An Approach to the Design of Shouldered Personal Load-Carrying Systems

by

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Abstract

Shouldered load-carrying systems are all around us. While their use and design range from the common purse or school backpack to the more specialized drum line marching carrier, their main function remains the same: to help the user move an object from Point A to Point B. The use of such shoulder load-carrying systems results in thousands of injuries every year. Online forums, blogs, newsgroups, and print media have responded with several suggestions for avoiding these injuries when using shouldered load-carrying systems. These suggestions often go unnoticed, however, due to their limited perception of how the average user typically approaches their shouldered load-carrying systems. For instance, though many forums discuss the dangers in carrying a load on one shoulder, there are several backpacks currently on the market that are "sling style," meaning that they are purposely designed to be carried on one shoulder. This is just one indication of the obvious disconnect that exists between the design and the user within the field of shouldered load-carrying systems. The goal of this research will be to offer an approach to designing shouldered load-carrying systems, by creating a set of strict guidelines and then applying these guidelines to the design of a shouldered load-carrying system in order to lower the chance of user injury.

Acknowledgments

To my loving wife for her constant support and patience throughout this process. You are my rock. To my parents and family thank you for being with me every step of the way.

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Definition of Key Terms and Acronyms

ACS – Agility Control System

Battery – The battery is the drum section that marches on the field as a group. The battery usually consists of snare drums, bass drums, tenor drums, and cymbals

Belly Plate – The part of the carrier that rest on the drummer's abdomen

Carrier - A piece of equipment designed for marching percussion that is worn by a drummer that a drum is then attached to (also called a harness or rack)

Crab Step – When the musician crosses one leg over the other, either marching on the toes or rolling the foot sideways

DIY – Do it yourself – a belief or practice that prompts an individual to solve problems using their own skills and resources instead of purchasing a solution

Drill – Refers a marching band members spot on the field in the shapes the marching band makes during a halftime or show performance

Drum Corp – A musical ensemble consisting of musicians playing a variety of drums and bugles. Drum and bugle corps frequently compete in regional and national contests and exhibit the highest order of marching entertainment available

Drum Key – A small T-shaped, wrench used to turn tension rods. Most often keys and rods are square-headed

Gait - The pattern of movement of the limbs of animals, including humans, during locomotion over a solid substrate

Indoor Drumline - An indoor percussion ensemble or indoor drumline consists of the marching percussion (or *battery*) and front ensemble (or *pit*) sections of a marching band or drum corps

J-Bar – The part of the carrier that the drum attaches to

Musculoskeletal – Relating to or involving the muscles and the skeleton

Paresthesia – A sensation of tickling, tingling, burning, pricking, or numbness of a person's skin with no apparent long-term physical effect. It is more generally known as the feeling of "pins and needles" or of a limb "falling asleep"

Set – A specific movement between two points of a marching band halftime performance or show

Tension Screws – The bolt that goes through holes in the rim of the drum, used to pull the head down across the bearing edge, and tighten or loosen for tuning

Introduction to the Problem

The use of a personal shouldered load-carrying system is fairly common around the world from the everyday school backpack to the more specialized drum line marching carriers. While these load- carrying systems achieve their main goal of helping a person move a load from Point A to Point B, they are also beginning to be linked to unexpected consequences. In a 2006 study researchers in Los Angeles, California sampled 1540 children ages 11to14 years in age and living in the metropolitan area. The results showed that an overwhelming 97% of the children studied used backpacks and that,

> Overall, 37% of the children reported back pain. … Of the children who reported back pain, 34% limited their activity due to the pain, 14% use medication for pain relief, and 82% believed their backpack either caused or worsened their pain. (Skaggs, Early, D'Ambra, Tolo, & Kay, 2006)

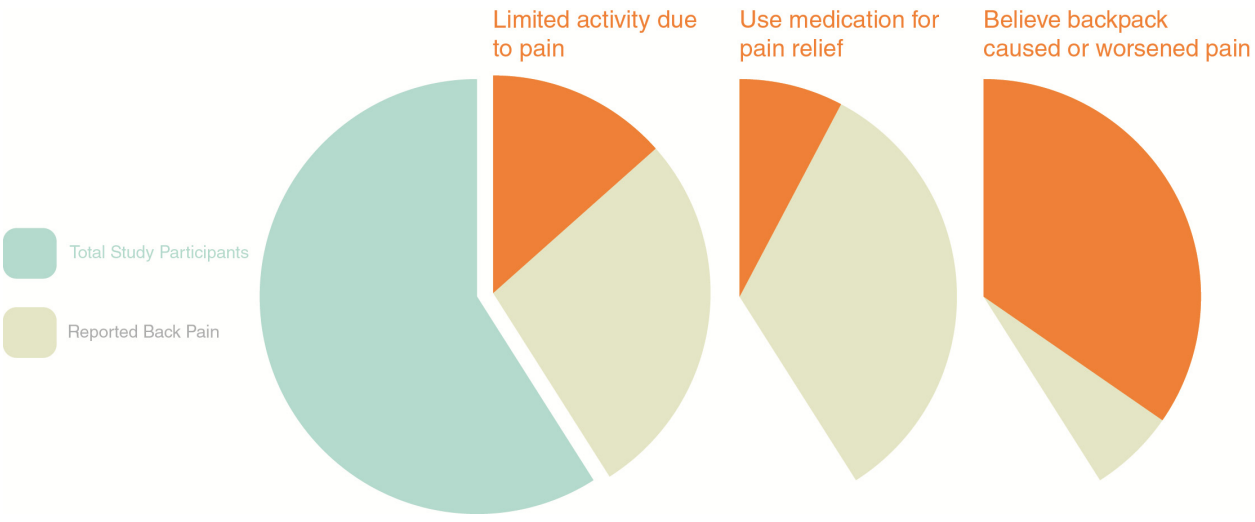


Figure 1: Injuries reported from wearing backpacks

Research has also been able to find a link between the wearing of a shouldered load-carrying system and changes in a user's gait and posture, which over time can result in chronic pain and various back and neck related problems.

In this modern area of internet use, there is a plethora of information on the perils of load-carrying systems that is quite literally at the consumer's fingertips. With this increase in public knowledge

> "Customers are becoming increasingly sophisticated in terms of their knowledge of human factors and the quality level of human factors that they expect with a product. … Users are no longer willing to accept difficulties in interacting with products as a price they must pay for *technical wizardry*" (2002, p. 2).

A simple search on the internet results in thousands of entries from blogs describing what to look for in shouldered load-carrying systems and how to correctly wear them, to reviews of current shouldered load-carrying system designs already on the market, to research on the dangers of improper shouldered load-carrying systems use.

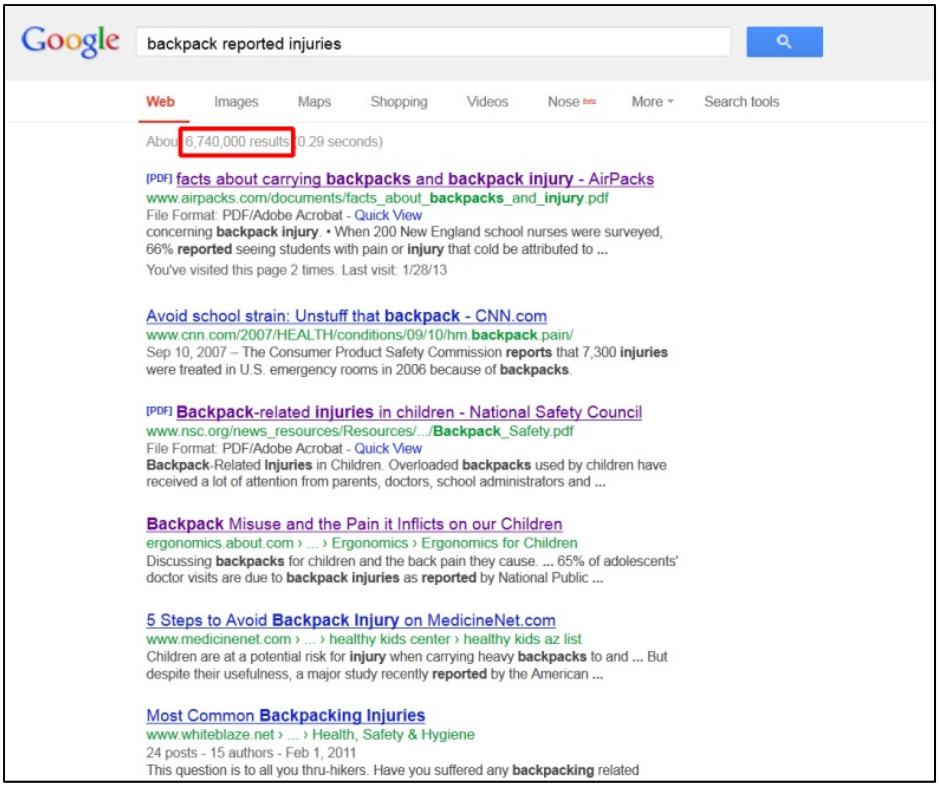


Figure 2: Standard Google Results Page for "Backpack Reported Injuries"

Consumers are more aware than ever of what they need, but this need is not often reflected in the designs of shouldered load-carrying systems available. For example, research shows that to avoid injury the bottom of a backpack should be no lower than four inches below the user's waist. The current design approach to backpacks is to create one product which can fit every size from the fifth percentile to the ninety-fifth percentile of the population and is then adjusted to fit by the user; meaning the adjustments for the shoulder straps are often quite long (see Figure 3). This provides an opportunity for a large portion of users to adjust the backpack to a point where it can cause lower back injury.

Figure 3: Long Adjustment Straps (Freeman, 2008)

Another design problem is that personal shouldered load-carrying systems are no longer just carrying something from Point A to Point B; they are now becoming fashion statements. Consumers now use shouldered load-carrying systems to show off their personality and to fit into the crowd. For the problem with straps is not as simple as that they are too long for some users; it's that the fashion trend is to wear to wear the backpack as low as it will go. It is the designer's responsibility to try and bridge this gap between fashion and function; to find a way to educate the user on the proper way to wear a shouldered load-carrying system and to still allow them be a part of the *cool crowd*.

Objective of Study

The objective of this study is to outline a more holistic approach to the design of shouldered load-carrying systems in order to alleviate user injuries as much as possible. To develop this approach, research will be done to discover what injuries occur most commonly through the improper use of shouldered load-carrying systems. Guidelines will then be developed based on this research and other criteria such as how the product is stored, if the injuries can be avoided, if other materials can be used, etc. Current shouldered load-carrying system designs will be deconstructed and evaluated piece by piece according to this set of guidelines. It is believed that by taking a more systematic approach to the design of personal shouldered load-carrying systems, a more user centered product from the everyday school backpack to the more specialized marching band carriers can be created.

Scope of Research

The goal of this research is to create an approach to the design of all load carrying systems, but the scope will be focused primarily on the design of shouldered load-carrying systems. This was done primarily because shouldered load-carrying systems are more accessible and offer a wide variety of specialized types. While I began my research primarily focusing on drum line carriers due to my personal experience in marching band, I believe the data collected can be applied in some way to all shouldered load-carrying systems; backpacks, camping equipment, purse etc. The appropriate safety features that I discuss in my research is especially relevant for the wider scope of my thesis, as it is these safety features that should provide the foundations for the design of all such load carrying systems.

Introduction to Research

Personal shouldered load-carrying systems are everywhere we look, but what exactly is a *personal shouldered load-carrying system*? A personal shouldered load-carrying system can be defined as any product that helps a person use their body (primarily their shoulders and torso) to transport a load from Point A to Point B; this can be anything from a person's hands to a top of the line hiking backpack. For the purposes of this study, the research will be centered on shouldered load-carrying systems; more specifically school backpacks and marching band drum line carriers. School backpacks were chosen because they represent a commonly used personal shouldered load-carrying system and because, "it is the backpacks used to carry books, the ones utilized most often by kids that have caused the most problems" (Busch, Szenasy, & Skelcher, 2005, p. 51).

Drum line marching carriers on the other hand were chosen to represent the more specially designed types of shouldered load-carrying systems that are available. It is believed that by developing an approach that can be applied to both of these extremes (common versus specialized), the shouldered load-carrying systems which fall in between can also be treated in the same manner. Military information will be used to bridge this gap between common and specialized equipment because, "military populations themselves are unique since they are neither biological populations nor random samples of biological populations" (Ulijaszek & Mascie-Taylor, 2005, p. 179).

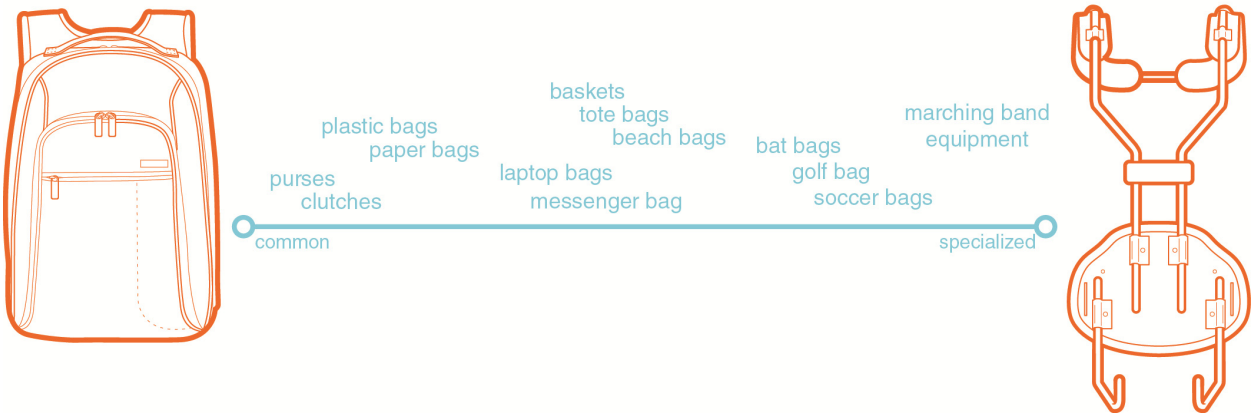


Figure 4: Examples of Common versus Specialized Shouldered Load-Carrying Systems

Why Do People Carry Things: Identity versus Safety

Humans as a species like to carry things, it is one of qualities that make us, *us*. As humans we are hardwired in our DNA to collect and carry things with us. From an early age we begin to accept that the objects we choose to carry as partially defining who we are as an individual. In Akiko Busch's 2005 book *The Uncommon Life of Common Things: Essays on Design and the Everyday* he states that as humans grow there, "… is the emerging awareness that the things one collects and carries help compose identity"(p. 47). This feeling that collecting objects and keeping them close is important starts at an early age:

> As infants, many children are carried around in some variation of the backpack - front packs and slings, back packs, multiuse packs that could be converted to little cribs and sleepers – and I suspect there must be lingering subliminal memory of this experience. That a backpack is the place where you carry around what matters in life has been imprinted upon them, and carrying around their own small packs confers importance,

> responsibility, and the quality small children love and desire most, authority. (Busch, 2005, p. 47)

This connection to the importance of what is carried may go even deeper than just childhood memories of being held by ones' parents. It may be linked to a more primal need passed down from the days of the first hunter-gathers where everything of importance needed to be carried with you. Humans, being the adaptive creatures they are, developed several methods to carry the items they needed utilizing their own bodies. Keeping the things that are the most important to them as close as possible to them: creates an emotional connection to the things they carry:

> … the things you carry on your back are *necessary* things follows a physical and emotional logic. A backpack connotes safety, self-reliance, rugged independence…A good backpack provides a sense of assurance; it gives credibility and a certain gravity to this impulse to collect and carry. With its legacy in hiking, camping, and climbing – indeed, survival in the wild with only what you can strap on your body – there is something about a backpack that suggests one is efficiently outfitted, prepared for whatever is to come. One is equipped with the essential.
> (Busch, 2005, p. 49)

This can be seen as a continuation or maturity of the beliefs that a backpack denotes importance, responsibility, and authority. The items one carries with them are now *important* because they have become necessary for one's survival, they are now *responsible* for keeping the wearer alive, and the backpack itself now gives the items within it *authority*, in that the wearer feels that "their backpack is nice, therefore the items inside it are nice too".

