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Comparison of features, usability, and load carrying design of recreational and travel backpacks when considering travel applications

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Comparison of features, usability, and load carrying design of recreational and travel backpacks when considering travel applications

by

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ABSTRACT

This research aimed to evaluate the differences between backpacks designed for travel and backpacks designed for recreation. A feature analysis was conducted by analyzing the top fifteen best-selling travel and recreational backpacks in order to identify the representative features for each type of bag. Following the feature analysis, four archetypal bags were selected (two of each type) to conduct an experiment to assess the load-carrying design and usability of the backpacks. A primary usability feature targeted with this study was packability – defined for the purpose of this research as the ease of packing quickly and efficiently. An experiment was conducted where participants were assigned to a backpack. Participants were required to pack items into the backpack and walk on a treadmill with the backpack on at a slow pace for 30 minutes. Following the treadmill task, participants were asked to find three items packed into the bag. Time to pack the bag and time to find the items were both measured. Discomfort surveys and force plate data were collected before and after walking on the treadmill to assess the load-carrying design of the backpack as it relates to comfort/discomfort of the user and heart rate data was collected throughout the experiment.

The results of this study indicate that recreational backpacks require additional exertion when compared to travel backpacks when walking at a slow pace for 30 minutes across even terrain as measured by a change in heart rate. The results also indicate a trend that travel backpacks require less time to pack, require less time to find items in the bag, and result in increased postural stability when compared to recreational backpacks.

CHAPTER 1: INTRODUCTION

Load carriage has been a focus of study for quite some time. Many different methods of load carriage have been investigated including, but not limited to, trunk vests, hip belts, shoulder satchels, head basket, hand bags, shoulder yokes, backpacks, and double packs (Knapik, Reynolds, & Harman, 2004). Optimal load carriage method depends on the size, shape, and weight of the load to be carried. The application of load carriage should also be considered, specifically, duration the load will be carried, climate of the environment, and terrain to be traversed. A final factor to be considered is the individual carrying the load. The physical condition of the user, his or her clothing choices, as well as personal preference can all play a role in identifying the best form of load carriage (Legg, 1985; Simpson, Munro, & Steele, 2011).

Backpacks are a common form of load carriage used for a variety of applications. For the purpose of this research, backpacks were classified into two categories: general use backpacks and special application backpacks. General use backpacks are designed to be used for a variety of day-to-day activities including use as a school/work bag, a day-trip bag, or a supplemental bag. Special application backpacks are designed with more specific applications in mind. Military backpacks, recreational backpacks, and travel backpacks are all examples of special application backpacks. Special application backpacks will be the focus of this research, specifically recreational and travel backpacks. Military backpacks have been the focus of extensive research (Heller, Challis, & Sharkey, 2009; Quesada, Mengelkoch, Hale, & Denniston, 1996; Birrell, Hooper, & Haslam, 2007; Stevenson et al., 2004). Many existing studies focus on the effect of load carriage in general (Martin & Nelson, 1986; Keren, Epstein, Magazanik, & Sohar, 1981; Qu & Yeo 2011) or comparing different types of load carriage (Legg &

Mahanty, 1985; Lloyd & Cooke, 2011; Soule & Goldman, 1969), but very few studies delve into the effect of variability within a single form of load carriage, i.e. different backpack designs (Legg, Perko, & Campbell, 1997).

Recreational Backpacks

Recreational backpacks are designed for outdoor recreational activities like hiking, camping, or mountaineering. Recreational backpacking involves carrying a load on the back for an extended period of time over miles of distance sometimes for multiple days at a time (Lobb, 2004). Recreational backpackers typically carry between one fourth and one third of their own bodyweight on their backs. (Dominelli, Sheel, & Foster, 2012). A survey conducted in New Zealand states that recreational backpackers, or "trampers," as they are referred to in New Zealand, estimate that they carry their backpacks for 5 or more consecutive hours for distances exceeding 11 kilometers per day typically for 1 or 2-3 day trips (Lobb, 2004). The effect of load carriage for these recreational backpackers can vary on different terrain, in different seasons, and for different durations (Simpson, Munro, & Steele, 2011).

