Domestic chair

Wei-Mien Hsu

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The College of Imaging Arts and Sciences
In Candidacy for the Degree of
MASTER OF FINE ARTS

DOMESTIC CHAIR

By

Wei-Mien Hsu

January 2004
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To My Family
TABLE OF CONTENTS

LIST OF ILLUSTRATIONS ........................................................................................................ iii
LIST OF TABLES ...................................................................................................................... vi

Chapter

1. Introduction .......................................................................................................................... 1

2. What is wrong with sitting? ............................................................................................... 3
   How does sitting cause back pain? ....................................................................................... 6
   What is low back pain? ......................................................................................................... 8

Anatomy ...................................................................................................................................... 9
   Understanding sitting
   Vertebrae
   Pelvis and Sacrum
   Intervertebral discs
   Bone
   Facet joints
   Neural Foramen
   Spinal Cord and Nerve Roots
   Muscles
   Skin

3. Sitting posture and seat design ......................................................................................... 17
   Unsupported Sitting-Upright ............................................................................................... 17
   Unsupported Sitting-Relaxed ............................................................................................... 18
Supported Sitting-Relaxed ................................................................. 19
Supported Sitting-Upright ............................................................... 20
Zero gravity .................................................................................. 20

4. Design process ............................................................................ 24
  Posture study ............................................................................. 24
  Relaxed sitting without leg supported .......................................... 25
  Relaxed sitting with leg supported .............................................. 25
  Zero gravity sitting .................................................................. 26
  Process of prototype .................................................................. 27

   Material
     Fabrics
     Resins

    Mold construction

  Releasing the part from the mold

  Prototype

  Final model

  Target users

  Body Measurements and Human Factors

5. Conclusion .................................................................................. 44

BIBLIOGRAPHY .................................................................................. 46
LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Relative loads</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Spine</td>
<td>9</td>
</tr>
<tr>
<td>3.</td>
<td>Pelvis and Scrum</td>
<td>11</td>
</tr>
<tr>
<td>4.</td>
<td>Intervertebral disc</td>
<td>12</td>
</tr>
<tr>
<td>5.</td>
<td>Joints</td>
<td>13</td>
</tr>
<tr>
<td>6.</td>
<td>Section of the spine</td>
<td>14</td>
</tr>
<tr>
<td>7.</td>
<td>Muscles and Tendon</td>
<td>15</td>
</tr>
<tr>
<td>8.</td>
<td>Skin</td>
<td>15</td>
</tr>
<tr>
<td>9.</td>
<td>Unsupported sitting posture-upright</td>
<td>17</td>
</tr>
<tr>
<td>10.</td>
<td>Unsupported sitting-relaxed</td>
<td>18</td>
</tr>
<tr>
<td>11.</td>
<td>Supported sitting-relaxed</td>
<td>19</td>
</tr>
<tr>
<td>12.</td>
<td>Supported sitting-upright</td>
<td>20</td>
</tr>
<tr>
<td>13.</td>
<td>Underwater body posture</td>
<td>21</td>
</tr>
<tr>
<td>14.</td>
<td>Astronaut under zero gravity</td>
<td>21</td>
</tr>
<tr>
<td>15.</td>
<td>X-rays spinal</td>
<td>22</td>
</tr>
<tr>
<td>16.</td>
<td>Children sitting</td>
<td>23</td>
</tr>
<tr>
<td>17.</td>
<td>Horse riding</td>
<td>23</td>
</tr>
<tr>
<td>18.</td>
<td>Mockup for posture study</td>
<td>24</td>
</tr>
<tr>
<td>19.</td>
<td>Relaxed sitting without appropriate leg supported</td>
<td>25</td>
</tr>
<tr>
<td>20.</td>
<td>Relaxed sitting with leg supported</td>
<td>25</td>
</tr>
</tbody>
</table>
21. Zero gravity sitting ................................................................. 26
22. Bi-directional fiberglass .......................................................... 28
23. Kevlar® Fabric ................................................................. 28
24. Graphite Fabric ................................................................. 28
25. Polyester Molding Resin ....................................................... 29
26. Vinyl Ester Resin ............................................................... 29
27. Epoxy Resin ................................................................. 29
28. Female mold ................................................................. 30
29. Mold sanding ................................................................. 31
30. Draft angle ................................................................. 32
31. Trimmed mold ............................................................... 34
32-1. Release edges ............................................................... 35
32-2. Insert screwdrivers-1 ....................................................... 35
32-3. Insert screwdrivers-2 ....................................................... 35
32-4. Blows with a rubber mallet ................................................ 35
32-5. Part release from mold ..................................................... 36
33. Prototype ................................................................. 36
33-1. Detail of prototype .......................................................... 36
34. Original base ............................................................... 37
35. Final model 1 .............................................................. 38
36. Final model 2 .............................................................. 39
37. Final model 3 .............................................................. 39
38. Final model 4  

