td>
<td>------------</td>
<td>------------</td>
<td>--------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Solo</td>
<td>X</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>X</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>X</td>
<td>Yes</td>
<td>To hard to stand</td>
<td>Yes</td>
<td>X</td>
<td>No, not comfortable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>X</td>
<td>No</td>
<td>for comfort</td>
<td>Yes</td>
<td>X</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>X</td>
<td>Yes</td>
<td>Pain in legs and back</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>X</td>
<td>No</td>
<td>Comfort, inst position</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>X</td>
<td>Yes</td>
<td>Intonation</td>
<td>Yes</td>
<td>X</td>
<td>No, stand to sit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>X</td>
<td>Yes</td>
<td>Back pain</td>
<td>Yes</td>
<td>X</td>
<td>No, stand to sit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>X</td>
<td>Yes</td>
<td>Better control of inst</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>X</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>X</td>
<td>No</td>
<td>More control</td>
<td>Yes</td>
<td>X</td>
<td>No, added sitting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Jazz</td>
<td>X</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>X</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, minor changes</td>
</tr>
<tr>
<td>12</td>
<td>X</td>
<td>Yes</td>
<td>Low Back Pain</td>
<td>No</td>
<td>X</td>
<td>X</td>
<td>No, stand to sit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>X</td>
<td>No</td>
<td>Comfort</td>
<td>No</td>
<td>X</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>X</td>
<td>Yes</td>
<td>Severe Low back pain</td>
<td>No</td>
<td>X</td>
<td>X</td>
<td>No, stand to sit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>X</td>
<td>No</td>
<td>Comfort</td>
<td>No</td>
<td>X</td>
<td>X</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>X</td>
<td>Yes</td>
<td>Numb left shoulder</td>
<td>No</td>
<td>X</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>X</td>
<td>Yes</td>
<td>For comfort</td>
<td>Yes</td>
<td>X</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>X</td>
<td>Yes</td>
<td>Comfort</td>
<td>Yes</td>
<td>X</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>X</td>
<td>Yes</td>
<td>For thumb position</td>
<td>No</td>
<td>X</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Jazz</td>
<td>X</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>X</td>
<td>Yes</td>
<td>For thumb position</td>
<td>No</td>
<td>X</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Jazz</td>
<td>X</td>
<td>Yes</td>
<td>Comfort</td>
<td>Yes</td>
<td>X</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>X</td>
<td>Yes</td>
<td>For thumb position</td>
<td>No</td>
<td>X</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Jazz</td>
<td>X</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Double Bass Postural Information
<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Same Posture For Career Change?</th>
<th>Why Not comfortable to stand</th>
<th>Diagnosed with Arthritis in Neck</th>
<th>Medical Therapy/Medication</th>
<th>Do you think you have a Postural Disorder, Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>No (stand to sit)</td>
<td>Not comfortable to stand</td>
<td>Spinal Misalignment</td>
<td>No</td>
<td>Yes, Pain</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td></td>
<td>Arthritis in Neck</td>
<td>Therapy/Medication</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>No</td>
<td>Legs Hurt/Back Pain</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>No</td>
<td>Not Comfortable</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>8</td>
<td>No (stand to sit)</td>
<td>More Stable Intonation</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>9</td>
<td>No (stand to sit)</td>
<td>Back Pain</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>10</td>
<td>Yes</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>11</td>
<td>No (stand to sit)</td>
<td>Better control of Bass</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>12</td>
<td>No (minor changes)</td>
<td>More Comfortable</td>
<td>Weak Back Muscles</td>
<td>Exercises</td>
<td>Yes, Pain</td>
</tr>
<tr>
<td>13</td>
<td>Yes</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>14</td>
<td>Yes</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>15</td>
<td>Yes (minor changes)</td>
<td>Comfort</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>16</td>
<td>No (stand to sit)</td>
<td>Low Back Pain</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>17</td>
<td>Yes</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>18</td>
<td>No (stand to sit)</td>
<td>Low Back Pain</td>
<td>Scoliosis/fused vert</td>
<td>Stretching/Exercise</td>
<td>Yes</td>
</tr>
<tr>
<td>19</td>
<td>Yes</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>20</td>
<td>No (altered posture)</td>
<td>Numb left shoulder</td>
<td>No</td>
<td>Yes (hypermobile joints)</td>
<td>No</td>