If the items a person carries with him or her are viewed as defining who they are on the inside, it can be said that what a person carries these items in becomes an outward symbol of *who he or she is*. As one student said while describing her backpack, "My pack," she says, "is something that defines me" (Horovitz, 2009). Several websites, Tumblr Accounts, Flickr accounts, and articles have been created and devoted to the simple question of "What is in your bag"? The company Timbuk2 utilizes its own website called whatsinyourbag.com as "a tribute to the big, squishy, bulky, salty, furry things we carry and simply cannot live without" ("What's In Your Bag," n.d.). On the site people are asked to post a picture of all the items in their bag (with a list), where they are from, their occupation, what can't they live without, and the most surprising thing they carry.

It is a unique social experience and a community that is built around users of the same brand to seeing how other users, some owning the exact same bag, utilizes their bags differently. Through the use of this online community, Timbuk2 gets access to free research into the mindsets of their current customers and how they are using their product. This allows Timbuk2 to spot current consumer trends and possibly consumer needs that are not being met and adapt to them.

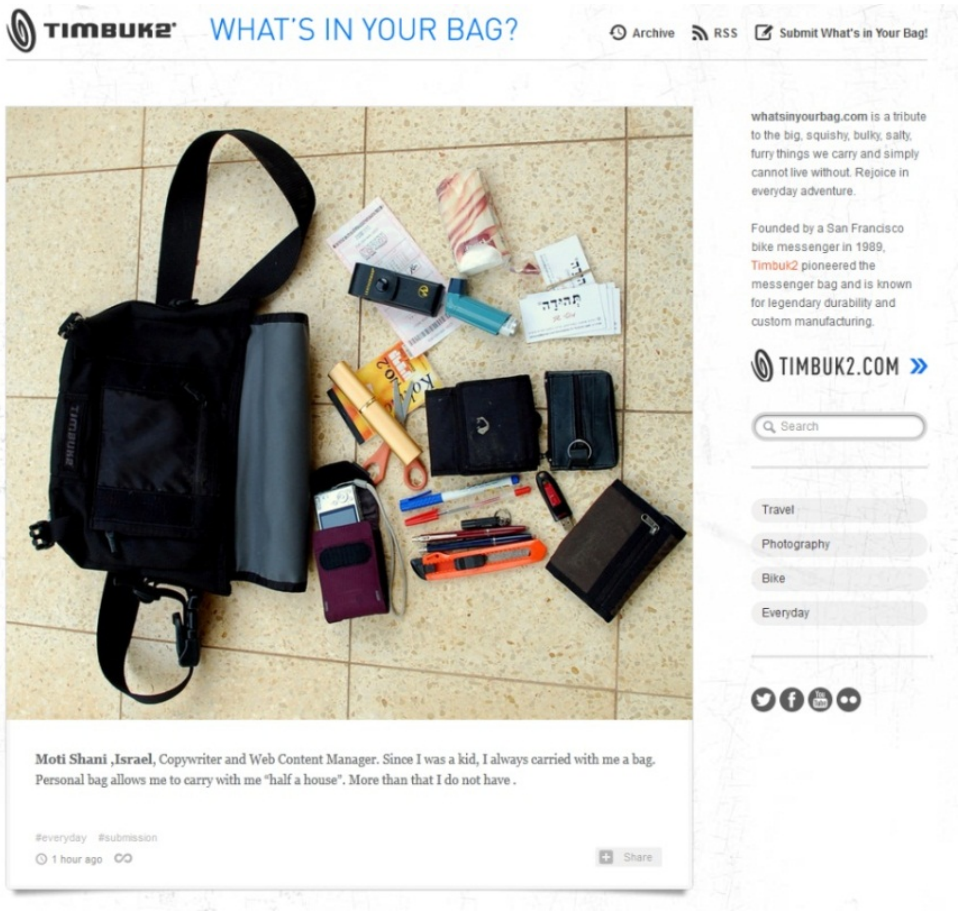


Figure 5: Typical Post Format on whatsinyourbag.com forum

Like any other tools, personal shouldered load-carrying systems have evolved to better fit the user's needs and expectations when transporting their necessities. People tend to give the objects they own *homes*. Take, for instance, keys; in some households people have a special place where they always place their keys upon walking through the door. When utilizing their backpacks they may select certain pockets to certain items and make sure always to put everything in its *correct place*. There's, "lots of gimmickry is used to sell backpacks. But above all, students now want techy tweaks to their packs. A private place to put the iPod. A pocket for the cellphone. A padded spot for the laptop" (Horovitz, 2009).

The bigger picture is that backpacks as a whole are beginning to be designed to serve more specialized purposes:

> … today there appears to be a specific backpack for each sport, all of them a way for children to feel that they are equipped, efficiently outfitted, that is to say *prepared* for whatever comes their way. Life is composed by categories of essentials. My sons have a backpack for their skateboard gear, another one strictly for snowboarding, another for their cameras. There is even a mini pack that attaches to the backs of their snowboard bindings…I have seen packs with side compartments that fold out, designed specifically for CD and MP3 players. All of which may be a way of recognizing that things, along with people, have a place in life. And who is to say what the essential tools for life are? (Busch et al., 2005, pp. 50–51)

This specialization of backpacks (see Figure 6) plays in to the idea of identity building. By purchasing a bag solely used for skateboarding the user is declaring to the world that he or she is someone who takes the sport seriously and a generic bag will not do. Schools are also pushing this specialized backpack trends, but for security reasons. Many schools around the United States are started requiring the students to have "full disclosure" backpacks (see Figure 7) to show what the students are packing. This feature however; takes away from another important feature that a backpack provides.

Figure 6: Skateboarding, Snowboarding, Skiing, and Surfing backpacks ("DAKINE Pivot Backpack @ Tactics.com," n.d.)

Figure 7: Full-Disclosure Bag ("JanSport Specter Backpack - eBags.com," n.d.)

Along with these feelings of self, security, and necessity comes another important characteristic: secrecy. "With all their pockets and zippered compartments, backpacks also embody the idea of legitimized secrecy…not for oneself but for one's things, for the objects of one's affections" (Busch et al., 2005, p. 49). This is may seem counterproductive to building and showcasing one's identity, but sometimes if an item is important enough to be carried it may also be important enough to conceal. Therefore, a personal shouldered load-carrying system needs to encompass these four ideals: identity, security, necessity, community, and secrecy. In an essence,

> "Backpacks have become command central," says Grant McCracken, a cultural anthropologist and research affiliate at the Massachusetts Institute of Technology. "When

you think about what's in them, they almost serve as mini-mobile homes". (Horovitz, 2009)

How People Carry Things: Need versus Culture

There are several factors which can affect the way that a person decides to carry an object or heavy load. These factors can be asked as a series of questions that only the user can answer. For example: the question of "can it be lifted" depends entirely on how strong the user is. All these questions fall into two main categories of factors that a person will use to choose a personal shouldered load-carrying system: need and culture. The *Need category* asks the question "How do I think this object(s) or load should be carried?" while the *Culture category* asks the question "How does society think I should carry this object(s) or load?"

A person's needs revolve around the task involved and that individual's personal physical fitness. When distances are involved, a person's strength and stamina are the important factors. If challenging terrain is being traveled over, then a person's ability to deal with a particular terrain and climate comes into effect. The object(s) relative size compared to the person is also a factor. If the object is small and light enough, it could simply be carried using just the person's hands to pick it up. However, this only works for small, light things or if the person doesn't need to use his or her hands for any other purposes. What happens when the task is too heavy or cumbersome or the distance too long? A personal shouldered load-carrying system must be selected and used; these systems range from simple cloth bags to hiking backpacks.

Culture can have just as big of an impact in manner in which objects are carried. A prime example of this can be seen by women in some African tribes who are known for being able to carry extremely heavy loads using only their heads. Carl Zimmer's (1995) article "*No Skycaps*

Needed" states, "The African women could carry a fifth of their weight … Some women could carry 70 percent of their weight". Researcher Charles Q. Choi states that "women do so mostly out of necessity, when they might need their arms to help travel over difficult terrain" (1995)**.** These women make this practice seem easy, yet it is anything but easy. It takes several years of practice to obtain the optimal gait required; the practice can also cause the participant to develop a concaved skull and a permanently concaved back. While there are arguably better ways to travel while carrying these loads that would still allow these women to use their arms while travelling, it would seem that because balancing these loads on one's head, it is the social norm and therefore has become the expected way in that region of the world.

Figure 8: Women in Ghana (Dweck, 2010)

Countries and geographical areas are not the only places that a culture can develop; on a smaller scale schools have been shown to be environments in which several subcultures can form. In school settings children instinctively form close social groups in an attempt to not be *left out* or teased by other students for being *uncool*. In Jonathan Chapman's (2005) book *Emotionally Durable Design: Objects, Experiences & Empathy* a study that was done by the Nomura Research Institute discovered that people's consumption patterns are very similar to the flocking behavior of birds:

> Seeking shelter, for example, essentially means the inclination to buy brand-name goods with the aim of seeking approval and support of others. Similarly, pursuing fashion means the desire to stay abreast of what others are doing, while adhering to specific features caters to the pride of demonstrating one's uniqueness by purchasing goods that are slightly different from those owned by others (2005, p. 45).

At school when something, such as an article of clothing, becomes popular children will make every attempt to get it so that they may remain in the *cool crowd*, which applies to backpack their selection as well. "A bag is a badge. It's a statement of how cool you are," says Alan Krantzler, marketing chief at luxury luggage maker Tumi" (Horovitz, 2009). When picking out a backpack, children and adults often look for two completely different things:

> Adults seek out safety and durability, says John Bartholomew, a product-line manager at L.L. Bean, but "kids choose a pack for two primary reasons: how it looks and capacity." Finding a backpack that satisfies both adult and child criteria can be tricky, Bartholomew

> says, because children's choice of backpack is one of the ways they tell the world who they are: "If they've chosen a particular color, if they've chosen a particular print, it means something to them." (Majerol, 2013)

While children may utilize this opportunity to start defining their self-image, they may also use it to define themselves within the crowd. If a particular TV character is popular amongst the children in their class or school they may gravitate toward the backpack that displays that character's image. This is because "people are very influenced by others' opinions and behaviors, especially when they are uncertain" (Weinschenk, 2011, p. 218), so children may just be looking at the backpack design they think would best help them to fit in. For example, the backpacks that come with pre-attached wheels have been shown in studies to be much better for children's backs, but they often are not purchased. There are two reasons for this: (1) kids do not like to use them because they fear being teased and (2) some schools have banned them as tripping hazards. The same principle applies to students wearing their backpacks as low as the straps will allow. While this method plays havoc with the user's balance and increases muscle strain, the possible discomfort is worth it because it allows for a chance to fit into the crowd.

The same idea of cultural influences on personal shouldered load-carrying system choice can be found in school marching bands where there is a strong sense of tradition. This use of *tradition* essentially creates a hive mind by stripping away a person's individuality and making several decisions for them: from the way that they stand, to the way they act during performances, to the style of music that they play. This allows for all the members of the marching band to focus on the task at hand, performing to the best of their ability and making sure that the others around them are doing the same. These decisions are made for the band by

the band directors and leadership with the goal of trying to improve the visual presence and sound of the band. By purchasing new equipment, band directors are trying to show other band programs how much they think their program is worth. This strong belief that "my band is better and therefore deserves better equipment" is transferred to the band members who now feel that because they have better equipment, therefore they *are* better and have an obligation to make this purchase seem worthwhile.

For most marching drum lines, the biggest determinant in which style/brand of carrier that will be used any given marching season is money, with some carriers such as the Mapex Quantum Q-Ball Carrier (see Figure 9) costing as much as $350.00 each. Larger profile bands such as drum corps and collegiate marching bands will end up getting sponsors who will donate

Figure 9: Mapex Q-Ball Carrier ("Mapex Quantum Q-Ball Marching Snare Drum Carrier," n.d.)

new equipment to them every year. The sponsors use this opportunity to use these bands as advertisements for their products. This allows for the band program to save money and to enhance the individual member's self-image because they are *good* enough to be sponsored, making them want to perform better because they know the sponsor is watching. If a band is not sponsored however, they will have to buy these new carriers themselves, but it has the same effect. Members of the drum line will feel like they can play better simply because they have newer equipment.

Injuries

The human back is a very sensitive area of the body, especially during the early years of development as this is when the body is growing and changing the most. Bones grow in response to how much stress or pressure is being applied to them. If a child wears a backpack that does not fit them correctly for a long period of time, there is a chance that bones could grow at an unnatural rate in that area of the body. More commonly if a child is carrying a backpack that is too big, too heavy, or improperly seated on their back it can produce acute pain or to chronic back pain. Dr. David Marshall, Medical Director for Children's Health Care of Atlanta Sports Medicine Program says, "It's estimated about 40 million kids are going to be carrying backpacks, and we're starting to see more and more back pain complaints from the doctors in the sports medicine program" (Charles, 2012). According to a 2012 study by the U.S. Consumer Product Safety Commission "between 2010 and 2011, backpack injuries in kids aged 5 to 18 increased 6.5%, from 12,924 to 13,766" (Charles, 2012).

There have been numerous studies done to discover the limit of much weight a person can carry before noticeable injury occurs. The percentage generally agreed upon is no more than

10% of the person's body weight with a maximum of 15% of their total body weight (see Figure 10).

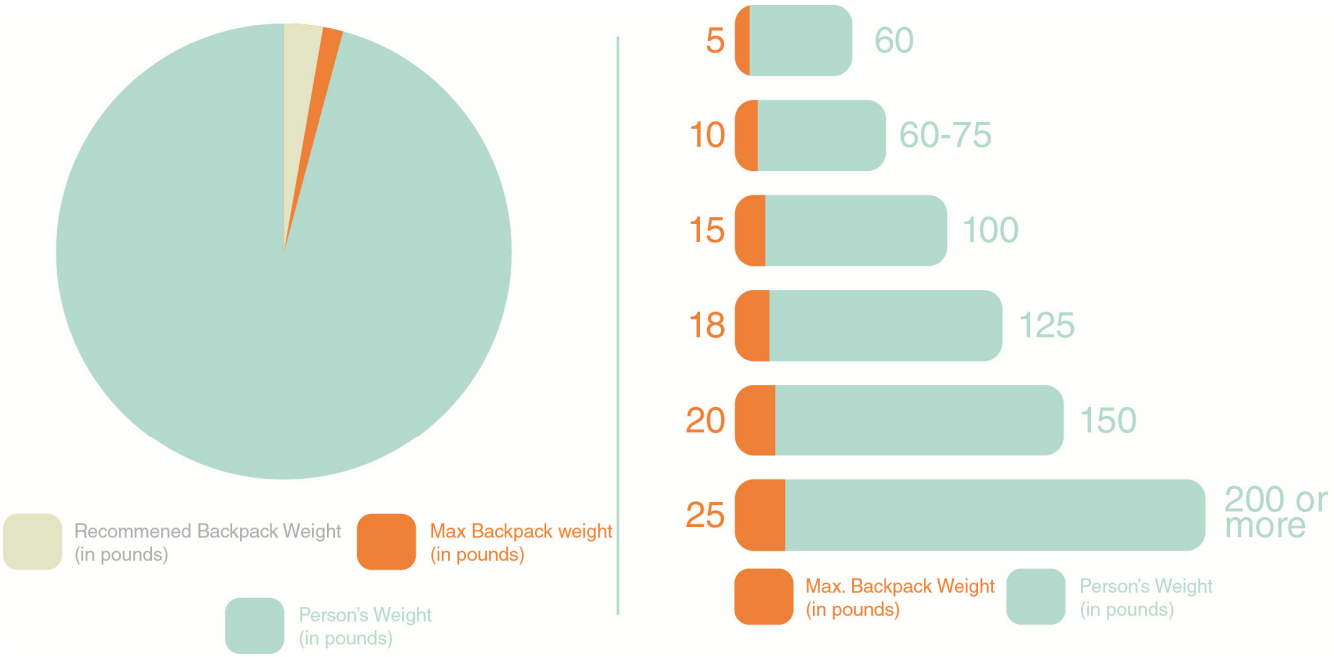


Figure 10: Body Weight versus Backpack Weight

This is not a lot of weight, especially when compared to elementary school children who can exceed these limits with only a few books and supplies.