39. Size/Fit reference  

40. Size measurement  

41. Model measurement
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The comparison Table</td>
<td>27</td>
</tr>
<tr>
<td>2. Body measurement of male population</td>
<td>42</td>
</tr>
<tr>
<td>3. Body measurement of female population</td>
<td>42</td>
</tr>
</tbody>
</table>
Chapter 1

Introduction

Back pain is extremely common in today's society. In the United States, approximately 90 percent of adults experience back pain at some time in their lives\(^1\) and 50 percent of persons in the working population have back pain every year\(^2\). Acute back pain is the fifth most common reason for all doctor visits and is the second leading cause of absenteeism from work\(^3\). Back injuries cause 100 million lost days of work annually, which is the most costly injury for employers, and the cost is growing. Back pain is more likely to occur between the ages of 30 to 50, which is the most productive period of most peoples' lives. Back pain is a common problem for all types of people, no matter what their job is, and there is no quick fix or total cure for most back problems.

Most episodes of back pain are self-limited, meaning that they will stop no matter what the treatment is. Unfortunately, back pain tends to reoccur. Therefore, it is very important for people with back pain history to always use good body mechanics when they are doing things such as watching television,

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eating, driving, typing, and reading. These daily actives are all related to one thing – “Seating.”

Seating is an issue for those who have a history of back pain. The action of “sitting” looks easy for healthy people, but for back pain sufferers, sitting is a difficult job to do and sitting for a long period is also not comfortable. After an eight hour workday, we spend most of our time at home. However, there is little home furniture that provides the right support for those people when they are suffering from back pain.

This need prompted me to develop a domestic chair that can provide correct body support for people who have back pain problems. The main purpose is to prevent sufferers from further injuring themselves by sitting in their daily life. To understand fully the thinking behind the design of this domestic chair, a cursory understanding of anatomy as well as the cause of back pain is presented.
Chapter 2

What is wrong with sitting?

You may think of sitting as a resting position. Actually, sitting is hard work for your back. It exerts much more strain on your spine than standing, and stresses your lower back muscles as they work to hold you upright. Slouching increases the pressure, and hunching over tenses the neck and upper back muscles. After an hour of sitting, spinal pressure increases significantly. Backache, headache, muscle stiffness and fatigue are common symptoms of prolonged sitting. These problems are directly related to poor posture.

Our body is not designed to sit for extended periods of time. Sitting in a typical slumped posture stretches the ligaments and muscles that extend the back. The stretched position causes the back extension muscles to be chronically active. Standing or lying down puts little pressure on the lower back vertebrae. Sitting correctly more than doubles the pressure to the spine, while sitting in a slumped position increases the pressure four times. In a resting or lying down position, the amount of pressure on the lumbar discs is the least. This is why lying down often helps relieve pain, because it reduces pressure on the discs. When standing, the amount of pressure exerted on the lumbar disc increases to twice
the amount of lying down. Lying down unloads the spine and truly gives your whole body a rest.

Although people could stand just as easily as sit for many activities, there are at least three good reasons why we prefer sitting:

1. Sitting uses about 20% less energy compared to standing to do the same work, so sitting comfortably helps to relieve fatigue.

2. Sitting helps to reduce the strain on our back muscles and on the intervertebral discs of the lumbar spine, providing that we sit back in a supported, reclined posture.

3. Sitting gives us greater postural stability for performing fine manipulative tasks such as eating with a knife, fork, sewing, writing, etc.
Our industrialized society is transforming into an information processing society. Many employees conduct business transactions while sitting. Sitting has become a way of life for many Americans. If you are one of many millions of office workers, sitting is how you spend most of your life. First, there is commuting then working at a desk, then it's home where you sit some more, or talk on the phone while parked in front of a computer or TV screen for a few more hours. Over time, the prolonged pressure and muscle strain can cause disk problems and chronic backache. Seventy percent of American work force now sit on the job\textsuperscript{4}. For computer users, the most frequent complaints are neck and shoulder pain, eyestrain, and back pain.

