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"Customized Bikes"

BUILDING A CYCLIST'S COMFORT GUIDE

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by

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ABSTRACT

This report, prepared for the Danish Cyclists' Federation, describes the research and web development of "A Cyclist's Comfort Guide" (www.dcf.dk/comfort/guide.htm), a web-reference for individuals with non-debilitating medical conditions that impair their ability to use a bicycle as a form a basic transportation. Using extensive background research, interviews, and a focus group, the Comfort Guide was systematically designed to inform users of a variety of bicycle parts and accessories capable of improving their bicycle-rider system.

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EXECUTIVE SUMMARY

On any given morning in Copenhagen, Denmark, the streets are filled with people making their way to work or school; one-third of those daily trips are made by bicycle. That figure is similarly impressive throughout the country, though the capital city has the highest number of commuter cyclists. Unlike in the United States, where riding a bicycle is relegated almost exclusively to the sports and recreation arena, cycling is a primary or only form of transportation for many in Denmark. Tragically, many Danes find it difficult to use their bicycles because of one or more medical conditions that cause them discomfort while cycling. There are thousands of these medical conditions, some of which prevent cycling altogether. The exact number of affected persons is impossible to guage because of the ambiguity of the problem – many people with difficulties such as back or neck pain never seek medical help. However, an idea of the magnitude of the problem can be grasped by looking at the 800,000 Danes suffering from some form of arthritis, one of the principal causes of cycling discomfort. For those with arthritis and countless others with a multitude of medical conditions, this threat to their mobility and independence is very real.

More than a decade ago, an occupational therapist named Kirsten Thorhauge realized this threat and began a project at the RevalideringsCentret, a rehabilitation and adaptive technology center in Herning, Denmark, to modify bicycles for people with conditions restricting cycling ability. The goal of her project was to use commonly available bicycle components to construct custom bicycles that are comfortable to ride, without making them stand out among the standard commuter bicycles seen by the thousands on Danish

streets. In 2002, Thorhauge contacted the Dansk Cyklist Forbund (DCF), the Danish Cyclists' Federation, with a request for further research on this topic. The DCF then requested a team from Worcester Polytechnic Institute. The goal of our project team, then, was to expand upon Thorhauge's research and create a resource for afflicted persons to use to modify their bicycles, thus maintaining, and often improving, their lifestyles. That resource is "A Cyclist's Comfort Guide," a web-based manual for bicycle modification.

While in Worcester, our team laid the groundwork for the future Comfort Guide by conducting extensive background research into a variety of topics. Bicycle use in Denmark and the U.S. was compared to gain a better understanding of the need for this project; bicycle design and cycling biomechanics were carefully reviewed in order to understand how the bicycle and rider interact, the aptly dubbed "bicycle-rider system"; and more than 25 different medical conditions were investigated to establish a clear picture of the many ways a person's cycling might be adversely affected. Additional research on website design was conducted while in Copenhagen.

One of the first and most critical tasks for our team upon arrival in Denmark was to confer with the DCF and focus the scope of our project. Researching more than two-dozen conditions and their associated symptoms was unfeasible for the amount of time we had. After consulting our background research and speaking to Thorhauge and the DCF, we concluded that a better way to approach the problem was to attack the symptoms of the conditions rather than the conditions themselves. This was possible

because, while there are thousands of conditions that could potentially affect a person's cycling abilities, many of the symptoms associated with those conditions are similar. In fact, upon careful investigation, three symptoms were identified as causing the majority of cycling difficulties: pain, reduced range of motion and reduced strength. Each of these symptoms could potentially affect any of fourteen different locations on the body: three muscle groups, eight muscle/joint systems, and three sections of the spinal column (Please see Figure A).

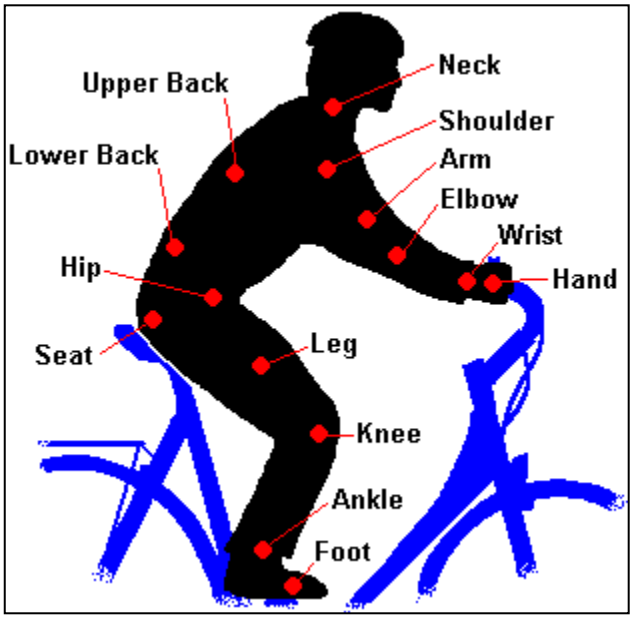

Figure A – Symptom location menu on Comfort Guide Homepage

The reasoning behind this approach was that nearly anyone, regardless of condition, would be able to identify the location of their symptom and find potential solutions to their cycling difficulty. Using this logic and the background research we conducted on medical conditions and cycling biomechanics, we then began developing solutions for each symptom at each location, more than ninety in all. These solutions were comprised of a variety of bicycle modifications and components, from the most mundane: an ergonomic bell; to the incredibly complex: a full suspension bicycle frame.

The second part of our task was to provide an instrument to distribute the information to those who need it, hence "A Cyclist's Comfort Guide." We conducted a simple cost-

benefit analysis with the DCF and decided that a website was the best method of putting the information in the hands of the greatest number of people. From there, we began developing the website's navigation scheme structure, page design, page layout, and graphics. Once a basic version of the website was completed, a focus group was run to evaluate the appearance and flow of the Comfort Guide, as well as the accessibility of the information. The website was then altered to reflect the suggestions of our focus group subjects. The bicycle modification lists resulting from our research were then inputted. As a result of this website development approach, the final version of our website has a simple and intuitive navigational structure:

- The home page includes a diagram of a cyclist with fourteen locations highlighted (Please see Figure A). A user selects the location of their symptom.
- The next screen then gives them a choice of one to three different symptoms. The user selects the symptom that affects them.
- Next, a large chart appears with a list of between two and fifteen bicycle modifications explaining how that modification might help them. The user selects the modification of their choice.
- Finally, a screen appears informing the user where that particular bicycle component or modification can be viewed online. Suggestions are included regarding the purchase of bicycle components.

Upon arrival in Denmark, the DCF made it clear that they would be responsible for building public awareness of our project after our departure. With that in mind, our

recommendations for an advertising campaign provide suggestions that will increase the exposure of the Comfort Guide. These suggestions include communication with other European Cyclist Federations as well as promotional campaigns and magazine articles within Denmark. An agreement between the DCF and the Cykelhandlernes Centralforening (Danish Bicycle Dealers Association) in which shops pledge to use "A Cyclist's Comfort Guide" to help people who come into their shops complaining of cycling difficulty is also suggested. Also among our recommendations is the need to translate "A Cyclist's Comfort Guide" into Danish, which is planned for completion in the summer of 2003 by a language student from the University of Copenhagen. Other translation suggestions include German and Dutch, as Germany and the Netherlands are the two largest manufacturers of comfort bicycles and components in the world.

When we began this project, it was clear that addressing every relevant condition and symptom would be unfeasible. With this in mind, we focused the scope to a feasible point in accordance to the time available to us and included recommendations for future work. It is our hope that "A Cyclist's Comfort Guide" becomes a foundation for future additions that will make cycling accessible to everyone.

AUTHORSHIP

This IQP report was a group effort. Each member of our team contributed their skills in unique ways, but it is impossible to specifically indicate which chapter or section was written by whom. Thus, we all take part of the credit for writing each section. Without this cooperation, neither ”A Cyclist’s Comfort Guide” nor this report would have been possible.

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1.0 INTRODUCTION

In Copenhagen, the capital of Denmark, one third of all citizens cycle to school or work every day, making bicycles an integral part of the Danish transportation structure. Cycling is truly part of the Danish culture. The Dansk Cyklist Forbund (Danish Cyclists' Federation), a non-governmental organization for Danish cyclists, is concerned with the well-being of all cyclists in Denmark, especially utilitarian cyclists. It is worth noting that while organizations like USA Cycling exist in the United States for cycling sport enthusiasts, in Denmark the Danish Cyclists' Federation (DCF) represents the interests of the everyday cyclist. Striving to make cycling a more prevalent, respected and useful form of transportation, the DCF works with the government and other non-governmental organizations, like the European Cyclists' Federation, to achieve those goals. An example of this is the "Bike to Work" and "Bike to School" campaigns the DCF coordinates every spring. According to Pedersen (2003), in 2002 approximately 100,000 individuals pledged to bike to work while 64,000 children pledged to bike to school.

One of the goals of the modern technological advancement is to level the playing field for people with differing physical abilities. In transportation, cars "equalize" people to a certain extent. Once motorists are in their vehicle, they are encapsulated in a different environment; their physical capabilities while on the road are almost secondary to those of their car. This is not true for cyclists. Cycling need not be strenuous for the able-bodied, but for people with limited joint motion, reduced muscular strength, or muscle and joint pain, cycling can be difficult and aggravating. For those who utilize cycling as their primary form of transportation, being physically unable to cycle is more than an

annoyance; it is an impediment to their mobility and autonomy. Ensuring that all people can cycle allows for greater independence and quality of life for everyone.

The range of conditions hindering cycling is extensive. Conditions as varied as whiplash, arthritis, and post polio syndrome can make cycling either too painful or too physically demanding. The goal of this project was to help cyclists minimize the adverse effects that cycling had on their physical condition. This help encompasses a wide-range of bicycle component modifications, bicycle accessories, and bicycle adjustments compiled into an online document, "A Cyclist's Comfort Guide". The project itself consisted of three overlapping phases:

- Determination of conditions affecting cycling and associated symptoms, contained largely in the "Background" section
- Development of modifications to alleviate symptoms, located in "Building A Cyclist's Comfort Guide: Foundations"
- Creation, publication and testing of the Comfort Guide, delineated in "Building A Cyclist's Comfort Guide: Structure."

This project will provide Danes with conditions that impede their cycling abilities with the knowledge to regain the mobility they require, while also allowing them to participate in what can truly be considered a national past time.

2.0 BACKGROUND

When a bicycle rider sustains injury or suffers from chronic pain, bicycling can become difficult. For recreational cyclists, this usually results in a decrease in the amount of time spent on a saddle, and could potentially lead to the discontinuation of cycling altogether. For utilitarian cyclists, however, the discomfort that cycling causes by aggravating their conditions is a discomfort that they are forced to bear. In this section, we review research in a number of domains that bear on finding practical solutions to cycling while suffering from common medical conditions. The background is organized as follows:

Bicycle culture

The Bicycle-Rider system

Medical conditions affecting cycling ability

The biomechanics of cycling

2.1 BICYCLE CULTURE IN THE U.S. AND DENMARK

In the United States, bicycling is largely a recreational pastime. It is a sport that presents challenges ranging from terrain and duration to speed and bicycle type, as demonstrated by USA Cycling (2002). Unfortunately, cycling as a form of transportation is not supported by the general infrastructure of most American cities, which primarily cater to motor vehicles. As pointed out by Untermann (1984), cyclists cannot feel safe in an automobile dominated transportation landscape. When bicyclists share the road with larger vehicles like cars and trucks, they are at a distinct disadvantage. Traffic planners in the United States estimate that half of all daily trips are less than 3 miles, an ideal

distance for commuter cycling, but the lack of bicycle paths that can ensure the rider's safety make bicycling a distinctly unattractive, and ultimately unused, option.

There was a push by individuals and U.S. government officials in the early 1970s to increase the profile of bicycling as a national form of transportation, especially in urban centers. This was exemplified by an initiative to make Washington, DC a "Showcase for Bicycling" by the U.S. Department of Transportation (1971), which resulted in the U.S. capital having many miles of paved and unpaved bicycle trails. Yet, according to the Washington Area Bicyclist Association (2003), the majority of these paths are scenic and entirely unsuited to utilitarian travel, thus the focus on bicycling has shifted from transportation to recreation. Beyond the "Showcase for Bicycling", little effort has been put forward recently in the US to encourage the public to use bicycles as a primary form of transportation. In a report from the U.S. Bureau of the Census (1990), only 0.4 percent of Americans cycled to work whereas 86.5 percent of people drove; proving that utilitarian biking is one of the least popular forms of transportation in the United States, far behind personal motor vehicles, public transportation and even walking.

In contrast to the U.S., cycling is an everyday activity in Denmark. Pedersen (2003) recounts that in Denmark, a nation with a population of approximately 5 million, there are about the same number of bicycles. Utilitarian cyclist travel is especially common in the Danish capital, Copenhagen, which is called a "City of Cyclists" by the City of Copenhagen Building and Construction Administration (2001). Every two years, the city of Copenhagen prints a "Bicycle Account" to monitor bicycle use and cyclists'

satisfaction. According to this "Bicycle Account", as of 2000, cycling traffic was up 14 percent from 1998. Thirty-four percent of people in Copenhagen cycle to work and, in central Copenhagen, up to 26,000 bicycles and mopeds can be seen on the streets on an average workday according Pedersen (2003). Cyclists cite poor bike paths or lack of bike paths as the biggest obstacle to cycling. This led the city of Copenhagen to invest DKK 9.1 million (1.3 million USD) into bike path maintenance in 2000.

Part of what makes Copenhagen so cyclist friendly is the prevalence of bicycle tracks, although, of course, there are never enough. In Copenhagen, most cycle tracks are separated from the motor vehicles' section of the road by a curb. This lends to a feeling of security for most cyclists. Despite calls for more bike lanes, Copenhagen does contain over 300 km of bicycle tracks. To help speed up the expansion of bicycle tracks, the city of Copenhagen (2001) has started to build temporary, simplified bicycle tracks that are separated from the motor vehicle lanes by a low barrier. Despite the rising occurrence of cycling accidents that lead to serious injury, only 3% of Danish adults use a bicycle helmet, according to Pedersen (2003). This is quite different from the United States where municipalities have laws dictating the use of bicycle helmets. The city of Copenhagen (2001) has cited improved cyclist security and greater commuter cycling as goals for their next two-year cycle. These are goals shared by the Dansk Cyklist Forbund (Danish Cyclists' Federation).

2.2 THE DANSK CYKLIST FORBUND

The Danish Cyclists' Federation (DCF) is a non-governmental organization that represents the interests of everyday bikers. Unlike most cyclists' organizations that concentrate on cycling sports, the DCF is an organization especially designed for utilitarian cyclists. The DCF works alongside the Danish government and other European cyclists' federations to make cycling a more prevalent, respected, and useful form of transportation.

Other than the central secretariat in Copenhagen, which employs 16 individuals, the DCF is an entirely volunteer based organization of roughly 60 chapters throughout Denmark. The chapters provide members with regional bicycle tours, a meeting place to discuss bicycle related issues, and workshop facilities. Membership to the DCF can be on an individual, family, or company scale, and requires a membership fee. At the end of 2000, the DCF had 23,000 registered members, a number that has remained fairly steady over the past 20 years.

The secretariat offers cyclists a free, bimonthly magazine, and provides legal assistance and advice in cycling matters. It also maintains a bicycle shop that sells folding bicycles, trailers, and difficult-to-find bicycle accessories. In its continual efforts to provide bicycling services to all Danes, the DCF recently decided to investigate possible solutions to the difficulties that an individual with chronic medical conditions or injuries would have to overcome to ride bicycles. When cycling to work is as common as driving to work or taking the bus, it is imperative that individuals be able to use their bicycles.

Many of the people initially interested in solving this problem are not themselves afflicted, according to Pedersen (2003), but are passionate none the less. The DCF's (2003) two main objectives are:

1. To improve safety, unhindered access, confidence and comfort for cyclists
2. To encourage a greater number of people to use a cycle - and to use it more often.

Ensuring that people with physical difficulties can ride bicycles helps to further these two objectives. Unhindered access to cycling for those with physical difficulties will increase their level of independence and confidence, encouraging more people to cycle.

2.3 THE BICYCLE RIDER SYSTEM – BICYCLE DESIGN

Bicycle design evolves in response to various common factors. From technological breakthroughs and usage needs, to fashion trends and economic markets, the design of the modern bicycle exhibits radical improvements from the first pedal-powered bicycle, introduced in 1839 by Kirkpatrick Macmillan, a Scottish blacksmith (Kingbay, 2003). Examples of such advancements over the past 160 years include wheel size, gearing, overall geometry, seat design, pedal design, and frame material. Thanks to modern materials science, the svelte machines ridden by top racers may weigh less than 6 kilograms, roughly the weight of two large textbooks, and are stronger, more comfortable, and more efficient than ever before (Kingbay, 2003).

With the help of new materials and recent advances in our understanding of biomechanics, bicycle manufacturers are in position to design for every body type and user demand. It seems incumbent upon designers to make cycling accessible to any person, overcoming many physical limitations, meshing the rider and machine into a

single unit, that is, the bicycle-rider system. In the pursuit of this mission, we must first examine the basics of modern bicycle design in order to better understand how to modify bicycles for these needs.

2.3.1 FRAME DESIGN – FIT FIRST

At the core of any bicycle is the frame, the platform that all other components are fastened to. That, more than any other single component, determines the characteristics of the bicycle. Will it be an ultra-lightweight racing machine or a solid utilitarian daily commuter? Will it be stiff and agile or supple and comfort-oriented? These characteristics are largely a function of the frame design, which can be divided into three major considerations: geometry, material, and flexibility.

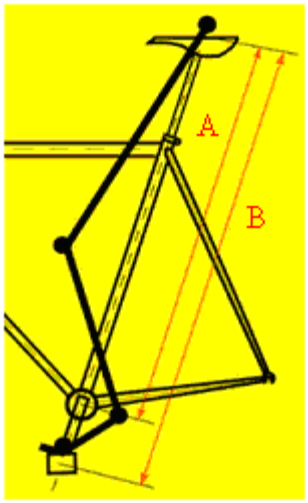
2.3.1.1 GEOMETRY

One of the major keys to designing an efficient bicycle-rider system is the careful fit of the frame to the intended rider. Currently, the high cost of having a frame custom designed to perfectly complement body type and cycling habits is prohibitive, but the principles used to perform such an operation are important to understand. Most bicycle manufacturers use average anatomical dimensions to design and build bicycles in a range of sizes so that consumers may have some degree of custom fit (Christiaans, 1998).

Frame geometry is determined by combining two factors: body shape and intended use, accommodating them through various angles and distances for the ultimate fit. Figures 2.0, 2.1, and 2.2 show some of the major pieces in this puzzle:

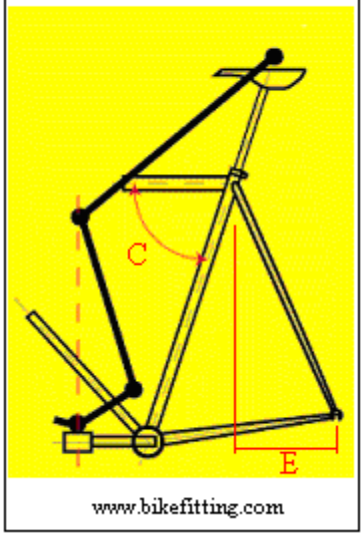
- Seat post length (2.0 - A) is a function of the length of the rider's leg from heel to pelvic bone and the length of the crank arm (2.0 - B) (DeLong, 1974). The difference between these two dimensions is 106 to 108 percent of the distance from heel to pubic bone (inseam), because "cycling with the anterior part of the foot and knee almost fully extended" is generally believed to be more efficient and less stressful on the body (Christiaans, 1998).

Figure 2.0 - Frame Measurements



- Frame angle (2.1 - C) is determined by the planned use of the bicycle and comfort requirements. For faster pedaling cadence, the angle is usually less than ninety degrees, while bicycles designed for hill climbing often have frame angles larger than ninety degrees (DeLong, 1974). In general, the closer the frame angle comes to ninety degrees, the more vibrations from road defects the rider experiences. According to Christiaans (1998), this is a major source of rider fatigue and pain.

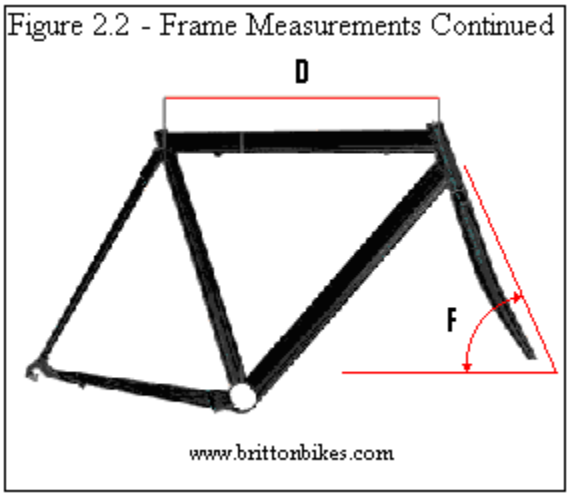
Figure 2.1 - Frame Measurements Continued



- Top tube length (2.2 - D) is determined by both intended use and trunk length of the cyclist. While shorter lengths force riders to sit in a more comfortable, upright

position (Namey, 1990), some riders prefer staying streamlined and choose longer top tube lengths in order to stretch low along the frame to reduce aerodynamic drag. Maneuverability and stability are inversely related (Christiaans, 1998) as functions of the distance from the top of the seat post to the center of the rear wheel (2.1 - E) and the angle the fork makes with the ground (2.2 - F) (DeLong, 1974). These two measurements along with top tube length dictate the wheelbase of the bicycle. Like in automobiles, a longer wheelbase means a more stable, less agile bicycle, characteristics that will determine use and rider comfort.

Figure 2.2 - Frame Measurements Continued



2.3.1.2 MATERIAL

In the quest to design ever more efficient bicycles, led primarily by the performance cycling market, frame materials show some of the greatest modern advancements in bicycle design. In stark contrast to the heavy steel frames of several decades ago, lightweight metal alloys and composite fiber matrices can cut frame weight by as much as 75% (Kim, 1990), while allowing designers to engineer the frame to selectively resist stresses. The characteristics of these new materials allow optimization of design for nearly any purpose and rider type.

2.3.1.2.1 METALS

Metal alloys are the traditional materials for bicycle frames. Thanks in part to advances in metallurgy from the aerospace and defense industries, they will continue to be at the forefront of bicycle design (Kim, 1990). Cutting edge machining and alloying techniques allow for the wide range of material choices available to designers.

Of the alloys commonly used today, aluminum alloys are perhaps the most common choice for the general cycling market due to their light weight, relatively low cost, and malleability. Since aluminum frames are often welded together, they can be made to be far stiffer than other types, creating, in effect, a one-piece, and consequently, more efficient frame (Kim 1990).

Originally developed in the 1950s, titanium alloys are strong and light, an ideal combination for bicycle frames (Merlin, 2003). Indeed these qualities and titanium alloys' extremely high resistance to corrosion make these materials very attractive, but very expensive option, due to extreme machining difficulty and low raw material availability. For the time being, most titanium frames are manufactured by high-end, custom frame design companies such as Merlin Metalworks in Lowell, Massachusetts USA, recognized as a leader in titanium frame design (Kim, 1990).

Despite the advanced materials available, steel still remains a viable option for bicycle designers, because of its low cost and manufacturing ease (Vanguard, 2003). Alloying steel with chromium is one common method of producing stronger, lighter frames.

2.3.1.2.2 COMPOSITES

Many top racers have the aerospace industry to thank for their lightweight bicycle frames. Like titanium alloys, carbon fiber was also developed in the continual search for lighter, stronger materials to use in airplanes. Unlike titanium alloys, however, carbon fiber has found its way into everything from rowing shells (Vespoli, 2003) and America's Cup sailboats (Harken, 2000), to ice hockey sticks (Everett, 2003) and bicycles. This composite material is made by embedding high-modulus carbon fibers in a polymer matrix. Such carbon fiber composites are light, extremely strong, and can be engineered for the expected stress load and direction on each tube (Kim, 1990). As a result of the high degree of control over stresses, tubes can be designed to absorb shock and stress that would normally transmit to the rider, thus potentially providing a more comfortable ride. Like titanium, however, carbon fiber requires a complicated manufacturing process that makes the cost prohibitive to most consumers. Many designers circumvent this problem by designing the frame of a metal alloy and only using composites in selected sections.

2.3.1.2.3 OTHER OPTIONS

While there are other material options being explored, including plastics and metal-polymer matrix composites that promise weight reductions of an additional 50% or more, they are used so rarely as to be impractical for the purpose of this project (Kim, 1990).

2.3.2 COMPONENTS – THE REST OF THE PUZZLE

To the frame of the bicycle are fastened a myriad of components including fork, wheels, cranks, cassette, handlebars, saddles, and brakes, each having an individually important role to play. Because of the modular nature of these parts, they are relatively easy and often less expensive to replace than the frame. These characteristics make components a major key in modifying the bicycle-rider system for people with medical conditions. Perhaps even more importantly, they give us a logical way to break up the bicycle when examining the biomechanics of cycling, a discussion that follows in section 2.6 of this project. While there are countless numbers of different parts available on the market today, for the purpose of this project, the components of a bicycle can be grouped into five major sections: fork, seat, drive train, handlebars, and brakes.

2.3.2.1 FORK

Like bicycle frames, bicycle forks can be made from a number of different materials, including the metal alloys and composites discussed above. Also like frames, different geometries and styles affect the riders comfort and agility. Among the considerations used in the design of forks, shock absorption is a primary concern. Curved forks create bending moments in the material itself when pressure is applied to the wheel rather than the compressive stresses produced in straighter forks. In bending, the fork absorbs some of the vibrations from bumps in an amount proportional to the elastic modulus of the material (Delong, 1974).

In an effort to make mountain bicycles more comfortable, Dia-Comp Inc. introduced the first fork with a suspension in 1987 (SRAM, 2002). Labeled "RockShox," the fork was modeled after those used in motorcycles (Kim, 1990). More recently, several companies have developed and marketed suspension systems for the rear wheel as well. Today a number of companies manufacture suspensions that use springs, oil, air, and polymers to elastically absorb stresses from the road.

2.3.2.2 SEAT

The bicycle seat, or saddle, looks nearly the same now as it did over one-hundred years ago, although recent designs are changing this trend. Modern saddle covers are made from many different materials including rubber, leather, Kevlar, suede, micro fiber, and polypropylene, and are filled or padded with various types of foams and fibers. The saddle shape can be narrow and relatively hard, or wide and cushioned with springs built in for extra comfort. Some even have cutouts in the nose to relieve pressure on the genitals or in the center to relieve pressure on the tailbone. There are no set rules for sizing saddles as there are for frame geometry; rather the choice is largely a matter of personal preference (Christiaans, 1998).

2.3.2.3 DRIVE TRAIN

The drive train is the motive link between the bicycle and rider. Power is transferred from the rider's legs to the pedals, which rotate and transfer the force load to a chain and eventually to the back wheel, thus driving the bicycle and rider forward. Like the

transmission in a car, different speeds can be achieved depending on the force applied and the gear ratios.

Pedals can be one of four types: standard, toe clipped, clipped, and so called “clip-less”. Standard pedals are just platforms that the rider pushes against on the down stroke, forcing nearly all work to be done by the quadriceps (thighs), while the other three pedal types allow hamstrings (back of legs) to engage as well. Pedals equipped with toe clips have straps that the rider can slip in and out of easily by sliding his foot forward or backward on the pedal. Clipped pedals are those in which the rider’s shoe is permanently attached to the pedal; these can be dangerous because the rider cannot remove his shoe from the pedal when he needs to stop, but are very efficient in transferring power to the wheels. Finally, the “clip-less” pedal is nearly identical to the clipped pedal except that the rider may twist his foot and the spring-loaded mechanism in the pedal releases the foot (DeLong, 1974).

The gears on a bicycle are classified in two groups: cranks (those attached to the pedals) and the cassette (the group of different sized gears that drive the rear wheel). Both types come in different sizes, expressed in the number of cogs on the gear, depending on intended use. Cranks come singly, or in sets of two or three, and cassettes are generally sold in sets of three, five, six, seven, eight, and nine. By combining different sizes and ranges, an almost infinite set of drive ratios is possible.

The controls for the gearing, or gear shifters, also vary in design and price. Lower priced models are most often bolted to the handlebars and must be rotated by the thumb to change gears. These gear shifters are often difficult to move and made of low quality steels. As gear shifters rise in price, so does the ease of operation and options available. All-terrain bicycles often come with shifters mounted on the underside of the handlebars, which the rider pushes back and forth to shift from one gear to another. Another type, most widely used on all-terrain bicycles, but recently appearing on road bicycles as well, is the "grip-shifter." This type is similar to those used on motorcycles, where the rider rotates the handlebar grip to change gears. The other type of shifter used on road bicycles is simply called the "speed shifter." It consists of a lever, located on the handlebars or the down tube, which is pushed forward or back to change gears. One defining characteristic of these more advanced components is the ease of use and indexing of gears. Shifters with indexing have set positions for each gear that allow accurate placement of the shifting mechanism in relation to the gears on the crank set or cassette.