A personal shouldered load-carrying system can affect the wearer's posture, however minutely. The body is a very fine tuned machine; even the smallest change can have a huge impact often without the wearer noticing it until it is too late. When carrying a backpack two things happen to a person's posture that can strain the body: their neck goes forward as the person leans forward in an attempt to reset their center of balance to a more natural position. This action strains the neck and back muscles,

for every inch your head moves forward, it gains 10 pounds in weight as far as the muscles in your upper back and neck are concerned, because they have to work that much harder to keep the head from dropping onto your chest. This also forces the muscles at the base of your skull to remain in constant contraction, putting pressure on nerves, which may cause headaches. (Day & Day, 2011)

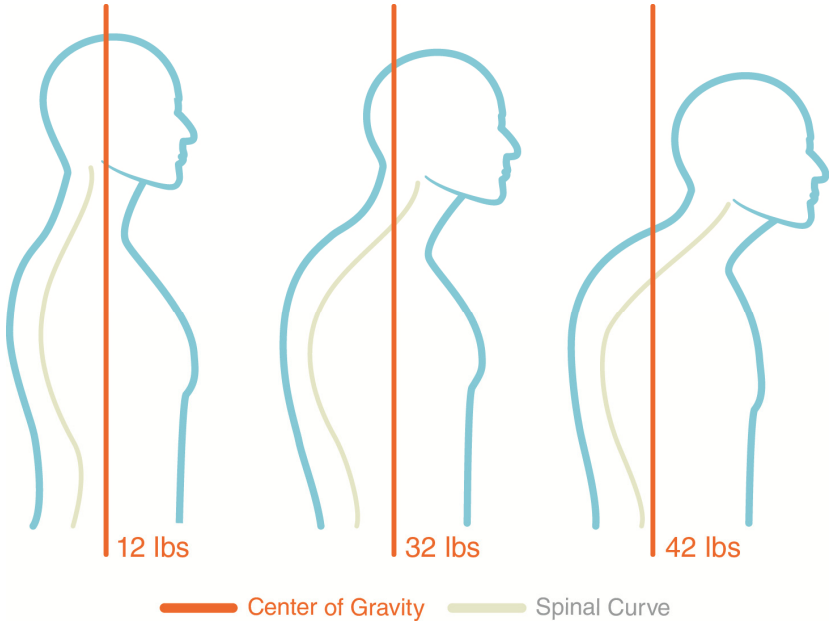


Figure 11: Neck Posture

The other areas that are affected are a person's gait and the natural curvature of the spine. Just carrying a backpack at 10% of the user's body weight for 30 minutes is enough to cause damage. Backpacks negatively affect the natural curve of the spine and its ability to restore its position, increasing chances of injury even if the backpack is not being worn. The change in gait happens as the person walks and as to constantly adjust their center of gravity to accommodate the heavy load they are now carrying. All these little changes begin to add up and to cause the user pain.

Studies have been done detailing the correlation between school backpack weight and the spike in reported back pain. According to the American Chiropractic Association (2012):

> This new back pain trend among youngsters isn't surprising when you consider the disproportionate amounts of weight they carry in their backpacks - often slung over just one shoulder. According to Dr. Bautch, a recent study conducted in Italy found that the average child carries a backpack that would be the equivalent of a 39-pound burden for a 176-pound man or a 29-pound load for a 132-pound woman. Of those children carrying heavy backpacks to school, 60 percent had experienced back pain as a result. ("ACA - Backpack Misuse Leads to Chronic Back Pain, Doctors of Chiropractic Say," 2012)

Lockers could help to alleviate some of this pain by lessening the time a child is wearing their backpack, but some school districts have started to get rid of their lockers due to overcrowded hallways and security issues. Some students also choose not to use their lockers because they may be placed too far away from their classes to make it feasible to use between classes, causing that student to carry around their backpack loaded with all of their supplies for the entire day.

The back muscles, while the most obvious, are not the only body parts to be affected by personal shouldered load-carrying systems. If the straps of a backpack are too thin or do not have enough padding, the Brachial plexus (Figure 12) can sustain severe damage often without the user feeling any pain. The brachial plexus is a network of nerves that originate near the neck and shoulder that is responsible for controlling muscle movement and sensation in the hand, wrist, elbow, and shoulder.

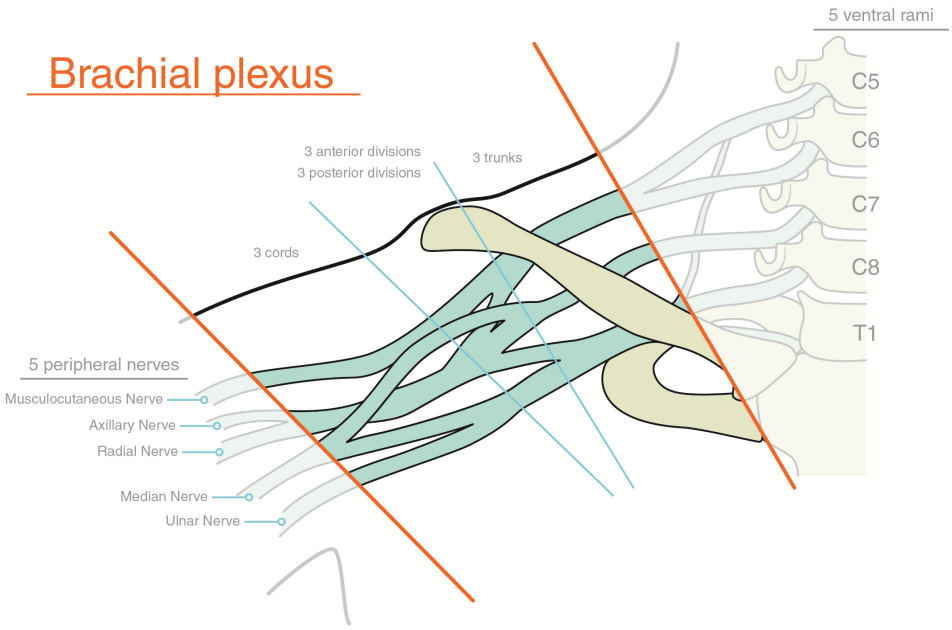


Figure 12: The Brachial plexus

Brachial plexus lesions or *Backpack Paralysis*, as it is commonly known, "typically presents with paresis, numbness, and paresthesias of the upper extremity after carrying a heavy backpack. The painless motor weakness most severely affects the shoulder girdle and elbow flexors." (Nylund, Mattila, Salmi, Pihlajamaki, & Makela, 2011). Busch (2005) describes Backpack Paralysis as "a kind of antique parlance that would have a certain charm were it not for the condition it describes, which is numbness and often, nerve damage, caused by excessive pressure applied to the nerves in the shoulder" (p. 52). When left unchecked this condition could become permanent.

While the weight of the load being carried is a factor in injury, it is not the only factor. The physical environment can have an often more subtle impact on the wearer of a personal shouldered load-carrying system. In a study for the Army by H.P. Crowell III et al. (1999), soldiers were asked to march carrying packs of various loads over various terrains and were then asked basic questions to study the psychological effects on them. As expected, the users were

aware of the extra energy being expended carrying the extra weight, but the terrain also added to the stress on the body without the user even knowing it. The study found that "terrain was a significant effect for all the physiological variables, but test participants did not perceive that terrain affected their workload during the conditions of the study" (1999, p. 37). Each surface represented its own challenges that the participants did not readily notice: "in general, energy increases as a function of increasing load, speed, or grade. … For example, loose sand and soft snow requires greater energy expenditure than does black top road" (1999, p. 12).

Weather and terrain are not the only parts of the physical environment that can act upon the user of a personal shouldered load-carrying system or the shouldered load-carrying system itself. Researchers at the Bi-County Community Hospital (Warren, MI) and Cincinnati Children's Hospital (Cincinnati, OH) studied the records of 247 children between the ages of 6 and 18 who were injured by backpacks. Surprisingly:

> the most common injury location was the head/face (22%) followed by the hand (14%) wrist/elbow (13%), shoulder (12%), and foot/ankle (12%). The back ranked sixth (11%). Of these back injuries, 59% were associated with carrying a backpack. The most common mechanism for injury was tripping over the backpack (28%), followed by wearing (13%), and getting hit by the backpack (13%). (Wiersema, Wall, & Foad, 2003)

Not only does the wearer of the personal shouldered load-carrying system risk injury from it, but so do the people that are around them.

Taken together, the results on the Army study (Crowell, 1999) and the Children's Hospitals study (Wiesema, Wall, and Ford, 2003) can be generalized to the shouldered load-

carrying devices particular to marching bands. Therefore, it is no surprise that along with the physical demands of marching bands come several injuries. Marching encompasses several of the traits that cause most injuries as discussed above; carrying a heavy instrument, changing terrains and environmental elements, and the occasional on field collision. Studies have been done over the years to learn about the injuries most common within the marching band setting. Jill Kilanowski (2008) studied the high school marching band camp clinic logs of a high school band and discovered that:

> There were 378 nursing intervention clinic visits for 178 students in 2005 and 596 visits for 224 students in 2006. The visit frequency peaked on Day 3 of full band camp practice. The most common complaint was lower musculoskeletal injury. (2008)

In a study done of the University of Michigan Marching Band over the course of a marching season 179 injuries were reported; of these "153 (85.5%) involved the lower extremities" (Mehler, Brink, Eickmeier, Hesse, & McGuire, 1996). Other studies show that:

> Most of the marching injuries start with the foot. However, these injuries can also be evidenced in the back, knees and ankles in addition to the feet. Furthermore, it can be difficult to analyze what is actually causing the injury because the drill is continually changing, Bales points out. (Greenwald-Gonella, 2010)

This injury starting point could be due to the change in performers' gait as they undergo the strain of supporting more weight while performing their drill movements. There is also a *play*

through the pain attitude taken by most band athletes, which only adds to the severity of the injury. When looking at drum line carriers, each drum provides its own unique set of problems that the performer needs to get around just getting to their sets. For instance, the bottom of a snare drums and tenor drums usually hangs roughly at the same height as the performer's knee caps cause them to use a *waddling* technique to march. Bass drummers on the other hand often have to crab step in order to keep the drums parallel with the sidelines. The drums also play havoc on the performer's center of balance, forcing it to be forward and low to the body.

Dissemination

There is an obvious disconnect between the way in which personal shouldered load-carrying systems are designed and what people actually need. Part of this stems from the increasing trend to simplify objects to the bare minimum both to empower the user and in some cases to cut down on production costs; this trend can best be seen in the current design elements employed by Apple. Unlike electronics, personal shouldered load-carrying systems are made to be worn by the consumer, by simplifying their design through elimination of elements, adjustment points for the consumer to use are often lost. Personal shouldered load-carrying systems also toe the line between functionality and simply being show pieces. As one student said, “It's a fashion statement," she says. "I want it to be practical, but I want it to express myself” (Horovitz, 2009). While consumers will pick a personal shouldered load-carrying system that they feel defines them, they also want a product that will not injure them and need information to find one.

There are a plethora of information on the *Do’s and Don’ts* available for the consumer to use while wearing a backpack: (1) the weight of the pack should be no more than 10% - 15% of that person’s total body weight, (2) use both straps, (3) the bottom of the back should sit no lower than 4 inches below the waist, (4) pack only what is needed, (5) minimize the amount of time you are wearing the pack, (6) place the heaviest items closest to the back, etc. Some of these rules appear to be common sense, but they have not translated well into design. An example would be that research clearly points out that wearing a backpack solely on one shoulder can cause more injury then using both straps. Though you cannot make the consumer use both straps you can be sure to not design backpacks the utilize the *sling-style* method. By

offering one as an option, from the designer's perspective it encourages the consumer to use it and injure themselves, which is irresponsible as a designer.

Figure 13: Ogio Newt II Mono

By designing bags to become more specialized with extra pockets and storage spaces designers are almost asking for children to over stuff them with needless items. Some of these rules cannot be fixed by a design change alone because they deal with human behavior; design cannot physically make someone pack their backpack correctly, but you cannot expect them to do it. These problems require a new way to educate the consumer.

Jordan's (2002) book *Designing Pleasurable Products* he describes designing around the four pleasures; Physio-pleasure, Socio-pleasure, Psycho-pleasure, Ideo-pleasure.
Jordon proposes taking a more holistic approach at looking at the user's lifestyle, habits, and needs rather than simply searching for the problem areas in a usability approach. Physio-pleasures are the "pleasures connected with touch, taste, and smell" (Jordan, 2002, p. 13) essentially anything the product does that can engage the users five main senses. Examples include "Nike … putting the same air technology used in its sneakers into backpack straps. The straps of several of its Edge Elite packs have air-filled chambers to make them more comfortable'' or "North Face's idea of a woman's pack used to be to make it pink. Now it has the $69 Isabella pack designed to fit the narrower shoulders and waist and wider hips of a woman's torso"(Horovitz, 2009). Similarly Psycho-pleasure "…includes issues relating to the cognitive demands of using the product and the emotional reactions engendered through experiencing the product" (Jordan, 2002, p. 14).

"For many students, a backpack is about more than what they have — it's about who they are" (Horovitz, 2009). These socio-pleasures "…includes a person's relationship with society as a whole – issues such as status and image may play a role here" (Jordan, 2002, p. 13). As humans are social creatures and value their identity in society,

> Image is everything. Perhaps no one knows that better than North Face designers. North Face designs student backpacks as hiking packs, not just book bags. "Our stuff says, 'Hey, I'm in touch with the great outdoors,' " says Robert Fry, product manager. But students tend to twist those outdoorsy designs to their own uses. The compression straps dangling from the bottom — once meant for sleeping bags or pads — are used by a few

> students to cart yoga pads around campus, says Wade Woodfill, product director. (Horovitz, 2009)

Backpacks are communing as interchangeable as clothing, as can be seen by the fact that "many students carry a day pack for school and also have a weekend or evening pack" (Horovitz, 2009).

Ideo-pleasures are "the aesthetics of a product and the values that a product embodies" (Jordan, 2002, p. 14). Personal shouldered load-carrying systems are a way of amplifying what the user believes in and showing their personal ideals. An example of this is,

> Jill Lin, a senior at the University of California, Irvine, recently went into the campus bookstore and spent $84 for a Mobile Edge Milano bag that has special pockets for her iPod, laptop and cellphone. It also has a faux crocodile skin — and a small, pink ribbon that shows her support for breast cancer victims. "It's a fashion statement," she says. "I want it to be practical, but I want it to express myself." (Horovitz, 2009)

The user is not the only one that can benefit from understanding the use of the four pleasures; the product itself can also undergo the same study. What is its primary function? What does it do when it is not in use? How is it stored? How is it placed on the body? These are all questions that can lead to a more symbiotic relationship between the user and the personal shouldered load-carrying system.