The act of sitting can place many stresses on the body. The most obvious human factors are the compressive forces experienced by the discs and the sustained static exertions maintained by the back muscles. In fact, the more we sit, the higher our risk of herniated discs and other troubles\textsuperscript{5}. Continuous sitting has disadvantages and potential long-term consequences.

\textsuperscript{4} Herman Miller Research Corporation, Internal documents (1989).
\textsuperscript{5} Eklund J. "Industrial seating and spinal loading," Linkoping, Sweden: University of Technology (1986).
How does sitting cause back pain?

Even with today's technology, the exact reason or cause of back pain problems can be found in very few people. Most times, the symptoms are blamed on poor muscle tone in the back, muscle tension or spasm, back sprains, ligament or muscle tears, joint problems. Sometimes nerves from the spinal cord can be irritated by slipped discs causing buttock or leg pain. This may also cause numbness, tingling, or weakness in the legs.

Sitting is one of the most frequent causes of back pain. The human body is not designed to sit for extended periods of time. We are designed to be upright, walking, running and on the move. Sitting and standing still for extended periods are detrimental to our health. Sitting in a typical slumped posture stretches the ligaments and muscles that extend the back. Over time, this weakens them so they are less able to respond when called to action. The stretched position causes the back muscles to decrease circulation to the working muscles. Alterations in circulation can cause pain. The typical response to pain is for the muscles involved to spasm against the pain.

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6 Be fit while you sit. Parks & Recreation, Aug2000, Vol. 35 Issue 8, p36, 1p
7 Kevin Logue, "The Science of Sitting," Professional Ergonomic Solutions
When we sit, we transfer the entire weight of the upper body to the buttocks and the thighs. The skin and muscles flatten out and the bony structure of the buttocks pushes into the soft tissue. The fat and muscle tissue that are in contact with the buttocks slowly move out and away from the bone leaving the skin as the last barrier before the chair. The pressure is increased because there is a reduced amount of tissue to disperse the weight. The remaining tissue, sustains pressure high enough to reduce blood flow. The longer you sit, the more the tissue moves away from the bony structures, causing increasing pressure on the remaining tissue.

Improper seating may not only cause back pain but also neck pain, eye strain, abdominal pain, leg pain and repetitive motion injuries (RMI). Improper seating is very difficult to identify as the source of those problems because it works insidiously. It may take months; even years to prove that improper seating is the source of the problem.

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Kevin Logue, "The Science of Sitting," Professional Ergonomic Solutions
What is low back pain?

Low back pain can be divided into two main types:

- Mechanical type pain.
- Compressive type pain

"Mechanical pain is often called back strain because it is linked with the movement, or "the mechanics" of the spine. This type of pain occurs when injury to the spine's discs, facet joints, ligaments, or muscles results in inflammation."9 The more you use the back, the more it hurts. A common cause of mechanical pain is disk degeneration. Discs do not have nerves, so excess pressure on the discs is not painful until the disc presses on nearby nerves. This is one reason back pain can begin without warning.

"Compressive pain is a result of pressure or irritation on the spinal cord, or nerves that leave the spine."10 A common cause of compressive pain is a herniated disk. If the disk is herniated and pushes into the spinal canal, it can cause pain by pressing the nerve. Usually it will cause muscle weakness, numbness, and pain.

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10 Ibid.
Anatomy

Understanding sitting

Sitting is a mechanical interaction between five important body elements: vertebrae, pelvis, discs between the vertebrae, muscles, and skin. The act of sitting is controlled by a complex interaction between the skeletal system and the soft-tissue structures.

Vertebrae

[Diagram of vertebrae]

The adult vertebral column consists of 26 bones, and is the most important structure in the body when sitting. The vertebrae are connected by ligaments and separated by intervertebral discs. Each vertebra supports the next one at three points called facet joints. The spinal column is grouped as follows:

- 7 cervical vertebrae in the neck
• **12 thoracic** vertebrae that articulate with the 12 pairs of ribs
• **5 lumbar** vertebrae of the lower back
• **1 sacrum** which is actually a fusion of 5 sacral vertebrae (fusion occurs from late teens to early 20's)
• **1 coccyx** or "tailbone" which is a fusion of 4 coccygeal vertebrae

Between each vertebra is a soft, gel-like cushion called an intervertebral disc. It helps to absorb pressure and keeps the bones from rubbing against each other. Each vertebra is held to the others by groups of ligaments. Ligaments connect bones to bones; tendons connect muscles to bones.