Given that recreational backpackers are traveling long distances while carrying a heavy load, it makes sense that recreational backpacks are designed with comfort in mind and are often equipped with complex frames and suspension systems. Recreational backpacks can be characterized partially by their wide, padded straps and hip belts as well as their adjustability (Legg, Perko & Campbell, 1997). Well-padded hip belts reduce the weight placed on the shoulders, which can reduce overall strain leading to fewer injuries. Recreational backpacks can be adjusted to fit the size of the person and many of these adjustments can be made while the user is walking. These adjustments help to reduce strain by shifting the location of where the

pressure of the load is being applied (Knapik, Harmann, & Reynolds, 1996). The combination of internal frame and curved shape allows the bag to be brought close to the carrier's body to minimize biomechanical strain (Legg, Perko & Campbell, 1997).

Travel backpacks

Travel backpacks are designed for travel and specifically a type of travel referred to as "travel backpacking." Travel backpacking can be distinguished from other forms of traveling by characteristics including the length of the trip, the rigidity of the itinerary, and the budget. Backpackers generally travel for weeks to months at a time and tend to have more flexible itineraries. In order to accommodate the longer trip, backpackers tend towards cheaper accommodations and transportation (Uriely, Yonay, & Simchai, 2002; Hecht & Martin, 2006; O'Reilly, 2006; Riley, 1988). When looking at Cohen's classification of travelers, backpackers can be classified as noninstitutionalized tourists. Noninstitutionalized tourists are characterized as one who travels with the intent to experience a place rather than see it. The noninstitutionalized traveler will sacrifice lush accommodations in order to understand the people and the culture of the place they are traveling (Cohen, 1972). These travel backpackers are generally young, middle class tourists (Hyde & Olesen, 2011).

Travel backpacks generally place less emphasis on backpack fit compared to recreational backpacks. The emphasis is instead on features of convenience like front panel loading, hideaways suspension straps, additional organizational pockets, and a removal daypack (Hostetter, 1997). *Backpacker* magazine classifies travel packs into five categories: backpackable luggage, hybrid luggage, luggable backpack, duffel bag, and padded duffel. Backpackable luggage generally refers to a pack that resembles a soft suitcase with attached backpack straps.

The focus of these backpacks is to function as luggage and they are not designed for recreational activities like hiking due to their less advanced suspension system. Hybrid luggage has the same travel focus of the backpackable luggage, but with padding and stabilizers that are much more similar to recreational backpacks. The luggable backpack is a backpack designed for both travel and recreational usage. This includes having the traditional features of a recreational backpack – size specific, frame, suspension system – while having travel features including a front panel loading style as opposed to the top loading style that is common for recreational packs. Duffel bags and padded duffels are other travel pack options, but they are not backpacks so will not be considered for this research (Prichard, 1996). According to Osprey, the backpack brand that was the focus of this study, travel packs continue to be popular because they target a specific user just as women's packs and children's packs target specific users (Siber, 2010).

Backpacker magazine also defined several features that consumers should look for when buying a travel pack. These include a side carry handle, detachable shoulder sling, hideaway suspension, organizer pockets, zip-off daypack and zip-off fanny pack, internal cinch straps, lockable zipper pull, wet storage, and interchangeable suspension (Prichard, 1996).

Comparing design features

In order to better understand the feature differences between backpacks designed for recreation and backpacks designed for travel, a product analysis was conducted. Initial analysis was completed by examining the variety and availability of both travel and recreation backpacks at REI.com, the Recreational Equipment Inc. (REI) website. REI is a cooperative that sells outdoor equipment and apparel. Table 1 below outlines some general differences between the backpacks advertised for travel and recreation applications.

Table 1: Differences in features, variety, and availability between backpacks designed for travel and backpacks designed for recreation.