</tr>
<tr>
<td>21</td>
<td>No (minor changes)</td>
<td>comfort</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>22</td>
<td>Yes (minor changes)</td>
<td>Comfort</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>23</td>
<td>Yes (minor changes)</td>
<td>comfort</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>24</td>
<td>Yes</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Subject Number</td>
<td>Pain and Why Playing?</td>
<td>How Long?</td>
<td>Did you see a Doctor?</td>
<td>Diagnosis and Treatment</td>
<td>Performance Anxiety?</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------</td>
<td>-----------</td>
<td>-----------------------</td>
<td>------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>1</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Yes Back</td>
<td>rare</td>
<td>No</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Rarely Low Back</td>
<td>Always</td>
<td>No</td>
<td></td>
<td>Yes, Mild</td>
</tr>
<tr>
<td>8</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Yes Low Back, Fatigue</td>
<td>Always</td>
<td>Yes</td>
<td>Stretching Exercises</td>
<td>No</td>
</tr>
<tr>
<td>10</td>
<td>Yes In left arm</td>
<td>No</td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>11</td>
<td>Yes Right Thumb Knuckle</td>
<td>2 Years</td>
<td>No</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>12</td>
<td>Yes Back/Both Hands</td>
<td>1 Year</td>
<td>No</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>13</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Sometimes Carpal Tunnel</td>
<td>3 Years</td>
<td>Yes, CTS-Splints/Medication</td>
<td>Yes</td>
<td>Tension in neck</td>
</tr>
<tr>
<td>15</td>
<td>Rarely LH:fingers/RH:thumb</td>
<td>No</td>
<td></td>
<td>CTS-Splints/Medication</td>
<td>Yes</td>
</tr>
<tr>
<td>16</td>
<td>Not now</td>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>17</td>
<td>Yes Upper Back</td>
<td>Always</td>
<td>No</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>18</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>20</td>
<td>Yes Numb Left Shoulder</td>
<td>4 Years</td>
<td>No</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>21</td>
<td>Yes Right Foot</td>
<td>2 Years</td>
<td>No</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>22</td>
<td>Yes Middle Back</td>
<td>2 Years</td>
<td>Chiropractor misalignment</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>23</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>24</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Subject Number</td>
<td>Shoulder Breadth</td>
<td>Upper Arm Length</td>
<td>Lower Arm Breadth to Knee</td>
<td>Hand Length</td>
<td>Hand Breadth</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------</td>
<td>-----------------</td>
<td>---------------------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>1</td>
<td>29.1</td>
<td>29.6</td>
<td>26.4</td>
<td>17.7</td>
<td>07.9</td>
</tr>
<tr>
<td>2</td>
<td>35.4</td>
<td>34.5</td>
<td>25.6</td>
<td>18.9</td>
<td>08.5</td>
</tr>
<tr>
<td>3</td>
<td>43.6</td>
<td>33.3</td>
<td>27.8</td>
<td>20.3</td>
<td>08.6</td>
</tr>
<tr>
<td>4</td>
<td>35.9</td>
<td>23.1</td>
<td>22.4</td>
<td>17.2</td>
<td>07.7</td>
</tr>
<tr>
<td>5</td>
<td>36.5</td>
<td>29.6</td>
<td>28.3</td>
<td>20.4</td>
<td>08.6</td>
</tr>
<tr>
<td>6</td>
<td>32.7</td>
<td>31.6</td>
<td>26.0</td>
<td>17.6</td>
<td>07.5</td>
</tr>
<tr>
<td>7</td>
<td>37.3</td>
<td>28.7</td>
<td>29.2</td>
<td>19.1</td>
<td>08.6</td>
</tr>
<tr>
<td>8</td>
<td>42.1</td>
<td>30.4</td>
<td>27.4</td>
<td>18.9</td>
<td>09.0</td>
</tr>
<tr>
<td>9</td>
<td>36.0</td>
<td>30.0</td>
<td>27.3</td>
<td>18.1</td>
<td>08.0</td>
</tr>
<tr>
<td>10</td>
<td>34.9</td>
<td>28.6</td>
<td>27.0</td>
<td>19.5</td>
<td>08.5</td>
</tr>
<tr>
<td>11</td>
<td>35.0</td>
<td>30.7</td>
<td>27.3</td>
<td>19.1</td>
<td>09.0</td>
</tr>
<tr>
<td>12</td>
<td>31.6</td>
<td>28.2</td>
<td>26.0</td>
<td>17.8</td>
<td>08.0</td>
</tr>
<tr>
<td>13</td>
<td>32.9</td>
<td>25.4</td>
<td>25.6</td>
<td>18.8</td>
<td>08.0</td>
</tr>
<tr>
<td>14</td>
<td>34.8</td>
<td>30.4</td>
<td>27.7</td>
<td>19.9</td>
<td>08.7</td>
</tr>
<tr>
<td>15</td>
<td>36.6</td>
<td>29.4</td>
<td>27.9</td>
<td>19.6</td>
<td>09.0</td>
</tr>
<tr>
<td>16</td>
<td>31.1</td>
<td>27.9</td>
<td>25.8</td>
<td>16.7</td>
<td>07.3</td>
</tr>
<tr>
<td>17</td>
<td>35.3</td>
<td>31.0</td>
<td>27.9</td>
<td>19.7</td>
<td>08.7</td>
</tr>
<tr>
<td>18</td>
<td>36.1</td>
<td>34.0</td>
<td>30.6</td>
<td>20.0</td>
<td>09.1</td>
</tr>
<tr>
<td>19</td>
<td>34.3</td>
<td>29.6</td>
<td>28.8</td>
<td>18.4</td>
<td>08.1</td>
</tr>
<tr>
<td>20</td>
<td>35.2</td>
<td>30.3</td>
<td>25.6</td>
<td>19.1</td>
<td>08.0</td>
</tr>
<tr>
<td>21</td>
<td>34.8</td>
<td>28.8</td>
<td>21.9</td>
<td>17.2</td>
<td>07.2</td>
</tr>
<tr>
<td>22</td>
<td>36.4</td>
<td>31.5</td>
<td>27.0</td>
<td>20.0</td>
<td>09.1</td>
</tr>
<tr>
<td>23</td>
<td>39.1</td>
<td>29.9</td>
<td>25.3</td>
<td>18.0</td>
<td>08.3</td>
</tr>
<tr>
<td>24</td>
<td>34.2</td>
<td>31.1</td>
<td>26.9</td>
<td>19.1</td>
<td>08.8</td>
</tr>
</tbody>
</table>