2.3.2.4 HANDLEBARS

Handlebars are available in four basic configurations: straight, road, aero, and utility. The straight handlebar is a single straight or slightly bent tube, which is most common on all-terrain bicycles because of the high degree of control and maneuverability it offers. The road handlebar consists of a short, straight bar, with two pieces curved in a semi-circular shape forward and down. It allows racers to lean further forward for a more aerodynamic position. Similar to this type is the aero handlebar, or aerobar. Aerobars

can be independent units, or bolted onto standard road handlebars. They allow the rider to lean forward and support his weight on his forearms rather than his hands, creating a very efficient aerodynamic form similar to a ski racer's tuck. Finally, the utility handlebar is curved in one of a number of configurations, generally allowing the rider to sit more upright. This type is the one most commonly found on "commuter" and "comfort" bicycles.

2.3.2.5 BRAKES

Bicycle brakes generally work by one of two methods. The first, which many people primarily learn to use as children, are almost exclusive to children's bicycles with single gears: the foot brake. This type of brake works by the rider pushing the pedal towards the rear of the bicycle and, because there is only one gear and no freewheel, the bicycle slows as the rotation of the wheel is stopped. The other type of brake used on today's bicycles is the hand brake. This type changes little between different types of bicycles and works by the rider squeezing a brake lever attached to the handlebars. The lever is attached to a cable, which causes two brake pads, usually made of rubber, to press against the rim of the wheel when pressure is applied by the rider to the brake lever.

2.4 THE BICYCLE-RIDER SYSTEM – RIDER ADAPTATIONS

As pointed out by Christiaans and Bremner (1998), comfort is a very personal quality, dependant upon many parameters. It is difficult to form a standard for how a bicycle should be made more comfortable. Perhaps the best option is to explain the various

possible adjustments and components available, and then allow the individual to discover the most comfortable combination by trial and error.

For a person who has been injured or has a chronic condition adversely affecting their cycling abilities, comfort while cycling is of particular importance. The affected individual must often obtain medical treatment as a means of coping with their condition, but there are other measures they can take to improve cycling ability. Mellion (1994) states that in addition to medical treatment, the cyclist can help their condition or prevent it from worsening by adjusting their bicycle or modifying their technique. In many cases, modifying cycling technique, whether posture or riding apparel, can prove to be both a less expensive and a more effective way of bringing the rider more comfort.

While anyone who rides a bike had to initially learn and practice, few people are taught to ride a bike correctly. Being able to balance on a bicycle and propel it forward are the beginning, and for many, the end of any training received on how to ride a bike. After a while, this improper technique can lead to cramped muscles and joint pain, characteristics of bicycle overuse. For most non-professional, low performance, everyday cyclists, these are pains that are unnecessary and will only aggravate existing conditions. Therefore, professional coaching or cycling advice is an option for increasing cycling efficiency and comfort.

It must be stressed that initially, changes in posture and technique could cause pain because the rider is not accustomed to them. However, Mellion (1994) asserts that

correct bicycle use will decrease stress in the long term. As soon as the rider's body becomes familiarized with the new positions and habits, the rider will experience a more comfortable ride. Please see Appendix A for a detailed discussion of several areas of the body that are common sources of cycling difficulty. In addition, some techniques for minimizing or eliminating that difficulty are explained.

2.5 CONDITIONS ADVERSELY AFFECTING CYCLING

For healthy individuals, the activity of cycling can be very enjoyable and constructive. It can allow them an efficient means of transportation and a great workout. Yet, for many individuals suffering from various physical conditions, the joy of cycling is overshadowed by the ailment's effects with every revolution of the pedals. The following sections provide a general discussion of conditions that can adversely affect a person's cycling ability.

Conditions affecting cycling can be categorized into three categories: traumatic injuries, chronic conditions, and overuse injuries, each of which contains multiple subcategories. Traumatic injuries include serious or violent shocks to the body, generally occurring instantaneously. A fractured elbow or a sprained ankle would be an example of a traumatic injury. Chronic conditions are those that persist all the time, a few examples would include arthritis and post-polio syndrome. Finally, there are overuse injuries. These are the most common type of injuries associated with exercise and are musculoskeletal injuries produced from repetitive motions of the tissues and joints. Please note that for this discussion, traumatic injuries and chronic conditions do not

necessarily deal with injuries incurred from cycling, whereas overuse injuries specifically refer to conditions created by the act of cycling. Examples of cycling overuse injuries include lower back pain and saddle sores.

No matter the type of condition (traumatic/chronic/overuse), modifications can often be made to the bicycle or rider, increasing mobility, decreasing pain, or perhaps allowing the rider to cycle in the first place. These modifications can consist of anything from a padded handlebar to a pair of riding gloves, or perhaps even a set of pre-ride stretches. Many times simple modifications to the rider are more effective than modifications to the bicycle itself. It is all part of the overall bicycle-rider system. Thus, buying cycling shoes might be cheaper and more effective for relieving foot pain than replacing pedals. Unfortunately, a modification that aids one individual's condition does not necessarily aid another individual's identical condition, as the anatomy of every person is different. The anatomical differences between men and women are probably the most notable of these differences, and there are bicycle modifications for this already present. For instance, women's saddles are usually slightly larger to allow for wider hips. In the end, this all makes the process of choosing the proper bicycle modification for an individual's specific condition extremely complicated.

Please note that proper medical attention should always be obtained for any persisting ailment, as there maybe a more serious underlying problem.

2.5.1 Overuse Injuries and Improper Cycling Habits

Many people turn to cycling to help alleviate the overuse injuries caused by other sports such as running or swimming. It is important to understand, however, that cycling also has a set of overuse injuries associated with it. These can include: lower back pain, saddle sores, penile numbness, and ulnar nerve neuropathy. These injuries are more common than many might expect. In one survey of recreational cyclists, 85% of the respondents reported some type of overuse injury, with neck pain (48.8%) as the leading injury and knee pain (41.7%) second. The same survey also noted that the severity of these injuries led 36% of those with overuse injuries to seek medical treatment (Holland, Madison and Wilber, 1995). In the 1983 Race Across America, severe overuse related neck pain caused Michael Sherman to disqualify after 2500 miles. He is quoted as saying "It felt like two steel rods were forcing my head down" (Mellion, 1994). Furthermore, even though Sherman's injury occurred under extreme circumstances, overuse injuries can force far less active riders to give up cycling altogether.

The actual term for cycling overuse injuries is somewhat of a misnomer, in that long periods of cycling alone will not lead to injury. In fact, among competitive cyclists, those who averaged over 1000 cycling miles a year were 2.7 times less likely to have overuse injury than those averaging less than 500 miles (Dannenberg, Kolodner, Mullady and Needle, 1996). Conversely, a study of recreational cyclists found that as yearly cycling mileage increased, so did the risk of overuse injuries (Holland et al, 1995). Combining these two studies can lead to the theory that professional cyclists, due to their superior cycling form, custom fit bicycles, and physical conditioning, are less susceptible to

overuse injuries, and therefore overuse injuries are not solely created by extensive cycling, but by a multitude of other factors. Supporting this theory, those competitive cyclists surveyed who had their bicycle tuned-up multiple times per year were half as likely to suffer overuse injuries as those who had tune-ups every few years. Gregor and Wheeler (1994) agree with this theory and state that "insufficient warm-up and cool-down, abrupt changes in exercise duration, intensity, frequency and/or modality can lead to muscle and tendon strain." More specifically for over usage in cycling, "poor riding habits, excessive hill training, excessive early season mileage, pushing big gears at low revolutions/minute, incorrect bike size, and cleat misalignments" (Gregor and Wheeler, 1994) can lead to overuse injuries. For these reasons, developing proper cycling habits and properly modifying the bicycle to fit the rider are necessary to prevent overuse injuries. For a detailed discussion of several common overuse injuries related to cycling, please see Appendix B.

2.5.2 CHRONIC CONDITIONS

A chronic condition can include anything from allergies to full paralysis. Hence, we will limit this discussion to conditions characterized by a decrease in range of motion, joint and muscle pain, and reduced strength. The end result of such chronic conditions and cycling is often the total abandonment of cycling, which can lead to a wide variety of practical and physical effects upon the afflicted individual, especially when cycling is their primary form of transportation. In order for our Comfort Guide to be an effective tool, we must address as many symptoms and symptom locations as possible. The

following sections discuss three conditions, arthritis, whiplash, and post-polio syndrome, that, when viewed together, affect nearly the entire musculoskeletal system.

2.5.2.1 ARTHRITIS

For millions of people world-wide, arthritis is a constant, nagging, and sometimes debilitating condition that impairs motion and forces many to live with constant pain; it is the most common cause of musculoskeletal disability in Western countries (Jones, 2001). While new drugs promise some degree of relief from arthritis symptoms, studies have shown that a mild cycling regimen can improve mobility and reduce pain caused by arthritis (Karper, 1986; Namey 1990; Mangione, 1999). The following paragraphs will discuss arthritis and its symptoms as well as outline the findings of the aforementioned studies.

There are currently more than 100 different known types of arthritis, each with its own distinct set of symptoms and treatment options. For the sake of this project we will discuss arthritis as a group of diseases with a common set of symptoms generally defined as those characterized by osteoarthritis and rheumatoid arthritis.

Arthritis is characterized by inflammation and damage to the lining and alignment of the joints, which causes pain, reduced range of motion, and reduced strength (Jones, 2001). Symptoms range in intensity from occasional soreness to constant debilitating pain. Any joint may be affected, some more often than others. Those joints with high incidence of arthritic symptoms include elbows, hips, knees, shoulders, wrists, and fingers. Other

symptoms may include: loss of appetite, loss of energy, fever, and anemia (Rheumatoid Arthritis, 2003).

While arthritis is more common in people over 45 years of age and more occurrences are found in women than men, arthritis can affect anyone of any gender at any age. Other risk factors include: obesity, history of joint injuries, history of high impact sports, and genetic pre-disposition. Some types of arthritis, including rheumatoid arthritis, are auto-immune diseases (Rheumatoid Arthritis, 2003).

Cycling has long been prized by physical therapists as an "ideal recreational physical activity" (Namey, 1990). The criteria for this classification help to clarify why it is so useful:

- Uses largest muscle groups in the body
- Non-concussive/atraumatic
- Lifetime activity available to all ages
- Aerobic exercise

Also, according to Namey (1990), bicycles are sufficiently variable that they can be adapted to the needs of nearly any arthritic condition. The fit of the bicycle is critical to the comfort of the rider, especially the arthritic rider, because cycling is one of the few sports where a machine must become an extension of the human body, hence the bicycle-rider system (McLennan, 1991). If the bicycle is fitted correctly to the rider and an exercise program is put together by a qualified professional, cycling can actually improve

strength and cardiovascular health (Karper, 1986), decrease pain (Resnick, 2001), and increase range of motion (Namey, 1990). This helps explain why cycling is considered one of the most effective treatments for arthritis, especially arthritis of the knee, for its exercise of the quadriceps and availability of high and low intensity workouts (Resnik, 2001).

The reasons cycling is so good for arthritis are numerous, including those listed above. Others good reasons are the fact that femur, hip, and ankle loads during cycling are "nearly independent" of body weight (Namey, 1990), and that exercise has revealed to slow the degeneration of muscle and joint tissue and increase balance (Resnik, 2001).

Like any physical activity, those with arthritis should not attempt cycling without consultation with a doctor. There are some principles to keep in mind that may increase the benefits and help to lessen the pain and motion difficulty associated with arthritis. One of these principles is that no aerobic activity should be attempted if the joints are not in shape to take the forces associated with that activity. Strength exercises with resistance training may be required prior to cycling (Namey, 1990). Take for example the knee and ankle: pedaling produces tensile stresses in addition to compression and tensional stresses, so the knee and ankle joints must be strengthened prior to exercise in order to reduce the risk of additional pain or injury through twisting of the joints (Resnik, 2001). Another important concept to keep in mind is the upper body position while sitting on the saddle. Careful consideration must be taken to alleviate pain associated with either compression of the spine or excessive bending. The most efficient

biomechanical position for the spine is the one that most closely approximates the most aerodynamic position (McLennan, 1991). This rule may not be applicable, however, for patients with excessive pain and reduced strength in the hands and arms because the more aerodynamic the position, the further the rider must lean over, thereby applying pressure to hands and arms. Finally, hand function, "the ability to use the hand in everyday activities," is also a critical measurement to consider as riders must be able to operate brakes and shifters properly to safely ride a bicycle (Fowler, 2001).

While arthritis can be a debilitating condition, there is no reason that patients should not be able to enjoy cycling like the rest of the population. Simple adjustments can mean less pain, increased strength, increased range of motion, and may even help to treat some of the symptoms of the disease (Namey, 1990; Resnik, 2001).

2.5.2.2 WHIPLASH

The term "whiplash" was first used by Crowe in 1928 to classify the pain resulting from acceleration-deceleration of the neck (Hammacher, Werken 1996). The term "whiplash" was then later replaced by the term "post-traumatic neck injury" (Mayou, Radanov 1995) in order to be more descriptive. Both these terms can be misleading in that other locations of the body can be affected and other symptoms besides pain can result from the acceleration-deceleration mechanism. Thus, the acronym WAD or Whiplash Associated Disorders, suggested by the Quebec Task force as a more inclusive conventional term, is commonly used among medical experts today (Galasko, Lovell 2002).

According to many automobile insurance companies in Western countries WADs have reached epidemic proportions (Hall, Moog, Quintner, Zusman, 2002), (Mayou, Bryant 1996). This increase in WADs can primarily be explained by the modern increase in automobile usage combined with seat belt usage. Biomechanically speaking, this makes logical sense as the seatbelt during a rear-end impact restrains the body allowing the head to move on pivot, resulting in the acceleration-deceleration loading on the cervical spine that causes whiplash. One concurring report in the UK recorded a three-fold rise in whiplash injuries from 1982 to 1983, when the compulsory seatbelt law was placed into effect (Galasko, Lovell 2002). Then again, it should be stated that the actual number of WADs will probably never be known, as many suffers of less serious WADs may never report their injuries.

For organizational purposes, the medical discussion of WADs maybe broken up into two major categories: acute and chronic. The distinction between these two categories is determined by the difference in required recovery time after the initial accident; three months is generally accepted as the acute/chronic barrier (Hammacher, Werken 1996). According to one study, the actual occurrence of chronic WADs in patients is about 40%, meaning that 60% of all WAD patients are symptom free within three months. Additionally, the same study indicates that 75% of all WAD patients are symptom free within 6 months (Hammacher, Werken 1996), (Bryant Mayou, 1996). Unfortunately, some WAD patients never completely recover and they have to endure the symptoms for the remainder of their lives.

Creating a distinction between acute WADs and chronic WADs is very important, as both the symptoms and treatment of each vary. For acute WADS the resulting symptoms include "neck pain, headaches and stiffness in the neck and shoulders… pain radiating into the arm(s), blurred vision, vertigo, dysphagia and cognitive impairment" (Hammacher, Werken 1996). Most of these symptoms usually subside or disappear within a few days. However, for some sufferers of acute WADs, symptoms can last a few months.

In comparison to acute WADs, chronic WADs are much more complex with regards to diagnosis, symptoms, and treatment. As far as diagnosis is concerned, the Quebec Task Force classifies chronic WADs into "four distinct categories: (1) neck pain with no physical signs, (2) neck pain, range of motion limitations, and tender points, (3) neck pain and neurological impairments, (4) neck pain and fracture or dislocation" (Benoist and Rouaud, 2001). The difficulty with this categorical diagnosis is that for three of the categories, there are no physical signs other than pain and discomfort. This lack of physical signs, in combination with the length of symptoms and a complex legal liability system in many countries, results in many medical experts believing categories 1 to 3 may be more psychological than physiological. This is to not to imply that medical experts believe all WADs sufferers are merely faking symptoms to receive monetary compensation. Instead, it is meant to suggest that the mental state, a belief of injury, of the individuals facilitates these symptoms; concisely put, level 1, 2, and 3 chronic WADs are largely believed to be psychosomatic.

Much research, of course, has been done on the physical existence of chronic WADs. These studies have included acceleration of cadavers or animals, analysis of hospital records, long-term study groups, comparisons of legal systems and even post-mortem studies. Nonetheless, much debate on the issue still remains, as many of the studies contradict each other. These contradictions can be blamed on a variety of factors, including the multitude of variables effecting chronic WADs and inherent flaws in many studies, including failure to account for other injuries caused by the initial accident (Mayou and Radanov, 1993).

The symptoms of chronic WADs vary greatly on an individual basis. Symptoms include: "neck pain, reoccurring headaches, visual disturbances, auditory disturbances, dizziness, tinnitus, muscle weakness and paresthesia, lower back pain, memory impairment, dysphagia, and temporomandibulare joint pain" (Benoist and Rouaud, 2001). The duration of these symptoms can range from a few months to a life time. The severity can, in some cases, be completely debilitating.

2.5.2.3 POST-POLIO SYNDROME

Post Polio Syndrome is a harsh blow to people who have survived the ravaging effects of the poliomyelitis virus. Poliomyelitis results in the loss of motor neurons. In order to compensate for this loss, remaining neurons sprout new endings to restore function to muscles. This excessive sprouting facilitates recovery and promotes long periods of stability when the individual may have normally functioning muscles. Anywhere from

10 to 40 years later, these neuronal sprouts may begin to deteriorate, leading to the loss of muscle function. This deterioration is called Post Polio Syndrome (PPS).

PPS is characterized by a history of polio, a period of functional stability, and muscle deterioration that cannot be attributed to any other cause (Grimby, 2002). Secondary symptoms include respiratory problems and loss of sensory. While the incidence rate is still uncertain, it is estimated that PPS occurs in 25% – 50 % of polio survivors (NIH, 2003).

Polio was rampant in Denmark in the 1940s and 1950s, but has since been eradicated. Denmark was declared "polio free" by the World Health Organization in December 2002. (http://www.polioeradication.org/vaccines/polioeradication/all/background/disease.asp, 2003). Today, there are 7000-8000 individuals in Denmark living with the after-effects of polio (PTU, 2003). Many of them suffer from PPS.

PPS is slowly degenerative and very unpredictable. The rate of degeneration is unrelated to age, gender, time elapsed since the initial poliomyelitis bout, or history of residual weakness. (Klein, Whyte, Esquenazi, Keenan and Polansky 2002). Diagnosis of PPS is largely a process of elimination. Neurological examination to remove the possibility of other conditions is often helpful.

Doctors at the National Institutes of Health in the United States have found drug regimens to be ineffective in the treatment of PPS (NIH, 2003). While there is some

debate about the effectiveness of exercise in the treatment of PPS, exercise is viewed, at worst, as not harmful and can lessen the severity of the symptoms (Klein, Whyte, Esquenazi, Keenan and Costello 2002). In a randomized parallel group study, 29 individuals with PPS participated in various treatment regimens including exercises and lifestyle changes to avoid overuse. It was determined that exercise was quite effective in showing a "significant difference in both number and severity of symptoms" (Klein et al, 2002). It is generally agreed that exercise is beneficial to treating PPS when it is low-impact and does not exceed the tolerance of the individual. An individual's tolerance is considered to be the point as which discomfort and/or fatigue sets in.

Cycling is a low impact exercise that could prove beneficial to individuals with PPS. As with any physical activity, individuals should consult a physician. In the case of cycling, the low impact and the potential for cycling systems with high power transference would allow individuals to cycle longer than the muscular degeneration associated with PPS might allow for other activities.

Since PPS is arbitrary in terms of severity and location, each case is very unique. The rate of muscle degeneration varies greatly. Mild cases of PPS might have no effect on an individual's cycling abilities, whereas severe cases of PPS would make cycling impossible. In general, individuals with PPS must be prepared to change their lifestyles to lowered mobility and strength. However, regular physical activity that uses the whole body, like cycling, can greatly maintain their mobility.

2.6 THE BIOMECHANICS OF CYCLING

The biomechanics of cycling is something that is extensively studied and well documented. By studying how the body moves and reacts while cycling, biomechanical engineers and kinesiologists have been able to improve and enhance the performance of professional cyclists. Engineers have traditionally concentrated on the hardware of the bicycle: the frame and components of the vehicle itself, while kinesiologists have examined the workings of the human body. This means that engineers have been constrained by the perceived limitations of the rider component while kinesiologists have been constrained by the standard build of the bicycle (Too, 1990). In effect, every component, how it is installed and how it causes stress on individual muscles and joints has been the focus of numerous studies.

The physiologic demands of cycling have been explored using a number of different methods and equipment: cycling ergometers, rollers, cycling trainers, treadmill cycling, high speed photography, computer graphics, strain gauges, electromyograms, wind tunnels, muscle biopsy, and body composition analysis (Faria, 1984). Whether direct or indirect, the effects of cycling on the human body have been monitored in numerous situations, generally by people wishing to optimize their performance for bicycle racing.

Two categories of overuse injuries have been identified: pathomechanical and overtraining (Boyd, 1996). Overtraining injuries occur when people cycle extensively. The injuries that we are more concerned with are pathomechanical in nature.

Pathomechanical injuries occur when the bicycle is ill-fitted to the rider and his/her needs.

Bicycling is a low resistance activity. It produces less stress at the joints than even walking. However, there are many adjustments that can be made to a bicycle to optimize the efficiency of cycling. Efficiency, in terms of cycling, is the ease with which the human body and the bicycle interact to produce work (O'Brien, 1991).

There are many aspects of the bicycle-rider system that can be adjusted. Some common ones are saddle position, shock absorber flexibility, back alignment, seating position, and pedaling cadence. Saddle position greatly affects the efficiency of the thighs. Thigh fatigue is most pronounced when the rider's knees are at an angle of 120-125 degrees. This indicates that the saddle is very low and that the pedaling strokes are not using the body weight of the rider, thus having negative effects on muscular output (Mandroukas, 1990). Shock absorbers increase rider comfort with minimal effect on efficiency. While reducing the effects of road shock significantly, the presence of both fork and saddle post suspension has little effect on exertion, measured by monitoring maximum oxygen intake (VO2) (Nielens, 2001). Toe clips and cleated shoes help reduce foot motion by keeping the foot stationary with respect to the pedal. This reduces the maximum load on the down-stroke, which peaks at 90 degrees of the crank angle (O'Brien, 1991). As cycling intensity increases, paravertebral lumbar (spinal) muscle tension increases, resulting in cyclists putting more strain on their backs when cycling. The back then bends more to

cope with this tension, resulting even more pressure on the back when cycling. The abdominal muscles, however, remain consistently relaxed.

How one sits on a bicycle is not at all like the normal physiologic sitting or standing positions. An important defense for the lumbar spine during load bearing activity while in a physiologic standing position is to increase intra-abdominal pressure, thus removing some of the load on the spine and placing it on the abdominal muscles. This is not possible when in a cycling posture, so load bearing gets transferred to hip flexion instead (Usabiaga, 1997). This places additional pressure on the hips, which are not meant to bear the higher load, instead of on the abdominal muscles that are.

Surprisingly, standard sitting position produces the greatest maximal power output when compared to recumbent or racing postures. Maximal power output produces the greatest speeds. This is especially true when going uphill (Welbergen, 1990). While one would expect cycling cadence to have a great deal of effect on the strain induced on the knees and hips, this was found to be untrue. Also, while professional cyclists are more efficient than commuter cyclists at high speeds, professional training has no effect on muscle exertion at average speeds (Marsh, 1995). The general trend is easily seen; dependence of optimization results on anthropometric parameters emphasizes the importance of tailoring bicycle equipment to the anthropometry of the individual (Gonzalez, 1989). Acute and chronic responses to cycling are complex. Ideally, the best way to protect the safety and health of the cyclist would be to closely monitor and work with the cyclist, coach, exercise scientist and physician (Faria, 1992) to provide the cyclist with the best

and most personalized care. This is not generally possible. Therefore, arming the cyclist with a collection of the knowledge already put forth by experts is a necessary and useful proposition.

Biomechanics is a necessary step for experts to use in order to support their suggestions and assertions about how people cycle and how to make cycling most efficient. The implementation of biomechanical knowledge by translating it into practical applications is a complex task. It is a task that has been done by numerous experts, from biomechanical engineers to cycling trainers and specialized bike fitting organizations. These are individuals who have devoted their expertise in biomechanics and cycling to suggest the best ways to optimize cycling and maximize comfort. Thus, our job will be to compile the known information from a number of different fields and researchers and extract practical knowledge from their findings so that we might apply it to improving the bicycle-rider system.

3.0 Stepping Closer to Our Goals

"The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them." – Sir William Bragg, Nobel Laureate, Physics, 1915

In a country, such as Denmark, where the human to bicycle ratio is nearly one to one, it stands to reason that injuries or chronic conditions would cause difficulty or prevent the use of bicycles in a significant percentage of the population. It follows that an organization like the Dansk Cyklist Forbund, whose goal is to promote cycling in Denmark, should react to this concern and seek a solution. This project, sponsored by the DCF, was devoted to finding that solution using existing technologies presented in a new, more useful manner. The following section provides a detailed explanation of the methods utilized to achieve this objective as well as reasons why these methods were chosen. This methodology was originally developed while our team was in Worcester and then modified over the course of our stay in Copenhagen. While using a wide range of methods in order to gain a complete understanding of the situation we came to realize that this project was not merely a research project, but a publication development project. The final product we endeavored to produce was an online help guide containing a catalog of bicycle parts, which changed the bicycle-rider system to increase the cycling comfort of the DCF membership and all cyclists. Issues targeted in this "Comfort Guide" ranged from pain and discomfort to reduced strength and reduced range of motion. Most importantly, our Comfort Guide was designed to provide a model for others add to, thus creating a living document to be continuously updated.

The audience (users) for our Comfort Guide can be divided into four distinct categories:

- The Dansk Cyklist Forbund – The DCF itself will use this Comfort Guide to aid their members in various ways, acting as a distributor of the information.
- Danish bicycle shops and bicycle professionals – Bicycle shops will also act as purveyors of the Comfort Guide and its content. However, since bicycle shops and their employees have more personal contact with the general public, especially those buying new bicycles or parts, bicycle shops may also use our Comfort Guide to give customers advice.
- DCF membership and the general public – The general public will have access to the Comfort Guide and its contents for their personal use.
- Medical professionals – Our Comfort Guide cannot take the place of professional medical knowledge and expertise. However, we hope that it will be viewed as a resource for medical professionals treating those with cycling difficulties.

Developing our Comfort Guide was a complicated process. Unlike pure research, we had to produce a published product that the general public will reference to help alleviate symptoms of their conditions. To this end, we carefully organized our information into an easy to use format, while providing ample information on how to properly modify the bicycle-rider system. In the following sections, we explain the process employed for identifying conditions and symptoms, finding and compiling solutions to those symptoms, and creating and publishing our Cyclist's Comfort Guide. The process itself consisted of three overlapping phases:

1. Determination of conditions affecting cycling and associated symptoms (Sections 3.1)
2. Development of modifications to alleviate symptoms (Sections 3. 2 and 3.3)
3. Creation, publication and testing of "A Cyclists' Comfort Guide" (Sections 3.4 and 3.5)

3.1 SELECTING TARGET CONDITIONS

The first objective was to identify the medical conditions affecting the cycling ability of DCF members so that we could focus on them. This was an essential first step, for without it our project's scope would have been overly broad. Upon consulting with the DCF, we decided to center the project on three specific conditions, designing this project as a template so future conditions might be added. Arthritis, post-polio syndrome, and whiplash were selected as the three principal conditions for our project focus for several reasons:

- The symptoms and symptom locations associated with these three conditions are very inclusive, covering most of the body. This allowed us to provide relevant information to a large portion of our target audience, while also allowing us to efficiently use our limited research time.
- These three conditions were identified to us by Jens E. Pedersen, director of the DCF, as important to the Danish cycling public. Subsequent research in the U.S. and Denmark supported that assertion.

- Selecting these conditions also allowed us to work closely with other Danish organizations that had shown interest in our project, namely the Landsforeningen af Polio, Trafik, og Ulykkesskadede (Danish Society for Polio and Accident Victims or PTU) and the Gigtforeningen (Danish Rheumatism Association).

3.1.1 Researching Target Conditions

After these conditions were selected, relating these conditions to their specific symptoms and symptom locations became essential. For this research we predominantly utilized a literature review of peer-reviewed journals relating to the specific conditions. Significant research had been conducted in the U.S. regarding arthritis at the University of Massachusetts Medical Center library in Worcester. Information still needed to be collected on post-polio syndrome and whiplash. This research was supplemented with journal articles obtained at Den Sorte Diamant (the Black Diamond), a research library in Copenhagen that is branch of Det Kongelige Bibliotek (the Danish Royal Library). Later, this research was further supplemented by interviews with DCF and Gigtforeningen employees.