	Travel	**Recreation**
Advertised Features	Laptop compartment Adjustable torso Carry-on size iPad/tablet compartment Removable daypack Checkpoint-friendly Wheeled	Adjustable torso Sleeping bag compartment Raincover Suspended mesh back panel Ultralight Removable daypack
Capacity	Range: 18-85 L • 11-20 (1) • 21-35 (3) • 36-50 (8) • 51-75 (9) • 76-100 (5)	Range: 20-105 L • 11-20 (2) • 21-35 (22) • 36-50 (63) • 51-75 (90) • 76-100 (18) • 101-150 (4)
Number of Options	26	182
Brands	Deuter(5) Eagle Creek (2) Osprey (8) Pacsafe(1) REI (5) Timbuk2 (4) Zoot (1)	Arc'teryx(5) Black Diamond (1) Deuter(19) Granite Gear (14) Gregory (50) JanSport(3) Kelty(9) Mammut(1) MountainHardwear(3) Mountainsmith(3) Osprey (36) Patagonia (2) REI (15) Sierra Designs (1) The North Face (20)
Price	$50.00-$99.99 (4) $100.00-$199.99 (18) $200.000-$499.99 (4)	$20.00-$49.99 (1) $50.00-$99.99 (17) $100.00-$199.99 (104) $200.00-$499.99 (64)

There are significantly more options for recreational backpacks than for travel backpacks (182 compared to 26). Additionally, there is a wider price range, a wider capacity range, and

more brand variety for recreational backpacks. The three brands highlighted in yellow produce both travel and recreational backpacks.

The next step in the analysis was identifying specific features that vary between the two types of backpacks. This study is intended to determine whether there is an advantage or disadvantage to using one of the two types of backpacks for travel applications. Because of this, the features identified focused on those that would be valuable for travel. For example, having a backpack that is security lock compatible would be desired for travel applications, but having a loop for an ice pick is likely not as desirable. A list of features was compiled by looking through the advertised features for backpacks as well as by examining the physical characteristics of the backpacks.

This feature list was then used as a checklist to compare the top 15 best selling travel backpacks and the top 15 best selling recreational backpacks. Two of the top 15 best-selling recreational backpacks were excluded because they were designed for children so the 16th and 17th best-selling recreational backpacks were added to the analysis.

From this data, it was concluded that one distinguishable feature difference between travel and recreational backpacks is how they open. 93% of backpacks designed for travel had a front panel opening similar to the one shown below in Figure 1 compared to 20% of backpacks designed for recreational activities.

Figure 1: Example of a front panel opening backpack

The alternative to this front panel is typically a top-loading design as seen below in Figure 2. These top opening compartments are secured with a drawstring. This feature lends itself to another distinguishable difference between travel and recreational backpacks. 80% of travel backpacks examined were security lock compatible while none of the recreational backpacks had this feature. This goes hand in hand with the loading style because only bags with zipper openings have the potential to be luggage lock compatible.

Figure 2: Example of a top-loading backpack

Another difference is the handles available. While all backpacks examined in both categories had top carrying handles, 60% of travel backpack top handles were padded whereas none of the recreational backpacks had padded handles (examples shown in Figure 3 and Figure 4). Additionally, 86.7% of travel backpacks had an additional side handle as shown below in Figure 5. None of the recreational backpacks had this feature. These padded and additional handles on travel backpacks are logical, as travelers might be more likely to carry their backpack in their hands than hikers because travelers are generally walking a shorter distance with their bags.

Figure 3: Backpack with a non-padded top carrying handle

Figure 4: Backpack with a padded top carrying handle

Another feature to suggest that travelers are more likely to carry their backpacks somewhere other than on their back is the duffel strap option. 60% of travel backpacks examined had the option to attach a strap to the side of the bag to carry it as a duffel bag over the user's shoulder as shown in Figure 6 below. None of the recreational backpacks examined had that feature.

Figure 5: Backpack with a side carrying handle

Figure 6: Backpack with a duffel strap option

Another feature unique to the travel backpack is the option to zip-away the backpack straps. This feature can be used in conjunction with the duffle strap option or the padded top/side handles. 73.33% of travel backpacks had this feature and none of the recreation backpacks had this feature. Figure 7 and Figure 8 below show an example of zip-away straps.