Adjustability is a major component of any personal shouldered load-carrying system. Henry Dreyfuss (2003) states that "we bear in mind that the object being worked on is going to be ridden in, sat upon, looked at, talked into, activated, operated, or in some other way used by

people individually or en masse". Consider a desk chair, for example; it is an item that people use every day and like a shouldered load-carrying system is capable of causing a great deal of back pain. Jordan (2002) notes that "the basic rule of creating comfortable seating seems to be to make seating as adjustable as possible" (p. 20), because "people come in all different shapes and sizes, and seats should be adaptable to this" (p. 21). This can have problems: the more adjustment points that are visible, the more likely for the user to be overwhelmed and confused.

> Adjustability is also the key to avoiding physical injury from using seating (Grandjean 1988). Unfortunately, back problems are rife in the Western world and seating design is often cited as a major cause of this. This can occur either because seating is not sufficiently adjustable to fit the user or because the user doesn't adjust the seating properly. The same may be true of the way that people use car seating. Many people do not adjust their car seats in the optimal manner – either because they do not know how to or because they do not think it is important (Jordan, 2002, p. 21)

Using chair design issues as a template, it can be seen that it is not simply enough that a personal shouldered load-carrying system have adjustment points. The system must not only be easy to adjust, but more importantly it must be easy to adjust properly.

Norman's 2002 book *The Design of Everyday Things* he discusses the psychology of perceived affordances. "When affordances are taken advantage of, the user knows what to do just by looking" (p. 9). These affordances are based solely on what the user thinks the product can or should do, but not necessarily what it can/should actually do. "By giving people cues about what they can do with a particular object, you make it more likely that they will take

action" (Weinschenk, 2011, p. 18). The adjustment straps on a backpack are simple enough for most users to figure out by forming a mental model of how the adjustment straps are supposed to be used based on past experience and to some extent current fashion trends.

> When considering anthropometrics and product design, the received wisdom is that the product's critical dimensions should be such that, at minimum, users with dimensions ranging from the fifth percentile to the ninety-fifty percentile of the user population should be catered for. (Jordan, 2002, p. 22)

Because shouldered load-carrying systems often have to fit such a large variety on users, there is a fine line when it comes to allowing for adjustments to be made to the fitting of a shouldered load-carrying system.

This affordance is often seen in the design backpack straps that allow for a large variation in the product's length, it is this affordance that also increases the chances for backpacks to be worn incorrectly and to injure the user. The opposite can be said about drum line marching carriers, in which adjustment points are routinely taken away in attempts to streamline the carrier profile and to reduce weight little by little.

Military research has found that the applications of such strict design percentiles can often lead to user problems because,

> Unfortunately such simple language leaves in doubt which body dimensions are to be accommodated across the 5^{th}-95^{th} percentile range, and implies the existence of mythical people whose body dimensions are all 5^{th} percentiles or all 95^{th} percentiles. …

> Furthermore, although accommodation of 90% of the population is the goal, simultaneous 5^{th}-95^{th} percentile accommodation for more than one dimension inevitably leads to less than 90% overall accommodation because body dimensions are not perfectly correlated with one another. (Ulijaszek & Mascie-Taylor, 2005, p. 191)

Because of the discrepancies that can occur in human body measures the U.S. Armed Forces have, "explicitly discouraged the use of percentiles in specifications … when more than one key design dimension is involved" (Ulijaszek & Mascie-Taylor, 2005, p. 191). The current recommendation is that,

> Principle components (PC) analysis be applied to reduce dimensionality of the multivariate space; then the anthropometric data are plotted in the new PC space and a 90, 95, or 98% accommodation circle (2 components) or sphere/ellipsoid (3 compartments) is fitted to the target population (Robinson, Robinette & Zehner,1992; Meindl, Zehner & Hudson, 1993), Mid-quadrant points on this accommodation surface represent the extreme body sizes and proportions present in the population, and these are transformed back into percentiles or actual population values for extreme case. (Ulijaszek & Mascie-Taylor, 2005)

While this may sound confusing, it's a fairly simple idea. For example if a designer is trying to design a backpack, if they try and design the product as a whole to fit the 5^{th} to the 95^{th} percentiles it will miss a large portion of the population, because people do not grow in strictly one percentile range. Instead the designer should design each part separately i.e. the straps and

the bag so that each is design for the 5th to the 95th percentiles of that specific body measurement. Once the product is assembled it will better fit the needs of a wider sector of the population.

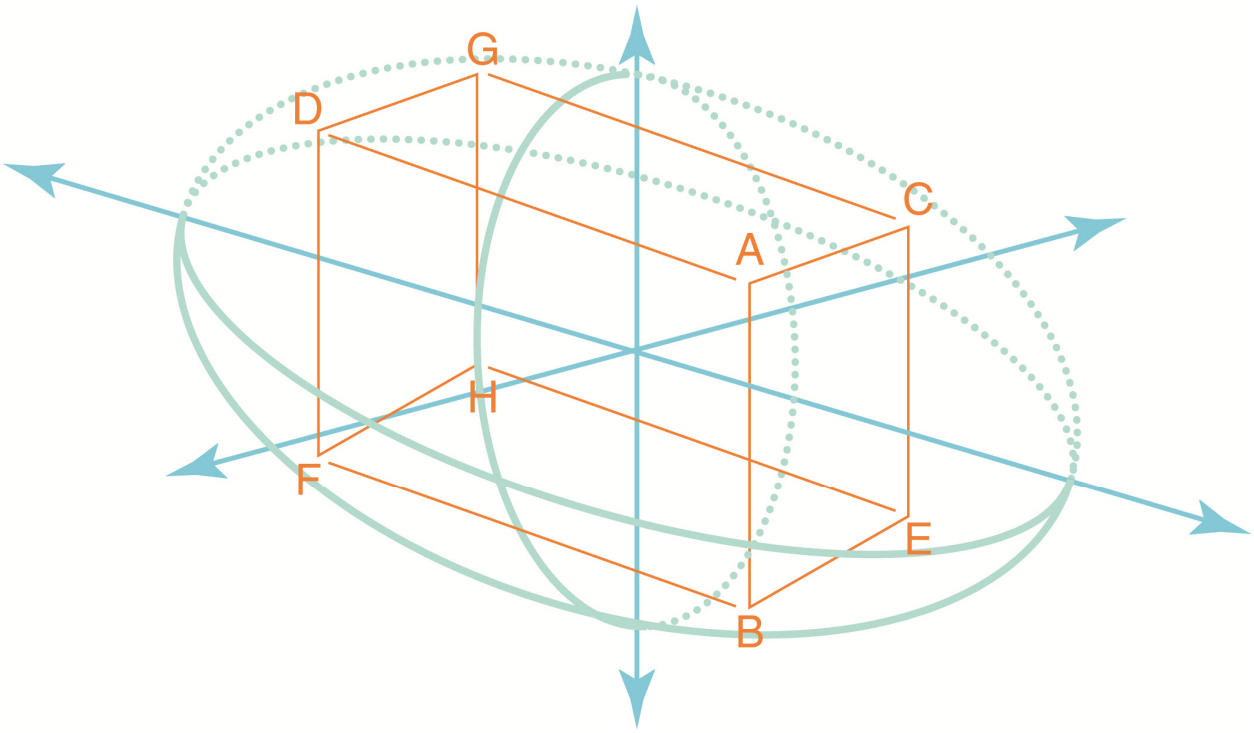


Figure 14: Example of mid-quadrant points on a three-dimensional accommodation surface

These are shouldered load-carrying systems and therefore can be broken down into their baser parts and studied. By taking a more holistic approach the individual failing points can be discovered and new, more innovative methods can be found. For instance, why do the shoulder straps have to be permanently attached to a backpack? Would it be better for them to be sold separately, allowing for the consumer to choose their ideal backpack and then to attach their ideal straps separately? This would allow the product to *grow* with the user, adjusting to their changing needs creating a more personal connection between the consumer and the product. It would also be a more sustainable approach by allowing consumers to *upgrade* their backpacks

instead of buying a new one. Similarly, why are drum line carriers usually made out of metal, hard plastic, of fiberglass when there are cheaper material options that are lighter and just as durable? These are all questions a new approach can answer.

The Guidelines

In order for this research to applied to a new design, a list of guidelines must first be generated because "these are the design constraints imposed on how the core benefit of the new product is to be delivered in a commercially realistic way" (Baxter, 1995, p 203). While researching to create a definitive *check-list* that every shouldered load-carrying system could use it became evident that there were three categories that each check point could fit into: what design can change, what design cannot change, and conditional requirements. Combining these lists as needed can lead to better, more user-centered designs. This task requires the designer to understand what problems are true design problems that must be changed and accepting what can only be changed by changing human behavior.

The requirements that design can change will become the focus of the universal guidelines or *the basics* that can be applied to all manner of personal shouldered load-carrying systems. They center primarily on the functionality of the product and its parts such as the size and adjustment points. The criteria that design cannot change are those that deal with how the consumer will in fact will use the product, including, for example, the guideline that a user should carry no more than 15% of their total body weight in a backpack. The designer has no control over how heavy a student's books and supplies are and furthermore they have no control over the amount of homework they may be assigned. It is a problem that can only be solved through external requirements involving changes in the education system. The same can be said about the bottom of the pack being no more than four inches below the waist because students often times will lower the backpack as low as it will go in order to match the current fashion trend. Knowing that children do this, the designer should find methods to lessen that amount of

extra adjustment that is available. Lastly, conditional requirements are those that are specific to the product being designed.

What Design Can Change

There are four main areas where design can have the greatest impact on the user experience while wearing a shouldered load-carrying system.

1. *Shouldered load-carrying system should be no wider than the user's back*: When wearing a load- carrying system, it should be no wider than the user's back or torso. If it is, there is a greater chance of major shift in the user's center of balance. The more pockets there are, the more likely a user can overpack, adding excess weight.
2. *Maximum adjustability with minimum adjustment points*: It is important to remember that users come in all shapes and sizes. A shouldered load-carrying system needs to be able to accommodate several different body shapes as easily as possible. Offering a minimal amount of adjustment points will lessen the chance of over-adjustment.
3. *Allow for the body dimensions of the 5th percentile to the 95th percentile*: Through the use of the adjustment points, the shouldered load-carrying system should fit the 5th through the 95th percentile. Knowing the size requirements of the target user can also affect several aspects, from the size of pack to the width of the shoulder straps.
4. *Shoulder straps should have sufficient padding and width*: When designing the shoulder straps for a shouldered load-carrying system, the width should be based on the user's height.

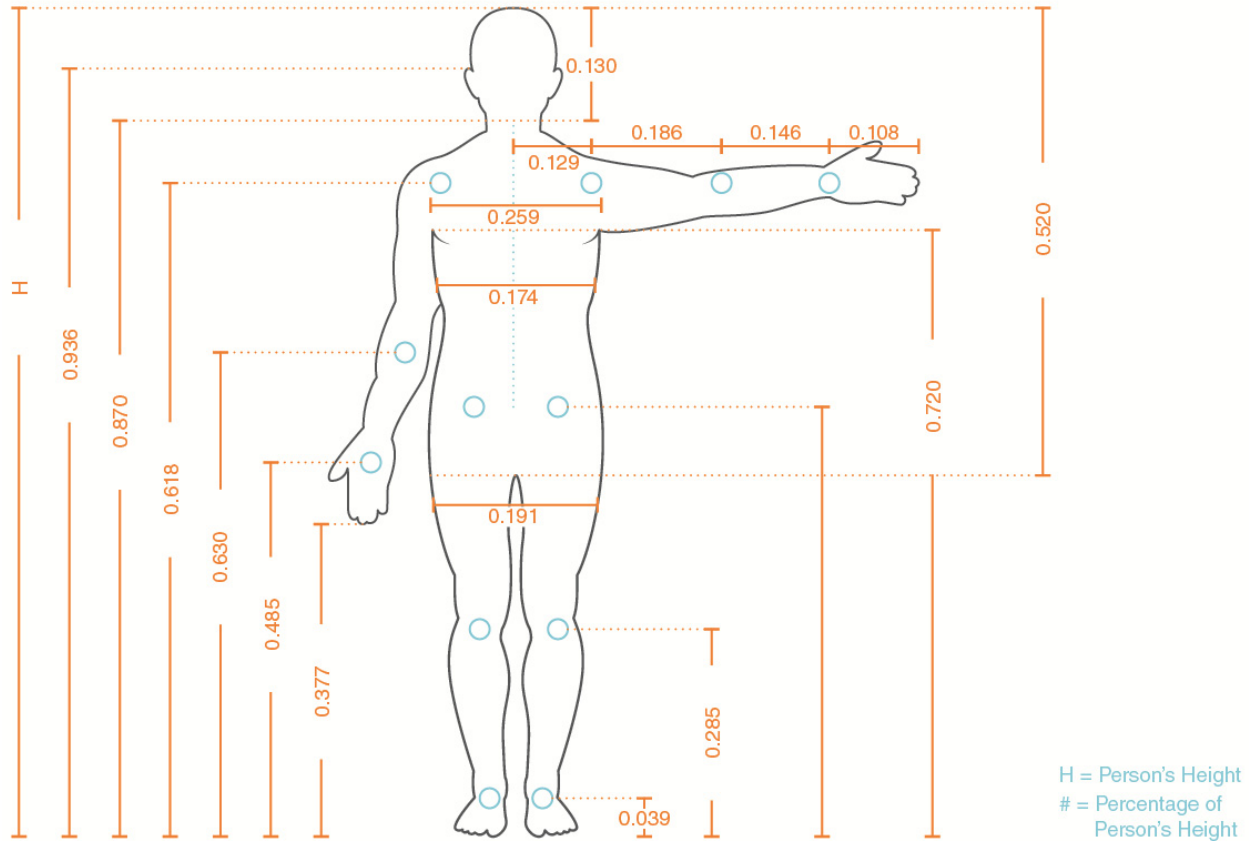


Figure 15: Anthropometric Dimensions (Drillis and Contini 1966)

According to Drillis and Contini, the commonly excepted limb segment length of a person's shoulder (the distance from a person's spinal cord to their shoulder joint) is 0.129% of their total height. When designing the straps, they should be no more than half of this segment length, which is roughly 0.0645% of the user's body height. This brings up the question of whether gel padding or foam padding is better. According to a 2008 forum on *roadbikereview.com* ("Bike shorts - Gel vs Foam," 2008.), If the padding is going to be placed on a part of the shouldered load-carrying system that is used repeatedly or is under a lot of stress there is a chance that a gel padding insert could rupture and leak.