Our interview with Kirsten Thorhauge, an occupational therapist at the RevalideringsCentret, was conducted in an in-depth qualitative interview form. The RevalideringsCentret, a rehabilitation and adaptive technology center in Herning, Denmark, helps Danes who have been in accidents learn new approaches to previously simple tasks and cope with these lifestyle changes. The open-ended, flexible interviewing method used was appropriate for the interview due to Kirsten's knowledge

of the project and the large amount of time available – one entire day. The chosen interviewing method allowed us to tailor the questions toward our objectives. The day was spent reviewing the work that Kirsten and her staff had completed in adaptive cycling and interviewing two individuals currently using modified bicycles as part of a physical therapy program. A short bicycle trip on these modified bicycles to test their comfort enhancing qualities was also conducted. (Please see Appendix C for an interview summary.)

A similar flexible interview format was used in our interview with the Gigtforeningen. It was slightly modified, as the interview had different goals. We spent an afternoon at the Danish Rheumatism Association presenting our project to them in hopes of future cooperation with the DCF, and asking questions about rheumatism and its effects on cycling in Denmark. These questions focused on confirming our arthritis research and reinforcing our approach to this project. In addition, the Gigtforeningen's web-consultant, Mads Lauridsen, showed us the approach they had taken to website structure and design, helping us in our own website development. (Please see Appendix D for an interview summary

3.1.2 DCF CHAPTER SURVEY – FOCUSING THE SCOPE OF OUR RESEARCH

The primary focus of the survey sent to all of the DCF chapter coordinators was to gather cycling related information about the DCF membership. The survey consisted of three multiple-choice questions and one short answer question. (Please see Appendix E for the survey results.) Every DCF chapter in Denmark received the survey: fifty-eight by email

and eighteen by conventional mail, in order to obtain the most comprehensive results. Contact information for the chapters was provided to us by the DCF secretariat. We requested the survey be returned 10 days after receipt. Five workdays after the mailing, follow-up emails and phone calls were made to remind the chapters to complete the surveys. A total of sixteen replies were collected: one paper survey and fifteen electronic, although nine of those electronic replies were explanations of why the survey subject could not or would not answer. Finally, thank you letters were sent to all chapters who completed the survey. The data collected from these returned surveys were then compiled into charts using Microsoft Excel.

3.1.3 Categorization and Simplification of Symptoms

While the surveys were being distributed and interviews conducted, the background research on medical conditions, gathered in the U.S. and Denmark, was organized into tables, constructed to allow simple relationships to be drawn between a wide range of conditions and symptoms (Please see Appendix F for Conditions-Symptoms table). These symptoms, for the sake of simplicity, were then grouped into more general categories. For instance, various types of pain in the knee, shooting, throbbing, and localized, were all classified as “knee pain”. We understood that making such generalizations could potentially result in the recommend of a modification that does not help the specific symptom. Weighed against the limited time we had to complete the project and our own lack of expertise in the field of sports medicine, we determined these risks were minimal and acceptable. In addition, we continued to stress that our Comfort Guide is intended to be only part of the solution for people with severe conditions. As

always, medical and bicycle professionals should be consulted before undertaking any modification.

3.2 Biomechanical Analysis and Application – The Core of Our Project

Our final product is a Comfort Guide, allowing people with conditions adversely affecting their cycling abilities to alleviate their symptoms through bicycle modifications. In order to create an effective product, we first needed to determine the symptoms and symptom locations. From there, we used simple biomechanical analysis to understand which motions and forces experienced during cycling aggravate those individual symptoms and came up with ways to reduce those motions and forces. We broke this part of our methodology into three steps:

Step #1: Determining the part of the cycling activity that aggravates the identified symptoms identified (Please refer to Figure 3.1).

This step was one of the most critical to our project because it made the connection between the symptoms and the aspects of cycling that aggravate those symptoms. To accomplish this objective, we used the background research already conducted in the biomechanics of cycling to evaluate the stresses on the body associated

Figure 3.1: Example of logic for step #1:

Location: Neck

Symptom: Reduced range of motion

Motion: Difficulty turning head

with cycling. We looked at each part of the cycling activity, from the moment the hands touch the handlebar to the point the rider dismounts. Each time a potential problem was identified, it was recorded along with the specific part of the bicycle causing of that problem. We originally compiled a list of more than one hundred potential troubles.

Step #2: Applying the principles of cycling biomechanics to change the bicycle-rider system (Please refer to Figure 3.2).

Once the correlation between the bicycle parts and the aggravation of symptoms was made, treatments in the form of bicycle modifications or adjustments, documented by the medical community were applied to the bicycle-rider system. Our first resource in this step was research already conducted in this area. Unlike solutions to individual conditions affecting cyclists, there is a plethora of information on general treatments for the symptoms of conditions such as knee pain due to arthritis, limited range of neck motion due to whiplash, etc. It was here that we began making new connection, thereby showcasing the need for research compilation and solidifying the purpose of our project. For example, suspension saddle posts are created to alleviate vibrations and shock to the lower back. Similarly, suspension forks can be used to alleviate shock and pain to the arms and shoulders.

Figure 3.2: Example of logic for step #2:

Location: Neck

Symptom: Reduced range of motion

Motion: Difficulty turning head

Problem: Looking to see other vehicles/people

While we made a number of new connections, there were several sources that had already done research related to our areas of interest. The majority of this research has been done with the purpose of improving cycling performance, but we believe that many of the same principles apply to making cycling more comfortable as well. Such sources included:

- Scientific Journals (our primary source)- Many journals of sports medicine, looking to improve the performance of competitive athletes, discuss how to improve bicycle efficiency. In some cases, we were able to adapt these improvements of the bicycle-rider system to the average rider, in order to relieve force or stress on their bodies. Additionally, research information on avoiding common overuse injuries due to excessive cycling also proved useful.

- Manufacturers' websites: Many well-known producers of bicycle parts publish their research online as a way of legitimizing the claims that they make about their product. After accessing the accuracy of this information, we could then use this information to help identify ways of changing the bicycle-rider system to alleviate identified symptoms.

- Online trade magazines: There are a number of bicycling magazines that publish their articles online, either for free or for a subscription fee. While most of these magazines are German, Dutch or Italian, some of these magazines are published in English and contain articles on bicycle comfort and performance modifications.

Step #3: Finding specific bicycle parts that perform the required modifications (Please refer to Figure 3.3).

This final step ties all the previous information together and applies it to develop a lists of bicycle parts for the Comfort Guide. We used several sources to collect the necessary information needed, focusing on the most easily obtainable components before looking into rarer parts.

Figure 3.3: Example of logic for step #3:

Location: Neck

Symptom: Reduced range of motion

Motion: Difficulty turning head

Problem: Looking to see other vehicles/people

Solution: Attach mirrors to handlebars

The primary source of part information was online retailers of bicycles and bicycle parts such as Performance Bike and Nashbar. Initially, we thought that it might be difficult to find companies willing to ship to Denmark, but this turned out not to be a problem. Nearly every large bicycle manufacturer in the world possesses a European warehouses and distributes parts from there. Those that do not possess European distribution points will ship to Denmark for a considerable fee.

3.3 VERIFYING OUR INFORMATION

Concurrently with conducting online research, we visited a number of bicycle shops in the Copenhagen area to assess the characteristics of these shops. We visited two categories of bicycle shops: small, specialized city shops and larger, more comprehensive

dealers. During these visits, we established a basic knowledge of the typical Danish bicycles shop's stock and gauged the level of shop employee expertise. We completed a standardized data collection form during each larger shop visit to record the information and conducted a brief interview of an employee. The interview questions focused on the volume of bicycle components sold and what the employee might do if a person with cycling difficulty entered their store looking for help. The store's floor was then inspected for types of bicycles, parts, rider accessories, and any unusual components.

The larger shops in Copenhagen were difficult to find among all the small dealers. Allan Carstensen, DCF bicycle shop manager and former bicycle shop owner, pointed us towards shops we would have interest in. He gave us a list of five larger shops we should visit. The small shops were chosen at random as we moved about the city on various excursions. Each time we saw a bicycle shop, we went in; we made sure we surveyed a range of shops in different parts of the city by using a telephone book to locate shops in areas we did not typically venture into. The results of these visits are contained in Chapters 4.0 and 5.0 of this report and Appendix G.

3.4 CONSTRUCTING "A CYCLISTS COMFORT GUIDE"

To ensure the feasibility of our Comfort Guide, we spent time discussing possible publication methods with our liaisons at the DCF, Jens Petersen and Ingrid Pedersen. This was a very important step, as we performed a simple cost-benefit analysis of different publication formats. From this discussion, it was concluded that a website

would be the easiest and cheapest way for the DCF to distribute the information in our Comfort Guide. An online publication would also be the easiest to update with new information and sections, and a web-based Comfort Guide would enable other interested organizations, such as the Gigtforeningen, to access the information.

3.4.1 WEBSITE DEVELOPMENT

To ensure the effectiveness of our Comfort Guide website, we spent significant time developing and designing the website format. This process began by investigating periodic publications such as "Family Health" and "Consumer Reports" as well as websites that allow the user to "design your own" product, like www.trekbikes.com or www.mini.com. These websites generally provide a range of choices in each step to design a bicycle or car to specification. To better understand how such companies present their information and what types of information they include, we classified their information into several categories: product description, distributor, visual representation, etc. We thus developed several different examples of possible website formats for our information and, from these examples, we used the best characteristics of each and constructed the framework for our Comfort Guide. This framework was then used as the material for a focus group to evaluate structure, format, and visual appearance of our information.

3.4.2 FOCUS GROUP

We had planned on a focus group of six to eight people, inviting nine with the assumption that some would not be able to attend. Those we invited included two employees of the Gigtforeningen, two employees of the RevalideringsCentret, an employee of the Hjælpemiddelinstituttet, a doctoral student in website design, and three employees of the DCF. The eventual attendance was only four, which was disappointing, but still enormously beneficial. The subjects of the focus group were: Jens Pederson, DCF director; Allan Carstensen; Finn Såbye, technical aids tester at the Hjælpemiddelinstituttet; and Annemette Thorhauge, doctoral student in web communications at the Københavns Universitet. Our choices for subjects reflected our desire to get the maximum input on the efficacy of the website's organization and communication of information. The focus group took place on Friday, April 11th, 2003, at 4:00pm. After the subjects arrived, we briefly presented our project and the goal of the focus group. Then each member was given a short role-play of an individual who possessed difficulties cycling due to a physical condition and was asked to find solutions to that problem using our website. Half an hour was provided for the participants to browse the website and evaluate its effectiveness during which they were observed. At the end of that time, an hour was spent discussing possible changes and improvements. A further discussion of the results of this focus group as well as ways they were implemented is located in section 5.0 of this project report.

3.4.3 Data Entry and Uploading

After the final format of our Comfort Guide was determined, it was then compiled and the data entered using a combination of Microsoft Word and Excel. The website was constructed using Microsoft FrontPage. As a website is the selected medium, an English version will be posted and eventually be translated into Danish. Further discussion of our choices in this case and the reasoning behind them may be found in section 5.0 of this project report.

3.4.4 Survey and Focus Group Results

The results of the several survey and focus groups were extremely important to our project in terms of establishing areas of focus and information for the user audience. Once gathered, the knowledge gained was used to improve the usefulness of our Comfort Guide. The data collected were also useful in compiling our recommendations for future changes and additions, which may be found in section 6.0 of this project report.

3.5 Development of Recommendations for the Future

As stated previously, our Comfort Guide is a model for future researchers to follow while providing practical information on a number of important conditions. It was not feasible for us to comprehensively address all problems in this domain. Thus we believed it was more important to lay a firm foundation. We developed a set of "Recommendations for the Future" in order to direct the DCF or future WPI project teams in further aiding Danish cyclists. These recommendations are a plan of attack on how to boost awareness

of our Comfort Guide, how to test the viability of our results, and how to create a support network for Danish bicyclists so that the knowledge in our Comfort Guide may continue to spread throughout Denmark and across national boarders. The recommendations consist of a list of ideas on how to publicize our Comfort Guide, list of methods to test our findings, and ideas for increasing the usefulness of the website. These recommendations were gleaned from our project team's brainstorming over the course of the project as well as input from our focus group and various suggestions received from reviewers that we were unable to incorporate before final publication. The Comfort Guide recommendations are included in this report as section 6.0.

4.0 Building a Cyclist's Comfort Guide – Foundations

The literature review we conducted on the topic of bicycle modification to improve comfort demonstrated that the information and research required to make bicycles more comfortable, while scant and scattered, was available. Often this research was done in regards to a specific condition or to improve the efficiency of a racing bicycle, or in regards to common cycling overuse conditions, but the same principles can be applied to many physical difficulties. The challenge, then, was two-fold: to collect information on bicycling comfort, uncovering the underlying principles that would make that information applicable to a wide range of physical abilities, and to present this information in an intuitive, easily accessible format that could be easily maintained and improved.

4.1 Identifying Conditions

There are thousands of medical conditions that could potentially make cycling difficult. Trying to address each one of them specifically and individually in a single project would be unfeasible. Thus, we had to choose a limited number of conditions that would be representative of a much larger group. This concept was effective because we were in no way trying to treat the conditions themselves, but reduce the aggravation of the symptoms. For example, we were not attempting to heal Parkinson's disease by changing a bicycle's braking system. Rather, we were suggesting that a more efficient set of brakes might be used to reduce the strength required from hand muscles weakened by Parkinson's disease. Given that the conditions we selected to concentrate on were

diverse enough in symptomatology, then someone with a known symptom at a specific location of the body, regardless of cause, could potentially use our recommendations. For example, lower back pain while cycling would be relieved in the same manner regardless of whether it was originally caused by whiplash from a traffic accident or by ankylosing spondylitis (Morbus Bechterew's disease).

Fortunately, the three conditions initially identified to us by our liaison, Jens Pedersen, are characterized by symptoms and symptom locations that are very inclusive: arthritis (rheumatism), whiplash, and post-polio syndrome (PPS). We gathered numerous journal articles on these three conditions while in the U.S., which made little additional research necessary while in Denmark. Additionally, nine other conditions researched in first phases of this project (Please see Appendix B) were used as references to confirm that our recommendations were applicable to as wide a range of medical conditions as possible.

During our visit to the RevalideringsCentret, the rehabilitation and adaptive technology center where the impetus for this project originated, we were encouraged to discover that the strategy explained above was one they had also used in their research. While their project focused almost largely on range of motion and strength issues, using whiplash, osteoporosis, ankylosing spondylitis and various types of arthritis as their base conditions, the principle was the same. The project at the RevalideringsCentret was quite advanced and more specialized than our own, in regards to the cycling equipment and testing of the equipment. Their project had reached a stage where some custom-made

comfort bicycles were being tested by people with the studied conditions. It was interesting to note that these affected individuals did not identify their cycling problems with their conditions, but rather with the symptoms of the condition that cycling aggravated. This further demonstrated the practicality of identifying symptoms and relieving them rather than attempting to address individual conditions.

More confirmation of the usefulness of our plan was obtained from the results of the surveys we conducted of the DCF chapters (Please see Appendix E). While statistical analysis of the survey results was not feasible, we were able to put together a list of conditions identified by the survey subjects. The results confirmed that the three conditions we chose would be applicable to nearly the entire range with the exception of respiratory and mental conditions. Laziness, although identified by one chapter director, was also not a condition we chose to address as the symptoms of arthritis, post-polio syndrome, and whiplash do not apply very well.

4.2 Classifying Symptoms

Once we identified the conditions to focus on, our next task was to identify the symptoms of those conditions. Each of the selected conditions was characterized by a number of symptoms that affect different parts of the body while cycling. Following the purpose of this project, all non-pathomechanical symptoms of the chosen conditions were ignored, as it would be impossible to address these by modifying a bicycle. With whiplash, for example, symptoms of tinnitus and headaches were ignored. Accordingly, classifying the types of symptoms that might affect each specific part of the body during cycling directed

the scope of the project upon three distinct symptom types: pain, reduced strength, and reduced range of motion. The three symptoms were to be found at fourteen locations on the body from the neck to the feet.

The next step was to relate the conditions, symptoms, and symptom locations in an easily understandable way. To accomplish this task we began by constructing a chart that correlated conditions with associated symptoms (Please see Appendix F) and a second chart correlating symptoms with locations where those symptoms characteristically occur (Please see Appendix H), as outlined in the methodology. The charts confirmed that at least one of the three identified conditions affected every major part of the body. The locations we chose to concentrate on were identified by sectioning the body into major muscle groups and joints used while cycling. These sections totaled fourteen, including three muscle groups: leg, arm, and seat (buttocks); five joints: wrist, elbow, ankle, knee, and hip; three muscle/joint systems: hand, shoulder, and foot; and three sections of the spinal column: lower back, upper back, and neck. At any of these locations, three symptoms were identified as potentially causing cycling difficulty: pain, reduced strength, and reduced range of motion. These were eventually narrowed down slightly because not every location could be affected by all three symptoms. For example, a joint such as the elbow does not have strength problems for the purposes of this project because the muscles of the arm provide strength to the joint. Similarly, the leg would not have range of motion difficulties because the knee is the body part with the range of motion concern. While such simplification was impractical for precise medical use, we

chose to make some generalizations to simplify the process due to our limited knowledge of orthopedics and biomechanics.

4.3 Defining Aggravating Principles and Using them to Modify the Bicycle Rider System

Using our research in the biomechanics, we defined several "aggravating" principles that applied to each symptom across all fourteen locations. The aggravating principles were general circumstances under which the symptoms of different conditions might be aggravated. They are listed below with examples of how they were used to develop our Comfort Guide.

- Pain can be aggravated by
    - Vibration
        - Road shock is the principal cause of vibration and impact transmitted to the body through the bicycle frame. Anything that can help to reduce vibration and jolting can be useful for reducing the pain a rider experiences.
        - Vibration is transmitted throughout the body from the point of origin. While vibration may originate in the handlebars, it will be transmitted through the hands and arms, and the neck might also be affected.
        - Example: Lower back pain can be alleviated by adding a suspension saddle post.

Explanation: Since vibration is often transmitted through the saddle to the buttocks and up to the lower back, by using a suspension saddle post that acts as a shock absorber, the pain experienced in the lower back can be reduced.

- Pressure
  - In order for the body to maintain any position, force equal to the weight of the body must be exerted on some portion of the body. When standing, the load is distributed across one point, the feet, and is dispersed vertically through the ankles, knees, etc. When seated on a bicycle, there are three separate points where pressure is applied: feet, buttocks, and hands. It follows then, that to reduce pressure applied to the hands more weight must be supported by the buttocks and feet. This is the principle we used in determining modifications that could be made: shift pressure away from the point of aggravation and more to the less problematic areas.
  - Example: Wrist pain can be alleviated by replacing the handlebar with one that sits higher and closer to the body.

    Explanation: By moving the position of the hands higher and closer to the body the rider sits in a more upright position, removing pressure from the hands and wrists. The reduction of pressure on the hands can help to reduce pain in the hands due to cycling.

- Reduced range of motion can be aggravated by
  - Any unnecessary/exaggerated motion in any direction

        - If a person's range of motion is reduced, unnecessary motions could cause aggravation at the joint where the motion is required.
        - Example: The need to move the knee in a way that might be difficult or impossible can be avoided by using a frame with a low step-over.

          Explanation: A frame with a low step-over requires the rider to lift the leg only 8 inches (20cm) off the ground to mount the bicycle. This is much less than the traditional bicycle that requires the rider to bring the leg over the saddle in order to ride

- Reduced strength may be a problem if:
    - Any required force is greater than the ability of the rider
        - If the rider has difficulty applying or cannot apply the required force in various motions to ride a bicycle, it will be difficult or impossible to cycle.
        - Example: Reduced strength in the leg can be addressed by adding multiple gears to the drive-train of the bicycle.

          Explanation: Adding extra gears to the bicycle helps to provide options for the rider in terms of the mechanical advantage available with each push of the pedal. By increasing the mechanical advantage, less strength is required to turn the back wheel and propel the bicycle forward.

In addition to these principles, we used explicit recommendations that we found in our background research for a wide range of conditions. Some of these ideas were specific and some we were able to extrapolate to be applied to other parts of the body. For example, gloves are often used by people with arthritis in their fingers to keep the joints warm and supple. Similarly, people with arthritis in the knees may consider using long,

warm pants for the same purpose. It is worth noting that a majority of the information gathered and prepared was found exclusively in scholarly journals seldom perused by people without an explicit research interest, or in volumes about cycling, which are not generally used as sources for medical knowledge. This information is not immediately accessible by medical practitioners, let alone to the average person with cycling difficulties, further emphasizing the importance of gathering this store of knowledge in one location and determining the fundamental principles that could then be expanded to apply to multiple symptomatologies.

The resulting information from our research and biomechanical analysis was organized into charts based on symptom type/symptom location combinations. For instance, arm/pain would be one chart with its own list of recommendations, and knee/range of motion would be another separate chart. Thirty-three separate charts were constructed in this manner and each chart contained up to fifteen separate recommendations. The information displayed on these charts include the name of the recommended modification/adjustment and a short blurb explaining how the recommendation could improve cycling comfort (Please see Appendix I). These charts are also displayed on our website.

4.4 Identification of Bicycle Parts

The general modification identified, our team then began the process of researching specific bicycle parts. These parts were to be displayed on the website as examples of the range of products available to the consumer. For each of 30 general modifications we

came up with, we identified five to fifteen specific bicycle parts made by a variety of manufacturers. In all, just over 300 specific parts were identified and placed in spreadsheets by type: men's saddle, suspension saddle-post, etc. For each part we recorded a picture of the part, the part's name, the manufacturer's name, where the part might be found, and the price. All this information was then compiled onto nineteen distinct "parts pages" that were included as part of our website (Please see Appendix J).

While we were collecting the information on the various parts, we were concerned that we might appear to be endorsing a specific manufacturer so we displayed a wide range of parts from as many different manufacturers as possible. We also included a disclaimer at the top of each parts page that explained that the parts displayed were merely an example of those available on the market. We hoped that a person accessing the site for help would take down the information about the specific part that might be useful to them, then take that information to their local bicycle shop and be able to purchase a part that would be similar to, if not the same as, the one on our website, justifying the premise of providing examples. When we ran our focus group, however, our subjects were very concerned that we appeared to be promoting the specific products we included on the website. They felt that the disclaimer was not enough to show that a promotional bias did not exist. Upon their suggestion, we changed the parts pages to merely included links to possible distributors with a black-and-white silhouette of each category of part. This change had several distinct advantages:

- We no longer appeared to be promoting any particular manufacturer.

- New parts are developed all the time, so a page with specific parts would need to be updated constantly. By not including specific parts, we greatly reduced the amount of maintenance the site would require.
- We no longer had to be concerned about copyright issues associated with using the pictures of each specific part.

While the shift away from having specific parts on our website was certainly for the better, a large amount of our research and efforts was rendered unusable and the parts pages were not as eye-catching as they had been with multiple color pictures of bicycle parts. As Carstensen said during the focus group discussion, "[Having pictures] is much sexier, but taking them out is more practical."

4.5 BICYCLE SHOP VISITS

While we were compiling our Comfort Guide, we also visited a number of bicycle shops in the Copenhagen area. The results of the visits were to be used primarily to establish a base knowledge of how shops in Denmark generally operate. We discovered, as we had initially suspected, that most shops stock a limited number of very common parts (i.e. tires, saddles, etc.) and order the rest through a variety of catalogs. We were pleased to find that nearly any part available in the U.S. is also available in Denmark and that nearly any bicycle shop can order and install a wide range of parts. Some of the more specialized components need to be ordered and installed at the larger dealers, but fortunately this was not a major problem for our purposes because such specialized parts are not usually useful to people with disabilities. The typical bicycle shop, like the hundreds that are located throughout the country, stocks a small selection of city bicycles

and shopping cycles. The larger stores also showcase specialized all-terrain, road racing, cyclocross, hybrid, and comfort bicycles. Most employees were very willing to help people with various medical conditions, mostly focusing on back and neck pain. We were impressed with the fact that, when asked what they would do if someone came in complaining of neck pain, several employees stated that it would be important to know the type of bicycling they might be doing in order to tailor the modification to the person's needs. This is a founding principle of our project, so we were happy to see this awareness.

5.0 BUILDING A CYCLIST'S COMFORT GUIDE – STRUCTURE

The website constructed to display the information collected and analyzed in our project was, in itself, a massive and time-consuming project. In its current state, the website contains over 90 individual solutions to a variety of symptom/symptom location combinations, organized into thirty-three separate webpages. There are also twenty individual bicycle part pages, fourteen symptom locations pages and ten supplementary informational pages, bringing the total number of pages in our website to seventy-seven. The size of the website brought forth concerns about user navigation. The website had to be simple and intuitive to use and, most importantly, informative. As a result, our site's structure and layout need to be adjusted repeatedly to optimize the user interface.

The decision to use a web based publication medium for our research was only finalized a few days after our arrival in Denmark. Prior to this, our project team had contemplated several different mediums of publication, including a hardcopy or a CD. The final decision, however, needed to be made by the DCF, as they would be responsible for the publication and distribution of the Comfort Guide. After a discussion about the advantages and disadvantages of the various mediums, a web-based medium was selected. The primary factors in the DCF's decision were the low distribution cost of a website, the ability to regularly update the information easily, and the number of individuals the information could reach.

5.1 SOFTWARE

Our website was designed on was Microsoft FrontPage, with the graphic design being created in Microsoft Paint. Neither of these programs was ideal for the creation of a professional website and much time during the project was spent dealing with the various shortcomings of both programs. The text and picture formatting issues of FrontPage and the inability to resize pictures without severe distortion in Paint were especially frustrating. Unfortunately, these programs were our only options. Software compatibility with the DCF website was our primary reason for using FrontPage, since the DCF used FrontPage to create their current website. This would prevent any untoward side effects that using a non-Microsoft package might create, while ensuring that the technical knowledge necessary to maintain the Comfort Guide was already present in the DCF staff. Lack of technical knowledge was also a factor in this decision, for our team's only experience in web design was in FrontPage. The absence of alternative options was our sole reasoning for using Microsoft Paint. It was the only graphics program installed on either of the laptops our project team possessed and any software the DCF could provide us was in Danish.

5.2 WEBSITE STRUCTURE

After selecting the software packages for the creation of our website, visualization of the site's basic structure began. We constructed a list of who would have contact with the Comfort Guide website and for whom it should be primarily designed. Our team concluded that three different groups of individuals would have contact with our site:

- Users: affected individuals, cycling experts, doctors, etc.)
- Webmasters: the DCF secretariat
- Creators: the members of our project team

Based upon the ideas in our Mission Statement, we decided that the users were of primary importance, followed by the webmasters and lastly the creators. This meant that our website would be designed primarily in the interest of those utilizing the information. Obtaining information from the website would have to be a simple and intuitive process. Website maintenance would be of secondary concern. We would do our utmost to ensure that updating information and adding parts to the website would be a simple, low maintenance process, but not at the detriment to user interface.

We then brainstormed general organizational webs. Initially, a searchable database structure and a tabular structure were both heavily considered as viable structural candidates. The database structure from the home page would be searchable by condition and symptom location combinations. The results of this query would then bring the user to a recommendations page of general modifications for the requested condition and symptom location combination. Users could then select a general modification, bringing up a list of specific bicycle parts. Advantages of using this searchable database structure would have included reduction in the amount of informational input and the ability for users to cross-reference multiple condition and symptom location combinations. Disadvantages included issues of integrating a database into a webpage, confusing user interfaces and considerable learning curves for webmasters putting new information into the site.

The other option, a tabular structure, was a far simpler design. However, organizing tables would require a much greater number of pages. From the home page of this structure, users would select their conditions from a table of conditions, taking them to a page where they would select their symptom location (leg, arm, etc.), followed by a page asking them to select their symptom type (pain, strength loss, etc.). This would then bring them to a recommendations page with general modifications, which would be followed by pages on specific bicycle parts. Advantages of this structure included a more intuitive navigational layout for the user, less required expertise for addition of new information, and less technical expertise required for construction. Disadvantages included a greater number of separate pages, redundant input of information, and lack of cross-referencing ability.

To select which of these two general structures to use, the team considered the target audience for the website. Ultimately, the deciding criterion was the user-friendliness of the two structures. The tabular layout was selected for our Comfort Guide website. The database structure would have offered the user more power and control. However, when compared to the confusion such a structure might have produced for some users, especially elderly users, we felt the tabular layout offered greater benefits. Additionally, the benefits afforded by the tabular structure in terms of easy addition of information appealed to us since the Comfort Guide was designed to be a living document that would continue to grow.

The determination to use the tabular structure for our website was not the end of our website's structural design. Two large changes required us to overhaul our site. The first change significantly improved the user-friendliness of our website. Our team determined that a bicycle rider with red pinpoints on various bodily locations (Please see Figure 5.2) was a more intuitive way of asking users to select their symptom location and appropriately the rider replaced the text on the pages where the user identified the affected body part. This rider also added a visual component to the website, breaking the textual monotony.