Each vertebra has a hole in the center, so they form a hollow tube that holds and protects the entire spinal cord and nerve roots. The spinal cord is a large collection of nerve tissue that carries messages from your brain to the rest of your body.
**Pelvis and Sacrum**

![Diagram of Pelvis and Sacrum]

The pelvis is the lower part of the trunk of the body which is composed of the right and left hip bones (the innominate bone, made up of the ilium, ischium, and pubis), the sacrum and the coccyx; it protects the lower abdominal organs and provides for the attachment of the legs. The pelvis is usually lighter and wider in females than in males\(^{11}\).

The base of the spine is called the sacrum which is formed by fusion of 5 sacral vertebrae. Its base connects with the last lumber vertebra, its apex with coccyx. The pelvis can tip forward or backward, which is changing the curvature of the lumbar region\(^{12}\).

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\(^{11}\) Mikel A Rothenberg, "Pelvis," M.D, Dictionary of Medical terms for the Nonmedical Person, 2000

Intervertebral discs

"Intervertebral discs are composed of an annulus fibrosus and a nucleus pulposus. Each disc has a strong fibrous outer casing - called the annulus fibrosus - and a soft, squishy, jelly-like interior called the nucleus pulposus - which is reinforced with strands of fibre."\(^\text{13}\)

The annulus fibrosus is the disc's outer layer and the strongest area of the disc. It helps keeping the disc's center intact. The nucleus is made up of tissue that has high water content. When we are born, the disc is comprised of about 80% water. As we age, the water content decreases and the disc become thinner. As a result you will get shorter.

\(^{13}\) Mikel A Rothenberg, "Intervertebral discs," M.D, Dictionary of Medical terms for the Nonmedical Person, 2000
Bone

Bones have four main shapes: flat, short, long, and irregular.\textsuperscript{14} All the bones together make up the skeleton. The skeleton, muscles, tendons, ligaments, and other components of joints form the musculoskeletal system.\textsuperscript{15} Bones serve as shields to protect delicate internal organs. They also provide shape and structure to the body.

Facet joints

Two vertebra meet together form the facet joints. They extend and overlap each other to form a joint between the neighboring vertebrae. The facet joints are as known as the "body knob". The facet joints limit the angle of your spine

\textsuperscript{14} Mikel A Rothenberg, "Bone," M.D, Dictionary of Medical terms for the Nonmedical Person, 2000
\textsuperscript{15} Mikel A Rothenberg, "Musculoskeletal system," M.D, Dictionary of Medical terms for the Nonmedical Person, 2000
moving. Without the facet joints, you would not have flexibility in your spine, and you could only move in very straight and stiff motions.

**Neural Foramen**

The neural foramen is the opening place that the nerve roots exit the spine and travel to the rest of the body. There are two neural foramen located between each side of vertebrae. The foramen creates a passageway for the nerves that carry signals between the spinal cord and the rest of the body.

**Spinal Cord and Nerve Roots**

![Spinal cord diagram](https://www.spineuniverse.com)

The spinal cord extends from the base of the brain through the vertebral canal to the upper part of lumbar vertebra. It is the major part of the central nervous system. There are 31 pairs of nerves connected to the spinal cord. They form the nerve roots that travel through "neural foramen." Each nerve root connects to specific part of the body.
Muscles

Muscles are bundles of fibers that can contract. Back muscles stabilize your spine. There are many small muscles in the back. Each muscle controls some part of the total movement between the vertebrae and skeleton. If muscles become tight or weak, back pain may occur.

Skin

Skin protects the body from injury, maintains body temperature, and provides a shield from the sun. Skin has a very rich blood supply that delivers oxygen to all layers. If that blood supply is cut off for more than 2 or 3 hours, the skin will die.
A common cause of reduced blood flow to the skin is pressure. Normal movement shifts pressure, so that the blood supply is not stopped for any prolonged period. Too much external pressure for long period time can reduce the blood flow and cause other kinds of damage.
Chapter 3
Sitting posture and Seat design

Each person has their own posture relating to their physiology and the chair they use. Even so there are some characteristics associated with our postures that are the same.

Unsupported Sitting-Upright

The angle between the torso and the legs is insufficiently large to enable the user to assume a lumbar curve. Further, you must exert force forward to form a lumber curve. This destabilizes posture, increasing huge loads acting on the ligaments. This can cause the ligaments to deform, weakening the structure of

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the joints and increasing loads on the spine. It is obvious that this posture takes more "muscle work" than other sitting postures.