Table 5: Anthropomorphic Measurements
<table>
<thead>
<tr>
<th>Number</th>
<th>Length</th>
<th>Width</th>
<th>Length</th>
<th>Neck Height</th>
<th>Endpin String</th>
<th>Vibrating Shoulder</th>
<th>Depth/Ribs Bridge</th>
<th>Depth/Ribs Low Bout</th>
<th>Width Low Bout</th>
<th>Depth Stool</th>
<th>Round or Taper of</th>
<th>Flat Back</th>
<th>Upper Bout</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>110.5</td>
<td>51.0</td>
<td>44.5</td>
<td>20.5</td>
<td>105.0</td>
<td>18.0</td>
<td>19.5</td>
<td>68.0</td>
<td>19.7</td>
<td>76.0</td>
<td>Round 17-18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>110.5</td>
<td>51.0</td>
<td>44.5</td>
<td>13.5</td>
<td>105.0</td>
<td>18.0</td>
<td>19.5</td>
<td>68.0</td>
<td>19.7</td>
<td>76.0</td>
<td>Round 17-18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>110.5</td>
<td>51.0</td>
<td>44.5</td>
<td>16.7</td>
<td>105.0</td>
<td>18.0</td>
<td>19.5</td>
<td>68.0</td>
<td>19.7</td>
<td>76.0</td>
<td>Round 17-18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>112</td>
<td>48.0</td>
<td>40.4</td>
<td>19.5</td>
<td>103.0</td>
<td>21.0</td>
<td>21.5</td>
<td>65.0</td>
<td>21.4</td>
<td>67.4</td>
<td>Round None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>109.3</td>
<td>48.0</td>
<td>42.2</td>
<td>28.0</td>
<td>105.0</td>
<td>18.0</td>
<td>21.3</td>
<td>65.2</td>
<td>21.4</td>
<td>74.8</td>
<td>Round 18-21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>108</td>
<td>52.0</td>
<td>45.4</td>
<td>17.0</td>
<td>104.2</td>
<td>18.2</td>
<td>19.7</td>
<td>64.8</td>
<td>20.4</td>
<td>76.0</td>
<td>Flat None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>111.4</td>
<td>49.8</td>
<td>46.0</td>
<td>34.0</td>
<td>106.8</td>
<td>21.4</td>
<td>21.4</td>
<td>65.4</td>
<td>21.4</td>
<td>75.0</td>
<td>Round 17-21.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>111</td>
<td>50.0</td>
<td>43.8</td>
<td>21.0</td>
<td>105.2</td>
<td>18.3</td>
<td>18.8</td>
<td>63.8</td>
<td>20.3</td>
<td>75.8</td>
<td>Round Slight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>111.2</td>
<td>49.4</td>
<td>44.5</td>
<td>21.3</td>
<td>104.0</td>
<td>21.0</td>
<td>21.0</td>
<td>65.4</td>
<td>21.0</td>
<td>77.2</td>
<td>Round 17-21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>110.6</td>
<td>50.0</td>
<td>46.8</td>
<td>25.0</td>
<td>107.0</td>
<td>21.3</td>
<td>21.3</td>
<td>64.0</td>
<td>21.3</td>
<td>76.5</td>
<td>Round 17.5-21.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>111</td>
<td>50.0</td>
<td>45.2</td>
<td>24.8</td>
<td>105.3</td>
<td>20.0</td>
<td>20.0</td>
<td>65.5</td>
<td>20.5</td>
<td>75.3</td>
<td>Round 16-20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>111</td>