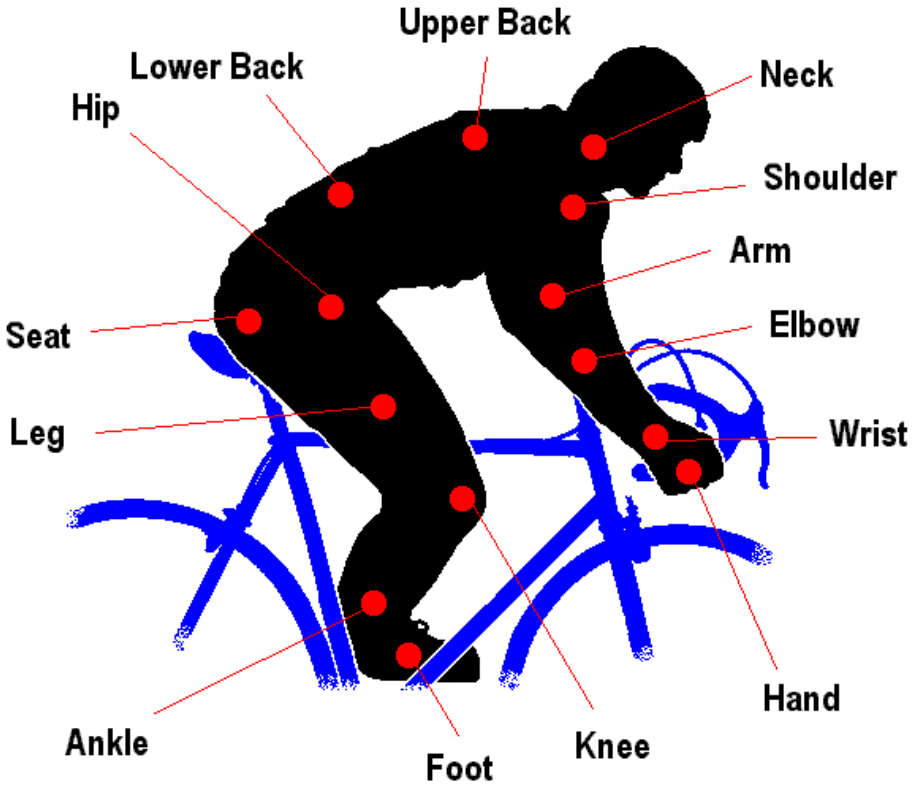


Figure 5.2 - Old bicycle mascot

The last major structural change we made was more a result of progress in our research than a web development idea. We concluded that the recommendations for improved rider comfort depended upon the type of symptom and its location regardless of the condition itself. For the purposes of our project, shoulder pain caused by either whiplash or post-polio could be treated in exactly the same way. Accordingly, the entire conditions selection step in our website's structural setup could be eliminated, making locations selection the user's first step. This not only reduced the number of steps required to get from the homepage to the recommendations pages, but also greatly simplified the process of updating the information for the webmaster.

5.3 WEBPAGE CREATION AND ORGANIZATION

Once the website's structure was determined, construction of the webpages and navigational structure began. Analyzing the general structure of our site, we categorized its pages into four types: "Symptoms" pages, "Solutions" pages, "Part" pages, and "Information" pages:

- Symptoms pages consisted of pages for each location requesting the user to select their symptom type. These pages were organized into a folder titled symptoms and given the naming designation "Symptom Types *Location Name*.htm". For example, the page asking the user select the symptom type for the ankle would be entitled "Symptom Type Ankle.htm" (Please see Appendix K). This organized folder naming scheme was extremely important for the site as a whole as it would greatly increase the efficiency with which the website could be updated by both the creators and the webmasters.

- Solutions pages consisted of a list of recommendations for bicycle modification corresponding to a symptom and its location. For instance arm (location) – pain (symptom) would have its own solutions pages (Please see Appendix I). This page would be given the designation "Solutions *Location Name Symptom Name.*htm"; in this case "Solutions Arm Pain.htm". All solutions pages were placed into a folder titled "Solutions" containing three subfolders titled "Loss of Strength", "Pain", and "Range of Motion".
- Part pages, our third category of pages, were originally designed to provide examples of specific parts for the users. A user could access these pages after clicking a general modification on a solutions page. From there, tables of information about price, manufacture, and distributional websites would be provided for various bicycle parts and accessories (Please see Appendix J). All part pages were placed into a folder entitled "Parts Pages" and were giving the designation "*Part Name.*htm".
- Information pages included various informative pages, placed into a folder entitled "About" to increase organization. These pages include the "Site Map", the "About" page, the "FAQ" page, the "Disclaimer" page, etc. These were named in a descriptive manner, without a specific naming protocol.

The only page not placed in a folder is the "Home" page of the website named guide.htm (Please see Appendix L).

From the home page to the user end point, the stage where the user would have the information they required, the web structure of the web pages originally progressed as follows: home page → location page → symptoms page → solutions page → part page.

Each page also linked to the home page via a "Home" button. All the Information pages could be accessed from the home page (Please see Figure 5.3)

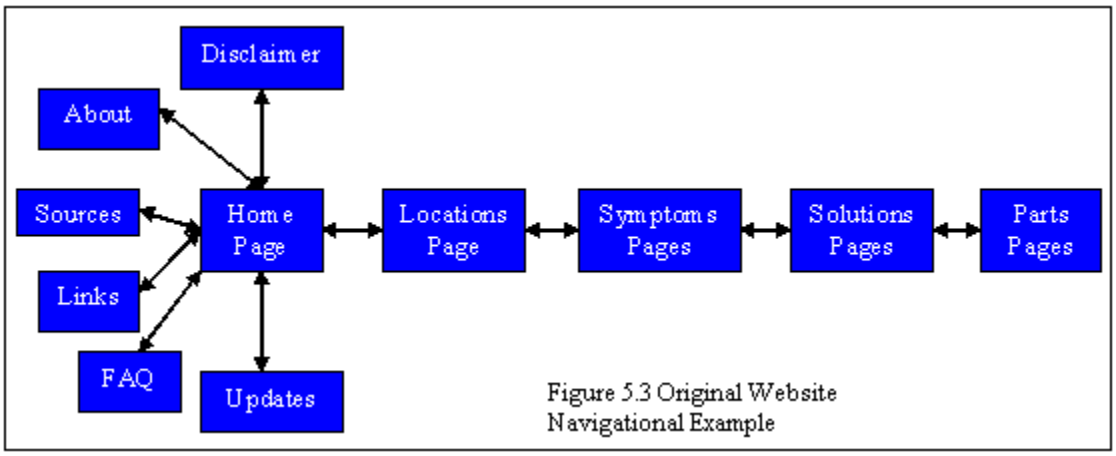


Figure 5.3 Original Website Navigational Example

5.4 Web Page Artwork and Professional Appearance

Designing a professional website involves more than just the quality of the information provided on the site; it is about designing a polished appearance. The importance of polished and professional website display cannot be underestimated in web development. It plays an integral part in the interactive communication process. If a website has a poor graphic user interface or if it is confusing for the user then the value of the site's information is diminished. Few users will trust information on a webpage that visually appears haphazardly constructed. Even fewer users will read instruction on how to navigate a webpage. Our team needed to grasp the aspects that make a website look and feel professional in order to create a functional and useful website. This was accomplished by surfing the web and analyzing the positive and negative aspects of various websites hosted by such organizations as Microsoft, CNN, WPI, and NASDAQ.

One of the first things we gleaned from these websites is the concept of a website theme. We adopted a display containing common visual elements on different pages as well as a common color scheme in the development of our Comfort Guide website. The theme established unity between the many different pages. A webpage template was created for every page except the home page. This template was roughly based on the DCF website. The DCF page works with frames, so our color schemes and the general feel of our Comfort Guide website had to work well with their website. Their usage of black and blue on the DCF website influenced our own pages. Both their logo and background were assimilated into the webpage template. Their logo was also modified into a home and back button for the site. Horizontal lines were added to the top and bottom of the template to enclose the space and give each page a feeling of completeness. A banner was also added using the shared borders feature. The template was placed onto every page in the website (Please see Appendix M). We quickly realized the recognition value of the bicycle rider and utilized him as a sort of site mascot.

Given that our project team contained no experts in the website design field, we sought the advice of the experts in order to improve our site's professionalism. Ensuring that the site was structured well and looked professional was essential. Online sources of the do's and the don'ts of website design were consulted to conform our website to the recommendations of the experts. "A Cyclist's Comfort Guide" was then modified according to these recommendations. For instance, all underlining of non-hyperlinked words were removed (WC3, 2003). Other suggestions from the experts included keeping individual page length under two screens (www.webstyleguide.com, 2002), providing an

additional text hyper-link for hyper-linked pictures (WC3, 2003), and the inclusion of site designer biographies (Nielsen, 1999).

Another positive aspect of webpage design our team adopted was the use of original graphics, often interactive. The bicycle rider, the homepage banner, the symptoms buttons, the home button and back button were all results of original graphic art. In the early stages of the website, the function of these graphics was held by text. However, after our website research, the text was replaced. This new, originally designed artwork proved to be much more visually appealing. The only downside to the web art was the amount of time that had to be allocated to its design. Hours were spent designing and polishing the graphics since the only available program was Microsoft Paint. Every graphic was created on Microsoft Paint and imported onto the webpage. Often, several attempts were needed to achieve the desired effect.

5.5 Disclaimer and Instructional Text

Having completed the structure and general page layouts, insertion of text to guide the user around the website began. The wording for this instructive text was carefully selected and added to our web pages in the forms of instructional blurbs and disclaimers. Great attention was placed on keeping these blurbs and disclaimers short, for we worried about losing the attention of our users. Nonetheless, the importance of the message needed to be emphasized, especially in the medical disclaimer above the solutions pages, as it was vital for the user to access and utilize the information properly. The importance

of these sentences cannot be overstated. As concise as they were, these sentences undoubtedly required forceful wording.

5.6 Pre-Focus Group Layouts of Solution and Parts Pages

Well designed navigational construction and visual presentation of a website only guarantees that the user can access the required information. Properly comprehending the information depends greatly on what information is provided and how it is presented to the user. The formatting of the solutions pages and part pages were meticulously crafted.

On the solutions pages, it was determined that users needed not only to identify what adjustment or modification to make, but also to discern why these could help. Additionally, the sources of our information (journal articles, etc.) were also included to lend credence to our suggestions. It was further determined that to increase user comprehension, the information contained on the solutions pages needed to be categorized into Frames, Bicycle Parts, Bicycle Adjustments, and Rider Accessories. The placement of this information on the page was also an important part of the formatting process. It was decided a left-to-right display of modification/adjustment, reasoning, and references, divided into charts by subcategories was best (Please see Appendix N).

The information selected for display on the parts pages included product name, manufacturer, a picture, the distribution website, and the price for the individual example

parts. Some of these pages were also split into categories. For example, the handlebars part page was separated into aerobars, handlebars, and bar ends. Parts were organized alphabetically to avoid promotion of any single product (Please see Appendix J)

5.7 The Focus Group and Its Effects

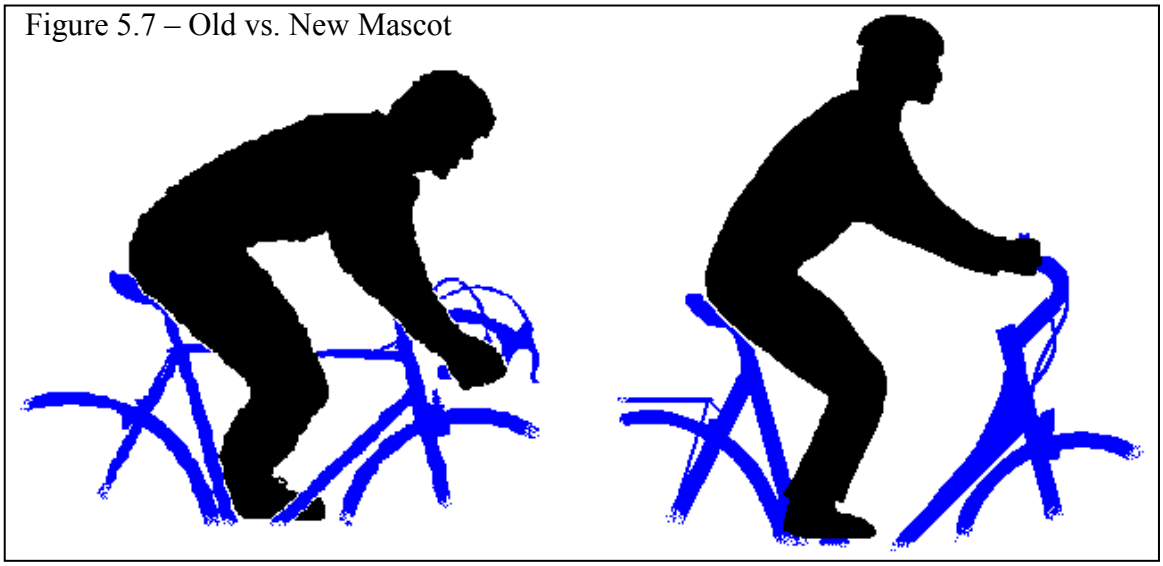
With the formatting of the website formulated, data entry could proceed. However, in the interests of user-friendliness, full-scale data entry was postponed and a focus group was conducted to increase the site's functionality. The goal of this focus group was to acquire feedback on the structure, format, and visual appearance of the website from the vantage point of a user. During the focus group, user feedback was provided in two ways: open discussion among the participants and observation of the participants as they browsed the site. Both types of feedback provided equally valuable information, after the participants switched their dialog from Danish to English. Overall, the participants of the focus group were very impressed with the site. Nonetheless drawbacks in the website's structure, layout, and display were discovered.

The largest criticism uncovered during the focus group was the concept of the part pages. Finn Såbye of the HMI and Allan Carstensen of the DCF, both technical experts cycling, were concerned that the parts pages appeared to endorse the specific parts. Also, the constantly changing bicycle market would necessitate regular updating and research for these pages. They suggested that the parts pages should consist of a generic picture of the part followed by a list of websites where the user could view examples. A well-worded disclaimer, specifically stating non-endorsement, was also strongly suggested.

These recommendations were thoroughly considered and included in our final parts pages (Please see Appendix L).

Other criticisms made in the focus group comprised mainly of clarity and simplicity issues. Our mascot was thought to be misleading and would have to be redrawn (Please see Figure 5.7). He was originally mounted upon a racing bicycle, not a comfort bicycle, and all the participants felt it presented the wrong image of the site.

Figure 5.7 – Old vs. New Mascot



The group also questioned why the mascot was not on the home page, where his presence would require one less click. As we had no response to this question, our mascot soon found himself a new home. Another clarity issue involved the placement of the bookmarks on the solutions pages. Both Annemette Thorhauge, communications doctorate student, and Jens Petersen, DCF director, found the bookmarks misleading and confusing. They were confused by the fact that the bookmarks were optional, not required, features. These bookmarks were moved to avoid this problem. Simplicity issues centered on what was seen as excessive, overly technical information: specifically

our references lists and sources page. The group participants pointed out that the average user would not use, understand, or care about our references. References would only bring forth confusion, and should, therefore, be removed. Their advice was followed; the references were removed and the sources page buried further into the web. Many other small drawbacks were also realized during the course of the focus group (Please see Appendix O). However, the focus group liked the overall look of the website. The color schemes and the web layout were considered intuitive and pleasing to the eye.

5.8 DATA ENTRY

The website, after a few days of adjustments based on the results of the focus group, was now ready for full scale data entry (Please see Figure 5.8 for final website structure).

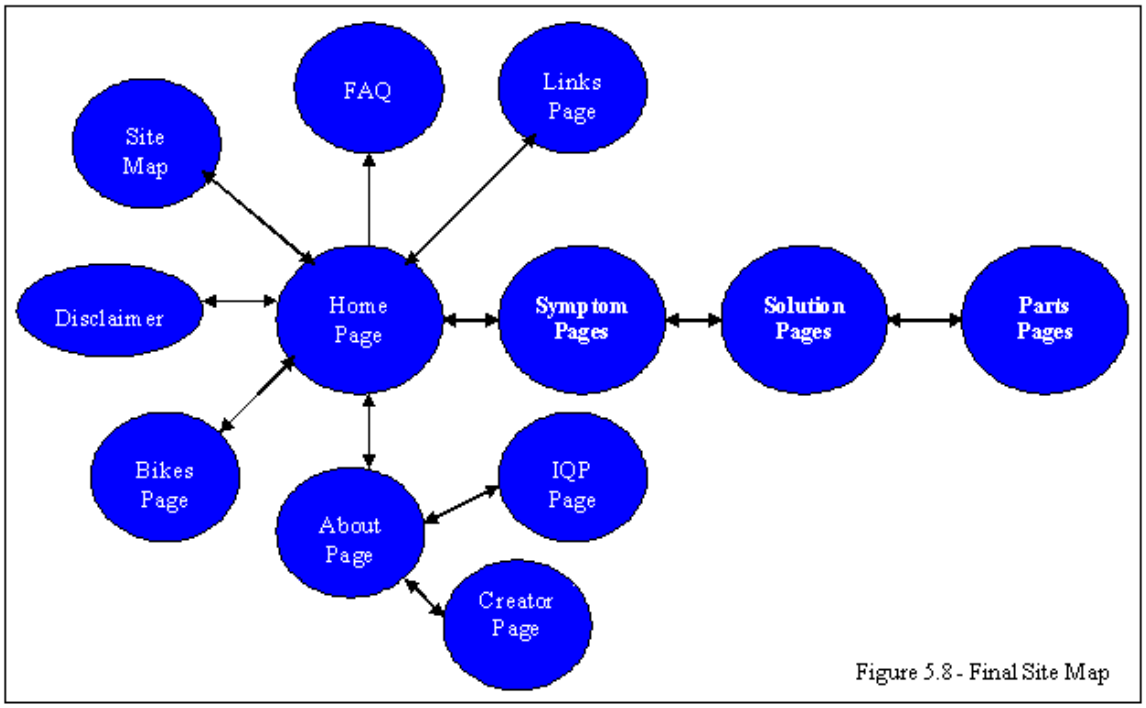


Figure 5.8 - Final Site Map

Two major sections of information existed in the Comfort Guide: solutions information and parts information. Prior to the focus group, a majority of the parts information had

already been added to the web, so that the participants could appreciate the entirety of the website effectively. However, as a result of the post-focus group changes, the amount of parts information displayed was greatly reduced. Web URLs to the various distributors became the only relevant information on the parts pages and all other information was removed.

The majority of the solutions information was complied into tables on Microsoft Excel spreadsheets. These tables were to be inserted into the webpage template to produce the Solutions pages. FrontPage, unfortunately, does not permit cutting and pasting of Excel spreadsheets. Instead Excel sheets would have to be inserted using the "Components" feature, which created visual formatting issues on the webpages. To avoid this, all spreadsheets were first pasted into Word, where the spreadsheets were automatically reformatted into tables. These tables could then be pasted into FrontPage.

5.9 UPLOADING AND FINISHING TOUCHES

Finishing touches on the website involved adding Information pages, deleting and renaming files/folders and enhancing page download rate. Webpages inserted at this point included a page about the IQP and a page about the website's creators. These pages were low priority as the audience for them was not the average user, but for people specifically looking at web design issues and for research purposes. They were designed to provide insight into why this site was created and by whom. Extra non-linked pages were then deleted, along with pictures no longer used on the site and the names of all remaining files were edited to assure accordance with the proper naming conventions.

Lastly, the paragraph ("¶") feature was turned on and all extraneous Microsoft comments were removed. Microsoft FrontPage automatically inserts numerous blank comments onto pages. By removing these, the download speed on a 28.8 modem improved by approximately six seconds per page. The website was now complete and ready for posting.

The posting of the Comfort Guide website did not proceed smoothly. Ideally, the DCF would have uploaded it to their FTP server, created a link from their home page, and "A Cyclist's Comfort Guide" would have been operational. In reality, only 25% of the site was operational. The rest of the site was plagued by broken links. After a few hours of inspection, we determined to the problem was that while Microsoft FrontPage was not sensitive to capitalization, the FTP server was. If a link on the FTP server was searching for a file, it would not find it unless the capitalization was identical. Fixing this problem involved altering seventy-seven page names and 858 internal links to contain only lowercase letters. The site was then uploaded to http://www.dcf.dk/comfort/guide.htm, where it is currently fully functional.

6.0 RECOMMENDATIONS FOR THE FUTURE

Although the base for "A Cyclists' Comfort Guide" has been constructed, there is always room for improvement and expansion. Bicycle technology will continue to progress and discomfort on bicycles will continue to occur. That is why the Comfort Guide must also continue to develop and grow. There are three primary areas where additional work is recommended to help cyclists optimize comfort:

- While the Comfort Guide can be of enormous help to people with cycling difficulties, it in no way takes the place of professional help from doctors, occupational therapists and bicycle experts. Ensuring that these groups are in contact with the people who need their help is important.
- The current Comfort Guide website is in need of publicity. If people are unaware of the Comfort Guide, then it is of no use.
- Finally, there are many potential additions that would make the Comfort Guide more useful to people with cycling difficulties, more useful to bicycle shop owners, and more medically accurate.

6.1 CREATING A SUPPORT NETWORK FOR PEOPLE USING THE COMFORT GUIDE

This Comfort Guide enables people by informing them of basic ways to reduce discomfort and educating them in the discourse of comfort bicycle manufacturers and bicycle dealers. Providing people with a support network of expertise is also necessary in ensuring they get the best help possible to overcome their cycling difficulties. This

support network would ideally consist of bicycle dealers, bicycle manufacturers and health care professionals. Exploring new ways of approaching the process of bicycle modification using this network has exciting possibilities, like adaptive technology centers recommending bicycle modifications to their patients or bicycle shops pledging to help people find comfort on their bikes.

6.1.1 GAINING THE SUPPORT OF THE MARKET

It seems intuitive that the market for comfort bicycles would be large, given the number of people who potentially have cycling problems and the extent to which people cycle every day. The survey of DCF chapters indicates that people have numerous conditions that impede their cycling ability. At the same time, they need to cycle, for leisure and transport; it is a part of Danish culture. Determining the market for comfort bicycles in Denmark would be of enormous help in getting the market forces moving to help these people. Performing a market analysis or consumer survey to determine how many people would benefit from comfort bicycles could be accomplished by surveying the general public, the DCF membership, and individuals who have discontinued cycling due to injury or chronic pain. Armed with this information, it would be possible to pique and sustain the interest of bicycle distributors in Denmark.

Many of the largest manufacturers of comfort bicycles are in Europe. The market for comfort bicycles is growing in Germany and the Netherlands, as is evidenced by the presence of catalogs of comfort bicycles from these countries. The presence of comfort bicycles is as yet unfelt in Denmark. The results of the DCF chapter survey and the

general impression gained from walking the streets of Copenhagen indicate that most people are content to utilize plain, often ill-fitted city bikes in their daily commutes. Interviews at bicycle shops indicate that most bicycle shops carry a narrow range of parts, but can order a wide range of components for educated customers. Availability depends on what parts distributors bring into Denmark. Thus, if these distributors could be made aware of the possibilities for comfort bikes, it might make comfort bicycles and specialized parts easier to obtain. A consumer survey of cyclists and former cyclists in Denmark could accomplish this.

6.1.2 BUILDING TIES WITH THE MEDICAL COMMUNITY

While bicycle dealers and parts distributors may be unaware of the help they can best provide to people with cycling difficulties, those in the medical community may not have the technical knowledge of bicycles necessary to help individuals with cycling difficulties. To produce the Comfort Guide, we decided to simplify the modification process by assigning modifications directly to the symptoms, disregarding the conditions. This is reasonable in many cases, but there are times when the condition itself will have a huge impact on how to manage the symptomatology. For example, many forms of arthritis benefit from regular, low impact exercise. Some forms of arthritis, however, can worsen severely if the individual exercises at all. Such cases only underscore the need for individuals to consult a medical professional who is familiar with their condition before modifying their bicycle or otherwise changing their cycling routines. This medical professional could be a family doctor, a specialist, or an occupational therapist.

Organizations like the Gigtforeningen (Danish Rheumatism Association), the Landsforeningen af Polio, Trafik og Ulykkesskadede (Danish Society of Polio and Accident Victims), the Danish Morbus Bechterew Society, the RevalideringsCentret and the Hjælpemiddelinstituttet (HMI) are an invaluable resource. The support that these organizations can provide individuals dealing with the respective conditions is both specific and readily available, but it is rare to have an individual at such organizations be an expert in cycling and how to improve cycling ability. Given ideas about bicycle modifications and specific knowledge of the patient's reduced cycling abilities, doctors and occupational therapists can help them to identify the bicycle features that would be most beneficial. Ensuring that these organizations and medical professionals working with people who have various conditions that impede cycling are aware of the Comfort Guide and how to use it will help to bridge this knowledge gap. Presenting the Comfort Guide to these organizations so that they can learn what it contains and publishing articles in their journals will help raise the profile of the Comfort Guide in the Danish medical community.

6.1.3 CREATING A LENDING LIBRARY OF BICYCLE PARTS AND ACCESSORIES

The HMI, in particular, works with individuals with a wide range of physical abilities. The HMI has lending libraries where individuals can borrow assistive technology devices to ensure that they fit their abilities and lifestyles before purchasing them. These lending libraries are located at HMI regional offices all over Denmark, so setting up a program where these lending libraries could also make available a variety of bicycle modifications

would greatly increase the potential benefit that bicycle modifications could provide. Therefore, presenting the Comfort Guide and its underlying principles while emphasizing the individuality and need for medical help of each person modifying their bicycle may be valuable in setting up such a program.

6.1.4 INSTATING BICYCLE SHOP COMMITMENT PLEDGES

One of the difficulties in proposing various bicycle parts is the question of how the individual should then go about obtaining the part. While many of the parts suggested in the Comfort Guide are available in larger bicycle shops, many of the smaller city bike dealers do not carry them and are unable to order them. It then becomes necessary to direct cyclists to the bicycle shops with the expertise and the willingness to order the necessary bicycle parts. The Danish Bicycle Dealer's Association website is currently linked in the Comfort Guide to help people locate a bicycle dealer to help them select and obtain parts. During the focus group we conducted, the suggestion was made to present the website to the Danish Bicycle Dealer's Association membership, perhaps by submitting an article in their magazine, "Cykelbranchen" (Please see Appendix P). Bicycle dealers who have the knowledge and ability to help people using the Comfort Guide could pledge to do so and their shops would, in return, be listed specifically on the Comfort Guide website. The DCF has worked with the Danish Bicycle Dealer's Association in the past, facilitating the implementation of such a pledge.

6.2 Comfort Guide Publicity

Almost everyone in Denmark has been on a bicycle at some point. For many people, cycling to work, to the park or to go shopping is second nature. Many people also experience discomfort on bicycles, but accept it as minor and inevitable. When extreme pain occurs, they may continue to cycle because they need to. Letting these individuals know that there are possibilities for preventing that pain is central to the purpose of the Comfort Guide. Before the Comfort Guide, information specific to bicycle fitting and modification for comfort was scattered and obscure. The Comfort Guide is intended to make that information centrally located and easily available. However, if the Comfort Guide is not well known, the information contained within it will remain obscure. Now that the information to help alleviate pain associated with cycling is centralized, it must be disseminated.

6.2.1 Raising the awareness of the general public

Ensuring that general awareness of the importance and possibilities of bicycle fit and comfort is raised is central to the motivations behind creating the Comfort Guide. The DCF has annual campaigns such as “Vi cykel til arbejdit” (We bike to work) and is well aware of the benefits that such programs can bring about to change peoples’ perceptions and habits. A similar campaign “Cyklen for alle” (Biking for everyone) could involve bicycle shops helping the cycling public to fit their bicycles while raising the profile of the website in order to help people with specific cycling difficulties. This would not only

emphasize the importance of bicycle fit, it would raise the profile of the Comfort Guide and perhaps persuade bicycle shop owners that there is a market for comfort bikes.

6.2.2 BRINGING RELIEF TO PEOPLE WITH CONDITIONS HINDERING CYCLING

Raising awareness specifically in communities where the Comfort Guide could potentially make the biggest difference is of utmost importance. While ensuring that everyone can have the most comfortable ride possible on their bike is significant, the Comfort Guide was created particularly for people with physical difficulties in mind. The RevalideringsCentret distributed articles about their work on comfort bikes in many magazines such "Helse" and the HMI magazine, "Hjælpemidler". These Danish-language publications are distributed amongst people who are likely to have cycling difficulties. Many of these same magazines should be contacted to publish an article about the Comfort Guide (Please see Appendix P).

6.2.3 EDUCATING EVERYDAY CYCLISTS

Publications that target the cycling communities such as the DCF magazine would also be an appropriate place to disseminate information about the Comfort Guide and the kind of help that it can provide. The DCF already has connections with other cycling federations in Europe through the European Cyclists' Federation. Informing the other federations of the Comfort Guide and how it might help their membership would be beneficial. Many of these federations also have periodicals. While the Comfort Guide is more distributable in English than it might be in Danish, it might be beneficial to consider

translating it into other languages as well. Most notably, since the market for comfort bicycles in Germany and the Netherlands is expanding so rapidly, it might be constructive to translate the Comfort Guide into German and Dutch.

6.3 COMFORT GUIDE EXPANSION AND DEVELOPMENT

At this stage, the Comfort Guide can stand on its own. It contains sufficient information and is structured such that it may be of significant help to many people with cycling difficulties. However, there are numerous future improvements and features that could make it more useful. There are also possibilities for further ensuring that the information is accurate and relevant to the Danish cycling public.