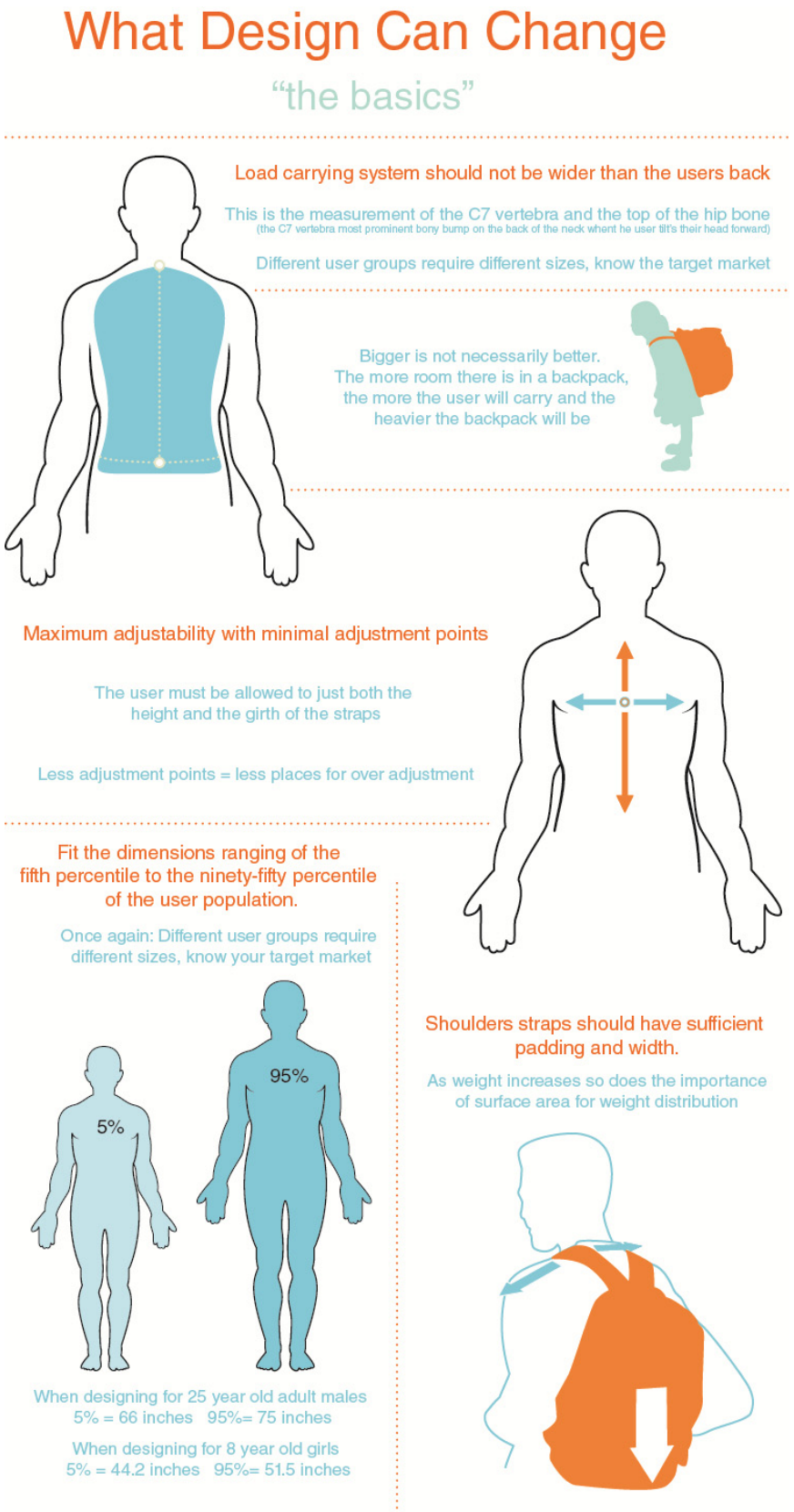


Figure 16: The Basics

What Design Cannot Change

The user has complete control over how he or she chooses to wear a shouldered load-carrying system and how much he or she chooses to carry. While the designer may have little to no control over the user's habits, there may still be ways to use the design of a shouldered load-carrying system to teach proper behavior.

1. *Weight carried should not exceed 15% of the user's body weight*: While there is no way to insure that the user does not carry access weight, designers can create shouldered load-carrying systems to better distribute weight. Also the user can be educated on the dangers of over-packing. Point of purchase displays are an efficient means for educating the user of his or her load carrying system.
2. *Shouldered Load-carrying system should be worn properly:* Although a designer cannot make the user wear the shouldered load-carrying system correctly, they can use the design to teach proper technique. Research shows that wearing a shouldered load-carrying system more than four inches below the user's waist can cause the user harm. Perhaps the shouldered load-carrying system can come with a mark that is located four inches above the bottom of shouldered load-carrying system to inform the user when it is too low. It is well known, as well, that wearing a shouldered load-carrying system on one shoulder instead of two has the capacity to injure the user; this is largely to due to the recent popularity of sling style backpacks. By removing this style of backpack from the market, designers can educate the user that it is better to use two shoulder straps.
3. *Limit time wearing a load carrying system*: Just 30 minutes of wearing a shouldered load-carrying system at 10% of the user's weight is enough to cause injury. Point of

purchase displays are, once again, a sufficient means for educating the user of the necessity for taking off his or her load carrying system frequently in order to avoid permanent damage.

4. *Avoid over packing*: When designing shouldered load-carrying systems, it is important to remain cognizant of the marketed audience. Younger individuals, for instance, are often at risk of over packing (schoolbooks, lunch boxes, laptops, etc.). The design of the shouldered load-carrying system should reflect this, offering fewer pockets to hold extra materials.

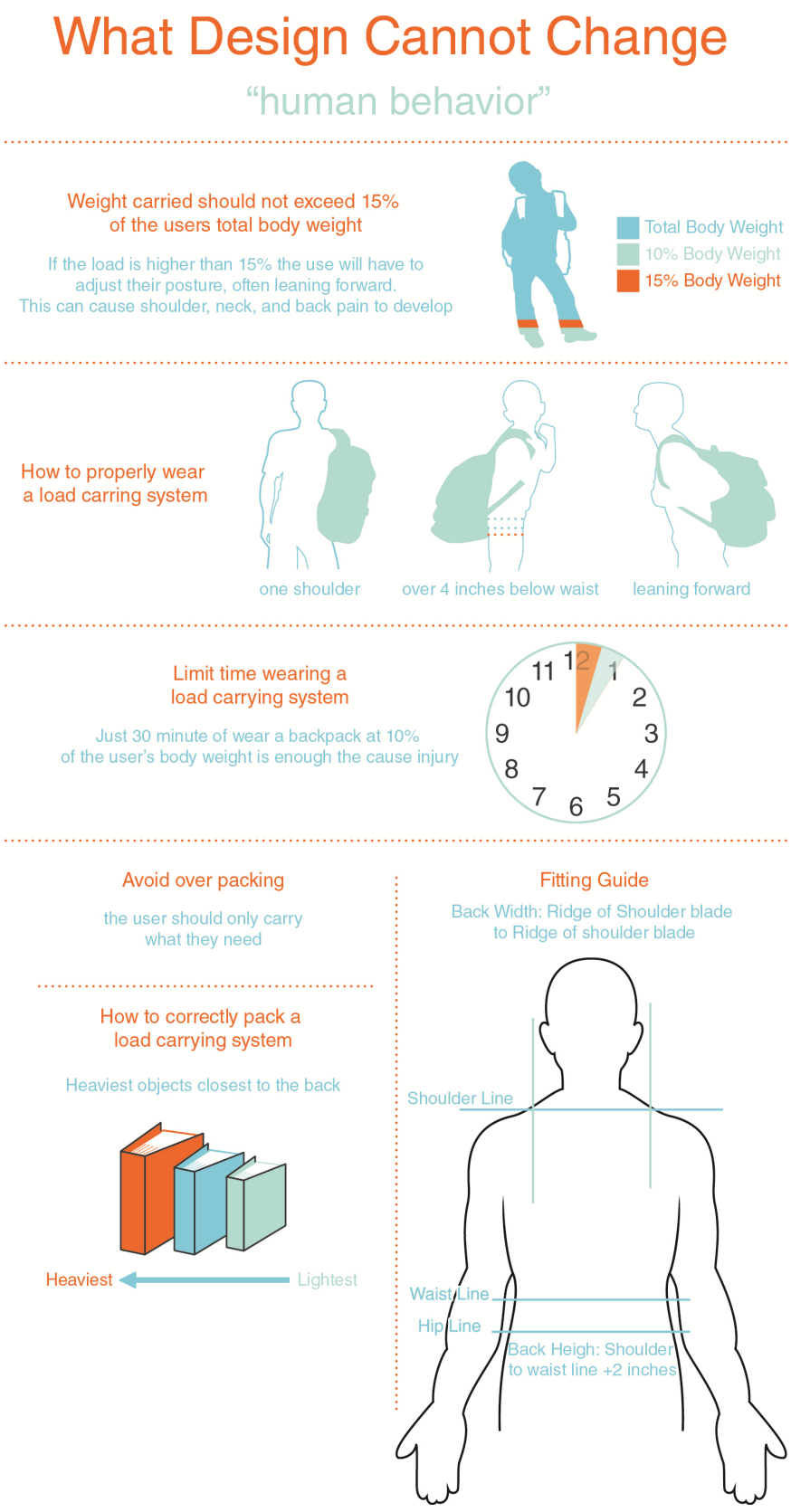


Figure 17: Human Behavior

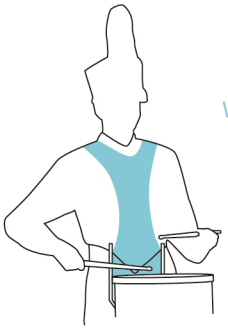
Conditional Requirements

For every shouldered load carrying-system there will always be requirements which are specific to that individual system's needs.

1. *Does the product have any other requirements for use?*: It is important to consider all the requirements that a specific shouldered load-carrying system will need. For instance, a drum line marching carrier must be able to fit underneath the performer's uniform, and must be slim enough not to impede the performer's playing. Considering a typical drum line member is expected to carry his instrument with him for long hours (during rehearsal, performances, and game days), the carrier must also be lightweight, while still remaining durable enough for use.
2. *Where is the product supposed to be stored?:* As a shouldered load-carrying system is only that when it is actually carrying a load, it is important to take into consideration where it will be kept when not in use.
3. *What is its specific use?:* Consider the specific job that the shouldered load-carrying system will be used for.

Conditional Requirements

“product specific”



Does the product have any other requirements for use

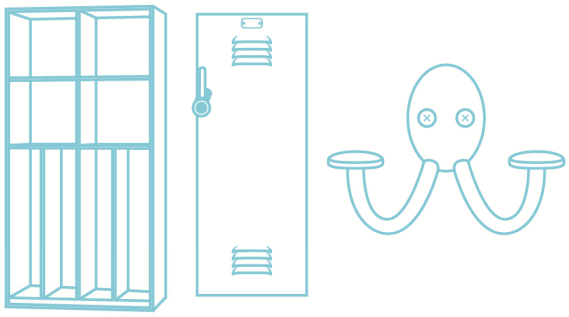
When the load carrying system is in use, are there any extra reguirements?

For Example: Marching Carriers are commonly worn underneath the performer's uniform

Where is the product store

Is there a specific place
the load carrying system will be kept?

What happens when it is not is use?



Cubbies Lockers Hooks

what is its specific use

What exactly will be carried?
Where will the load carrying system be used?
By whom?
What the user's traits and needs?

Figure 18: Product Specific

Introduction to Project

This documentation will be primarily focused on the design considerations of a Marching Band Drum line carrier. Participation in various marching organization for ten years demonstrated a large opportunity for improvement in the design of drum carriers. Currently the Auburn University Marching Band Drum Line is using the Pearl CXS-1 CX Airframe Snare Carrier style carrier released in 2010, which will serve as the basis for comparison as being one of the best carriers on the market.

Figure 19: CXS-1 Airframe Product Line ("CX Air Frame | Pearl Drums," n.d.)

According to Pearl Drum's official website, these carriers are:

"Elegantly Simple. Incredible Solid. These are the words that best describe the new CX AIRFRAME Carrier from Pearl, which combine a lightweight, simplistic design with

> rugged durability. Field tested by the Santa Clara Vanguard and Blue Knights Drum and Bugle Corps, this revolutionary breakthrough in Carrier design is highly adjustable with minimal moving parts, making this the perfect Carrier for players of all sizes and skill levels. The CX AIRFRAME Carriers feature a solid rod, form-fitting upper shoulder frame attached to a thin aluminum belly plate with extreme range of motion. The ACS (Agility Control System) Belt unites the player to their instrument for optimal stability in today's modern use of body movement. The shoulder and belly pads are removable for cleaning and are built with a "Stealth" design; the Carriers practically disappear under the uniform." ("CX Air Frame | Pearl Drums," n.d.)

The reviews on snarescience.com (2012), however, point out some of the flaws that have been uncovered as more people use this design. Some of the common complaints refer to the weight distribution and size adjustments, the features that Pearl Drum is saying are the best:

> Post 2 (Jun 29, 2010): harness doesn't even touch your chest like most other harnesses do. The rods in front of your chest stick out about an inch or so from your body, so in reality the harness is just sitting on your shoulders and grabbing on your back.

> Post 6 (Jun 29, 2011): For many high schoolers, though, students can't/don't fill up the harness enough to let the chest plate sit on them.

> Post 7 (Jul 5, 2011): Being a bass player, I find that the weight distribution is a bit sketchy. I like to think I have good posture with a drum, and I come out of rehearsal with

> a hurting back, which shouldn't be the case. I'm tall. These harnesses are great for tall people. But if you're short, particularly around the 5 foot 4 inch and below people, the harness is not adjustable enough to be comfortable. The belly plate will be in the way, it cannot be moved high enough for the player to be comfortable." (2012)

Another issue that has been discussed among current members of the Auburn University Drum Line is the tendency for the shoulder padding to come loose and move around because it is not attached directly to the shoulder bar itself, or worse, during practice in the summer heat, the glue used attaching the padding to the straps can melt.

Understanding the Current Design

In order to fully understand the current design of the CXS-1 CX Airframe carriers, it is also important to understand the marching style that it was developed for. There are three main marching styles in the United States: military, corps, and show. Military and corps style are the most popular styles. Military bands are characterized by long strides (six steps to 5 yards) and precise, straight lines. The military style is not as widespread as corps and can be seen at Texas A & M, which boasts the largest military-style marching band in the nation. Corps style, on the other hand, utilizes smaller steps (eight steps to 5 yards) and a more free form marching formation, with band members forming various shapes and complicated patterns on the field. It is the most widely used style and is also the style used by the Auburn University Marching Band. Show-style marching is usually seen at Historically Black Colleges and Universities such as Tuskegee University and characterized by high-step marching and often, on-field dancing.

As corps style marching became more popular, the carriers had to change from a sling wrap around the performer (used in military style marching) to a more rigid frame. This would allow the drum to remain stable as the performer marched around the field to his or her sets. The rigid frames also allowed for a more universal design, as the same harness – with a few minor adjustments – could be used with any marching drum. One of the first carrier styles to be developed was the fiberglass vest carrier, which was designed to be one size fits all with minimal adjustments. If the vest carrier did not fit the performer's body size, band instructors would often have to take a DIY approach, drilling holes and using bolts to add adjustment points.

The vest then gave way to the T-Bar design, named after its most prominent feature, the T-shaped central bar. This design allowed for more adjustments to be made in both the height and shoulder length of the carrier, giving it greater flexibility and comfort to the performer. The carrier design is the same for all marching drums; for bass drums the J-Bars which hold the drum are flipped and two hooks are added. Drum attachments vary between companies, but this has no effect on the carrier design as a whole. While there appears to be no reason for the jump from fiberglass to metal marching carriers, the assumption could be made that a metal carrier is easier to change (i.e. drill extra holes, add pieces, bend, etc.) than the fiberglass ones. The vest carriers and T-bar carrier design are found most often in high school marching bands as they are generally cheaper. The designs featuring aluminum piping are seen more often in summer drum corps or collegiate marching bands that are sponsored by these companies. On a side note the color of the carrier is also important, although it appears to an insignificant choice. The general color that is used in carrier design is either white or black; this is done because these two colors blend in best to the uniforms worn by most marching bands.