<td>54.0</td>
<td>47.5</td>
<td>16.8</td>
<td>108.5</td>
<td>16.0</td>
<td>20.0</td>
<td>64.5</td>
<td>20.0</td>
<td>75.5</td>
<td>Round 16-19.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>111</td>
<td>48.3</td>
<td>45.0</td>
<td>19.8</td>
<td>104.4</td>
<td>21.3</td>
<td>21.3</td>
<td>64.8</td>
<td>21.0</td>
<td>75.2</td>
<td>Round 17-21.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>111</td>
<td>48.0</td>
<td>45.8</td>
<td>21.9</td>
<td>105.0</td>
<td>17.0</td>
<td>21.5</td>
<td>65.4</td>
<td>21.6</td>
<td>75.2</td>
<td>Round 17-21.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>108</td>
<td>53.0</td>
<td>44.5</td>
<td>27.5</td>
<td>106.5</td>
<td>18.0</td>
<td>22.0</td>
<td>64.6</td>
<td>22.2</td>
<td>73.0</td>
<td>Flat 18-22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>119</td>
<td>52.3</td>
<td>48.7</td>
<td>18.3</td>
<td>112.0</td>
<td>20.2</td>
<td>21.5</td>
<td>67.8</td>
<td>22.5</td>
<td>77.0</td>
<td>Round None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>109</td>
<td>53.7</td>
<td>49.4</td>
<td>24.4</td>
<td>109.5</td>
<td>17.5</td>
<td>21.4</td>
<td>67.8</td>
<td>22.0</td>
<td>76.2</td>
<td>Round 17.5-21.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>108</td>
<td>48.4</td>
<td>49.8</td>
<td>13.0</td>
<td>108.0</td>
<td>18.0</td>
<td>18.5</td>
<td>60.8</td>
<td>18.9</td>
<td>67.0</td>
<td>Round 18-18.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>108</td>
<td>52.0</td>
<td>45.4</td>
<td>21.3</td>
<td>104.0</td>
<td>16.1</td>
<td>19.7</td>
<td>64.5</td>
<td>20.5</td>
<td>76.5</td>
<td>Flat 16.1-19.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>108.3</td>
<td>51.9</td>
<td>45.1</td>
<td>25.5</td>
<td>104.3</td>
<td>19.5</td>
<td>19.5</td>
<td>64.8</td>
<td>20.0</td>
<td></td>
<td>Flat 15.8-19.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>110.5</td>
<td>51.0</td>
<td>44.8</td>
<td>18.8</td>
<td>104.2</td>
<td>19.0</td>
<td>21.5</td>
<td>68.4</td>
<td>22.0</td>
<td></td>
<td>Round 19-21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>115.5</td>
<td>48.6</td>
<td>45.9</td>
<td>20.2</td>
<td>104.0</td>
<td>17.2</td>
<td>21.3</td>
<td>64.3</td>
<td>21.3</td>
<td>76.8</td>
<td>Round 17.2-21.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>111.5</td>
<td>53.4</td>
<td>46.9</td>
<td>16.2</td>
<td>104.0</td>
<td>15.4</td>
<td>21.8</td>
<td>63.2</td>
<td>21.8</td>
<td>77.6</td>
<td>Flat 15.4-21.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>110.5</td>
<td>50.7</td>
<td>44.7</td>
<td>25.5</td>
<td>106.5</td>
<td>17.5</td>
<td>21.5</td>
<td>65.0</td>
<td>21.5</td>
<td>75.8</td>
<td>Round 17.5-21.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX D