6.3.1 BRIDGING LANGUAGE BARRIERS

The website must be translated into Danish. This Comfort Guide was constructed with the DCF membership as the primary audience. While many Danes do speak English fluently, it would easier to comprehend new information when it is presented in their mother tongue. The DCF has already agreed to have the Comfort Guide translated into Danish. The employment of a language student from the University of Copenhagen is being negotiated for the summer of 2003 to accomplish this task.

6.3.2 Assuring standards of maintenance and user compatibility

"A Cyclist's Comfort Guide" website was designed to keep maintenance at a minimum. Standard website maintenance will still be necessary: maintaining external links, keeping the bicycle part distributors' list updated, receiving ideas about new solutions and adding them to the Comfort Guide. Users and visitors to the Comfort Guide website should be encouraged to share their experiences and any methods that have helped them to cycle despite physical difficulty. This will help to expand the knowledge base of the Comfort Guide.

6.3.3 Recommended additions to the Comfort Guide

There are sections that could be added to the Comfort Guide to make it more comprehensive. These would include general instructional pages on bicycle fit and solutions to additional symptoms that hinder cycling.

6.3.3.1 Adjusting the bicycle-rider system

While correct cycling technique and proper bicycle fit can greatly improve the functioning of the bicycle-rider system, this knowledge is often confined to the competitive cycling world. The Comfort Guide repeatedly exhorts the importance of proper bicycle fit and touches upon ways that it can be improved. However, conveying the full importance of cycling technique and bicycle fit on both efficiency and comfort would require entirely new sections in the Comfort Guide. These sections would both convey the importance of these two aspects of cycling and explain how they can be

achieved. They would most likely be in the form of links from the homepage that visitors would be encouraged to read before searching for specific parts.

6.3.3.2 MAKING THE SYMPTOMS PAGES MORE INCLUSIVE

In our research of different conditions that can impede cycling ability and in the survey that was done of DCF chapters, there were three areas of symptomatology that were less prevalent and thus not included in the preliminary version of the Comfort Guide. These were balance problems, loss of sensory input (numbness), and skin irritation. There is potential for including these symptoms in various locations in the Comfort Guide.

6.3.4 ENSURING ACCURACY AND USEFULNESS

The accuracy and usefulness of the Comfort Guide are foremost in concern when considering its future. Having medical professionals and bicycle experts review the information contained within the Comfort Guide, perhaps in a focus group atmosphere, will help substantiate its veracity. While much work was done to ensure the accuracy of the information in the Comfort Guide, it would not go amiss to have the information reviewed and critiqued further.

Feedback from people who use the Comfort Guide should also be encouraged. Their suggestions for improvement could prove invaluable. For the Comfort Guide website to be useful, people must have access to it, use the suggestions contained within it, and find

them beneficial. These criteria can be determined by surveying the people who access and use the Comfort Guide.

6.4 Requesting a future WPI project group

Given the number of tasks and projects that should be implemented to realize the full potential of the Cyclist's Comfort Guide, we strongly suggest that another IQP project group be obtained. The Comfort Guide website is an excellent example of how technology can be used to improve the quality of life for a large number of people. The work that needs to be done on the Comfort Guide website to ensure its continued usefulness, accuracy and dissemination is an interesting and contemporary intersection of technology and society.

7.0 CONCLUSION

Thousands of medical conditions exist that could potentially affect the cycling ability of a rider. Anything from arthritis to a broken finger could potentially disrupt the intricate balance of the bicycle-rider system. Researching ways to treat cycling difficulties for the full spectrum of conditions would take decades and a team of researchers. Fortunately, another approach to this problem is possible. Bicycling difficulties due to varied conditions may be dealt with by addressing their distinct symptoms. Intuitively, this is only logical as a bicycle part cannot cure arthritis, but it can relieve arthritic knee pain while cycling. Given the overlapping of symptoms between various conditions, the resulting bicycle parts research can be conducted on fewer than one hundred symptom and symptom location combinations.

The knowledge needed to improve cycling comfort is researched and available. It is in scientific journals, cycling magazines, bicycle manufacturers' specifications and in the minds of cycling experts. The problem is that the average bicycle rider cannot readily access this knowledge and does not know where to search for it. This was the true objective of our project: to research the knowledge on improving bicycling comfort and to effectively communicate that knowledge to individuals who need it. A web-based comfort guide was perfect for this objective, as it enable the information to reach the greatest number of people while also allowing the information to be continually updated as new knowledge was located.

The website we created, A Cyclist's Comfort Guide, is a living document, an ongoing work. From the beginning, our limited time on this project and the ever changing world of cycling prevented this project from ever being stagnant. It is our hope that the DCF continues to update this work with the eventual goal of making cycling accessible to everyone.

--WPI BikeDenmark Projektgruppen

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APPENDIX A - COMMON PROBLEM AREAS

Feet
Correct positioning of the feet on the pedal can greatly decrease load on the ankle and increase mobility of the foot on the pedal. Sloane (1970) demonstrates the proper use of a pedal and indicates that the most common mistake cyclists make is placing the arch of their foot on the pedal of their bicycle. The best way of pedaling is to place the ball of the foot on the pedal. This exerts pressure most evenly and will prevent excessive pressure on the arch of the foot. A strap can be used to position the foot correctly on the pedal and keep it there, proving to be a valuable tool in retraining the cyclist's feet positions on the pedal.

Shoulders and Back
Neck and back pain is the primary complaint of high performance cyclists (Mellion, 1994). Three steps are suggested to alleviate these problems: bicycle adjustment, technique change, and medical treatment. The step that is most in the hands of the rider is technique change, for alleviating neck pain has much to do with the positioning of the shoulders and upper back.

Ensuring that the rider's posture is flexible prevents road shock from being transmitted directly to the neck and shoulders. Any unevenness or hardness in the road surface will transmit through the frame of the bicycle to the saddle and handlebars, and on to the neck and shoulders. If the bicycle is not designed to absorb this shock, then the body must adapt. Keeping elbows unlocked and preventing the neck from hunching into the shoulders are greatly beneficial in this respect.

Before mounting the bicycle, stretching the entire body can help alleviate the jarring effects of road shock on the body (Mellion, 1994). By strengthening the muscles that support the shoulders and spine, muscle tensions and chronic pains can be better managed. Pain in the neck and shoulders can also result from the angle that the neck must be maintained at to view the road. The cyclist can improve this condition by stretching their neck both before and during cycling. Some exercises that can be done while riding include: shoulder shrugs and rolling the neck from side to side (Mellion (1994). On a final note, it must be noted that while it is easy to do these stretches while riding a bicycle, when riding a bicycle in a city environment, the rider must remain vigilant to their surroundings.

Lower Back
When an individual is mounted on a bicycle, there are two points of load: the lower back and knees, and the shoulders and upper back. For most everyday cyclists, the majority of the load is set on the lower back and knees. This can aggravate any pre-existing conditions that cause stress and pain in those areas of the body. If the load is too great on the lower back, then the load should be shifted onto the upper limbs (Usabiaga et al. 1997). By shifting their weight onto their shoulders and upper back, cyclists can decrease the pressure they put on their lower back and knees. Additionally, if proper spinal

alignment is ensured, overall pressure on the spine will decrease significantly. However, this requires proper physical training as the postures necessary to shift one's weight can be counter intuitive and difficult to maintain initially. If not done correctly, shifting one's weight while cycling could result in additional back pain for the rider.

Wrists

Much of a cyclist's wrist pain is a direct result of poor cycling habits. Most cyclists tend to keep their hands and wrists locked in a single position on the handlebars, and this is generally discouraged. Flexibility of position will not only decrease the effects of road shock, it will also decrease fatigue. By moving the fingers and hands subtly on the handlebars, riders can prevent cramping of the hands and wrist pain (Sloane E.A., 1970).

APPENDIX B - COMMON OVERUSE CONDITIONS

Achilles Tendonitis
Described as intense irritation and inflammation to the muscle connected to heel, Achilles tendonitis is extremely painful during cycling. Although foot and ankle overuse injuries among cyclists are uncommon, Achilles tendonitis is by far the most common (Cohen, 1993). Over-flexing of the foot or not maintaining proper contact with the pedal is usually the cause (Holmes et al, 1994). This is usually a result of improper shoe-pedal interface and occasionally incorrect saddle height or leg length discrepancy.
A change in footwear or pedals, as well as adjustment of the foot on the pedals will usually alleviate Achilles tendonitis. Cycling shoes are highly recommended. As always if an individual has a leg length discrepancy, they should fit the bicycle to their longer leg, then modify the other side with shoe orthotics or pedal shims (Kronisch, 1998; Holmes et al, 1994; Cohen, 1993).

Foot Problems
Cycling overuse problems in the foot are rare. Ever since the adoption of the clipless pedal system, the number of cycling related foot overuse injuries has decreased. The increased availably of proper cycling footwear is also a contributing factor. Today, the most common cycling foot overuse injuries are Achilles tendonitis (described above) and overall numbness. When dealing with the feet, the general rules to remember are: always maintain proper foot-pedal interface contact, use the appropriate size pedals, and allow natural movement in the ankle. If these rules do not work then cycling in lower gears or the purchase of cycling-specific shoes are recommended (Gregor and Wheeler, 1994; APMA, 2002).

Iliotibial Band Friction Syndrome
Reoccurring friction of the iliotibial band across the lateral femoral epicondyle is the cause of Iliotibial band syndrome (ITB Syndrome). Due to the cyclic nature of pedaling, the syndrome is common in cyclists. One clinic reports that of 254 cyclists reporting knee pain over a two year period, 24% had ITB syndrome (Holmes, Pruitt and Whalen, 1993). The symptoms of ITB syndrome are generally a sharp or stabbing pain in the lateral portion of the knee. Furthermore, this pain is usually cyclic with each peddling stroke (Weiss, 1994).

Knee extension past 150^{O} on the down stroke while pedaling is the traditionally recognized cause of ITB syndrome, although lack of proper degrees of pedal float may also be a factor (Conti-Wyneken, 1999). Treatments for ITB syndrome involves adoption of clipless pedals as opposed to fixed, moving or adjusting the saddle's distance from the pedals and the saddle-post's height height for approximately 30^{O} of knee flexion at the bottom of the pedal stroke, reducing the average pedaling rate to 80 revolutions/min or less, and pre-ride stretching of the ITB (Holmes et al, 1993; Conti-Wyneken, 1999). If ITB syndrome is primarily occurring in one knee, this could be a sign that there is a discrepancy the leg length, in which case, the individual will need to fit the bicycle to

their long leg, and then modify the other side with shoe orthotics or pedal shims (Conti-Wyneken, 1999; Kronisch,1998).

Lower Back Strain
According to various sources 30-70% of cyclist report some type of lower back pain while cycling (Blankstein, Brosh, Chechik, Oran, and Salai 1999). Ordinarily, the origins of this pain are from improper posture, which generates torque on the lower vertebrae or riding vibration from the pedals. The pain itself will generally dissipate a short time after cycling is completed. If it persists, it could be symptomatic of serious lower back injury.

The source of improper lower back posture while cycling is usually improper cycle fit. The most common mistake is the belief the saddle should be horizontal. Ideally, however, the angle of anterior saddle inclination should be between 10-15 degrees above the horizon as this will help reduce lumbar and tensile pelvic vectors (Blankstein et al, 1999). Another common mistake is the belief that anatomically the rider's back should be parallel with the ground, and thus the reach of the handle bars is extended. Although having the back in this position is aerodynamically superior, anatomically the most comfortable position is perpendicular to the ground. In order to correct this contradiction, the saddle and handlebar heights should be adjusted to achieve the proper back arch. For utility bicycles an upright sitting position is preferable (Blankstein et al, 1999; Mellion, 1994; Mellion, 1991).

Other modifications that may alleviate cycling back pain include wider tires, lower tire inflation, suspension, a change in riding habit to maintain proper riding position, and pre-ride stretching and strengthening exercises (Kronisch, 1998; Rafoth, 2002).

Medial Plica and Medial Pattelofemoral Ligament Pain
Medial knee pain is the leading type of knee pain among cyclists. The two most common places for these overuse related injuries are in the medial plica and the medial pattelofemoral ligament (MPLF). Pain in the area is ordinarily described as a disabling pain with every pedal repetition in conjunction with a popping sensation. The suggested treatment for these conditions is adjustment of the bicycle fit to achieve a knee flexion of 25-30 degrees at the bottom of the pedal cycle and, if need be, switching to a floating pedal system (Holmes et al, 1994; Kronisch, 1998).

Neck and Shoulder Strain
Neck and shoulder pain from overuse is a leading bicycle overuse injury along with knee pain, especially in long distance bicycling. One survey of 113 respondents from a 500-mile bicycle tour reported that 66.4% had some sort of neck and shoulder pain and 20.4% had substantial symptoms. The area of primary concern was the trapezius muscle, where almost all symptoms occurred (Weiss, 1985). A majority of neck and shoulder pain in cyclists originates from the excessive load on the arms to create an aerodynamic riding position. Hyperextension of the neck and to a lesser degree head rotation to glance over the shoulder accompanied with terrain variations also contribute to neck and shoulder pain (Mellion, 1994).

Solutions to alleviate neck and shoulder pain vary greatly with the initial source of the pain. If a cyclist's pain is induced by constant traffic glances over their shoulder, then a mirror either on their cycle or on their helmet is needed. If neck hyperextension is the source of the problem, then handlebars should be moved up to adjust their body closer to a seated position. If there is excessive load on the arms, then the distance between the seat and handle bar, the "reach" distance, should be decreased. Other solutions include adding front suspension, lower tire inflation, pre-ride stretches and changes in riding habits and position (Cohen, 1993; Kronisch, 1998; Mellion, 1994; Richmond, 1994).

Penile Numbness

Numbness can occur in the genitals of male cyclists during prolonged periods of cycling. This condition is believed to be a result of pressure from the rider-saddle interface obstructing the nerves. In a study of pressure concentrations on a saddle, it was found that during cycling, pressure was largely concentrated on the urogenital triangle region, unlike sitting in a chair, where pressure is mainly distributed across the thighs (Breitenstein, Clark, Lowe, Schrader, and Turner, 2002). Thus, researchers believe that the prolonged unnatural pressure distribution causes the condition. The best method for alleviating this condition is to minimize the amount of time in contact with the bicycle seat, whether it requires reduction in cycling time or habitual cycling changes. It is highly recommended that when male cyclists stop and talk that they do not straddle the bicycle between their legs (Breitenstein et al, 2002; Weiss, 1994).

It is worth noting here that although no proven relationship between penile numbness and erectile dysfunction (ED) exists, ED is associated with bicycling. In one report from the Massachusetts Male Aging Study, evidence indicated an increased risk of ED for those cycling 3+ hours a week (Marceau et al, 2001).

Saddle Sores

Saddle sores actually comprise of a multitude of conditions including chafing, skin ulceration, and ischial tuberosity (tailbone) pain. Depending upon the precise conditions various treatments are involved.

Chafing, defined as an irritation of the skin resulting in inflammation, redness, and mild pain, is usually found on the inner thighs of cyclists. This is caused primarily by the repetitive shearing motion between the nose of the saddle and the inner thigh resulting from pedaling. Possible modifications to decrease chafing comprise of regularly washing riding shorts and using riding shorts with seamless chamois lining. Another suggested, but as yet unproven, modification is the use of an unpadded saddle (Weiss, 1985). Conversely, research has shown that steroid skin creams are not effective at reducing chafing (Weiss, 1994).

Saddle related skin ulcerations generally occur when chafing is not treated. Saddle related ulcerations are nothing more than skin in contact with the saddle being worn down until it ruptures. These painful sores often result in the abandonment of cycling until the wounds heal. Skin ulcerations can also make other non-cycling activities

uncomfortable. The treatment for skin ulcerations is time away from a bicycle and the possible modifications to prevent them are identical to those for chaffing (Weiss, 1985; Weiss, 1994).

Pain in the ischial tuberosity (tailbone), also known as ischial bursitis (IB), is the result of extreme friction on the tail bone. Symptoms often include redness, tenderness, and pain in the ischial tuberosity (Weiss, 1994). In cycling, IB is usually the result of a saddle's lack of padding in the appropriate area, although improper saddle height or a leg length discrepancy can be at fault. IB is also far more common at the beginning of training seasons because the affected area is no longer conditioned for riding (Cohen, 1993). Overall, the key to preventing IB is to maintain a tail bone-saddle interface at all times during pedaling (Conti-Wyneken, 1999).

Traumatic Injuries Affecting Cycling

Although this section does not solely focus on traumatic injuries incurred while cycling, it should be stated that a great number of traumatic injuries are caused by cycling accidents, mainly due to the lack of rider protection and high travel speeds. Most of the injuries are minor breaks or sprains, although some are serious or even fatal (this section does not include fatalities). In 1992, 11.2% of all traffic fatalities in Denmark involved a cyclist (Ekman, Karlsson, Schelp, Svanstrom, and Welander 1999). Cycling fatalities are mostly a result of collisions and lack of proper helmet wear.

In an epidemiological report of western Sweden on nonfatal bicycle traumatic injuries, it was found that 31 percent of injuries dealt with the head and face, 16 percent with the hand or wrist, 11 percent with the shoulder and clavicle, 12 percent with the knee, and 30 percent injured another part of the body. A majority of traumatic cycling injuries occur in the upper body, as accidents usually send the cyclist toppling head-first off their bicycle. The same report also indicated that the type of injury incurred were fractures, cuts, and luxations/dislocations/sprains (Eilert-Petersson and Schelp, 1995). This helps to create a outlook on the most common serious injuries among cyclists. It is important to note, however, that the estimates are probably low because many cycling accidents go unreported, especially less serious accidents.

Ulnar Nerve Neuropathy (Gunyon's Canal Syndrome)

Gunyon's Canal Syndrome is primarily caused by excessive pressure on the handlebar-palm interface; other factors include road vibration. Improper handlebar padding, overly strong grips, and rugged terrain are all contributing factors (Rafoth, 2002). According to Richmond (1994), the syndrome is comprised of three clinical syndromes:

- Type I, the most common, results in both sensory and motor function loss.
- Type II results mainly in motor function loss.
- Type III results only in loss of sensory functions. This condition, however, is not permanent and usually subsides shortly after dismounting.

Suggested treatments for Gunyon's Canal Syndrome include a firm but relaxed grip, frequent changes in hand grip position, attachment of a handlebar with multiple grips, padded riding gloves, suspension, lower tire inflation, and proper adjustment of the

bicycle's "reach", so less than one-third of the rider's weight is on the handlebars (Kronisch, 1999; Rafoth, 2002; Richmond, 1994). In a report of 117 cases of ulnar neuropathy, all 117 riders reported no continuing symptoms after making the appropriate modifications to their bicycle (Richmond, 1994).

APPENDIX C – REVALIDERINGSCENTRET VISIT SUMMARY

Interviewers: J. Bayreuther, S. Shrestha, J. Lofgren
Where: RevalideringsCentret
Gudhjemvej 2
7400 Herning
Denmark
When: Wednesday, April 2, 2003 (Full day)
How: In person
With whom: Kirsten Thorhauge, Occupational Therapist
Johnny Arildtoft, Technical Aids
Also present: Holly Ault, Project Advisor

- Introductions
- Presentation of DCF/WPI project
  - The DCF's objectives
  - Research into conditions: arthritis, whiplash, post-polio syndrome
  - Using cycling as a form of physical therapy
  - Using commonly found parts to modify bicycles in order to make cycling more comfortable
  - Making the knowledge available on a website
- Presentation of RevalideringsCentret project
  - Many of the same objectives
  - Producing custom-made bicycles to achieve comfort
- Review of bicycles constructed for RevalideringsCentret
  - 6 bicycles, tailored to individuals who come to the center to obtain help concerning lifestyle changes due to injury
  - Please see pictures
- Interview with people who use comfort bicycles
  - Two women – one a mother and one formerly a teacher. Both sustained back and neck injuries and are currently unemployed.
  - The mother sustained overuse injuries in her back and carpal tunnel syndrome from factory work. She was distressed because she could not cycle with her children or teach them how to cycle. This was highly detrimental to her family life. She was an avid weekend cyclist but is unable to cycle on a conventional city bike because the pressure on her back is unbearable. The wide handlebars and hydraulic brakes on the comfort bicycle also prevent wrist pain. Cycling on the comfort bicycle at the RevalideringsCentret is something she looks forward to.
  - The former teacher was an avid horseback rider and cyclist. She used to cycle to work, but was forced to discontinue after sustaining whiplash injuries in a traffic accident. She used to help re-train people who had sustained chronic disabilities from accidents before her own accident. She was very touched by our interest and the work that Kirsten Thorhauge had done. She was in tears by the end of the

interview. On her bike, she indicated that the suspension frame in combination with the suspension fork and suspension saddle post relieved a lot of the pressure from her spine. Additionally, the adjustable handlebars allowed her to change the position of her neck and shoulders most comfortably.

- RevalideringsCentret Project methodology
  - Utilized a similar methodology as the DCF/WPI project
  - Initially focused on 4 conditions: Morbus Bechterew (ankylosing spondylitis), Rheumatism, Whiplash and Osteoporosis.
  - These conditions were chosen because they presented many different symptoms and full range of symptom locations.
  - The idea was primarily to reduce road shock and impact shock. In many cases, reducing the amount of force required to perform many of the motions necessary on a bicycle were also of priority.
  - They were very frustrated by the availability of comfort bicycle parts in Denmark.
  - They felt that the project should have generated much more interest than it did.
  - They were pleased to hear that many of the other organizations we had contacted (PTU, Gigtforeningen) had referred us to their work.
  - The felt that their efforts were often stone-walled by bicycle dealers and parts distributors, as these groups were more interested in selling racing parts or standard city bike parts.
- Comfort bicycle testing
  - We were given the opportunity to test some of the comfort bikes in the area around the RevalideringsCentret.
  - The bikes absorbed shock very well. The only impacts that could even be felt were when the bike was taken over a 10cm curb. The smoothness of the ride over gravel, through potholes and on uneven asphalt was extraordinary.
  - Other features, such as the adjustable handlebars were tested and the idea of adjusting the fit of the handlebars to best fit the shoulder span and stance of the individual was very comfortable and intuitive.
  - Adjusting bicycle fit to the individual using quick release levers on the handlebars and saddle post and using conventional wrenches was compared. Not only did the quick release levers not require outside tools, they also ensured that bicycle fitting was a fast and minutely adjustable process that could be completed without delay or frustration.
- The future of comfort bicycles in Denmark
  - There are many publications where the results of the RevalideringsCentret project were published. We should look into advertising the Comfort Guide in similar websites
    - Hjælpemidler (HMI magazine)
    - Helse (Danish language magazine
    - Danish Bicycle Dealer's Society
    - Morbus Bechterew (Danish Morbus Bechterew Society magazine)
    - DCF Magazine

APPENDIX D – GIGTFORENINGEN VISIT SUMMARY

Interviewers: J. Bayreuther, S. Shrestha, J. Lofgren
Where: Gigtforeningen
Gentoftgade 118
2820 Gentofte
Denmark
When: Tuesday, April 1, 2003 1400
How: In person
With whom: Lene Bonnerup, Occupational Therapist
Vibeke Skat-Rørdam, Marketing Director
Mads Lauridsen, Communications and Web Consultant

- Introductions
  - The interviewers were all 3rd year students working with the DCF to create a Comfort Guide to be used by people who found cycling difficult.
  - The interviewees were all employees of the Gigtforeningen, the Danish Rheumatism (Arthritis) Association.
- Presentation
  - The DCF's objectives
  - Kirsten Thorhauge's work at the RevalideringsCentret
  - Research into conditions, especially arthritis
  - Using cycling as a form of physical therapy
  - Using bicycle modifications to make cycling more comfortable
  - Making the knowledge available on a website
- Gigtforeningen
  - Organization
    - Approximately 800,000 individuals afflicted with rheumatism in Denmark
    - Anyone can become member
    - Membership consists largely of people with rheumatism or people who have a family member with rheumatism
    - Whiplash and Fibromyalgia were recently classified in Denmark to be forms of rheumatism. The Gigtforeningen now provides support services for people with the conditions in addition to other forms of rheumatism.
  - Exercise campaign
    - Many people with rheumatism in Denmark do not exercise as they believe it is bad for their condition.
    - Last year, the Gigtforeningen had an exercise program to dispel this idea.
    - Exercises included jogging, swimming and cycling.
    - Pre and post exercise stretching and warm-up routines were compiled.
    - The campaign was spread through the Gigtforeningen website, their magazine, and through small booklets that were distributed to their membership.

        - The importance of personal medical care was stressed. While many forms of rheumatism benefit from exercise, the extent of the exertion varies greatly and some forms of rheumatism worsen with exercise.
    - Website
        - The Gigtforeningen uses their website extensively to communicate to their membership, to advertise the work they are doing, to provide services to their membership, etc.
        - They were enthusiastic about linking to our website, once it was complete.
        - They supported the idea of having a website Comfort Guide, provided the need for medical consultation was emphasized.

- Focus Group
    - We invited all three to attend a focus group to assess the format of our website.
    - Future communications will occur via e-mail.
        - Lene Bonnerup lbonnerup@gigtforeningen.dk
        - Vibeke Skat-Rørdam vsrordam@gigtforeningen.dk
        - Mads Lauridsen malauridsen@gigtforeningen.dk

APPENDIX E – DCF CHAPTER SURVEY RESULTS

Question #1: Are you aware of any medical conditions that adversely affect the cycling ability of your members? If so, please list the conditions below:

Condition Name		# Chapters
Danish	*English*	
Adipositas	Adipositas (Obesity)	3
Astma	Asthma	1
Blindhed/dårligt syn	Weakened eyesight	2
Brækkede ben	Broken leg	1
Byld I enden	Hemorrhoids	1
Dårlige knea	Bad knees	1
Dovenskab	Laziness	1
Gigt	Arthritis	1
Kolde fœdder/taer om vinteren	Cold feet (in the wintertime)	2
Langsom reaktionsevne	Slow reaction	1
Ledegigt	Rheumatism in the hands, wrists, ankles	1
Museskade	Carpal Tunnel Syndrome	1
nedsat balanceevne	Bad balance	1
Ondt I ryggen	Back pain	2
Osteoperose	Osteoperosis	1
Overbelastninger af knae	Overuse of the knees	1
Parkinson	Parkinson's	1
Piskesmeld	Whiplash	1
Rygelunger	Emphysema	1
Rygskader - diskuspolaps	Slipped disc	2
Sclerose	Sclerosis	1
Slidgigt knæ, hofter, ryg, fœdder	Arthritis in the knee, hip, back, feet	2
stift knæled	Stiff knees	1
Stress - ingen motivation	Stress - no motivations	1

Question #2: What type of bicycles do your members typically use on a daily basis?

(please mark appropriate percentage)

Types of Bicycles		Percentage	# Chapters
Danish	*English*		
Citybike	City Bike	0-10%	
		11-25%	2
		26-50%	1
		51-75%	2
		76-100%	1
Mountainbike	Mountain Bike		
		0-10%	4
		11-25%	2
		26-50%	
		51-75%	
		76-100%	
Racercykel	Road Race Bike		
		0-10%	3
		11-25%	2
		26-50%	1
		51-75%	
		76-100%	
Sportscykel	Sports Bike		
		0-10%	1
		11-25%	1
		26-50%	1
		51-75%	1
		76-100%	
Shoppingcykel	Shopping Bike		
		0-10%	1
		11-25%	2
		26-50%	
		51-75%	1
		76-100%	2
Liggecykel	Recumbant		
		0-10%	6
		11-25%	
		26-50%	
		51-75%	
		76-100%	

Chapters Not Answering 1

Question #3: For what purpose do your members use their bicycles on a daily basis? (please mark appropriate percentage)

Bicycle Use		Percentage	# Chapters
Danish	*English*		
Transport	Transportation	0-10%	
		11-25%	
		26-50%	1
		51-75%	2
		76-100%	3
Fornojelsesture	Pleasure		
		0-10%	1
		11-25%	2
		26-50%	1
		51-75%	2
		76-100%	
Cycletraening	Training		
		0-10%	3
		11-25%	1
		26-50%	2
		51-75%	
		76-100%	
Chapters Not Answering	1		

Question #4: How would you rate your membership's overall bicycle knowledge? (please mark the appropriate answer)

Bicycle Knowledge	# Chapters
Ability	
None	1
Capable of changing a tire	5
Capable of routine maintenance and minor repairs	5
Capable of major repairs or modifications	4
Capable of building a personalized bicycle	2

APPENDIX F – CONDITIONS – SYMPTOMS TABLE

Symptoms	Arthritis (Rheumatism)	Post-Polio Syndrome	Whiplash
Loss of Sensory Input		X	
Loss of Strength	X	X	
Pain	X	X	X
Reduced Range of Motion	X		X
Skin Irritation			

APPENDIX G – BICYCLE SHOP SURVEY RESULTS

All the shops had workshops where they could perform varying levels of work on bicycles. At the smaller shops, these services included simple repairs like patching tires. The smaller shops sold city bikes and shopping cycles as well as simple parts, like lights and generic saddles. The owners of these shops were generally not knowledgeable about non-standard bicycle parts, such as suspension forks. They did not sell these parts and did not have the means to obtain them.