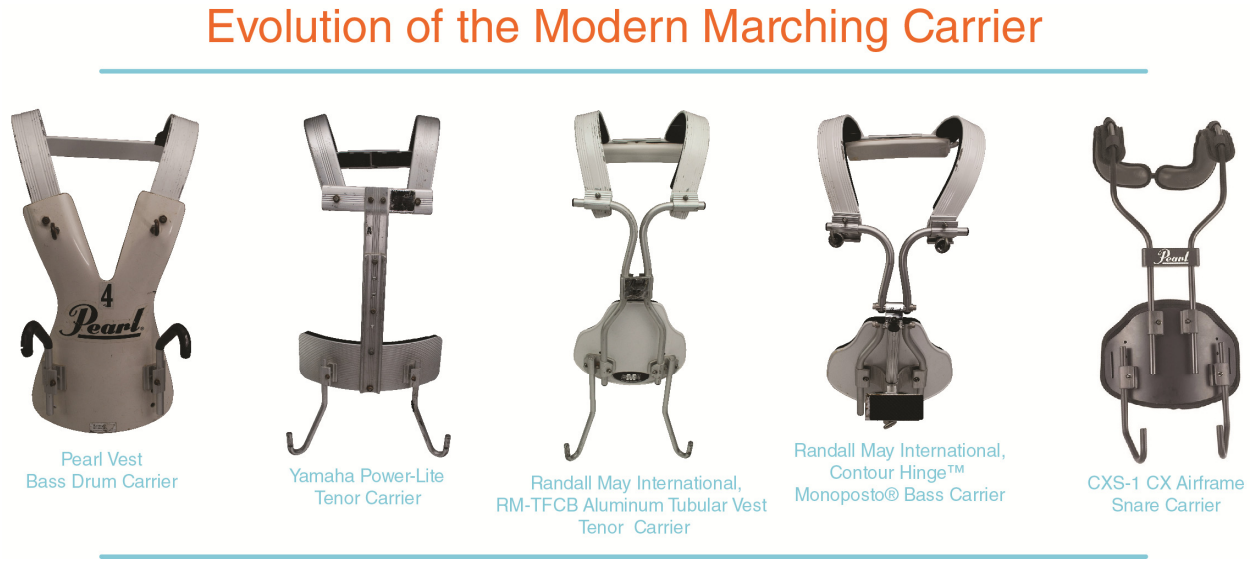


Figure 20: Evolution of the Modern Marching Carrier

The CXS-1 CX Airframe Carrier does have some features that set it apart from the other previous carrier designs available, such as removable padding, allowing the pads to be washed and the ACS for added stability, but when looking at the design as a whole and comparing it to the various other designs, it is not as revolutionary as it may seem. The CXS-1 CX is similar to the vest style carriers in that it is one size fits all when it comes to user chest size. In contrast the Randal May International models allow the performer to move the shoulder pieces and adjust them to their specific chest size. The CXS-1 CX does, however, offer a large number of adjustments to be made up and down on the belly plate and J-Bars. Similarly the ACS gives the drum more stability, but it is not useful with every body type and therefore often goes unused.

Who Wears These Carriers

It's important to remember that these carriers are supposed to be designed to be worn by a very wide range of body types and body figures. In some schools students as young as the 7th grade are allowed to march in the high school marching band. This means that is a possibility for an 11 year old to be wearing a carrier that is going to be extremely too big for them.

Total Height and Weight Percentiles

Male	5th	10th	15th	25th	50th	75th	85th	90th	95th
11 years old	54.7	55.2	56	57.1	58.8	60.6	61.8	63.1	64.2
	69.5	74.3	76.1	79.1	93.4	119.9	134.0	147.2	161.9
25 years old	64.4	65.5	66.5	67.4	69.4	71.5	72.6	73.1	74.1
	128.7	137.9	143.9	153.2	176.5	206.6	224.0	240.4	257.5

Female	5th	10th	15th	25th	50th	75th	85th	90th	95th
11 years old	54.1	55.1	55.5	57.4	59.3	61.4	62.1	62.7	63.6
	66.2	69.4	72.8	79.5	95.6	124.5	138.9	147.2	175.5
25 years old	59.9	60.6	61.3	62.2	64.1	67.0	67.6	68.9	64.2
	107.2	114.8	118.5	126.3	149.4	181.2	208.9	227.3	264.5

Person's Height (in inches) Person's Weight (in pounds)

Figure 21: Total Height and Weight Percentiles

Torso Height Percentiles

Male	5th	10th	15th	25th	50th	75th	85th	90th	95th
11 years old	21.3	21.5	21.8	22.3	22.9	23.6	24.1	24.6	25.0
25 years old	25.1	25.5	25.9	26.3	27.1	27.9	28.3	28.5	28.9

Female	5th	10th	15th	25th	50th	75th	85th	90th	95th
11 years old	21.1	21.5	21.6	22.4	23.1	23.9	24.2	24.5	24.8
25 years old	23.4	23.6	23.9	24.3	25.0	26.1	26.4	26.9	27.4

Person's Height (in inches)

Figure 22: Torso Height Percentiles

According to the sizing chart in Figure 21 and 22, a carrier should be designed to fit body sizes from 54.1 inches tall with a torso height of 21.1 inches, 66.2 pounds all the way up to 74.1 inches tall with a torso height of 28.9, 257.5 pounds. Both of these measurements must be taken into account as some drum lines try and "level" the drums forcing every drum to be at the same height as the center snare drummer's. This is not a very easy task for most carriers and often results in *frankensteined* carriers that are made by combining bits and pieces from two or more carrier types.

Marching in the battery is no longer reserved for men; women are beginning to show that they are just as capable as men at playing and performing. The problem is that the current carrier designs are made to fit the male figure, not making allowances for the chest and hip areas of the female physique. This result is compression in the chest region and bruising in the hip area. The

only options for females, in such cases, is to wear sports bras, add towels for extra cushioning, and to *learn to deal with it*. None of these, of course, are efficient solutions.

Adjustment Points

The ability to adjust the carrier to fit the performer is one of the most important aspects of any modern drum carrier. Modern carriers utilize the same bolt design as the standard marching drum tension screw (see Figure 23 & 24). This allows the performer to not need any special tools other than a drum key (see Figure 25) to adjust their carrier quickly. This idea is based off an assumption that *they are drummers so they always have drum keys on them,* while in reality this may not always be the case. Personal observation has shown that drum line members rarely have a drum key on them. This means that they will have to spend valuable practice time searching to find the one person who had the drum key, complicating what should be an easy adjustment. It's a common occurrence because often the carriers are adjusted during the beginning of the season when all the members receive their drum assignments. After this initial round of adjustments drum keys will go missing because of their small size or from theft.

Figures 23 & 24: Current Adjustment Bolt System

Figures 25: High Tension Drum Key

As with most designs, there are some adjustment points that were designed for a completely different purpose than they actually get used for. An example of this is the central hinge point on the Randall May International Contour Hinge™ Monoposto® Bass Carrier (Figure 26). This hinge was designed for when the harness is stored. It would allow the harness to be folded in half to take up less space when the carrier is not in use. However, from personal observation I have notice the hinge is used primarily by the larger players in order to adjust the front of the drum carrier around their girth and to let to the drum sit level for playing. Just the simple act of drumming has been linked to the development of carpal tunnel syndrome. If the player's drum is uneven the chances are only increased.

Figures 26: Randall May International Contour Hinge™ Monoposto® Bass Carrier

When Auburn University changed to the CXS-1 CX carrier, the girth adjustment allowed by the Randall May International carrier was one of the first adjustments that the players wanted back.

The CXS-1 CS Airframe carrier like other carriers utilizes the tension screw bolts, but only allows two main adjustment spots (see Figure 27). The belly plate as a whole is the primary adjustment point sliding up or down the center poles to adjust to the performer's height. Secondary adjustment points can be found on the J-Bar. The J-Bars can be moved as well as the clamps that attach them to the belly plate. If these adjustments do not fit the performer, they will have to adjust their playing and marching styles. Furthermore, without the contour hinge many large players have to adapt to playing on drums that are tilted up. Both of these options can increase the chance of the performer developing carpal tunnel syndrome or back injuries.

Figure 27: CXS-1 CS Carrier Adjustment Spots

Life of a Carrier

When in use, the carrier has one responsibility, to keep the drum stable as the performer marches and plays. On performance days the drum line members with the exception of the bass drummers will have to conceal their carriers underneath their uniforms. This requires these drummers to use uniform jackets that are a few sizes bigger than they would otherwise need. Often times the sleeves of these uniforms are too long and must then be held in place by rubber bands or hair ties. Also if the drummer sits down while wearing the carrier under their uniform, the rigid structure causes the collar of the uniform to sit uncomfortably high on the drummer's neck. Another problem that often occurs is when a drummer drops anything while they have the carrier on, the rigid frame impedes their ability to bend at the waist and to retrieve what was dropped.

As with most personal shouldered load-carrying systems, a drum carrier is not always in use and has to be stored. More often than not after practice the carriers are simply thrown into a large pile in the corner of the room and pulled out the next day for practice. The same event happens when the marching band has to travel to another school during the football season or for marching competitions; the drums are nicely packed away in their boxes and stacked while the harnesses are tossed on top of each other. This adds extra wear and tear to the carriers that can be avoided. The CXS-1 CS carriers also come with an extra removable part, the ACS. Because not every performer wears them there is the potential for the piece to go missing. This can cause a problem, as in Auburn University's case, when the sponsor asks for the old carriers back before they will give you the new ones. If pieces are missing the sponsors will not exchange the old harnesses for the new ones.

Design Application

The first step of this design approach is to compile a check-list of all the criteria that needs to be met and then evaluate them based on what is possible (see Table 1). The check-list will consist of the basic guidelines listed earlier as well as conditional requirements that pertain solely to marching band members' needs.

Criteria	Yes	No
Shoulders should have sufficient padding and width	•	
Easy to adjust quickly	•	
Maximum adjustability with minimal adjustment points	•	
Fit the dimensions ranging of the fifth percentile to the ninety-fifty percentile of the user population.	•	
Should be no wider than the users back	•	
Distribute weight more evenly	•	
Support a drum	•	
Keep a drum stable	•	
Accommodate multiple drums	•	
Fit underneath a uniform	•	
Durable	•	
Light Weight	•	
Educate user on proper settings	•	

Economically Priced	•	
Easily replaceable parts	•	
Carry less than 15% of users total body weight		•
Help the user's posture	•	
Should allow the user to bend at the waist to retrieve fallen items (sticks, drum key, music, etc.)	•	
Limit time carrying a heavy load		•

Table 1: Criteria List

While a change in the design can have a positive effect on the majority of the items on the list, there is one that it cannot; that the user should carry no more than 15% of their body weight. It is difficult because the band program itself has no real control over size range of who will try out for any given position. The same concept applies to the person trying out; they often will not know what spot they have until the end of try-outs and they may be asked to try several different instruments before they are assigned one, all of which have different weights.

Figure 28: Marching Drum Weights

Drum carriers often weigh between 6 and 12 pounds alone, which may not seem like a lot until the drum is added to the equation (see Figure 28). This means that a potential performer could be carrying anywhere from 20 pounds at the lightest to 33 pounds at the heaviest for the duration of the marching season. If we follow the suggested 15% rule, the performer will need to weigh at least 133 pounds at a minimum. Similarly the design has no effect on the amount of time spent practicing with the carrier on, so with that in mind the designer must recognize that long practices are a common occurrence and allow for the best weight distribution possible.

The current CXS-1 CX Airframe Carrier was dissected and evaluated on a piece-by-piece basis (see Figure 29). This carrier consists of eleven main parts: two removable shoulder cushions, a continuous shoulder frame, removable ACS strap and cushion, belly plate, four height adjustment brackets, and two J-bars. When evaluating the individual parts by the suggested design criteria listed above there were several criteria which the carrier failed to meet: easy to adjust quickly, maximum adjustability with minimal adjustment points, fit the 5th through the 95th percentile comfortably, and no wider than the users back.

Figure 29: Carrier Parts

The CXS-1 CX carrier only has two adjustment points, both of which require the use of a drum key. This requires the marcher to keep a drum key on them at all times even to make minor adjustments. While the these adjustment points do allow for a fairly large number of adjustments to be made height-wise, it does seem to favor a particular body type: tall, lean, broad shouldered. As it has been stated in user reviews of the carrier, performers with smaller body frames cannot comfortably wear this carrier. Since the shoulder frame is not adjustable the design is able to comfortably fit performers with a specific body type; tall, lean, and broad shouldered. This could be due to the Pearl's primary design user testing being done using current drum corps members, who are commonly bigger and in better shape than the average high school or college performers.

The next step of this approach was to map out the current pain hot spots caused by the CXS-1 CX and other carriers. These spots were defined by personal experience and talks with current drum line members (see Figure 30). Unsurprisingly the biggest hot spot was the

performers' back; this is partially due to fact that while wearing the drum, it is pushing down on the performers' abdomen forcing them to over adjust by leaning back to keep their center of gravity. The shoulders were the next hot spot, followed by the abdomen. These problems come from two areas: the weight of the drum and an ill-fitting harness. While these problems may be extremely difficult to solve by design alone, because they involve physics, they can nonetheless be addressed in the concept design.

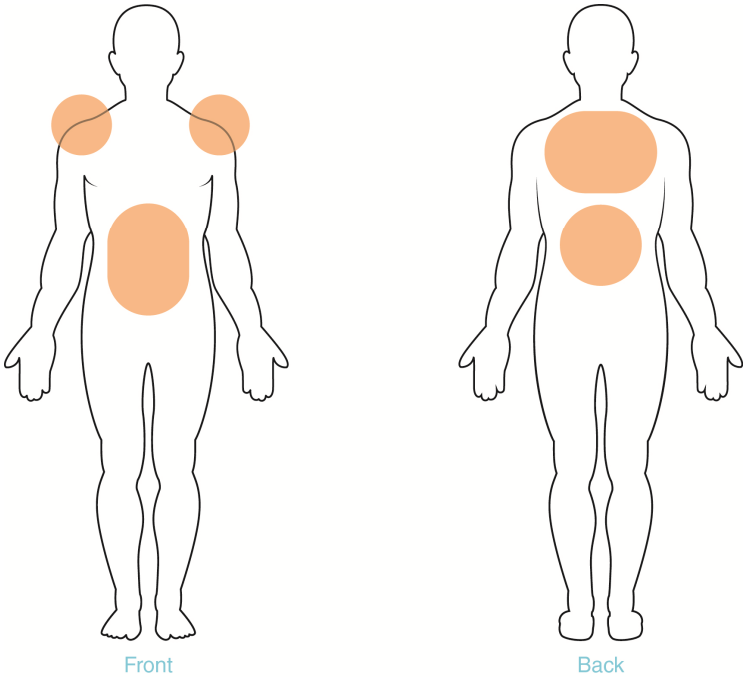


Figure 30: Injury Hotspots

Another issue is that the ACS does not fit all body shapes. It is too big for performers with smaller frames and it doesn't sit correctly on performers with larger girth. Because of this many performers choose not to march with it.

Part of the issues involved with the fitting problem of the drum carrier could be the target group on which the design research was done, which is drum corps members. From my experience in marching band, the people that join drum corps tend to be the performers in the

best physical shape on the field. In general, they practice more, often joining indoor drum lines when the regular marching season is over and joining a drum corps the indoor season ends. This means that they are typically marching in some capacity for 11 out of the 12 months of the year, allowing for them to stay in shape. This is drastically different than the traditionally high school or university band members who only march for 3 months during the football season and then take the rest of the year off to perform in concert bands.

Figure 31: Rio Norte Junior High School Drum Line ("Rio Norte drum line marches to success," n.d.)

Figure 32: 2011 Madison Scouts Snare Line ("snarescience.com • View topic - DCI Drum Finish Encyclopedia," n.d.)

As it can be seen in Figures 31 and 32, the Rio Norte Junior High School and Madison Scouts have similar equipment, but the Madison Scouts have adjusted better to the long hours in a carrier.

Concept Development

Concept development began by focusing on of the driving factor of how to make the proposed design as universal as possible. As it has been noted, these carriers have to fit a large cross section of the population, making the adjustment points crucial. Next, eliminating the need for special tools to do this adjusting had to become a priority as well. It was important that if users need to adjust their carriers, they could do it quickly and easily. Research was also done

into current methods of dealing with frontal load carriage, which could then be incorporated into the final design.