Unsupported Sitting-Relaxed

![Fig. 10 Unsupported sitting-relaxed](Source: Corlett and Eklund, 1984)

This is a very typical posture for many people. All chairs have backrests, but are you using it? In a typical office, many employees work all day without using their backrests. It is very difficult to sit upright and unsupported for long periods of time. Most people would rather slump than use the muscles to sit upright. This position is uncomfortable and fatiguing. When this happens they are reversing the lumbar curve. Posture support shifts from the muscles to the ligaments that support the spine. The ligaments deform, and there is an increased risk of damage to the spine and joints.

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Reclined postures have advantages. They reduce loads on the spine and muscle work. Back supports help stabilize posture by relieving the amount of effort used to fight gravity. But leaning back also has disadvantages. This reclined posture opens the torso-thigh angle and tilts the pelvis\textsuperscript{18}. Many intensive computer users slump against their backrest, locking in their pelvis and causing them to lose their lumbar curve. "This will lead to increased pressure on and within the discs, both from forces arising from the stretched muscles and ligaments and the increased wedging at the anterior edges of the disks"\textsuperscript{19}. There are also functional limitations associated with reclining. It is hard to read the screen and reach the mouse when you lean back. However, the problem is not just reclining itself so much as reclining in a static posture.

\textsuperscript{18} Grandjean, Ergonomics in Computerized Offices, pp.145, 126.
Supported Sitting-Upright

"The lumbar supports on backrests helped promote lordosis compared to straight backrests while performing tasks, but not during passive sitting and reading."¹²⁰ Lumbar supports are only effective if they are properly designed and adjusted for the user. The users must also learn to sit "properly" in the chair, so they can avoid slumping. Lumbar supports often stabilize postures, reduce muscle loads, and help promote comfort. In some cases, they may promote a lumbar curve.

Zero gravity

While researchers keep searching for a "better" way to sit, a new "correct" seated posture is being identified. This posture was first observed in astronauts and underwater workers. What seemed to be a natural resting posture for humans in low gravity was characterized by a slight bending of the knees, a

open angle between the torso and the thigh (128-135 degrees), a restoration of the lower-back curve found while standing, and upward floating arms. Both the knees and elbows were held rather widely apart.\textsuperscript{21}

![Fig.13 Underwater body posture](source: NASA)

![Fig.14 astronaut under zero gravity](source: NASA)

Independent studies also reveal that by approximating this natural body position, you can relieve tension in key muscle groups (including muscles in the low back,

neck, shoulder, and forearm) by as much as 75%\textsuperscript{22}. This reduction in muscle tension translates into safer, more comfortable seating.

"J.J. Keegan, an American Orthopedic surgeon, made in 1953 a series of x-rays of people lying on their sides which documented the large movements that took place in the lumbar section of the spinal column as the position changed from standing (a) to right angle sitting (c) and bent-over positions (d). (b) is the natural resting position, as when you lie on your side while sleeping. The lumbar curve is retained and the muscles are relaxed and well-balanced. (Fig.15) A sitting posture that approaches the natural resting position (b) is a more suitable position and allows the spine to carry the body weight in a more comfortable way. This is "Balanced Seating"."\textsuperscript{23}

A seat that tilts forward encourages this natural posture. Opposing muscle groups are balanced and the lumbar curve is preserved producing balanced seating. During balanced seating, the back is straight, the joint angles are open and the muscles are relaxed. This position provides greater mobility and relieves pressure on the lungs and stomach.

\textsuperscript{22} Chaffin DB and Andersson GBJ, "On myoelectric back muscle activity and lumbar disc pressure in sitting posture" doctoral dissertation, University of Gothenburg, New York: John Wiley & Sons (1991)

We can observe this action in our surrounding. Children in school often tilt forward on the legs of their chair to relieve backpressure. By tilting their chairs forward, they avoid bending their backs. It allows the front and back muscles to relax. While riding a horse, the rider sits upright. She retains lumbar curve because the thighs are sloping downwards. This is exactly the same position as the neutral resting position, or sitting on a chair seat that tilts forward. This means the rider is in the perfect position for “Balanced Seating”²⁴

Chapter 4
Design process

Posture study

To better understand sitting postures, a study model was made. Using oriented strand board (OSB) and steel tubes to make a simple mockup for studying different sitting postures. After the testing, there were three mockups made for advanced testing.
Relaxed sitting with lumbar supported

![Image](Fig.19 Relaxed sitting without appropriate leg supported)

This posture is a typical posture for office workers. For the last century, work chairs in school, factories and offices have been designed for sitting upright. An open angle between the torso and the thigh is too wide. It is hard to reach the desk when you lean back. It is impossible to sit this way for long. It results in fatigue, discomfort, and poor posture.