We surveyed 4 larger shops:

- Cykel City, www.cykelcity.dk, 1800 Frederiksberg
- Bike Buster, www.bikebuster.dk, 1103 København K
- Saxil Cykler ApS, 1800 Frederiksberg
- Rolsted Cykler City Vest, www.rolsted-cycler.dk , 2610 København KS

At the larger, more inclusive shops, the workshops could attach any of the components available at the shops and do more extensive repairs. The majority of their business is in selling bicycle components. Approximately half of all customers who buy a component at their shop then request that the shop attach it onto their bicycle.

All the larger shops carried similar types of bicycle components. Some of the more expensive options included suspension forks, carbon frames and hydraulic brakes. Most of the parts sold in these larger stores were more expensive than the kind of parts sold in the smaller stores. They all sold many parts, such as saddles, suspension stems, and tires. They also carried a full range of bicycle types: city bikes, mountain bikes, road racing bikes, and shopping cycles.

All the shops said that they could order parts if a customer requested them, provided that the distributor had access to them.

They had all had customers come in looking to change their bike to relieve pain, particularly neck and back pain. They had suggested that these customers use suspension saddle posts, wide padded saddles, higher handlebars or higher handlebars.
At Cykel City, we were pleased to see that they realized that the modification depended on the individual's bicycle usage – whether they were a utilitarian cyclist, a racer, or a mountain biker.

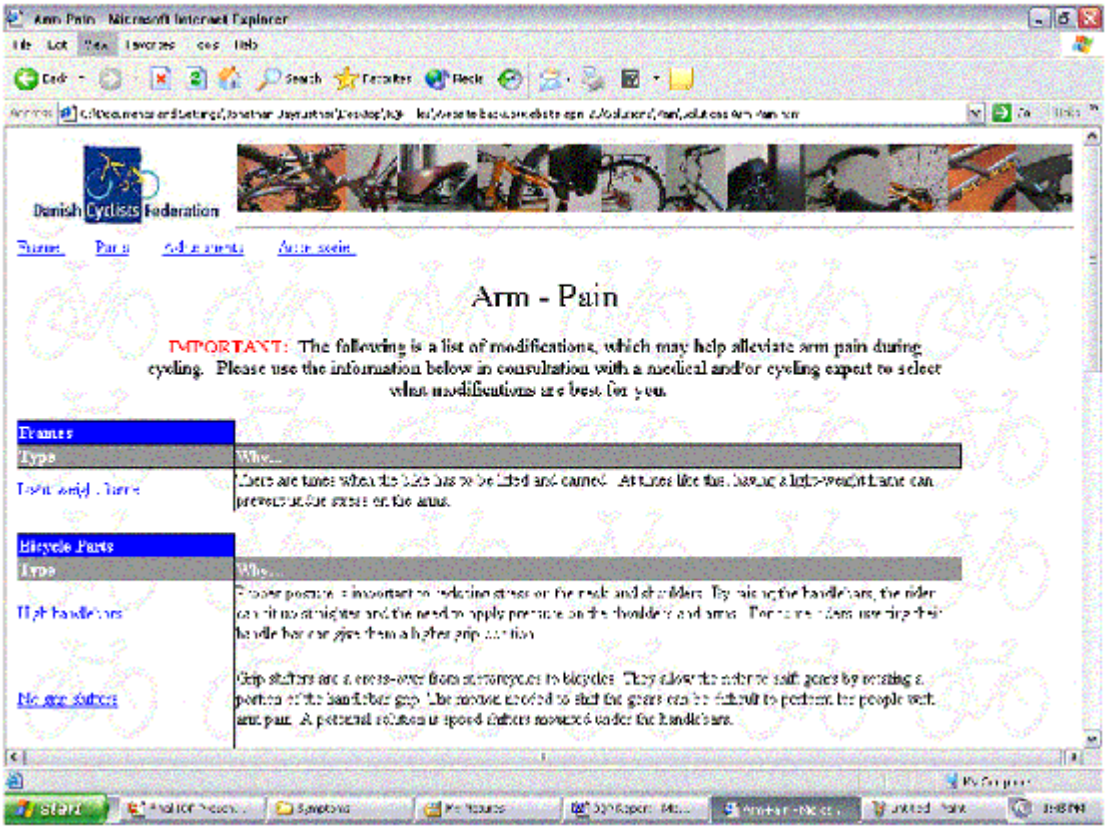
At Bike Buster, they were familiar with bicycle fit and had a machine to precisely measure riders to determine the best bicycle fit for them. They stated that these measurements were customized for racers and would not be suitable for people with chronic pain. However, they also said that they had the expertise to determine good bicycle fit by visually assessing the rider and how he positioned himself on the bicycle.

APPENDIX H – SYMPTOMS – LOCATIONS TABLE

Locations	Loss of Sensory Input (N/A)	Loss of Strength	Pain	Reduced Range of Motion	Skin Irritation (N/A)
Neck	X		X	X	X
Upper Back		X	X	X	X
Lower Back		X	X	X	X
Shoulders		X	X	X	X
Arms	X	X	X		X
Elbows			X	X	X
Wrists			X	X	X
Hands	X	X	X	X	X
Hips			X	X	X
Seat	X		X		X
Legs	X	X	X		X
Knees			X	X	X
Ankles			X	X	X
Feet	X		X	X	X

APPENDIX I –SOLUTIONS TABLES AND PAGE EXAMPLE

This is an example of a Solution Pages as displayed in A Cyclist's Comfort Guide.



Loss of Strength

Arm – Loss of Strength

Frames	
Type	**Why...**
Light-weight frame	There are times when the bike has to be lifted and carried. At times like this, having a light-weight frame can prevent undue stress on the arms.

Bicycle Parts	
Type	**Why…**
Wide, non-adjustable handlebars	Wide handlebars help to correct posture while riding a bicycle. By bringing the handlebars higher and closer to the body, the rider needs to lean forward less to hold on and steer the bicycle. It is important to note that handlebars should be no wider than the width of the rider's shoulders. Otherwise, by making the handlebars wider, less force is needed from the arms to turn the bicycle. Using adjustable handlebars can cause undue stress on the elbows due to the movement, therefore non-adjustable handlebars are preferred.
Speed shifters	Gears can make cycling much easier by decreasing the amount of power you need to expend to make the bicycle move. However, changing the gears to fit your needs using traditional gear shifters can be awkward, difficult or painful to your fingers and hands. Speed shifters are placed in a much more convenient place and change with greater ease, thus they will cause less undue strain on the arms.
Turn signal lights	Signaling turns on a bicycle requires that the rider hold out the arms in various positions that may be difficult if the arms and shoulders are weak. Turn signal lights can take the place of hand signals, but local laws should be consulted as to whether or not turn signal lights are legal for bicycles.

Bicycle Adjustments	
Name	**Why...**
Raise handlebars	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and reduce neck strain. For some riders inverting their handle bar can give them a higher grip position.

Rider Accessories	
Type	**Why…**
Basket	Carrying anything while cycling is dangerous for anyone, but in the case the holding an item is difficult, the danger is increased. A basket attached to the handlebars can provide a place to store small items and free the hands for steering and balancing the bicycle.
CO_2 tire pump	Inflating tires with a conventional pump can be difficult and often requires large amounts of force to reach the desired pressure. A simple solution to this can be a compressed gas pump, which

	typically uses a standard carbon dioxide cylinder to inflate the tires with the simple press of a button.
Wheel mounted rack	Carrying anything while cycling is dangerous for anyone, but in the case the holding an item is difficult, the danger is increased. A rack attached to the rear of the bicycle can provide a place to store a large amount of cargo and free the hands for steering the bicycle. The rear axle is the most stable location for such a rack to attach and allows the rack to move with the wheel in the case the bike has a rear suspension.

Hand – Loss of Strength

Frames	
Type	**Why...**
Light-weight frame	There are times when the bike has to be lifted and carried. At times like this, having a light-weight frame can prevent undue stress on the hands.

Bicycle Parts	
Type	**Why…**
Ergonomic bell	In many cities, bells are required on all bicycles for safety. Some bells can be difficult to ring depending on physical condition, therefore a bell with a ring mechanism that takes little force to activate is very important.
Foot brakes	Foot brakes are activated by simply pushing back on the pedals in the opposite direction of normal pedaling. A mechanism in the drive train applies a stopping force to rear wheel, slowing the bicycle. Many city bicycles are equipped with a foot brake and a hand brake for the front wheel. One disadvantage to foot brakes, however, is that they are usually not sold separately as parts, and must be purchased as part of a new bicycle. For people with hand and wrist difficulties, foot brakes provide a safe alternative to hand-pull brakes.
Hydraulic brakes	In standard hand brakes a cable is attached to the end of the brake lever, and, when the lever is pulled, the cable presses the brake pads against the wheel rim, slowing the bicycle. Hydraulic brakes work in the opposite way. When the brake lever is pulled, hydraulic fluid is compressed in a tube which pushes small brake pistons against a vented disc attached to the wheel, slowing the bicycle. They are more reliable than standard pull-brakes and require significantly less force to operate and so are easier on the hands.
Larger grips	Large handlebar grips provide relief for the hands by spreading the weight applied to the hands across a wider area. Larger grips also decrease the range of motion and strength required to grasp the handlebar, for those riders who have trouble closing their hands.
Longer brake levers	Longer brake levers provide a simple mechanical advantage to the operator, making applying the brakes easier.
Speed shifters	Gears can make cycling much easier by decreasing the amount of power you need to expend to make the bicycle move. However,

	changing the gears to fit your needs on traditional gear shifters can be awkward, difficult or painful to your fingers and hands. Speed shifters are placed in a much more convenient place and change with greater ease.

Bicycle Adjustments	
Name	**Why...**
N/A	N/A

Rider Accessories	
Type	**Why…**
CO_2 tire pump	Inflating tires with a conventional pump can be difficult and often requires large amounts of force to reach the desired pressure. A simple solution to this can be a compressed gas pump, which typically uses a standard carbon dioxide cylinder to inflate the tires with the simple press of a button.

Leg – Loss of Strength

Frames	
Type	**Why...**
Light-weight frame	A light-weight frame requires less force to propel the bicycle and rider forward. Less force means less stress on the legs and less strength exerted to propel the bicycle.

Bicycle Parts	
Type	**Why…**
Long crank arm	A longer crank arm provides a simple mechanical advantage to the rider, making pedaling easier.
Multiple gears	Multiple gears help to provide a mechanical advantage that help to make cycling easier and more efficient. They can help to reduce the force needed to propel the bicycle. Less force means less stress.
Clipped pedals	Favored among bicycle racers, clipped or "floating pedals" come in a variety of configurations. Clipped pedals transfer power from the rider to the pedals more efficiently because drive force can to applied throughout the pedaling motion. With platform pedals, the drive force is applied in a pushing motion. With clipped pedals drive force is also applied on the upstroke. It should be noted that clipped pedals can aggravate certain knee and ankle conditions, so this must be weighed against the need for more efficient pedaling.
Small crank gear	This simply increases the mechanical advantage on behalf of the person pedaling. By making the crank gear smaller and the drive gear larger, each pedal rotation only rotates the rear wheel a fraction of a revolution, this makes it easier to pedal, but also slower.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale. However, lower tire pressures mean more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.

Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat also helps to position the rider the correct distance from the handlebars to reduce the stress on the legs, by ensuring that the rider is at no time standing on the pedals. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.
Saddle height adjustment	This is just a specific part of overall proper bicycle fit, and is one of the most critical adjustments. If the saddle is too high, it may cause the rider to stretch to reach the pedals, and, if the saddle is too low, it can cause the knees to over-rotate or apply too much stress when applying drive force to the pedals. Both of these problems can cause unnecessary stress on the knee and cause unnecessary exertion from the leg. When seated on the saddle with one leg at the bottom of the pedal stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
N/A	N/A

Lower Back – Loss of Strength

Frames	
Type	**Why...**
N/A	N/A

Bicycle Parts	
Type	**Why…**
N/A	N/A

Bicycle Adjustments	
Name	**Why...**
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat helps to position the rider the correct distance from the handlebars to reduce the stress on the lower back. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.
Saddle height adjustment	If the saddle is too high, it may cause the rider to stretch to reach the pedals, causing unnecessary pressure on the lower back. When seated on the saddle with one leg at the bottom of the pedal stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
N/A	N/A

Shoulder – Loss of Strength

Frames	
Type	**Why...**
N/A	N/A

Bicycle Parts	
Type	**Why…**
Wide, non-adjustable handlebars	Wide handlebars help to correct posture while riding a bicycle. By bringing the handlebars higher and closer to the body, the rider needs to forward less to hold on and steer the bicycle. It is important to note that handlebars should be no wider than the width of the rider's shoulders. By making the handlebars wider, less force is needed to turn the bicycle. Using adjustable handlebars can cause undue stress on the elbows due to the movement, therefore non-adjustable handlebars are preferred.
High handlebars/Long handlebar stem	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and reduce shoulder strain. For some riders inverting their handle bar can give them a higher grip position.

Bicycle Adjustments	
Name	**Why...**
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat also helps to position the rider the correct distance from the handlebars to reduce the stress on the upper back and shoulders. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.
Saddle height adjustment	If the saddle is toigh, it may cause the rider to stretch to reach the pedals, causing unnecessary pressure on the shoulders. When seated on the saddle with one leg at the bottom of the pedal stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
N/A	N/A

Upper Back – Loss of Strength

Frames	
Type	**Why...**
N/A	N/A

Bicycle Parts	
Type	**Why…**
High handlebars/Long handlebar stem	Proper posture is important to reducing stress on the back. By raising the handlebars, the rider can sit up straighter and reduce back strain. For some riders inverting their handle bar can give them a higher grip position.

Bicycle Adjustments	
Name	**Why...**
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat also helps to position the rider the correct distance from the handlebars to reduce the stress on the upper back and shoulders. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.
Saddle height adjustment	This is just a specific part of overall proper bicycle fit, and is one of the most critical adjustments. If the saddle is too high, it may cause the rider to stretch to reach the pedals, causing back strain. When seated on the saddle with one leg at the bottom of the pedal stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
N/A	N/A

Pain

Ankle – Pain

Frames	
Type	**Why...**
Light-weight frame	Less weight in the frame means there is less force needed to propel the bicycle and rider forward. Less force means less stress on many joints, including ankles.
Low step-over	A bicycle with a low step-over allows the ankle to bend less while getting on. Less bending means less stress on the ankle.
Suspension frame	Suspension helps to reduce road shock transmitted up through pedals, thus reducing impact damage and fatigue to the ankle.

Bicycle Parts	
Type	**Why…**
Long crank arm	A longer crank arm provides a simple mechanical advantage to the rider, making pedaling easier and thus reducing stress on the ankles.
Platform pedals (non-clip)	This type of pedal is standard on most city and comfort bicycles, but some include “cage type” two clips. Both the clipped pedals and cage-type clips can cause rotational stresses on the ankles while cycling, so it is important for the feet to be free to rotate on the pedals to minimize this stress.
Saddle post suspension	Like a full suspension bicycle, a suspension seat post helps to reduce road shock transmitted through the saddle to the back and legs. It is usually not as effective as a full suspension at reducing road shock, but can be added to a standard bicycle with little difficult and costs much less than a new bicycle.
Small crank gear	This simply increases the mechanical advantage on behalf of the person pedaling. By making the crank gear smaller and the drive gear larger, each pedal rotation only rotates the rear wheel a fraction of a revolution, this makes it easier to pedal but travel forward will be much slower.
Threaded spacers	Similar to pedal shims, threaded spacers essentially help to line up

	the body in a more natural position with the pedals. They move the pedals away from the bicycle and allow the feet to be more in line with the hips. This causes less stress on the hips, knees, and ankles.
Wide, padded saddle	The wider the saddle is, the more the weight of the body is distributed on the saddle, which decreases the pressure on any one point. In addition, the extra padding helps to reduce the road shock transmitted through the saddle to the body. Less road shock means less impact stress on all the legs joints, including the ankles.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, as it is with ankle pain, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat also helps to position the rider the correct distance from the handlebars to reduce the stress on the ankle. This adjustment should be in conjunction with proper ankle angle and handlebar adjustments.
Saddle height adjustment	If the saddle is too high, it may cause the rider to stretch to reach the pedals and put excess load on the ankles, and, if the saddle is too low, it can cause the knees to over-rotate or apply too much stress on the ankles when applying drive force to the pedals. Both of these problems can cause unnecessary stress on the ankle. When seated on the saddle with one leg at the bottom of the pedal stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
Ankle brace	Braces of all types are available for many different joints. They can be obtained at most sporting goods stores. It is very important to consult a medical expert or physical therapist before using a brace as the wrong brace or improper usage can actually harm the joint rather than help.

Leg warmers	Leg warmers do exactly that – keep the lower legs warm. This can be useful for people with lower leg or ankle conditions because the warmth helps to keep the muscles warm and flexible.
Shoe inserts	Just like pedal shims, shoe inserts can help to correct leg length discrepancies since most people have one leg that is slightly longer than the other. In addition orthopedic inserts can provide extra support while cycling. Like most other modifications, it is very important to consult a medical expert before using shoe inserts.

Arm – Pain

Frames	
Type	**Why...**
Light-weight frame	There are times when the bike has to be lifted and carried. At times like this, having a light-weight frame can prevent undue stress on the arms.

Bicycle Parts	
Type	**Why…**
High handlebars	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and the need to apply pressure on the shoulders and arms. For some riders inverting their handle bar can give them a higher grip position.
No grip shifters	Grip shifters are a cross-over from motorcycles to bicycles. They allow the rider to shift gears by rotating a portion of the handlebar grip. The motion needed to shift the gears can be difficult to perform for people with arm pain. A potential solution is speed shifters mounted under the handlebars.
Padded handlebar grips	Road shock can cause numerous problems throughout the body and is transmitted through the various bicycle-rider contact points: handlebars, seat, and pedals. Adding padded grips can help to reduce road shock transmitted from the handlebars to the hands and arms.
Suspension fork	Road shock is transmitted to the bicycle from the road through the wheels. By having a suspension system in the fork, the road shock transmitted through the front wheel is reduced. That shock is transmitted up to the arms and can cause unnecessary stress.
Turn signal lights	Signaling turns on a bicycle requires that the rider hold out the arms in various positions that may be difficult if the arms are in pain. Turn signal lights can take the place of hand signals, but local laws should be consulted as to whether or not turn signal lights are legal for bicycles.
Wide handlebars	Wide handlebars help to correct posture while riding a bicycle. By bringing the handlebars higher and closer to the body, the rider needs to forward less to hold on and steer the bicycle. It is important to note that handlebars should be no wider than the width of the rider’s shoulders. By making the handlebars wider, less force is

	needed to turn the bicycle. Using adjustable handlebars can cause undue stress on the elbows due to the movement, therefore non-adjustable handlebars are preferred.

Bicycle Adjustments	
Name	**Why...**
N/A	N/A

Rider Accessories	
Type	**Why…**
Basket	Carrying anything while cycling is dangerous for anyone, but in the case the holding an item is difficult, the danger is increased. A basket attached to the handlebars can provide a place to store small items and free the hands and arms for steering and balancing the bicycle.
CO_2 tire pump	Inflating tires with a conventional pump can be difficult and often requires large amounts of force to reach the desired pressure. A simple solution to this can be a compressed gas pump, which typically uses a standard carbon dioxide cylinder to inflate the tires with the simple press of a button.
Padded gloves	Gloves can be an easy way to reduce road shock transmitted though the hands to the arms, shoulders, and neck. They also can help to keep the hands warm.
Wheel mounted rack	Carrying anything while cycling is dangerous for anyone, but in the case the holding an item is difficult, the danger is increased. A rack attached to the rear of the bicycle can provide a place to store a large amount of cargo and free the hands for steering the bicycle. The rear axle is the most stable location for such a rack to attach and allows the rack to move with the wheel in the case the bike has a rear suspension.

Elbow – Pain

Frames	
Type	**Why...**
Light-weight frame	There are times when the bike has to be lifted and carried. At times like this, having a light-weight frame can prevent undue stress on the elbows.
Low step-over	A bicycle with a low step-over allows the knee needs to bend less while get on. While mounting the bicycle, the elbows do not need to support the body. This relieves stress on the elbows.

Bicycle Parts	
Type	**Why…**
Speed shifter	Gears can make cycling much easier by decreasing the amount of power you need to expend to make the bicycle move. However, changing the gears to fit your needs on traditional gear shifters or grip shifters can be awkward, difficult or painful to your elbows. Speed shifters are placed in a much more convenient place and change with greater ease.
Suspension fork	Road shock is transmitted to the bicycle from the road through the wheels. That shock is transmitted up to the elbows and can cause unnecessary stress. By having a suspension system in the fork, the road shock transmitted through the front wheel is reduced.
Turn signal lights	Signaling turns on a bicycle requires that the rider hold out the arms in various positions that may be difficult if there is pain in the elbows. Turn signal lights can take the place of hand signals, but local laws should be consulted as to whether or not turn signal lights are legal for bicycles.
Wide, non-adjustable handlebars	Wide handlebars help to correct posture while riding a bicycle. By bringing the handlebars higher and closer to the body, the rider needs to forward less to hold on and steer the bicycle. By making the handlebars wider, less force is needed to turn the bicycle. It is important to note that handlebars should be no wider than the width of the rider's shoulders, as this is the most natural position for the elbows. All of these changes help to create less stress on the arms and elbows. Using adjustable handlebars can cause undue stress on the elbows due to the movement, therefore non-adjustable handlebars are preferred.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.

Rider Accessories	
Type	**Why…**
CO_2 tire pump	Inflating tires with a conventional pump can be difficult and often requires large amounts of force to reach the desired pressure. A simple solution to this can be a compressed gas pump, which typically uses a standard carbon dioxide cylinder to inflate the tires with the simple press of a button.
Elbow brace	Braces of all types are available for many different joints. They can be obtained at most sporting goods stores. It is very important to consult a medical expert or physical therapist before using a brace as the wrong brace or improper usage can actually harm the joint rather than help.
Long sleeved shirt	A long sleeve shirt helps to keep muscles and joints warm, preventing cramps and pain.

Foot – Pain

Frames	
Type	**Why...**
Suspension frame	Suspension helps to reduce road shock transmitted up through pedals, thus reducing impact damage and fatigue to the feet.

Bicycle Parts	
Type	**Why…**
Clipped pedal (also see Road cycling shoes)	Favored among bicycle racers, clipped or “floating pedals” come in a variety of configurations. Clipped pedals transfer power from the rider to the pedals much more efficiently because drive force can to applied throughout the pedaling motion. With platform pedals, the drive force is applied in a pushing motion, engaging the quadriceps muscles. With clipped pedals drive force is also applied on the upstroke, which engages the hamstrings muscles as well. The combination of the two muscle groups means that it takes less force by any single muscle group to propel the bicycle forward. It should be noted that clipped pedals can aggravate certain knee and ankle conditions, so this must be weighed against the need for more efficient pedaling.
Large pedal	Large pedals provide relief for by spreading the weight applied to the feet across a wider area. The larger area also helps to provide better control and grip.
Wide, padded saddle	The wider the saddle is, the more the weight of the body is distributed on the saddle, which decreases the pressure on any one point. In addition, the extra padding helps to reduce the road shock transmitted through the saddle to the body. Less road shock means less impact stress on the feet.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer’s recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.

Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat also helps to position the rider the correct distance from the handlebars to reduce load on the hands and feet. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.
Saddle height adjustment	If the saddle is too high, it may cause the rider to stretch to reach the pedals and lean on the feet, and, if the saddle is too low, it can cause the knees to over-rotate or apply too much stress when applying drive force to the pedals. Both of these problems can cause unnecessary stress on the feet. When seated on the saddle with one leg at the bottom of the pedal stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
Fitted shoes with stiff sole and flexible upper body (eg: hiking boots)	During cycling, the feet flex in different directions. However, if that flexion is kept to a minimum, pedaling efficiency is increased and the risk of aggravation of conditions associated with the feet is decreased. A stiff-soled shoe can help to decrease the flexion of the foot, while having the shoe fitted correctly with a flexible upper is also very important for comfort. This concept is taken to the extreme in road bicycle shoes designed to be used with clipped pedals, in which the shoe sole is actually fixed in one position, but the concept can be applied to simply wearing stiff soled shoes while pedaling. In many cases this will mean wearing one pair of shoes while riding and carrying another in a bag or basket on the bicycle to change into when the destination is reached.
Road cycling shoes	When using clipped pedals, road cycling shoes must be used to clip the feet into the pedals.
Shoe inserts	Just like pedal shims, shoe inserts can help to correct leg length discrepancies since most people have one leg that is slightly longer than the other. In addition orthopedic inserts can provide extra support while cycling. Like most other modifications, it is very important to consult a medical expert before using shoe inserts.

Hand – Pain

Frames	
Type	**Why...**
Light-weight frame	There are times when the bike has to be lifted and carried. At times like this, having a light-weight frame can prevent undue stress on the arms.

Bicycle Parts	
Type	**Why…**
Wide, non-adjustable handlebars	Wide handlebars help to correct posture while riding a bicycle. By bringing the handlebars higher and closer to the body, the rider needs to lean forward less to hold on and steer the bicycle. It is important to note that handlebars should be no wider than the width of the rider's shoulders. Otherwise, by making the handlebars wider, less force is needed from the arms to turn the bicycle. Using adjustable handlebars can cause undue stress on the elbows due to the movement, therefore non-adjustable handlebars are preferred.
Speed shifters	Gears can make cycling much easier by decreasing the amount of power you need to expend to make the bicycle move. However, changing the gears to fit your needs using traditional gear shifters can be awkward, difficult or painful to your fingers and hands. Speed shifters are placed in a much more convenient place and change with greater ease, thus they will cause less undue strain on the arms.
Turn signal lights	Signaling turns on a bicycle requires that the rider hold out the arms in various positions that may be difficult if the arms and shoulders are weak. Turn signal lights can take the place of hand signals, but local laws should be consulted as to whether or not turn signal lights are legal for bicycles.

Bicycle Adjustments	
Name	**Why...**
Raise handlebars	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and reduce neck strain. For some riders inverting their handle bar can give them a higher grip position.

Rider Accessories	
Type	**Why…**
Basket	Carrying anything while cycling is dangerous for anyone, but in the case the holding an item is difficult, the danger is increased. A basket attached to the handlebars can provide a place to store small items and free the hands for steering and balancing the bicycle.
CO_2 tire pump	Inflating tires with a conventional pump can be difficult and often requires large amounts of force to reach the desired pressure. A simple solution to this can be a compressed gas pump, which typically uses a standard carbon dioxide cylinder to inflate the tires with the simple press of a button.
Wheel mounted rack	Carrying anything while cycling is dangerous for anyone, but in the case the holding an item is difficult, the danger is increased. A rack attached to the rear of the bicycle can provide a place to store a large amount of cargo and free the hands for steering the bicycle. The rear axle is the most stable location for such a rack to attach and allows the rack to move with the wheel in the case the bike has a rear suspension.

Hip – Pain

Frames	
Type	**Why...**
Suspension frame	Suspension helps to reduce road shock transmitted up through saddle and pedals, thus reducing impact damage and fatigue to the hips.
Low step-over	A bicycle with a low step-over allows the hips to bend less while mounting. Less bending means less stress on the hip.
Proper frame fit	This is essential for anyone, regardless of physical condition. A properly fit bicycle means that no unnecessary stresses are exerted on the body. This could involve anything from a simple adjustment to the seat height, to buying an entirely new bicycle.

Bicycle Parts	
Type	**Why…**
Gender specific saddle	In the last decade an increasing awareness of the need to specifically design saddles for men and women has grown, and many saddles are now available that have cut-outs to relieve pressure on sensitive areas. Men's saddles typically have a cut-out in the nose and women's are usually in the middle to rear. As women typically have wider hips, saddles made for women are usually wider, allowing for more support.
Pedal shims	Since most people have one leg that is slightly longer than the other, pedal shims may be used to even out that length. They can usually be bolted or clipped on to existing pedals. An expert should always be consulted before using pedal shims.
Saddle post suspension	Like a full suspension bicycle, a suspension seat post helps to reduce road shock transmitted through the saddle to the hips. It is usually not as effective as a full suspension at reducing road shock, but can be added to a standard bicycle with little difficult and costs much less than a new bicycle.
Threaded spacers	Similar to pedal shims, threaded spacers essentially help to line up the body in a more natural position with the pedals. They move the pedals away from the bicycle and allow the feet to be more in line with the hips. This causes less stress on the hips, knees, and ankles.
Wide, padded saddle	The wider the saddle is, the more the weight of the body is

	distributed on the saddle, which decreases the pressure on any one point. In addition, the extra padding helps to reduce the road shock transmitted through the saddle to the body. Less road shock means less impact stress.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.
Saddle fore & aft adjustment	Like the advantage proper saddle adjustments create for knee angle, proper fore/aft adjustment of the seat also helps to position the rider the correct distance from the handlebars to reduce the stress on the hips. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.