Figure 7: Example of a backpack with zip-away backpack straps (before)

Figure 8: Example of a backpack with zip-away backpack straps (after)

As emphasized by the preceding features, travel backpacks are designed for carriage over shorter distances. This fact becomes clear when looking at how travel backpacks are designed to fit the user. 20% of travel backpacks are designed to be gender specific while 60% of recreation backpacks are gender specific. Similarly, only 20% of travel backpacks are available in multiple sizes as opposed to "one-size fits all," while 93.33% of recreation backpacks are available in multiple sizes.

Given that the travel backpack appears to be designed for shorter distance travel, an emerging feature of travel backpacks is the removable daypack. This is a small backpack attached to the main pack that can be removed and carried on its own. An example of a removable daypack is shown below in Figure 9 and Figure 10. 46.67% of travel backpacks examined had removable daypacks while only 6.67% of recreation backpacks had removable daypacks.

Figure 9: Example of a removable daypack attached to the front of the main pack

Figure 10: Example of a removable daypack removed from the main pack

While all recreational backpacks examined have a built in frame, only 66.67% of travel backpacks had a frame. This fact emphasizes further the idea that travel backpacks are designed with less emphasis on the load carrying and ergonomic design when compared to recreational backpacks. This is also noticed more qualitatively when looking at the suspension system of recreational backpacks compared to travel backpacks. There are generally more components and more padding on the recreational suspension system than the travel suspension system.

Airplane carry-on capability is a desirable feature when considering the travel application. Whether a recreational backpack is carry-on compatible or not is not specified in the detailed product descriptions. Additionally, height-length-depth measurements are not provided for recreational backpacks so it is difficult to determine if a bag will in fact meet the 9 by 14 by 22 inch bag requirement of most airlines. However, when comparing recreational and travel backpacks visually, hiking backpacks generally seem to be designed taller and less wide than travel backpacks which can restrict the carry-on compatibility. 40% of travel backpacks were identified as carry-on compatible, whereas carry-on compatibility was not specified for any recreational backpacks.

An additional usability feature to consider when traveling is storage space for electronic devices. A user is more likely to need a laptop or tablet when traveling than during a recreational activity where access to electricity is limited. 66.67% of travel backpacks are designed with laptop compartments and 46.67% are designed with tablet compartments, while none of the recreational backpacks have either of these features. Table 2 shows a summary of these feature differences.

Table 2: Percentage of backpacks that have a given feature

	Travel	**Recreation**
Front panel open	93.33%	20%
Security Lock Compatible	80%	0%
Top Carrying Handles	100%	100%
Padded Handles	60%	0%
Side Handles	86.67%	0%
Duffel Strap Option	60%	0%
Zip Away Straps	73.33%	0%
Gender Specific	20%	60%
Multiple Sizes Available	20%	93.33%
Frame	66.67%	100%
Removable Daypack	46.67%	6.67%
Carry-on Compatible	40%	--
Laptop/iPad Compartment	66.67%/46.67%	0%/0%

While similar capacity (average 56.33 L vs. 57.73 L) and weight (3 lbs 11.8 oz vs. 4 lbs 1.72 oz) are seen for travel and recreational backpacks, other features seem to be quite variable. For example, recreational backpacks tend to have more exterior features such as number of exterior straps (6.67 compared to 3.2) and number of exterior pockets (7.13 compared to 4.8). The price tag is also quite different with the average recreational backpack costing $234.24 and the average travel backpack costing $164.73. This is summarized in Table 3 below.

Table 3: Metrics for each type of backpack

	Travel	**Recreation**
Number of Exterior Straps	3.2	6.67
Number of Exterior Pockets	4.8	7.13
Capacity (L)	56.33	57.73
Price (Full Price)	$164.73	$234.24
Weight	3lbs11.8oz	4lbs1.72oz

Usability factors for travel applications

One of the primary usability factors considered in this research is packability. One feature that has a large effect on packability of a backpack is how it can be loaded. Recreational

backpacks tend to be top loading. This means that an opening at the top of the bag is the primary way to access the contents of the main pocket. This can be beneficial when performing recreational activities because the lack of zippers makes the bag more durable. Loading from the top also allows for more compression. Most travel backpacks have a front panel for loading. This means that there is a horseshoe-shaped zipper on the front face of the backpack that allows you to pull the face of the bag out of the way displaying the whole contents of the main pocket of the bag. This allows for easier packing and organization of personal items (Nelson, 2001).