Relaxed sitting with leg supported

![Image](Fig.20 Relaxed sitting with leg supported)

This is a comfortable sitting position with the leg and lower back appropriately supported. The open angle between the torso and the thigh is 90-110 degrees.
“Recently, it was widely believed that people sat with a 90-degree bending of the hip joint while preserving lordosis of the back.”\textsuperscript{25} This posture looks very nice, but it cannot be maintained for a long time.

**Zero gravity sitting**

![Figure 21. Zero gravity sitting](image)

This is the most comfortable sitting over all. It realigns the sitter’s center of gravity. In this posture, the sitter is almost laying down. This not only puts the minimum pressure on the spine, but also the torso and the thigh are open between 128-135 degrees. The posture matches to the “zero gravity posture” and achieves “balance seating”. It can eliminate lower back strain and ultimately prevent chronic back pain.

Process of Prototype

For further feasibility testing of zero gravity sitting, a prototype was made.

Carbon fiber was selected for the chair shell. Carbon fiber is not only strong enough to hold an adult's weight\textsuperscript{26}, but provides the chair the ability to flex, while maintaining a thin look. Cushions are provided to support different parts of the body such as neck, lumbar, hip, thigh, and leg. The stainless steel base gives the chair stability and support. To understand how to fabricate a carbon fiber chair, a cursory understanding of the process is presented.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|}
\hline
\hline
Fabric Specifications & Style 7781, 9 oz., E-glass & 5.6 oz., 3K Graphite & 5 oz. Kevlar\textregistered \\
\hline
Laminate Construction & 10 Plies Glass & 10 Plies Carbon & 10 Plies Kevlar\textregistered \\
\hline
Laminate/Resin Content & 50% Resin / 50% Glass & 56% Graphite / 44% Resin & 51% Kevlar\textregistered / 49% Resin \\
\hline
Elongation @ Break % & 1.98\% & 0.91\% & 1.31\% \\
\hline
Tensile Strength, PSI & 45,870 PSI & 75,640 PSI & 45,400 PSI \\
\hline
Tensile Modulus, PSI & 1,520,000 PSI & 8,170,000 PSI & 3,770,000 PSI \\
\hline
Flexural Strength, PSI & 66,667 PSI & 96,541 PSI & 34,524 PSI \\
\hline
Flexural Modulus, PSI & 3,050,000 PSI & 6,480,000 PSI & 2,500,000 PSI \\
\hline
\end{tabular}
\caption{The Comparison Table}
\end{table}

Source: www.carb.com
Material

Fabrics

There are many reinforcing fabrics available that are used with the resins. The three types of reinforcing fabrics most commonly used are fiberglass, Kevlar® and carbon fiber (graphite). Each possesses different qualities and advantages. All three are usually available in tows or rovings, veil mats and woven fabrics. Additionally, fiberglass is available as a chopped strand mat, which consists of short, randomly oriented fibers held together by a binder.

In this project, carbon fiber was chosen for chair shell. Even though carbon fibers is expensive, it offers exceptionally high strength and stiffness, in combination with extreme lightweight.
The three main types of room-temperature-curing resins used in composite fabrication are polyester, vinyl ester and epoxy resins. Polyester resin is a general-purpose resin suitable for a wide variety of applications. Vinyl ester resin possesses qualities that fall between polyester and epoxy resins.

Epoxy resins are not as forgiving in their measurement as polyester resins\textsuperscript{27}, but epoxies provide a greater strength and dimensional stability. Epoxy hardener rations can’t be varied, and adequate temperatures (at least 70 degrees F) must be maintained during the curing process. Epoxy resin systems cost more than polyester resins. Epoxy resins are also highly recommended for use with Kevlar\textregistered and carbon fiber.

Mold Construction

Male and female molds are two fundamental types of forms, but they yield significantly different finished parts. The least time consuming and cheapest method is the male or positive mold. This is a form that mimics the final shape of the part, but the part is fabricated over its outer surface. It is true that this type of mold is quicker to construct, but each part produced will have a rough outer texture which requires laborious finishing.

Female or cavity molds are generally more costly but finishing time is significantly reduced because every part emerges with a smooth outer surface. Female molds also lend themselves to use with core materials because the outer skin is always smooth regardless of how inconsistent the core is inside the part.
The surface of the female mold must be finished at least as well as the desired surface on the part to be produced.