Rider Accessories	
Type	**Why…**
Shoe inserts	Just like pedal shim shoe inserts can help to correct leg length discrepancies since most people have one leg that is slightly longer than the other. In addition orthopedic inserts can provide extra support while cycling. Like most other modifications, it is very important to consult a medical expert before using shoe inserts.

Knee – Pain

Frames	
Type	**Why…**
Suspension frame	Suspension helps to reduce road shock transmitted up through pedals, thus reducing impact damage and fatigue to the knees.
Light-weight frame	Less weight in the frame means there is less force needed to propel the bicycle and rider forward. Less force means less stress on many joints, including knees.
Low step-over	A bicycle with a low step-over allows the knee needs to bend less while get on. Less bending means less stress on the joint.
Proper frame fit	This is essential for anyone, regardless of physical condition. A properly fit bicycle means that no unnecessary stresses are exerted on the body. This could involve anything from a simple adjustment to the seat height, to buying an entirely new bicycle.

Bicycle Parts	
Type	**Why…**
Hand brakes	The foot-brakes common on many city bicycles can be difficult to use for people with knee problems, so handbrakes may be an easier option. Several different types are available, from hydraulic to cable-pull, at all price levels. Just be sure to consult local bicycle regulations before switching to handbrakes.
Multiple gears	Multiple gears help to provide a mechanical advantage that help to make cycling easier and more efficient. They can help to reduce the force needed to propel the bicycle. Less force means less stress.
Platform pedals (non-clip)	This type of pedal is standard on most city and comfort bicycles, but some include “cage type” two clips. Both the clipped pedals and cage-type clips can cause rotational stresses on the knees while cycling, so it is important for the feet to be free to rotate on the pedals to minimize this stress.
Pedal shims	Since most people have one leg that is slightly longer than the other, pedal shims may be used to even out that length. They can usually be bolted or clipped on to existing pedals. An expert should always be consulted before using pedal shims.
Small crank gear	This simply increases the mechanical advantage on behalf of the

	person pedaling. By making the crank gear smaller and the drive gear larger, each pedal rotation only rotates the rear wheel a fraction of a revolution, this makes it easier to pedal but travel forward will be much slower.
Threaded spacers	Similar to pedal shims, threaded spacers essentially help to line up the body in a more natural position with the pedals. They move the pedals away from the bicycle and allow the feet to be more in line with the hips. This causes less stress on the hips, knees, and ankles.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.
Saddle fore & aft adjustment	This is an adjustment that should be used in conjunction with saddle height adjustment. It works in a similar way to create the correct knee angle. At the bottom of the stroke, the shin should be vertical and the knee angle should be between 25 and 35 degrees.
Saddle height adjustment	This is just a specific part of overall proper bicycle fit, and is one of the most critical adjustments. If the saddle is too high, it may cause the rider to stretch to reach the pedals, and, if the saddle is too low, it can cause the knees to over-rotate or apply too much stress when applying drive force to the pedals. Both of these problems can cause unnecessary stress on the knee. When seated on the saddle with one leg at the bottom of the pedal stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
Knee brace	Braces of all types are available for many different joints. They can be obtained at most sporting goods stores. It is very important to consult a medical expert or physical therapist before using a brace as the wrong brace or improper usage can actually harm the joint rather than help.
Shoe inserts	Just like pedal shim shoe inserts can help to correct leg length

discrepancies since most people have one leg that is slightly longer than the other. In addition orthopedic inserts can provide extra support while cycling. Like most other modifications, it is very important to consult a medical expert before using shoe inserts.

Leg – Pain

Frames	
Type	**Why...**
Suspension frame	Suspension helps to reduce road shock transmitted up through saddle and/or pedals, thus reducing impact damage and fatigue to the legs.
Light-weight frame	Less weight in the frame means there is less force needed to propel the bicycle and rider forward. Less force means less stress on the leg muscles.
Low step-over	A bicycle with a low step-over requires the legs to bend less while getting on the bicycle. Less bending means less flexing of the leg muscles and less pain.
Proper frame fit	This is essential for anyone, regardless of physical condition. A properly fit bicycle means that no unnecessary stresses are exerted on the body. This could involve anything from a simple adjustment to the seat height, to buying an entirely new bicycle.

Bicycle Parts	
Type	**Why…**
Long crank arm	A longer crank arm provides a simple mechanical advantage to the rider, making pedaling easier.
Saddle post suspension	Like a full suspension bicycle, a suspension seat post helps to reduce road shock transmitted through the saddle to the back. It is usually not as effective as a full suspension at reducing road shock, but can be added to a standard bicycle with little difficult and costs much less than a new bicycle.
Small crank gear	By making the crank gear smaller and the drive gear larger, each pedal rotation only rotates the rear wheel a fraction of a revolution, this makes it easier to pedal but travel will be slower.
Threaded spacers	Similar to pedal shims, threaded spacers essentially help to line up the body in a more natural position with the pedals. They move the pedals away from the bicycle and allow the feet to be more in line with the hips. This causes less stress on the hips, knees, and ankles by having the legs placed in a natural position.
Wide, padded saddle	The wider the saddle is, the more the weight of the body is

	distributed on the saddle, which decreases the load on the legs. In addition, the extra padding helps to reduce the road shock transmitted through the saddle to the body. Less road shock means less impact stress.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat also helps to position the rider the correct distance from the handlebars to reduce the stress on the legs. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.
Saddle height adjustment	This is just a specific part of overall proper bicycle fit, and is one of the most critical adjustments. If the saddle is too high, it may cause the rider to stretch to reach the pedals, and, if the saddle is too low, it can cause the knees to over-rotate or apply too much stress when applying drive force to the pedals. Both of these problems can cause unnecessary stress on the knee. When seated on the saddle with one leg at the bottom of the pedal stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
Shoe inserts	Just like pedal shim shoe inserts can help to correct leg length discrepancies since most people have one leg that is slightly longer than the other. In addition orthopedic inserts can provide extra support while cycling. Like most other modifications, it is very important to consult a medical expert before using shoe inserts.
Warm pants	Warm pants help to keep muscles and joints warm to help prevent cramps and pain.

Lower Back – Pain

Frames	
Type	**Why...**
Low step-over	A bicycle with a low step-over requires the body to bend less when mounting the bicycle. Less bending means less stress on the lower back.
Suspension frame	Suspension helps to reduce road shock transmitted up through saddle, thus reducing impact damage and fatigue to the back.

Bicycle Parts	
Type	**Why…**
High handlebars	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and reduce back strain. For some riders inverting their handle bar can give them a higher grip position.
Saddle post suspension	Like a full suspension bicycle, a suspension seat post helps to reduce road shock transmitted through the saddle to the back. It is usually not as effective as a full suspension at reducing road shock, but can be added to a standard bicycle with little difficulty and costs much less than a new bicycle.
Wide handlebars	Wide handlebars help to correct posture while riding a bicycle. By making the handlebars wider, less force is needed to turn the bicycle. All of these changes help to create less stress on the upper body.
Wide, padded saddle	The wider the saddle is, the more the weight of the body is distributed on the saddle, which decreases the pressure on any one point. In addition, the extra padding helps to reduce the road shock transmitted through the saddle to the body. Less road shock means less impact stress on the lower back.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is

	therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat helps to position the rider the correct distance from the handlebars to reduce the stress on the lower back. This adjustment should be in conjunction with proper saddle height and handlebar adjustments.
Saddle height adjustment	Proper height adjustment of the seat also helps to reduce the stress from unnecessary forces exerted on the back. This adjustment should be in conjunction with proper saddle fore & aft and handlebar adjustments.

Rider Accessories	
Type	**Why…**
Padded shorts/pants	Padded clothing is often a simple solution to reducing shock transmitted to the body from the various points of contact with the bicycle. It usually costs less than suspension systems and is more readily available. The amount of shock dampening is limited, however, and may not be enough for some riders.

Neck – Pain

Frames	
Type	**Why...**
Suspension frame	Suspension helps to reduce road shock transmitted up through saddle and handlebars, thus reducing impact damage and fatigue to the neck.

Bicycle Parts	
Type	**Why…**
High handlebars	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and reduce neck strain. For some riders inverting their handle bar can give them a higher grip position.
Mirrors mounted on handlebars	An important part of staying safe on a bicycle is keeping a vigilant watch for potential obstacles. For some people the constant twisting to see behind and to the sides can be difficult. Mirrors can help to reduce the frequency of twisting and turning the neck by providing a view behind the rider.
No aerobars	Many bicycle racers use aerobars to help them ride in a more aerodynamic position. Unfortunately, that position can cause stress on the back and neck, so they should be avoided when back and neck stress is a problem.
Padded handlebar grips	Road shock can cause numerous problems throughout the body and is transmitted through the various bicycle-rider contact points: handlebars, seat, and pedals. Adding padded grips can help to reduce road shock transmitted from the handlebars to the hands, and ultimately to the shoulders and neck.
Padded saddle cover	Similar to a padded saddle or padded clothing, a padded saddle cover can help to reduce the road shock transmitted through the saddle to the rider. That stress travels up the back to the neck.
Suspension fork	Road shock is transmitted to the bicycle from the road through the wheels. By having a suspension system in the fork, the road shock transmitted through the front wheel is reduced. That shock is transmitted up to the neck and can cause unnecessary stress.

Suspension saddle post	Road shock is transmitted to the bicycle from the road through the wheels. By having a suspension system in the saddle post, the road shock transmitted through the rear wheel is reduced. That shock is transmitted up to the seat, back and neck and can cause unnecessary stress and pain.
Wide tires	Wide tires help to absorb some of the road shock transmitted through the wheels. Tires come in a variety of widths, from the thinnest road tires at about 19mm to the widest that can be more than 40mm.
Wide, padded saddle	The wider the saddle is, the more the weight of the body is distributed on the saddle, which decreases the pressure on any one point. In addition, the extra padding helps to reduce the road shock transmitted through the saddle to the back and neck. Less road shock means less impact stress.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat helps to position the rider the correct distance from the handlebars to reduce the stress on the neck. This adjustment should be in conjunction with proper saddle height and handlebar adjustments.
Saddle height adjustment	Proper height adjustment of the seat helps to reduce the stress from unnecessary forces exerted on the neck. This adjustment should be in conjunction with proper saddle fore & aft and handlebar adjustments.

Rider Accessories	
Type	**Why…**
Mirror mounted on helmet	An important part of staying safe on a bicycle is keeping a vigilant watch for potential obstacles. For some people the constant twisting to see behind and to the sides can be difficult. Mirrors can help to reduce the frequency of twisting and turning of the neck.

Padded gloves	Gloves can be an easy way to reduce road shock transmitted though the hands to the arms, shoulders, and neck. They also can help to keep the hands warm.
Padded shorts/pants	Padded clothing is often a simple solution to reducing shock transmitted to the body from the various points of contact with the bicycle. It usually costs less than suspension systems and is more readily available. The amount of shock dampening is limited, however, and may not be enough for some riders.

Seat – Pain

Frames	
Type	**Why...**
Suspension frame	Suspension helps to reduce road shock transmitted up through saddle, thus reducing impact damage and fatigue to the seat.

Bicycle Parts	
Type	**Why…**
Gender specific saddle	In the last decade an increasing awareness of the need to specifically design saddles for men and women has grown, and many saddles are now available that have cut-outs to relieve pressure on sensitive areas. Men's saddles typically have a cut-out in the nose and women's are usually in the middle to rear. As women typically have wider hips, saddles made for women are usually wider, allowing for more support.
Padded saddle cover	Similar to a padded saddle or padded clothing, a padded saddle cover can help to reduce the road shock transmitted through the saddle to the rider.
Saddle post suspension	Like a full suspension bicycle, a suspension seat post helps to reduce road shock transmitted through the saddle to the back. It is usually not as effective as a full suspension at reducing road shock, but can be added to a standard bicycle with little difficulty and costs much less than a new bicycle.
Wide, padded saddle	The wider the saddle is, the more the weight of the body is distributed on the saddle, which decreases the pressure on any one point. In addition, the extra padding helps to reduce the road shock transmitted through the saddle to the body. Less road shock means less impact stress.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.

Rider Accessories	
Type	**Why…**
Padded shorts/pants	Padded clothing is often a simple solution to reducing shock transmitted to the body from the various points of contact with the bicycle. It usually costs less than suspension systems and is more readily available. The amount of shock dampening is limited, however, and may not be enough for some riders.

Shoulder – Pain

Frames	
Type	**Why...**
Light-weight frame	There are times when the bike has to be lifted and carried. At times like this, having a light-weight frame can prevent undue stress on the shoulders.
Suspension frame	Suspension helps to reduce road shock transmitted up through saddle and/or pedals, thus reducing impact damage and fatigue to the back/knees.

Bicycle Parts	
Type	**Why…**
High handlebars	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and reduce strain to the shoulders. For some riders inverting their handle bar can give them a higher grip position.
Mirrors mounted on handlebars	An important part of staying safe on a bicycle is keeping a vigilant watch for potential obstacles. For some people the constant twisting to see behind and to the sides can be difficult. Mirrors can help to reduce the frequency of twisting and turning by providing a view behind the rider.
No aerobars	Many bicycle racers use aero bars to help them ride in a more aerodynamic position. Unfortunately, that position can cause stress on the shoulders and neck, so they should be avoided when shoulder and neck stress is a problem.
Padded handlebar grips	Road shock can cause numerous problems throughout the body and is transmitted through the various bicycle-rider contact points: handlebars, seat, and pedals. Adding padded grips can help to reduce road shock transmitted from the handlebars to the hands, and ultimately to the shoulders and neck.
Padded saddle cover	Similar to a padded saddle or padded clothing, a padded saddle cover can help to reduce the road shock transmitted through the saddle to the neck and shoulders.

Suspension fork	Road shock is transmitted to the bicycle from the road through the wheels. By having a suspension system in the fork, the road shock transmitted through the front wheel is reduced. That shock is transmitted up to the neck and can cause unnecessary stress.
Suspension saddle post	Road shock is transmitted to the bicycle from the road through the wheels. By having a suspension system in the saddle post, the road shock transmitted through the rear wheel is reduced. That shock is transmitted up to the seat, back and shoulders and can cause unnecessary stress and pain.
Wide tires	Wide tires help to absorb some of the road shock transmitted through the wheels to the arms, back and shoulders. Tires come in a variety of widths, from the thinnest road tires at about 19mm to the widest that can be more than 40mm.
Wide, padded saddle	The wider the saddle is, the more the weight of the body is distributed on the saddle, which decreases the pressure on any one point. In addition, the extra padding helps to reduce the road shock transmitted through the saddle to the body. Less road shock means less impact stress.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat helps to position the rider the correct distance from the handlebars to reduce the stress on the shoulders. This adjustment should be in conjunction with proper saddle height and handlebar adjustments.
Saddle height adjustment	Proper height adjustment of the seat also helps to reduce the stress from unnecessary forces exerted on the shoulders. This adjustment should be in conjunction with proper saddle fore & aft and handlebar adjustments.

Rider Accessories	
Type	**Why…**
Mirror mounted on helmet	An important part of staying safe on a bicycle is keeping a vigilant watch for potential obstacles. For some people the constant twisting to see behind and to the sides can be difficult. Mirrors can help to reduce the frequency of twisting and turning by providing a view behind the rider.
Padded gloves	Gloves can be an easy way to reduce road shock transmitted though the hands to the arms, shoulders, and neck.
Padded shorts/pants	Padded clothing is often a simple solution to reducing shock transmitted to the body from the various points of contact with the bicycle. It usually costs less than suspension systems and is more readily available. The amount of shock dampening is limited, however, and may not be enough for some riders.

Upper Back – Pain

Frames	
Type	**Why...**
Suspension frame	Suspension helps to reduce road shock transmitted up through saddle and pedals, thus reducing impact damage and fatigue to the back.

Bicycle Parts	
Type	**Why…**
High handlebars	Proper posture is important to reducing stress on the back. By raising the handlebars, the rider can sit up straighter and reduce back strain. For some riders inverting their handle bar can give them a higher grip position.
No aero bars	Many bicycle racers use aerobars to help them ride in a more aerodynamic position. Unfortunately, that position can cause stress on the back and neck, so they should be avoided when back and neck stress is a problem.
Padded handlebar grips	Road shock can cause numerous problems throughout the body and is transmitted through the various bicycle-rider contact points: handlebars, seat, and pedals. Adding padded grips can help to reduce road shock transmitted from the handlebars to the hands, and ultimately to the back and neck.
Padded saddle cover	Similar to a padded saddle or padded clothing, a padded saddle cover can help to reduce the road shock transmitted through the saddle to the rider's back.
Suspension fork	Road shock is transmitted to the bicycle from the road through the wheels. By having a suspension system in the fork, the road shock transmitted through the front wheel is reduced. That shock is transmitted up to the neck and back and can cause unnecessary stress.
Suspension saddle post	Road shock is transmitted to the bicycle from the road through the wheels. By having a suspension system in the saddle post, the road shock transmitted through the rear wheel is reduced. That shock is transmitted up to the seat, back and neck and can cause unnecessary stress and pain.

Wide tires	Wide tires help to absorb some of the road shock transmitted through the wheels, which causes unnecessary jarring and vibration to the back. Tires come in a variety of widths, from the thinnest road tires at about 19mm to the widest that can be more than 40mm.
Wide, padded saddle	The wider the saddle is, the more the weight of the body is distributed on the saddle, which decreases the pressure on any one point. In addition, the extra padding helps to reduce the road shock transmitted through the saddle to the back. Less road shock means less impact stress.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures mean higher rolling resistance and more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat helps to position the rider the correct distance from the handlebars to reduce the stress on the back. This adjustment should be in conjunction with proper saddle height and handlebar adjustments.
Saddle height adjustment	Proper height adjustment of the seat also helps to reduce the stress from unnecessary forces exerted on the back. This adjustment should be in conjunction with proper saddle fore & aft and handlebar adjustments.

Rider Accessories	
Type	**Why…**
Padded gloves	Gloves can be an easy way to reduce road shock transmitted though the hands to the arms, shoulders, and back.
Padded shorts/pants	Padded clothing is often a simple solution to reducing shock transmitted to the body from the various points of contact with the bicycle. It usually costs less than suspension systems and is more readily available. The amount of shock dampening is limited, however, and may not be enough for some riders.

Wrist – Pain

Frames	
Type	**Why...**
Light-weight frame	There are times when the bike has to be lifted and carried. At times like this, having a light-weight frame can prevent undue stress on the wrists.

Bicycle Parts	
Type	**Why...**
Aerobar	Many bicycle racers use aerobars to help them ride in a more aerodynamic position. That position puts a large portion of the weight of the upper body on the forearms and shoulders, while taking weight off their wrists and hands. This transfer of weight can be helpful for some people.
Ergonomic bell	In many cities, bells are required on all bicycles for safety. Some bells can be difficult to ring for people with wrist pain. Therefore a bell with a ring mechanism that takes little force to activate is very important.
High handlebars/Long handlebar stem	Proper posture is important to reduce the amount of pressure applied to the wrists and hands. By raising the handlebars, the rider can sit up straighter and reduce the load supported by the wrists. For some riders inverting their handle bar can give them a higher grip position.
Multiple grip handlebars	Multiple grip handlebars provide several different option for the rider to grip the handlebars. The rider may find one more comfortable than another, but they are also designed so that the rider can move their hands around, distributing pressure on the hands and reducing the symptoms associated with keeping the hands in one position with pressure on them.
Padded handlebar grips	Road shock can cause numerous problems throughout the body and is transmitted through the various bicycle-rider contact points: handlebars, seat, and pedals. Adding padded grips can help to reduce road shock transmitted from the handlebars to the hands and wrists.
Quick release levers	Many of today's bicycles have quick-release levers to adjust the saddle height, remove wheels, and sometime adjust the handlebars. These levers mean that no small tools that can be difficult to grip are needed to make minor adjustments to the fit of the bicycle.

Suspension fork	Road shock is transmitted to the bicycle from the road through the wheels. That shock is transmitted to the wrists and can cause unnecessary stress. By having a suspension system in the fork, the road shock transmitted through the front wheel is reduced.
Wide tires	Wide tires help to absorb some of the road shock transmitted through the wheels, reducing jarring impact during cycling. Tires come in a variety of widths, from the thinnest road tires at about 19mm to the widest that can be more than 40mm.

Bicycle Adjustments	
Name	**Why...**
Correct tire inflation	Tires should be inflated to the manufacturer's recommendations, which are usually printed on the sidewall of the tire itself. Typically there is a range specified which varies with the type of bicycle and tire. If road shock is a concern, the tire should be inflated to the low end of the scale, however, lower tire pressures means more force needed to propel the bicycle forward. It is therefore important to balance the need for reduced road shock with the force needed to propel the bicycle.

Rider Accessories	
Type	**Why…**
CO_2 pump	Inflating tires with a conventional pump can be difficult and often requires large amounts of force to reach the desired pressure. A simple solution to this can be a compressed gas pump, which typically uses a standard carbon dioxide cylinder to inflate the tires with the simple press of a button.
Gloves covering the wrist	Gloves can be an easy way to reduce road shock transmitted to the hands and wrists. They also can help to keep the hands and wrists warm as cold can make pain more intense.
Wrist brace	Braces of all types are available for many different joints. They can be obtained at most sporting goods stores. It is very important to consult a medical expert or physical therapist before using a brace as the wrong brace or improper usage can actually harm the joint rather than help.

Reduced Range of Motion

Ankle – Reduced Range of Motion

Frames	
Type	**Why...**
Low step-over	A bicycle with a low step-over requires the knees and ankles to bend less while get on the bicycle. Less bending means less stress on the joint.

Bicycle Parts	
Type	**Why…**
Platform pedals (non-clip)	This type of pedal is standard on most city and comfort bicycles, but some include “cage type” two clips. Both the clipped pedals and cage-type clips can cause rotational stresses on the ankles while cycling, so it is important for the ankles to be free to rotate on the pedals to minimize this stress.
Short crank arm	Reducing the length of the crank arm can help to reduce the angles the hip, knee, and ankle must rotate through for each pedaling revolution. It is important to note, however, that a shorter crank arm requires more force to be exerted for forward motion than a longer one, so the need for reducing pedaling motion should be carefully weighed if strength loss or joint stress is a problem.

Bicycle Adjustments	
Name	**Why...**
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat helps to position the rider the correct distance from the handlebars to reduce the need for the rider to bend forwards. This adjustment prevents the rider from placing too much pressure on the handlebars and pedals, ensuring that the ankle is not forced to move under the weight of the rider. This adjustment should be in conjunction with proper saddle height and handlebar adjustments.
Saddle height adjustment	This is just a specific part of overall proper bicycle fit, and is one of the most critical adjustments. If the saddle is too high, it may cause the rider to stretch to reach the pedals, and, if the saddle is too low, it can cause too much stress when applying drive force to the pedals. Both of these problems can cause unnecessary stress on the ankle. When seated on the saddle with one leg at the bottom of the pedal

	stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
N/A	N/A

Elbow – Reduced Range of Motion

Frames	
Type	**Why...**
Low step-over	A bicycle with a low step-over does not require the rider to lean on the elbow to hoist themselves onto the bicycle. This relieves stress and reduces the need for elbow movement.

Bicycle Parts	
Type	**Why…**
Turn signal lights	Signaling turns on a bicycle requires that the rider hold out the arms in various positions that may be difficult if the range of motion in the shoulders, elbows or wrists is impaired. Turn signal lights can take the place of hand signals, but local laws should be consulted as to whether or not turn signal lights are legal for bicycles.
Speed shifter	Gears can make cycling much easier by decreasing the amount of power you need to expend to make the bicycle move. However, changing the gears to fit your needs on traditional gear shifters can be awkward, difficult or painful to your elbows and hands. Speed shifters are placed in a much more convenient place and change with greater ease.
Suspension fork	Road shock is transmitted to the bicycle from the road through the wheels. That shock is transmitted up to the elbows and can cause unnecessary stress. By having a suspension system in the fork, the road shock transmitted through the front wheel is reduced.
Wide, non-adjustable handlebars	Wide handlebars help to correct posture while riding a bicycle. By bringing the handlebars higher and closer to the body, the rider needs to lean forward on the elbows less to hold on and steer the bicycle. By making the handlebars wider, less force is needed to turn the bicycle. It is important to note that handlebars should be no wider than the width of the rider's shoulders, as this is the most natural position for the elbows and arms. All of these changes help to create less stress on the upper body.

Bicycle Adjustments	
Name	**Why...**
N/A	N/A

Rider Accessories	
Type	**Why…**
CO_2 tire pump	Inflating tires with a conventional pump can be difficult and often requires large amounts of force to reach the desired pressure. A simple solution to this can be a compressed gas pump, which typically uses a standard carbon dioxide cylinder to inflate the tires with the simple press of a button.
Elbow brace	Braces of all types are available for many different joints. They can be obtained at most sporting goods stores. It is very important to consult a medical expert or physical therapist before using a brace as the wrong brace or improper usage can actually harm the joint rather than help.
Long sleeved shirt	A long sleeve shirt helps to keep muscles and joints warm, preventing cramps and pain.

Foot – Reduced Range of Motion

Frames	
Type	**Why...**
N/A	N/A

Bicycle Parts	
Type	**Why…**
N/A	N/A

Bicycle Adjustments	
Name	**Why...**
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat helps to position the rider the correct distance from the handlebars to reduce the stress on the feet by placing no more than the necessary amount of pressure on the feet and allowing them to lie in a natural position. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.
Saddle height adjustment	This is just a specific part of overall proper bicycle fit, and is one of the most critical adjustments. If the saddle is too high, it may cause the rider to stretch to reach the pedals, and, if the saddle is too low, it can apply too much stress on the feet when applying drive force to the pedals. When seated on the saddle with one leg at the bottom of the pedal stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
N/A	N/A

Hand – Reduced Range of Motion

Frames	
Type	**Why...**
N/A	N/A

Bicycle Parts	
Type	**Why…**
Ergonomic bell	In many cities, bells are required on all bicycles for safety. Some bells can be difficult to ring for people with hand pain, therefore a bell with a ring mechanism that takes little force to activate is very important.
Foot brakes	Foot brakes are activated by simply pushing back on the pedals in the opposite direction of normal pedaling. A mechanism in the drive train applies a stopping force to rear wheel, slowing the bicycle. Many city bicycles are equipped with a foot brake and a hand brake for the front wheel. One disadvantage to foot brakes, however, is that they are not sold separately as parts, and must be purchased as part of a new bicycle. For people with hand and wrist difficulties, foot brakes provide a safe alternative to hand-pull brakes.
Hydraulic brakes	In standard hand brakes a cable is attached to the end of the brake lever and when the lever is pulled, the cable presses the brake pads against the wheel rim, slowing the bicycle. Hydraulic brakes work in the opposite way. When the brake lever is pulled, hydraulic fluid is compressed in a tube which pushes small brake pistons against a vented disc attached to the wheel, slowing the bicycle. They are more reliable than standard pull-brakes and require significantly less force to operate.
Large handlebar grips	Large handlebar grips provide relief for the hands by spreading the weight applied to the hands across a wider area. Larger grips also decrease the range of motion required to grasp the handlebar, for those riders whom have trouble closing their fingers.
Short brake levers	Short brake levers require less motion to grip and apply the brakes. They do, however, require more force than longer ones, so the importance of reducing the motion needed to pull the brakes with the need the reduce the force needed.
Speed shifters	Gears can make cycling much easier by decreasing the amount of power you need to expend to make the bicycle move. However, changing the gears to fit your needs on traditional gear shifters can be

	awkward, difficult or painful to your fingers and hands. Speed shifters are placed in a much more convenient place and change with greater ease.

Bicycle Adjustments	
Name	**Why...**
N/A	N/A

Rider Accessories	
Type	**Why…**
N/A	N/A

Hip – Reduced Range of Motion

Frames	
Type	**Why...**
Low step-over	A bicycle with a low step-over requires the hips to bend less while get on the bicycle. Less bending means less stress on the hips.
Proper frame fit	This is essential for anyone, regardless of physical condition. A properly fit bicycle means that no unnecessary stresses are exerted on the body. This could involve anything from a simple adjustment to the seat height, to buying an entirely new bicycle.

Bicycle Parts	
Type	**Why…**
Short crank arm	Reducing the length of the crank arm can help to reduce the angles the hip, knee, and ankle must rotate through for each pedaling revolution. It is important to note, however, that a shorter crank arm requires more force to be exerted for forward motion than a longer one, so the need for reducing pedaling motion should be carefully weighed if strength loss or joint stress is a problem.

Bicycle Adjustments	
Name	**Why...**
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat helps to position the rider the correct distance from the handlebars to reduce the stress on the hips. The less the rider has to lean into the handlebars, the less stress is placed on the hips. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.
Saddle height adjustment	This is just a specific part of overall proper bicycle fit, and is one of the most critical adjustments. If the saddle is too high, it may cause the rider to stretch to reach the pedals and if the saddle is too low, it can cause the hips to over-rotate or apply too much stress when applying drive force to the pedals. Both of these problems can cause unnecessary stress on the hips.