INTEROBSERVER AGREEMENT
Table 7: Interobserver Agreement

<table>
<thead>
<tr>
<th>Subject</th>
<th>Beam Torso Orientation</th>
<th>Left Arm Orientation</th>
<th>Right Arm Orientation</th>
<th>Head Orientation</th>
<th>Bend at Vertical Coxa Joint Orientation (Observed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>Y</td>
</tr>
<tr>
<td>1</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>4</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>5</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>6</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>7</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>8</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>9</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>10</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>11</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>12</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>13</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>14</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>15</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>16</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>17</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>18</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>19</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>20</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>21</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>22</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>23</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>24</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>
APPENDIX E

SUMMARY OF EVALUATIONS
SUMMARY OF EVALUATIONS

Results By Element

Table 8: I Beam

7 Subjects (29%) did not meet established criteria

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Reason for Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Lean to left shoulder</td>
</tr>
<tr>
<td>8</td>
<td>Not balanced on stool, leans to the right</td>
</tr>
<tr>
<td>9</td>
<td>Right side of pelvis not on stool, uneven shoulders</td>
</tr>
<tr>
<td>11</td>
<td>Rounded shoulders, forward and uneven</td>
</tr>
<tr>
<td>13</td>
<td>Weight on one leg, hips uneven</td>
</tr>
<tr>
<td>19</td>
<td>Right shoulder lower than left</td>
</tr>
<tr>
<td>21</td>
<td>Shoulders not even</td>
</tr>
</tbody>
</table>
Table 9: Vertical Orientation of Torso

19 Subjects (79%) did not meet established criteria.

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Reason for Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>2</td>
<td>Great Rotation, right shoulder forward</td>
</tr>
<tr>
<td>3</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>4</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>6</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>7</td>
<td>Rotation of shoulders to right on shifts</td>
</tr>
<tr>
<td>8</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>9</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>10</td>
<td>Slight Rotation, right shoulder forward</td>
</tr>
<tr>
<td>11</td>
<td>Rotation, right shoulder forward with a rounded upper back</td>
</tr>
<tr>
<td>12</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>16</td>
<td>Slight Rotation, right shoulder forward</td>
</tr>
<tr>
<td>17</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>18</td>
<td>Slight Rotation, right shoulder forward</td>
</tr>
<tr>
<td>19</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>20</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>22</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>23</td>
<td>Rotation, right shoulder forward</td>
</tr>
<tr>
<td>24</td>
<td>Rotation, right shoulder forward</td>
</tr>
</tbody>
</table>
Table 10: Coxa Joint

8 Subjects (33%) did not meet established criteria

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Reason for Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Instrument position prevented movement at Coxa joint</td>
</tr>
<tr>
<td>3</td>
<td>Stretched from back to reach</td>
</tr>
<tr>
<td>7</td>
<td>Instrument position prevented movement at Coxa joint</td>
</tr>
<tr>
<td>9</td>
<td>Instrument position prevented movement at Coxa joint</td>
</tr>
<tr>
<td>11</td>
<td>Rounded back, no movement from the hip</td>
</tr>
<tr>
<td>15</td>
<td>Instrument position prevented movement at Coxa joint</td>
</tr>
<tr>
<td>17</td>
<td>Bent from the upper back</td>
</tr>
<tr>
<td>24</td>
<td>Bent from the upper back</td>
</tr>
</tbody>
</table>
Table 11: Head over Shoulders