Before beginning construction of the mold, a release agent must be applied to the mold. This is the most important step in the process, because if the release agent fails to perform, the mold can't be removed without damaging the part and the mold. A little extra effort at this point is better than hours spent trying to correct damage to the part and mold. The release agent can be a combinatory of parting wax or PVA.

When using wax, apply four coats, waiting one hour between the second and third coats. After the final wax coat has been buffed, spray three thin mist coats
of PVA and allow it to dry for 30-45 minutes. Be sure to apply the release agent to the surface of any flanges and dams.

How you intend to release the mold and part will also impact the design and construction. The first consideration is the draft angle of the mold. This is the angle of the sides of the mold compared to its base. A mold with zero draft has flat sides perpendicular to the bottom. On a mold with positive draft, the sides are wider at the top than they are at the base. Parts will easily pop out of a mold with positive draft. The sides of a mold with negative draft are tighter at the top than at the bottom. For obvious reasons, parts are impossible to remove from a mold with negative draft.

Once these steps have been completed, it is time to begin applying the surface coat. After mixing the proper amount of catalyst and resin, you’re ready to brush the surface coat. Once you start brushing, keep the material flowing; don’t start and stop at the end of each pass like brushing paint on a wall. Do not allow any initial pass to stack-up before adding the next layer.
Once the surface coat has been applied, it's critical to stabilize it with the first layer of carbon fiber within 1.5 to 5 hours. This will help prevent the surface coat from shrinking or lifting off the surface of the mold. The first layer of carbon fiber is also the most critical layer in the mold to lay down without trapping air bubbles. All air pockets directly beneath the surface coat are prone to cracking. With the stabilizing layer in place, the mold could sit in that condition for days before being completed.

The flange areas will need some strips cut to the proper width to butt into the corner of the parting dam to exclude air. However, this is about the only area where they are needed. Pre-cut many reinforcement strips so 2-3 layers can be added at a time before the resin starts to gel.

Using a brush, pre-wet the surface with properly catalyzed resin, and then place the carbon fiber on the mold. The reinforcement will soak up much of the resin. Begin by butting pre-cut strips into the angles where the dam meets the mold. Then apply frayed patches on the main surface overlapping nicely onto the flange. Roll the air out of the laminate at least every other layer. Once all of the layers are in place and have properly cured, use clean rags to wipe away any excess resin that might remain on the surface.
Extra support structures need to be added. Make paper templates of the mold contour where the panel is to attach. Cut the wood to shape so it fits well against the mold. Use the resin and reinforcement to bond it to the back of the mold. Join all other similar pieces to the mold in the same way. Once cured, this will add even greater rigidity to the mold.

![Fig.31 Trimmed mold](image)

When all the portions are complete and cured, it is time to trim the mold. Trimming is actually best achieved with a saw. With the perimeter entirely trimmed, construction is complete.
It is time for releasing the part from the mold! Release wedges can be used to help coax the part off the mold. Insert the screwdrivers carefully around the edges of the mold and gently tap them into place, progressing evenly around the edges. Slowly, the two should separate. If problems still persist, light blows with a rubber mallet can send vibrations through the mold causing separation. Heavy pounding can actually fracture the mold itself.
Fig. 32-5 Part release from mold

Prototype

Fig. 33 Prototype

Fig. 33-1 Detail of prototype
This furniture is designed to accommodate the natural resting position. After testing the prototype, it is comfortable to sit on. Sitters easily achieve “Balanced seating”. They can hold that position for longer than any other posture. But still, there are some points that need to be changed.

1. Simplify the base design

After analyzing the prototype, the original base design is too complicated. All components of the base are separated. This assembly also makes the base unstable. It was difficult for the users to assemble so many components at the same time. It will slow down the manufacturing process. The front/rear stretchers are combined to the legs. The screw pads are combined to the curved slat. These changes will increase not only the stability of the base, but also decrease the assembly time.
2. Color design

The black and white color of the chair gives the chair a modern and elegant look. After long term use, the white leather tends to get dirty. The users might want to replace the cover. It will be at an extra cost to consumers and manufacturer. By changing the color, the leather can last longer than white leather.

3. Seat cushions design

The smooth plane form of the cushions provides a more consistent image of simplicity, cleanliness, and modernity. They are the final element to compose the domestic chair.

**Final model**

After modifying the prototype, a final model was presented.

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Fig. 36 Final model 2

Fig. 37 Final model 3
Target users

The domestic chair is the prefect addition for the home and office room. It affords the most comfortable body position for taking a short nap or resting.