This process began with the use of principle component analysis which would allow for the design to fit the largest range of users possible. The current carrier design consists of four main parts: the shoulder straps, connecting T-bar, belly plate, and the J-bars.

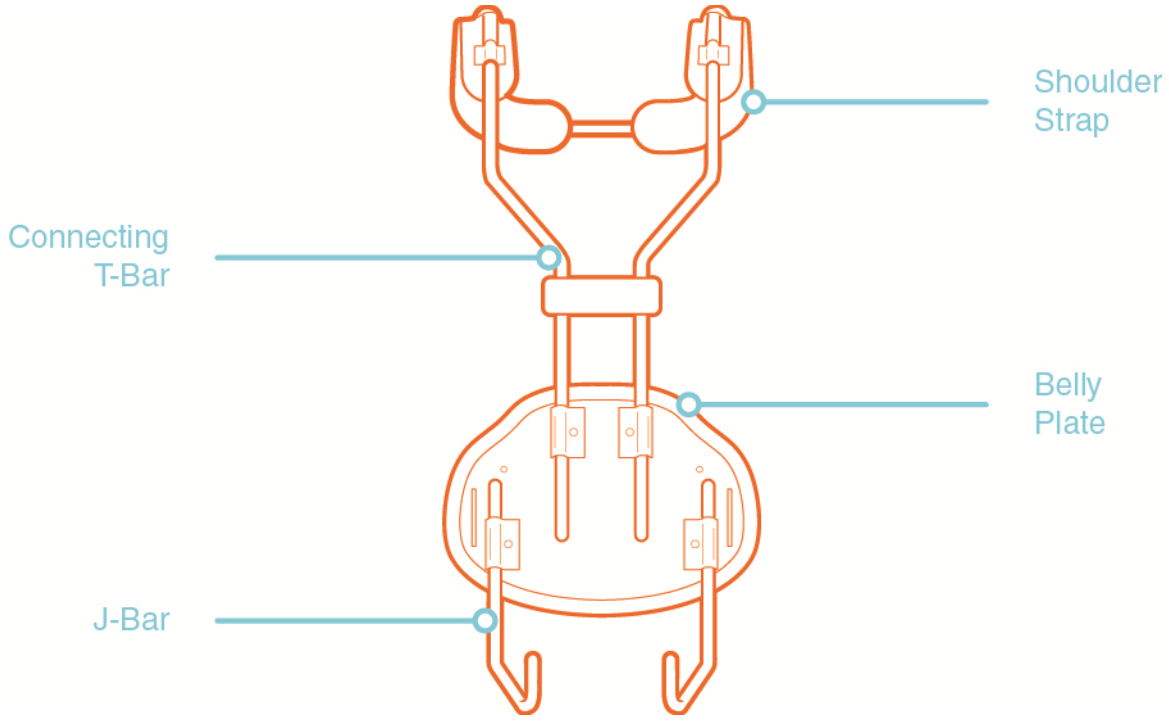


Figure 33: Principle Component Analysis of a Carrier

When looking at these parts individually the connecting T-bar was shown to be responsible for the majority of the adjusting to the performer's body. The main problem is that it is a one way adjustment, just up and down. Even if the belly plate is all the way up, the T-bar poles can still stick out and can accidently be caught on things. Secondly the shoulder straps have no way of adjusting to different body types. After discussing the current carrier design with professors in Auburn University's Kinesiology Department the discovery was made that the only hard point

that was needed on a carrier was the belly plate. The surface area of the belly plate is what helps to distribute the weight most easily across the performer's abdomen. Furthermore: a rigid structure is needed to keep the J-Bars in place.

This could allow the designs to do away with the bent pipe, rigid frames in favor of soft, body fitting frames made from straps. These tighter fitting frames would also be much lighter than the current carriers on the market. Early concepts revolved around the adaption of a kayaking life vest, but were soon abandoned because of the amount of heat retention they could have. Also the full vest design would end up taking up as much storage space as the current carriers. A switch was then made to use a simple strap design, utilizing a combination of the current carrier design and the older sling style drum carriers (see Figure 34)

Figure 34: Ludwig Cadet Bass Drum Sling ("Ludwig Cadet Bass Drum Sling-Black," n.d.)

Research was done into how other companies and designs deal with front load carriage, most specifically maternity products. A key insight was made while studying the adjustment points on Baby Bjorn carriers. At the crossing point of the straps on the users' back there is a

small plastic square. This plastic square is actually an adjustment point (see Figure 35) that allows the user to move the weight distribution to better fit their back.

Figure 35: Baby Bjorn Baby Carrier Original ("BABYBJÖRN Baby Carrier Original," n.d.)

The shoulders were the next area of interest, because with any strap design there was a possibility of injuring the brachial plexus. To avoid this injury the straps would need to be wide enough to distribute the weight evenly. Once again research on current products had to be done. Several strap designs were consider before setting on the current designs used on many golfing bags, because they allowed the user to carry the maximum amount of clubs (i.e. weight) with minimal pressure in one area of their shoulders. The strap itself was able to remain relatively

slender, while using shoulder pads that get larger as they get closer to the shoulder to distribute the weight. Shoulder straps would not be enough to keep the drum stable; a hip belt would also be needed.

Figure 36: Izzo Golf Ionetix Dual Straps (Izzo Golf Ionetix Dual Strap for Carry Bags, 2009)

For this, the current design of the ACS was looked at as well as the hip belts on hiking backpacks. This strap would serve the dual purpose of stabilizing the drum on the performer while helping to distribute the weight on the performer's hips. A bonus to the design going frameless is the ability to add extra padding. The current carrier designs are dictated by the frame and the ability to fit underneath a uniform, so the padding cannot be very thick. This new design does not have this same space problem, allowing for thicker padding to be used.

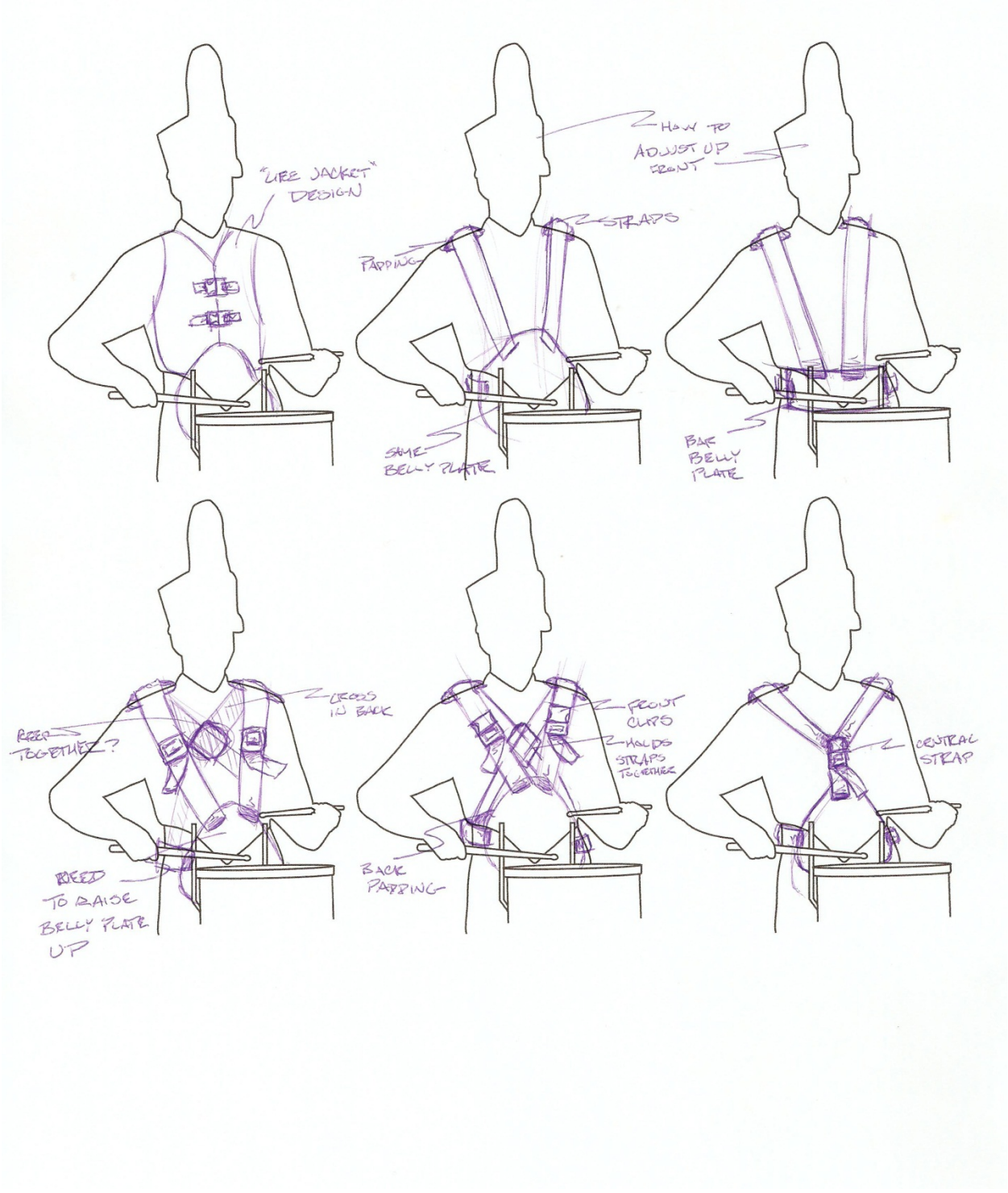


Figure 37: Concept Sheet 1

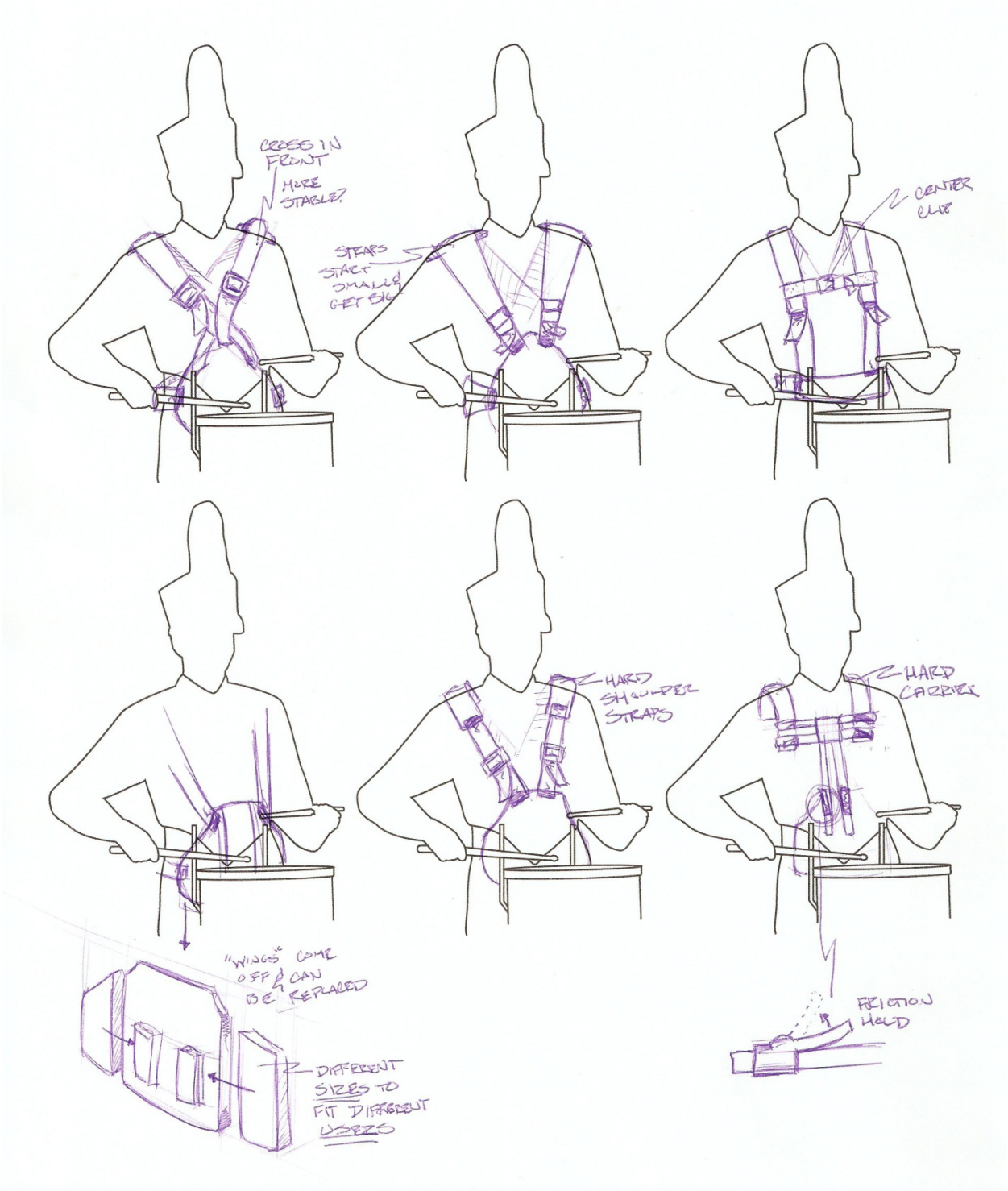


Figure 38: Concept Sheet 2

Figure 39: Final Carrier Concept Sketch

Sketch Model

Once the final sketch was made, production on a sketch model began. This model would serve as a proof of concept and to see what design features would need to be changed or adjusted. The belly plate was made from plastic and then formed on a belly plate from an older model of carrier. The J-bar hooks and J-bar attachments also came off of the older carrier. Once assembled the carrier's total weight was negligible, consisting mainly of the J-bars. Insight that came from making this model and research was to change the design of the belly plate to a more rounded shape. Rounding the corners allowed the belly plate to be made smaller, thus allowing it to fit smaller body types. IN addition, the rounded corners would also be better for female marchers. It was also noted the straps could be made shorter.

Figure 40: Carrier Sketch Model

Prototype

By utilizing the guidelines set forth at the beginning of the design process major issues were able to be resolved. The *Mark 1* prototype gives the user maximum adjustments while eliminating extra weight and the need for special tooling.

Problem	Solution
Shoulders should have sufficient padding and width	The shoulder pads used in this design distribute the weight of the drum evenly across the users shoulders
Easy to adjust quickly	The buckle attachments allow for the performer to use their hands to make quick adjustments to the carrier size
Maximum adjustability with minimal adjustment points	The three adjustment points allow for the performer to change the height and girth of the carrier easily
Fit the dimensions ranging of the fifth percentile to the ninety-fifty percentile of the user population.	The adjustment allows for enough flexibility to fit most body sizes
Should be no wider than the user's back	The strap management in the back allows for the performer to adjust the weight load on their back
Distribute weight more evenly	The performer can adjust weight distribution
Support a drum	The belly plate gives the drum ample

	support
Keep a drum stable	The back brace also serves to steady the drum on the performer
Accommodate multiple drums	All that is needed is the addition of hooks to the shoulder straps to accommodate bass drums
Fit underneath a uniform	The strap design allows for a much lower profile on the performer, allowing them to get a uniform that fits
Durable	The straps are durable enough for use, and easily packed away when not in use
Light Weight	By taking away most of the metal involved in current carrier designs, a significant amount of weight was eliminated
Economically Priced	The strap design will be cheaper to produce than bent metal, so the carrier will be economically achievable for any marching band
Easily replaceable parts	Straps are much easier to replace than bent piping
Should allow the user to bend at the waist to retrieve fallen items (sticks, drum key, music, etc.)	If the performer drops anything, the straps will give them the flexibility to pick the

	item(s) up

Table 2: Problem Solutions

The *Mark 1* Prototype allows for a wide variety of body types to wear the carrier comfortably, because it is no longer a rigid frame placed on top of the body. The straps allow for a more secure fit, making the carrier become part of the performer.