18 Subjects (75%) did not meet established criteria

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Reason for Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>2</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>3</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>5</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>6</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>8</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>9</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>10</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>11</td>
<td>Lateral position to right side of body</td>
</tr>
<tr>
<td>12</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>15</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>17</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>18</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>19</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>20</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>22</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>23</td>
<td>Anterior position of the head</td>
</tr>
<tr>
<td>24</td>
<td>Anterior position of the head</td>
</tr>
</tbody>
</table>
Table 12: Left arm Orientation

21 Subjects (88%) did not meet established criteria

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Reason for Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>2</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>4</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>6</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>7</td>
<td>Some Ulnar deviation of the wrist, and Palmer Flexion in thumb position</td>
</tr>
<tr>
<td>8</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>9</td>
<td>Palmer flexion of the wrist</td>
</tr>
<tr>
<td>10</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>11</td>
<td>Tendency for ulnar deviation of the wrist</td>
</tr>
<tr>
<td>12</td>
<td>Palmer Flexion, and ulnar deviation of the wrist</td>
</tr>
<tr>
<td>13</td>
<td>Palmer flexion of the wrist</td>
</tr>
<tr>
<td>14</td>
<td>Ulnar deviation of the wrist in thumb position</td>
</tr>
<tr>
<td>15</td>
<td>Palmer Flexion of wrist in the lower positions, and ulnar deviation in thumb position</td>
</tr>
<tr>
<td>16</td>
<td>Palmer flexion of wrist in thumb position</td>
</tr>
<tr>
<td>17</td>
<td>Palmer flexion of wrist in thumb position</td>
</tr>
<tr>
<td>18</td>
<td>Ulnar deviation of the wrist in thumb position, and radial deviation in lower positions</td>
</tr>
<tr>
<td>19</td>
<td>Ulnar deviation of the wrist in lower positions, and palmer flexion in thumb position</td>
</tr>
<tr>
<td>20</td>
<td>Palmer flexion of wrist in thumb position</td>
</tr>
<tr>
<td>21</td>
<td>Ulnar deviation of the wrist in thumb position, palmer flexion in the lower positions</td>
</tr>
<tr>
<td>22</td>
<td>Palmer flexion and ulnar deviation of the wrists throughout</td>
</tr>
<tr>
<td>24</td>
<td>Ulnar deviation of the wrist in thumb position</td>
</tr>
</tbody>
</table>
Table 13: Right Arm Orientation

21 Subjects (88%) did not meet the established criteria

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Reason for deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>2</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>3</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>4</td>
<td>Radial deviation of the wrist</td>
</tr>
<tr>
<td>6</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>7</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>8</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>9</td>
<td>Ulnar deviation of the wrist and movement from neutral to palmer flexion</td>
</tr>
<tr>
<td>10</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>11</td>
<td>Tendency toward ulnar deviation of the wrist</td>
</tr>
<tr>
<td>12</td>
<td>Ulnar deviation and palmer flexion of the wrist</td>
</tr>
<tr>
<td>14</td>
<td>Palmer flexion of the wrist</td>
</tr>
<tr>
<td>15</td>
<td>Ulnar deviation of the wrist</td>
</tr>
<tr>
<td>16</td>
<td>Palmer flexion of the wrist</td>
</tr>
<tr>
<td>17</td>
<td>Ulnar deviation and palmer flexion of the wrist</td>
</tr>
<tr>
<td>18</td>
<td>Palmer Flexion of the wrist</td>
</tr>
<tr>
<td>19</td>
<td>Palmer flexion of the wrist</td>
</tr>
<tr>
<td>21</td>
<td>Wrist moves between radial and ulnar deviation</td>
</tr>
<tr>
<td>22</td>
<td>Ulnar deviation of the wrist, severe</td>
</tr>
<tr>
<td>23</td>
<td>Wrist moves between ulnar and radial deviation</td>
</tr>
<tr>
<td>24</td>
<td>Ulnar deviation and palmer flexion of the wrist</td>
</tr>
</tbody>
</table>