"Evidence is mounting that sleep - even a nap - appears to enhance information processing and learning. New experiments by NIMH grantee Alan Hobson, M.D., Robert Stickgold, Ph.D., and colleagues at Harvard University show that a midday snooze reverses information overload and that a 20 percent overnight improvement in learning a motor skill is largely traceable to a late stage of sleep that some early risers might be missing. Overall, their studies suggest that the brain uses a night's sleep to consolidate the memories of habits, actions and skills learned during the day."29

Body Measurements and Human Factors

Because this product is designed to fit most people, its size is divided into 3 major groups which are small, medium, and large. Users can choose what size they desire by using this diagram. Table 1 and 2 show the data of body measurement. By using the data, the size of chair can be determined. Fig.40 shows the detail measurement of 3 kinds of chair.

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Fig.39 Size/Fit reference

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30 Henry Dreyfuss Associates, "The measure of Man & Woman", 2002
<table>
<thead>
<tr>
<th></th>
<th>99 Percentile Man</th>
<th>50 Percentile Man</th>
<th>1 Percentile Man</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head to Hip joint</td>
<td>35.5&quot;, 902mm</td>
<td>32.6&quot;, 828mm</td>
<td>30.1&quot;, 765mm</td>
</tr>
<tr>
<td>Hip joint to Knee</td>
<td>18.4&quot;, 467mm</td>
<td>16.7&quot;, 424mm</td>
<td>15.2&quot;, 386mm</td>
</tr>
<tr>
<td>Knee to Ankle joint</td>
<td>18&quot;, 457mm</td>
<td>16.6&quot;, 422mm</td>
<td>14.7&quot;, 373mm</td>
</tr>
<tr>
<td>Weight</td>
<td>244 LB, 111.2 KG</td>
<td>172 LB, 78.4 KG</td>
<td>100.3 LB, 45.6 KG</td>
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</tbody>
</table>

Table 2. Body measurement of male population

<table>
<thead>
<tr>
<th></th>
<th>99 Percentile Woman</th>
<th>50 Percentile Woman</th>
<th>1 Percentile Woman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head to Hip joint</td>
<td>33.2&quot;, 844mm</td>
<td>30.6&quot;, 777mm</td>
<td>28.5&quot;, 423mm</td>
</tr>
<tr>
<td>Hip joint to Knee</td>
<td>16.9&quot;, 429mm</td>
<td>15.4&quot;, 391mm</td>
<td>13.8&quot;, 351mm</td>
</tr>
<tr>
<td>Knee to Ankle joint</td>
<td>16.4&quot;, 417mm</td>
<td>15.1&quot;, 384mm</td>
<td>13.3&quot;, 338mm</td>
</tr>
<tr>
<td>Weight</td>
<td>217.6 LB, 98.9 KG</td>
<td>137.5 LB, 62.5 KG</td>
<td>93 LB, 42.2 KG</td>
</tr>
</tbody>
</table>

Table 3. Body measurement of female population

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31 Alvin R. Tillry, "The Measure of Man & Woman", {John Wiley & Sons, Inc., 2002}
32 Ibid.
33 Ibid.

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Chapter 5

Conclusion

The design of a comfortable chair for people has fascinated designers and human factors researchers for many years. Industry has produced many examples of seating for people, and "human factors" work on the study of appropriate seating dynamics has gone on for a long time. Technology relating to appropriate long-duration seating has developed considerably in the past ten years.

However, the industry has not focused much on how back pain sufferers sit in their daily life. After clearly defining the problem and studying the relevant human factors and medical articles, I set out to design a chair for back pain sufferers. This thesis focuses specifically on an appropriate lounge seating solution and the issues related to back pain sufferers sitting for long periods of time. After researching sitting postures, the form of the chair was designed to echo the “zero gravity sitting” posture. It greatly enhances comfort when sufferers occupy seating for long periods of time and offers greater chair variability to accommodate a wider range of adult body dimensions.

From the design process of the lounge chair, I have been challenged when dealing with the form of the chair, composite materials, and mold making. It has been good practice to learn how to make the form of the base and chair
concordant, how to use carbon fiber, and fabricate a mold. I am very glad that I have the chance to focus on the needs of back pain sufferers. This has been a very valuable experience to me and it will help me in my future career. Also, it is important to understand that there is a distinction between the seating behaviors of back pain sufferers and of healthy adults.

The lounge chair plays an important role of our daily life, and its role in supporting comfort and positive behavior should not be underestimated. It is necessary for industry to understand that it is equally important to design home furniture and office furniture for the improvement of body posture and health.
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