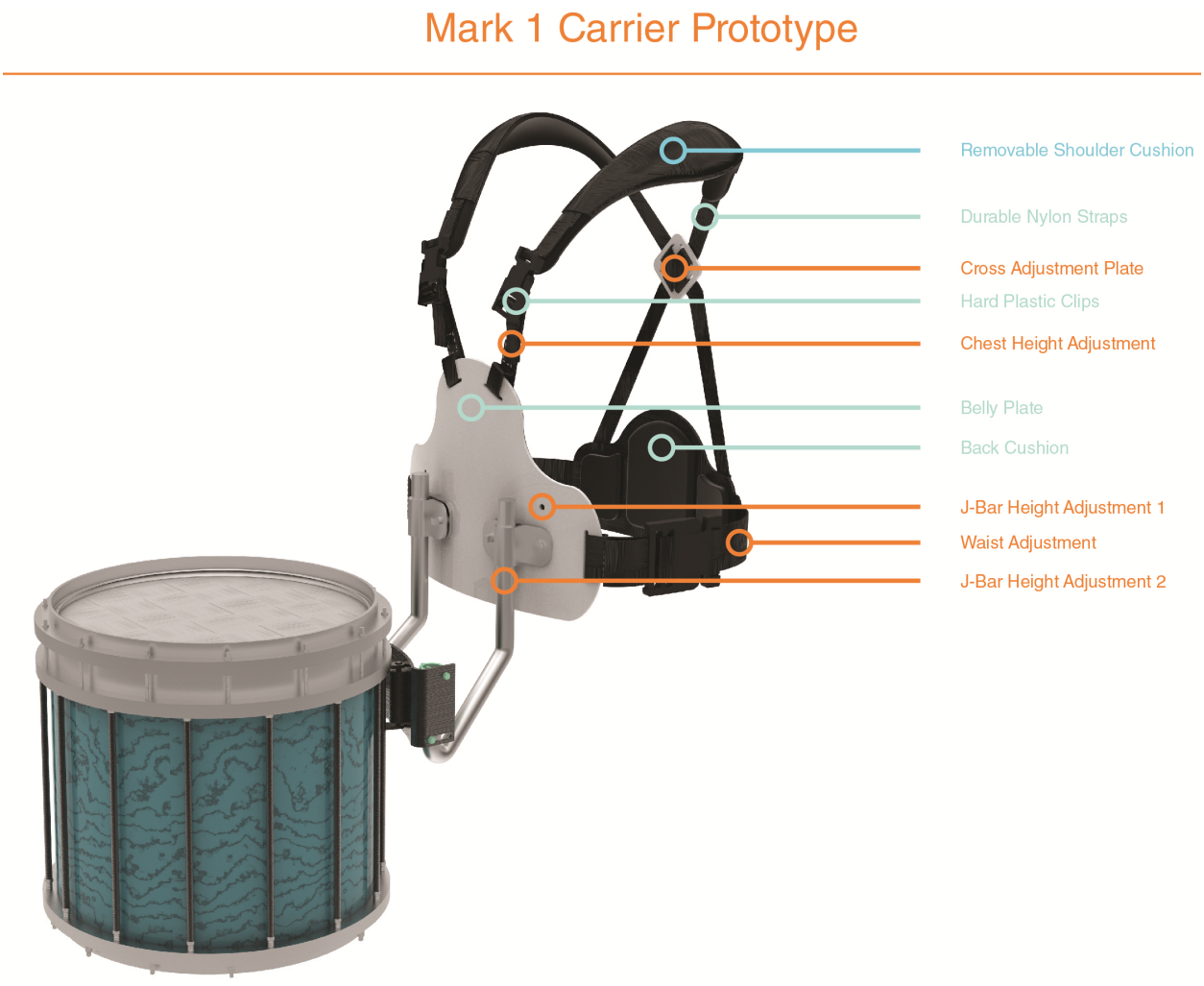


Figure 41: Mark 1 Prototype Parts

As it can be seen in Figure 42, one of the biggest changes in the design is the amount of adjustment points. These adjustment no longer require the user to search for a drum key. They simply can grab the strap and pull, allowing for fast adjustments on the fly. The straps themselves are also interchangeable. If they do not fit a particular user, they can be easily taken off and exchanged for another size. This allows the company to provide carriers in particular sizes such as small, medium, large, etc. which would allow for greater percentiles of the population to be fitted by a carrier.

Mark 1 Carrier Straps

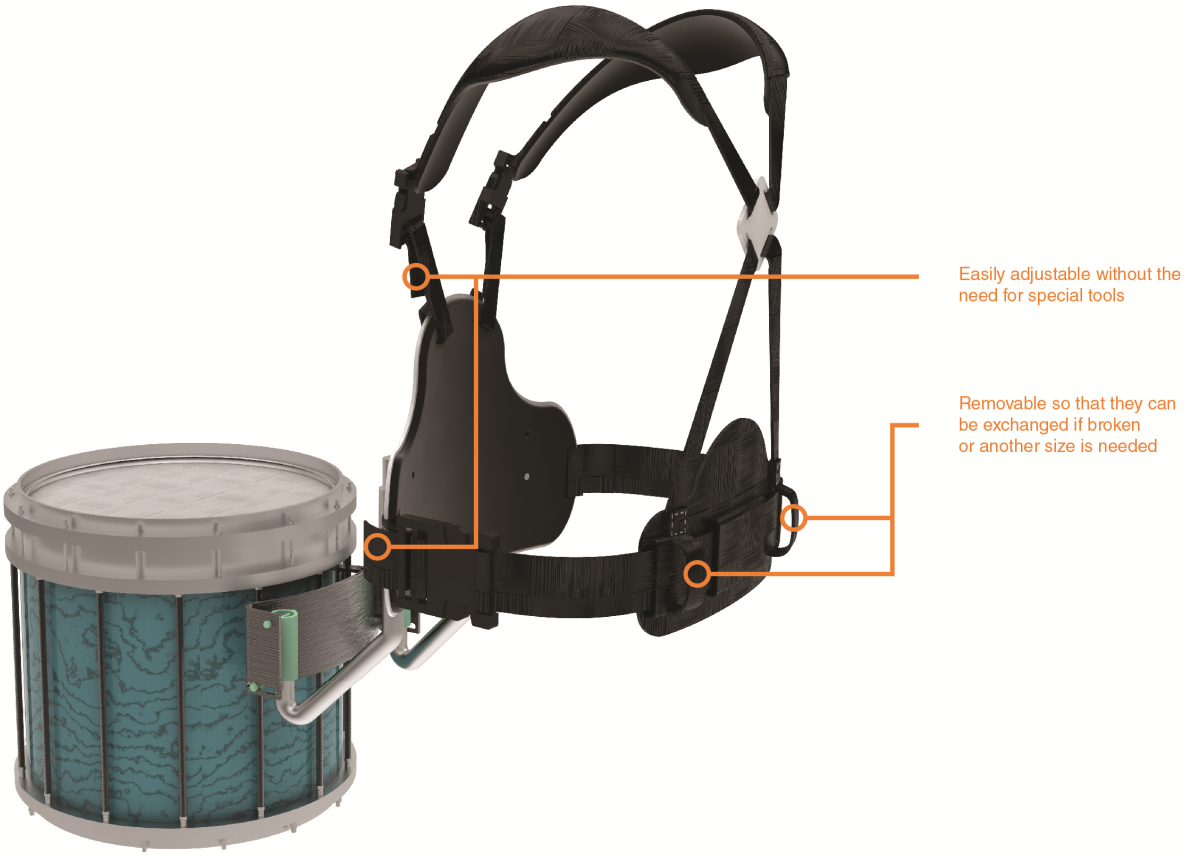


Figure 42: Mark 1 Prototype Straps

The materials used were chosen because they are stiff, but flexible. This allows for the carrier to distribute more weight evenly while still conforming to the performer's body. Similarly, better storage options are available because the carrier itself can be compressed to take up less space. Figure 43 shows how the Mark 1 Carrier takes up half the space that the traditional carrier takes up. The Mark 1 is even capable of being stored in a backpack. This sleek design will allow the carrier to practically disappear underneath the performer's uniform and allow them to wear one that fits properly instead of getting a jacket that is a few sizes too big (see Figure 45).

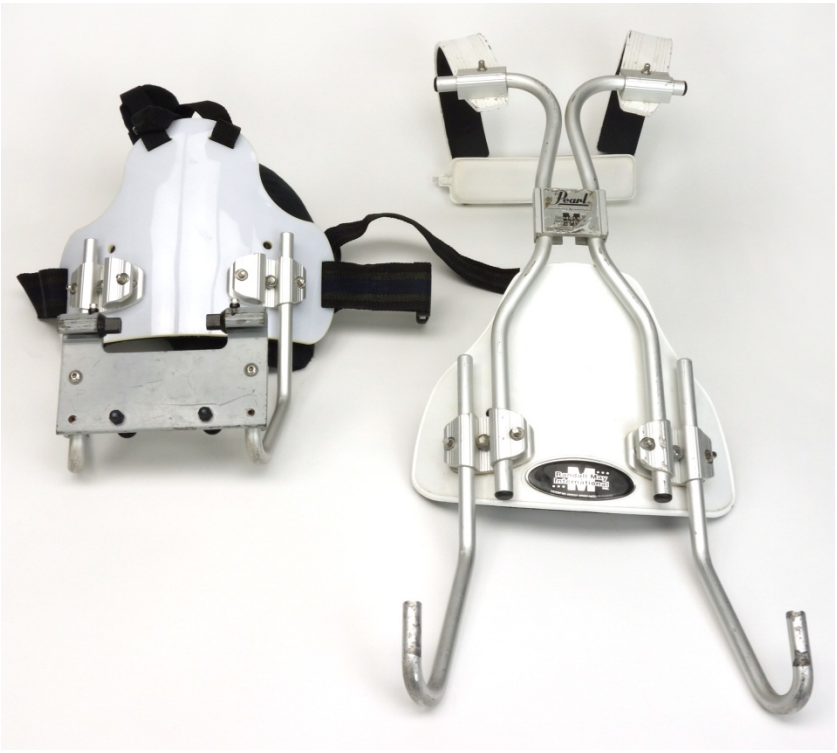


Figure 43 Mark 1 vs. Traditional Carrier Storage Size

Figure 44: Mark 1 with and without a drum

Figure 45: Mark 1 vs. Traditional Carrier Uniform Size

Figure 46: Mark 1 Prototype underneath Uniform

Figure 47: Mark 1 Prototype in Uniform

Recommendations for Future Study

Through the implementation of these guidelines, a better user-based marching carrier is possible; however, research can still be done to locate stronger materials that will retain the same rigid strength of metal, while still being as flexible as nylon straps. The rigid harness of other carriers, as well, cannot be ruled out completely when looking at its use with both the tenor and bass drums. Both of these drums have their own sets of user requirements that must be met. The width and size of tenor drums, for instance, may require a more rigid structure to keep the drums balanced. Similarly, bass drums may require a rigid harness as they often have logos on the drumheads which must remain stationary; bass drums are also struck differently than their snare

and tenor counterparts. Also further research can be done in locking clamps that can be used to hold the J-bars that can be adjusted by the user's hands instead of by using a drum key.

Implications and Applications of Study

While the redesign of shouldered load-carrying systems helps to alleviate some of the injuries that are reported, the design itself is not enough for the universal negation of such injuries. Teaching the consumer better habits will place a major part in this process, as even the most efficient of designs means little if the consumer uses it wrong. The implementation of point-of-purchase displays in areas where consumers buy shouldered load-carrying systems such as backpacks, camping gear, and sports equipment can thus aid the consumer in making more informed decisions on their purchases (See figure 48).

An example of creating a better design and educating the user on its correct use would be a "Build-A-Backpack" system. In this system, the consumer would be able to go to a store and pick the parts of the backpack that fit their needs the best (straps, pack type, accessories, etc.), and then build it, either in the store or, with proper instruction, in their homes. Principle Component Analysis would be used to design each of these elements separately so that various sizes could be created (small, medium, large, etc.). This would allow for any type of backpack to fit any user comfortably instead of designing one pack to try and fit the 5^{th} through the 95^{th} percentiles. Infographics may be implemented to help educate the consumers as they are making their selections, letting the consumer know what sizes and shapes are best for their unique use. Similarly, the creation of a modular backpack would allow for the backpack to "grow" with the user, adapting accordingly to their varying sizes. Such a process would serve not only to alleviate the mass number of injuries stemming from the use of ill-fitting shouldered load-carrying

systems, it would also increase consumer loyalty to the particular brand of shouldered load-carrying systems, as the product itself necessitates the return of said consumers for better-fitting parts.

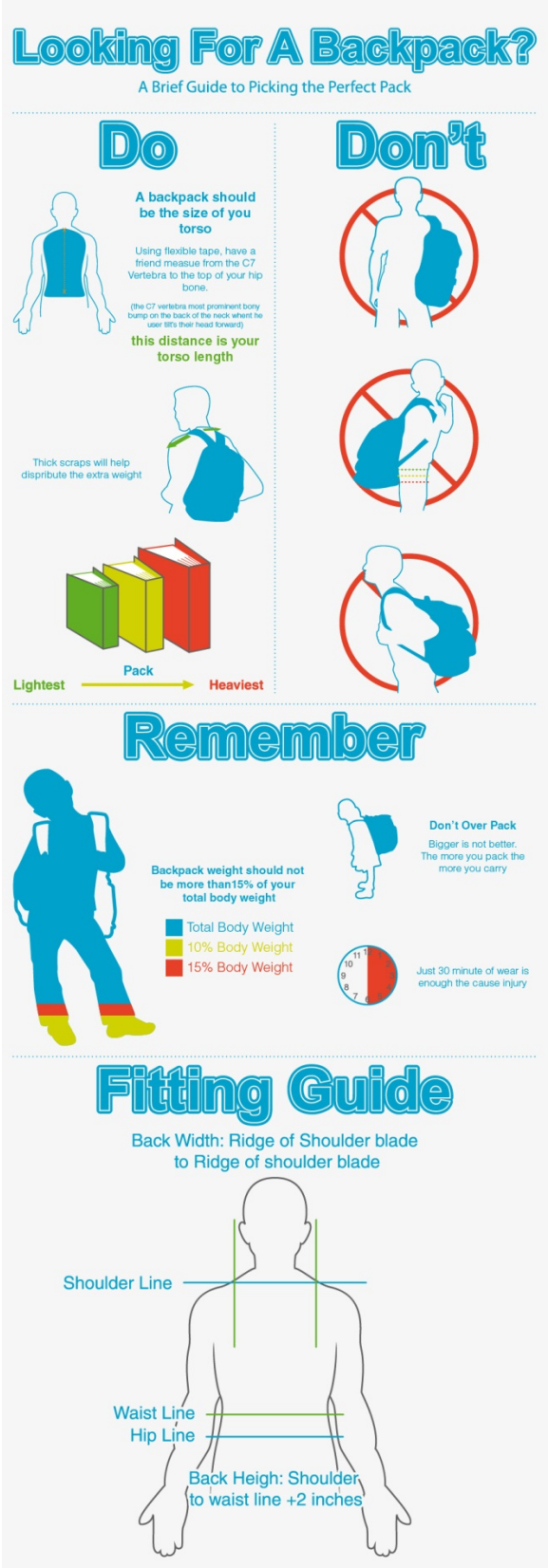


Figure 48: Backpack Choice Infographic

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