Rider Accessories	
Type	**Why…**
N/A	N/A

Knee – Reduced Range of Motion

Frames	
Type	**Why...**
Low step-over	A bicycle with a low step-over means that the knees need to bend less to get on the bicycle. Less bending means less stress on the knees.
Proper frame fit	This is essential for anyone, regardless of physical condition. A properly fit bicycle means that no unnecessary stresses are exerted on the body. This could involve anything from a simple adjustment to the seat height, to buying an entirely new bicycle.

Bicycle Parts	
Type	**Why…**
Multiple gears	Multiple gears help to provide a mechanical advantage that help to make cycling easier and more efficient. They can help to reduce the force needed to propel the bicycle. Less force means less stress exerted on the knees and legs.
Short crank arm	Reducing the length of the crank arm can help to reduce the angles the hip, knee, and ankle must rotate through for each pedaling revolution. It is important to note, however, that a shorter crank arm requires more force to be exerted for forward motion than a longer one, so the need for reducing pedaling motion should be carefully weighed if strength loss or joint stress is a problem.
Platform pedals (non-clip)	This type of pedal is standard on most city and comfort bicycles, but some include “cage type” clips. Both the clipped pedals and cage-type clips can cause stresses on the knees while cycling, so it is important for the feet to be free to rotate on the pedals to minimize this stress.
Threaded spacers	Threaded spacers help to line up the body in a more natural position with the pedals. They move the pedals away from the bicycle and allow the feet to be more in line with the hips. This causes less stress on the hips, knees, and ankles. Threaded spacers must be fit to the individual's hip and knee widths.

Bicycle Adjustments	
Name	**Why...**
Saddle fore & aft adjustment	This is an adjustment that should be used in conjunction with saddle height adjustment. It works in a similar way to create the correct

Saddle height adjustment	knee angle. At the bottom of the stroke, the shin should be vertical and the knee angle should be between 25 and 35 degrees. This is just a specific part of overall proper bicycle fit, and is one of the most critical adjustments. If the saddle is too high, it may cause the rider to stretch to reach the pedals, and, if the saddle is too low, it can cause the knees to over-rotate or apply too much stress when applying drive force to the pedals. Both of these problems can cause unnecessary stress on the knee. When seated on the saddle with one leg at the bottom of the pedal stroke, the knee should be bent between 25 and 35 degrees for proper saddle height.

Rider Accessories	
Type	**Why…**
N/A	N/A

Lower Back – Reduced Range of Motion

Frames	
Type	**Why...**
Low step-over	A bicycle with a low step-over allows the back to bend less in order to get on the bicycle. Less bending means less stress and difficulty.

Bicycle Parts	
Type	**Why…**
High handlebars/Long handlebar stem	Proper posture is important to reducing stress on the back and shoulders. By raising the handlebars, the rider can sit up straighter and reduce back tension. For some riders inverting their handle bar can give them a higher grip position.
Mirrors mounted on handlebars	An important part of staying safe on a bicycle is keeping a vigilant watch for potential obstacles. For people with lower back stiffness, the constant twisting to see behind and to the sides can be difficult. Mirrors can help to reduce the frequency of twisting and turning by providing a view behind the rider.
Wide handlebars	Wide handlebars help to correct posture while riding a bicycle. By bringing the handlebars higher and closer to the body, the rider needs to lean forward less to hold on and steer the bicycle. By making the handlebars wider, less movement is needed to turn the bicycle. All of these changes help to create less stress on the lower back.

Bicycle Adjustments	
Name	**Why...**
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat helps to position the rider the correct distance from the handlebars to reduce the stress on the lower back. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.
Saddle height adjustment	Proper height adjustment of the seat also helps to reduce the stress on the back from unnecessary forces exerted on the back. This adjustment should be in conjunction with proper knee angle and handlebar adjustments.

Rider Accessories	
Type	**Why…**
Mirror mounted on helmet	An important part of staying safe on a bicycle is keeping a vigilant watch for potential obstacles. For some people the constant twisting to see behind and to the sides can be difficult. Mirrors can help to reduce the frequency of twisting and turning by providing a view behind the rider.

Neck – Reduced Range of Motion

Frames	
Type	**Why...**
N/A	N/A

Bicycle Parts	
Type	**Why…**
Adjustable handlebar stem	Bicycle fit is one of the most important ways to prevent aggravation of various physical conditions from occurring while cycling. An adjustable handlebar stem helps to fine-tune the fit of the bicycle to each rider's specific needs. Having handlebars that are too low for the rider causes the rider to lean on the shoulders and bend the neck while cycling. Raising the handlebars places less pressure on the rider's neck.
High handlebars/Long handlebar stem	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and reduce neck tension. For some riders inverting their handle bar can give them a higher grip position.
Mirror mounted on handlebars	An important part of staying safe on a bicycle is keeping a vigilant watch for potential obstacles. The constant twisting to see behind and to the sides can be difficult. Mirrors can help to reduce the frequency of twisting and turning by providing a view behind the rider.

Bicycle Adjustments	
Name	**Why...**
N/A	N/A

Rider Accessories	
Type	**Why…**
Mirror mounted on helmet	An important part of staying safe on a bicycle is keeping a vigilant watch for potential obstacles. For some people the constant twisting to see behind and to the sides can be difficult. Mirrors can help to reduce the frequency of twisting and turning by providing a view behind the rider.

Shoulder – Reduced Range of Motion

Frames	
Type	**Why...**
N/A	N/A

Bicycle Parts	
Type	**Why…**
Adjustable handlebar stem	Bicycle fit is one of the most important ways to prevent aggravation of various physical conditions from occurring while cycling. An adjustable handlebar stem helps to fine-tune the fit of the bicycle to each rider's specific needs. Having handlebars that are too low for the rider causes the rider to lean on the shoulders while cycling. Raising the handlebars places less pressure on the rider's shoulders.
High handlebars/Long handlebar stem	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and reduce shoulder tension. For some riders inverting their handle bar can give them a higher grip position.
Turn signal lights	Signaling turns on a bicycle requires that the rider hold out the arms in various positions that may be difficult if the range of motion in the shoulders, elbows or wrists is impaired. Turn signal lights can take the place of hand signals, but local laws should be consulted as to whether or not blinkers are legal for bicycles.

Bicycle Adjustments	
Name	**Why...**
	N/A

Rider Accessories	
Type	**Why…**
CO_2 tire pump	Inflating tires with a conventional pump can be difficult and often requires large amounts of force to reach the desired pressure. A simple solution to this can be a compressed gas pump, which typically uses a standard carbon dioxide cylinder to inflate the tires with the simple press of a button.

Upper Back – Reduced Range of Motion

Frames	
Type	**Why...**
N/A	N/A

Bicycle Parts	
Type	**Why…**
Adjustable handlebar stem	Bicycle fit is one of the most important ways to prevent aggravation of various physical conditions from occurring while cycling. The adjustable stem is able to place the handlebars higher or lower and closer or further away from the body as needed. Having handlebars that are too low for the rider causes the rider to bend their back while cycling. Raising the handlebars places the rider's back in a more upright position.
High handlebars/Long handlebar stem	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and reduce back tension. For some riders inverting their handle bar can give them a higher grip position.
Turn signal lights	Signaling turns on a bicycle requires that the rider hold out the arms in various positions that may be difficult if the range of motion in the shoulders or back is impaired. Turn signal lights can take the place of hand signals, but local laws should be consulted as to whether or not turn signal lights are legal for bicycles.

Bicycle Adjustments	
Name	**Why...**
N/A	N/A

Rider Accessories	
Type	**Why…**
CO_2 tire pump	Inflating tires with a conventional pump can be difficult and often requires large amounts of force to reach the desired pressure. A simple solution to this can be a compressed gas pump, which typically uses a standard carbon dioxide cylinder to inflate the tires with the simple press of a button.

Wrist – Reduced Range of Motion

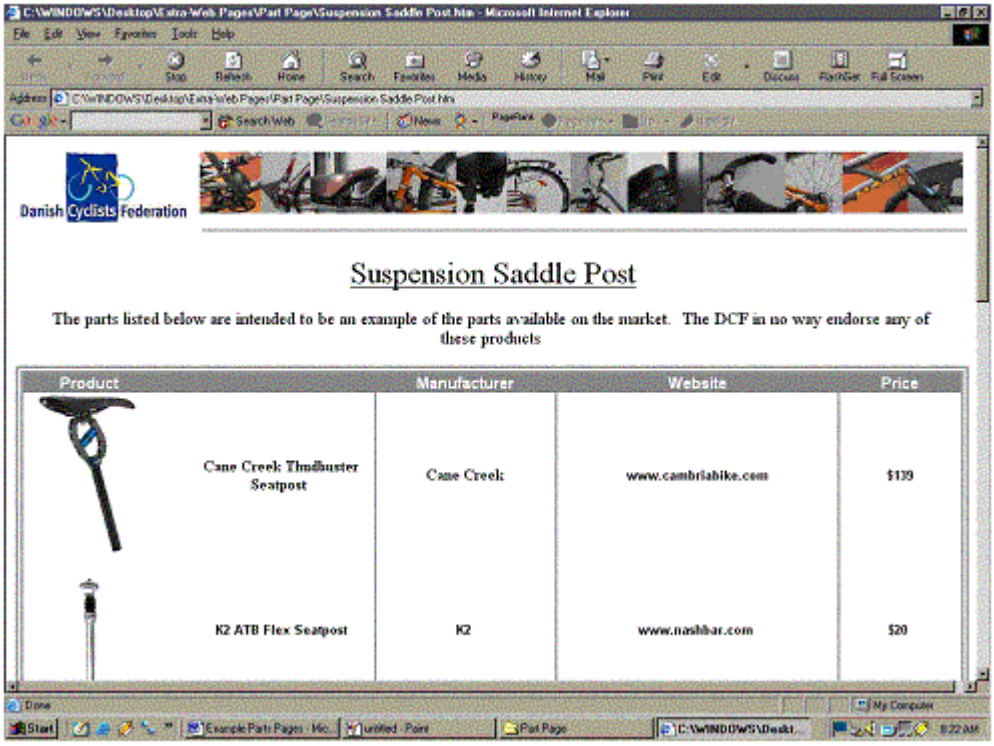
Frames	
Type	**Why...**
N/A	N/A

Bicycle Parts	
Type	**Why…**
Multiple grip handlebars	Multiple grip handlebars provide several different option for the rider to grip the handlebars. The rider may find one position more accessible than another, due to their reduced range of wrist motion. They are also designed so that the rider can move their hands around, distributing pressure on the hands and reducing the symptoms associated with keeping the hands in one position with pressure on them.

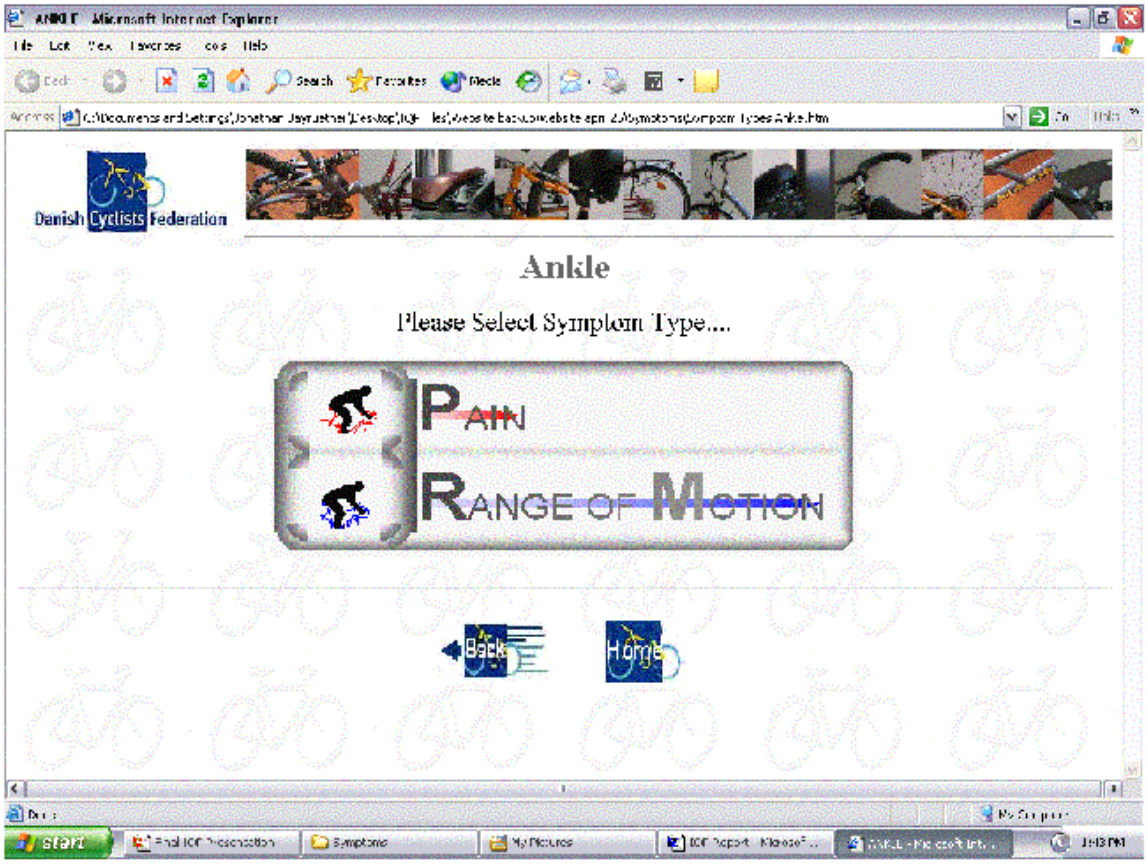
Bicycle Adjustments	
Name	**Why...**
Saddle fore & aft adjustment	Proper fore/aft adjustment of the seat helps to position the rider the correct distance from the handlebars, reducing the pressure the rider places on the wrists by leaning on the handlebars. This adjustment should be in conjunction with proper handlebar adjustments.
Saddle height adjustment	This is one of the most critical adjustments to overall proper bicycle fit. If the saddle is too high, it may cause the rider to stretch to reach the pedals and thus apply excessive force on the wrists and hands.

Rider Accessories	
Type	**Why…**
N/A	N/A

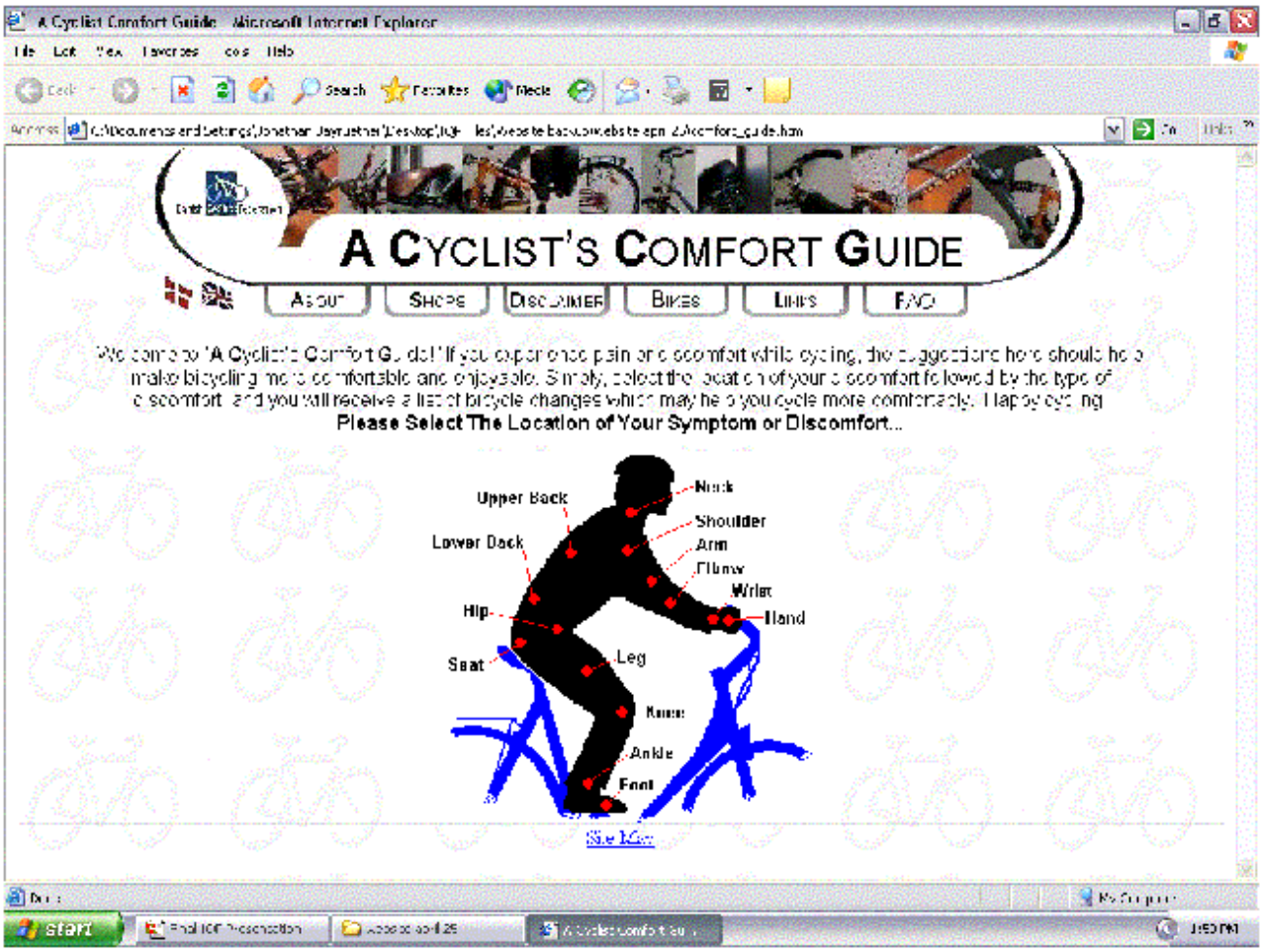
APPENDIX J – PRE-FOCUS GROUP PARTS PAGE EXAMPLE



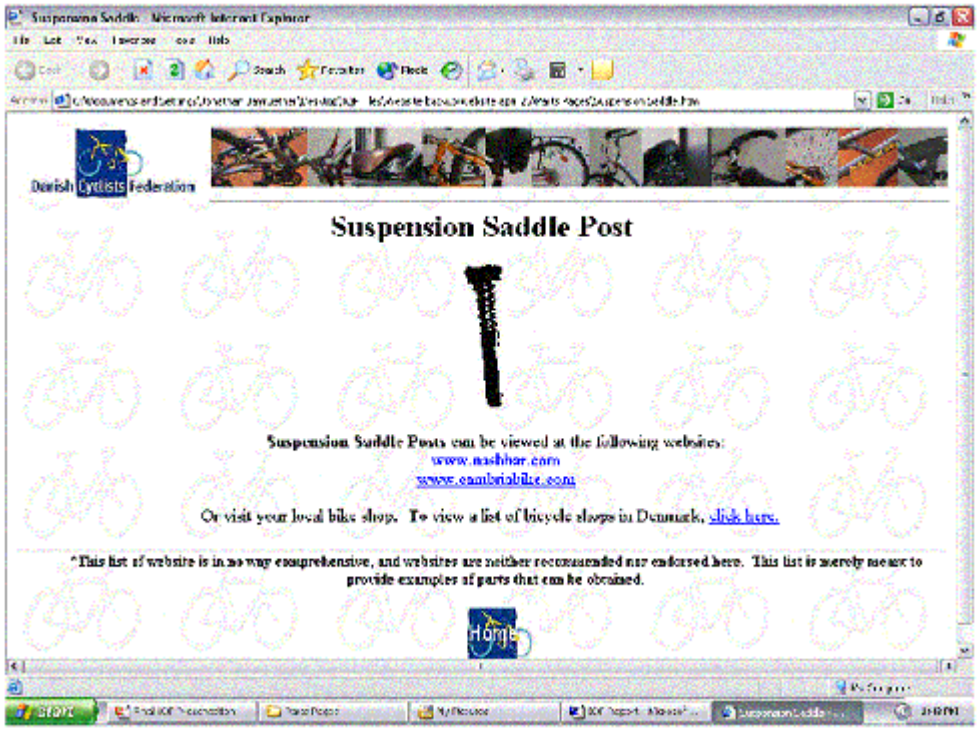
APPENDIX K – SAMPLE SYMPTOMS PAGE



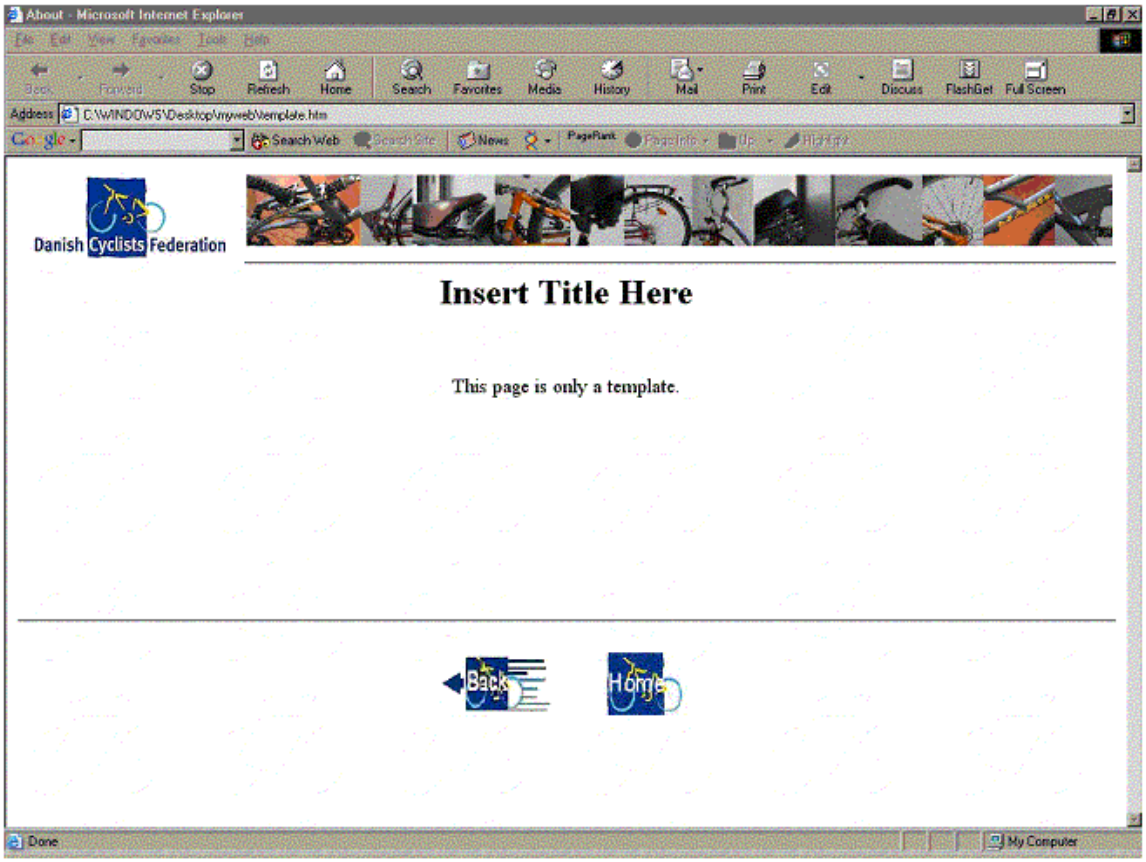
APPENDIX L – SAMPLE HOME PAGE



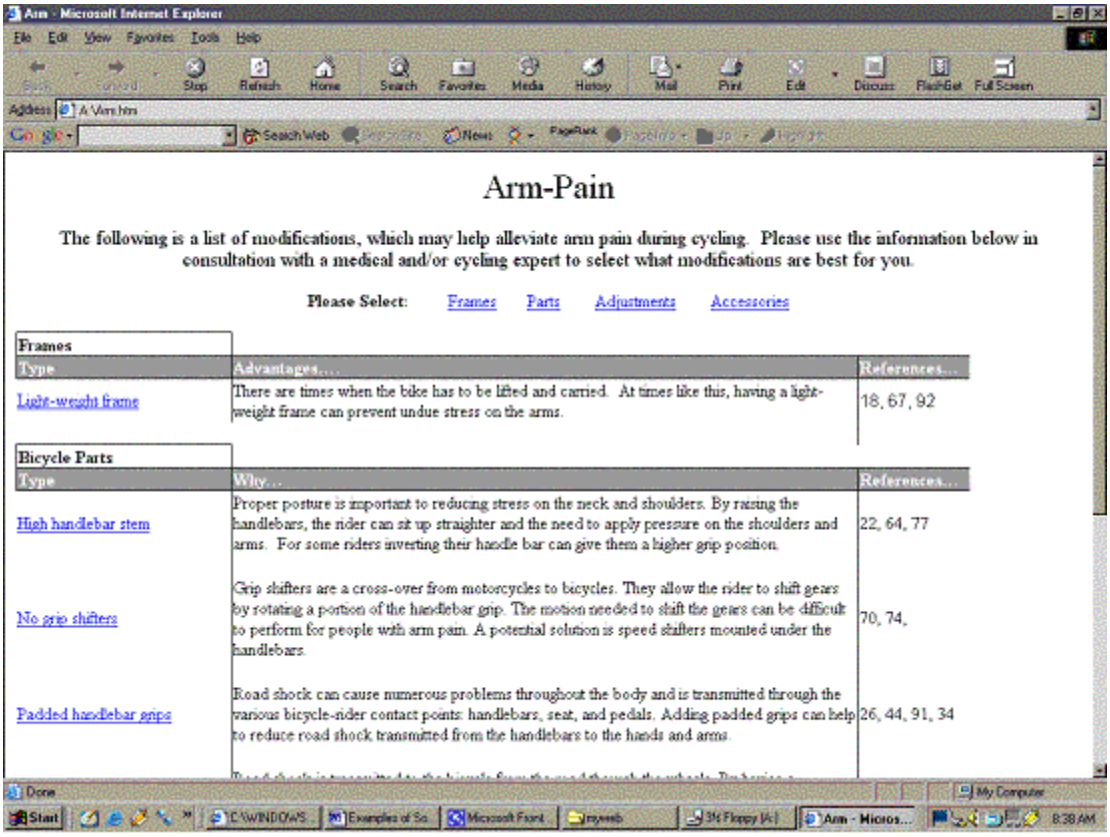
APPENDIX M – NEW PARTS PAGE EXAMPLE



APPENDIX N – WEB PAGE TEMPLATE



APPENDIX O – ORIGINAL SOLUTIONS PAGE EXAMPLE



Arm - Microsoft Internet Explorer

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Arm-Pain

The following is a list of modifications, which may help alleviate arm pain during cycling. Please use the information below in consultation with a medical and/or cycling expert to select what modifications are best for you.

Please Select: Frames Parts Adjustments Accessories

Frames

Type	Advantages...	References...
Light-weight frame	There are times when the bike has to be lifted and carried. At times like this, having a light-weight frame can prevent undue stress on the arms.	18, 67, 92

Bicycle Parts

Type	Why...	References...
High handlebar stem	Proper posture is important to reducing stress on the neck and shoulders. By raising the handlebars, the rider can sit up straighter and the need to apply pressure on the shoulders and arms. For some riders inverting their handle bar can give them a higher grip position.	22, 64, 77
No grip shifters	Grip shifters are a cross-over from motorcycles to bicycles. They allow the rider to shift gears by rotating a portion of the handlebar grip. The motion needed to shift the gears can be difficult to perform for people with arm pain. A potential solution is speed shifters mounted under the handlebars.	70, 74,
Padded handlebar grips	Road shock can cause numerous problems throughout the body and is transmitted through the various bicycle-rider contact points: handlebars, seat, and pedals. Adding padded grips can help to reduce road shock transmitted from the handlebars to the hands and arms.	26, 44, 91, 34

Done My Computer

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APPENDIX P – FOCUS GROUP SUGGESTIONS

Suggestion	Utilized
- Bicycle Rider needs to be riding a comfort bicycle not a racing bicycle	Y
- The disclaimer above the solution pages needs to be more visible	Y
- Make reasons on solution pages more consistent: why, how, advantages	Y
- Redesign the parts pages and included links only no specific part information	Y
- Include information regarding specific medical conditions	N
- Remove the sources link from the home page	Y
- Tone down the bluntness of the FAQ	N
- Use a database based website to allow users to cross-reference multiple symptoms	N
- Insert a section on proper cycling technique	N
- Link the website from netdoktor.dk and sundhed.dk	N/A
- Explain in the blurbs what the obscure bicycle parts/accessories are	Y
- Move bicycle rider to homepage and save a click	Y
- Increase the information on the about page	Y
- Link a Shops page off the homepage	Y
- Bookmarks on solutions pages are confusing and need to be moved	Y
- The text on the home page needs to be a little more informative	Y
- The average user will not need references to the solutions	Y
- Insert a section on the different load point of the body during cycling	N

APPENDIX Q – LIST OF MAGAZINES

Publication	Editor	Email
Helse	Kirsten Engel	helse@helse.dk
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