Given that travel backpackers are traveling for extended periods of time and recreational backpackers tend to travel for just a few days, it makes sense that the features of travel bags lend themselves to ease of packability while possibly sacrificing ergonomic design. Because of this, the two usability factors this research focuses on are packability, defined as the ease of packing quickly and efficiently, and ergonomic design as it relates to comfort/discomfort for the user.

Research hypothesis

Based on the preceding information regarding design and usage of recreational and travel backpacks, it is predicted that, for the travel application, backpacks designed for travel will be more efficient when it comes to packability. That is, packing a travel backpack as well as finding an item in a packed travel backpack will be quicker when compared to performing the same tasks with a recreational backpack. Additionally, it is predicted that users will indicate more discomfort when carrying a loaded travel backpack as opposed to a loaded recreational backpack and will also exhibit reduced stability and increased exertion.

CHAPTER 2: COMPARISON OF FEATURES, USABILITY, AND LOAD CARRYING DESIGN OF RECREATIONAL AND TRAVEL BACKPACKS WHEN CONSIDERING TRAVEL APPLICATIONS

Abstract

This research aimed to evaluate the differences between backpacks designed for travel and backpacks designed for recreation. A feature analysis was conducted by analyzing the top fifteen best-selling travel and recreational backpacks in order to identify the representative features for each type of bag. Following the feature analysis, four archetypal bags were selected (two of each type) to conduct an experiment to assess the load-carrying design and usability of the backpacks. A primary usability feature targeted with this study was packability – defined for the purpose of this research as the ease of packing quickly and efficiently. An experiment was conducted where participants were assigned to a backpack. Participants were required to pack items into the backpack and walk on a treadmill with the backpack on at a slow pace for 30 minutes. Following the treadmill task, participants were asked to find three items packed into the bag. Time to pack the bag and time to find the items were both measured. Discomfort surveys and force plate data were collected before and after walking on the treadmill to assess the load-carrying design of the backpack as it relates to comfort/discomfort of the user and heart rate data was collected throughout the experiment.

The results of this study indicate that recreational backpacks require additional exertion when compared to travel backpacks when walking at a slow pace for 30 minutes across even terrain as measured by a change in heart rate. The results also indicate a trend that travel backpacks require less time to pack, require less time to find items in the bag, and result in increased postural stability when compared to recreational backpacks.

Introduction

Backpacks are a common form of load carriage used for a variety of applications. For the purpose of this research, backpacks were classified into two categories: general use backpacks and special application backpacks. General use backpacks are designed to be used for a variety of day-to-day activities including use as a school/work bag, a day-trip bag, or a supplemental bag. Special application backpacks are designed with more specific applications in mind. Military backpacks, recreational backpacks, and travel backpacks are all examples of special application backpacks. Special application backpacks will be the focus of this research, specifically recreational and travel backpacks. Military backpacks have been the focus of extensive research (Heller, Challis, & Sharkey, 2009; Quesada, Mengelkoch, Hale, & Denniston, 1996; Birrell, Hooper, & Haslam, 2007; Stevenson et al., 2004). Many existing studies focus on the effect of load carriage in general (Martin & Nelson, 1986; Keren, Epstein, Magazanik, & Sohar, 1981; Qu & Yeo 2011) or comparing different types of load carriage (Legg & Mahanty, 1985; Lloyd & Cooke, 2011; Soule & Goldman, 1969), but very few studies delve into the effect of variability within a single form of load carriage, i.e. different backpack designs (Legg, Perko, & Campbell, 1997).

Recreational backpacks are designed for outdoor recreational activities like hiking, camping, or mountaineering. Recreational backpacking involves carrying a load on the back for an extended period of time over miles of distance sometimes for multiple days at a time (Lobb, 2004). Recreational backpackers typically carry between one fourth and one third of their own bodyweight on their backs. (Dominelli, Sheel, & Foster, 2012). A survey conducted in New Zealand states that recreational backpackers, or "trampers," as they are referred to in New Zealand, estimate that they carry their backpacks for 5 or more consecutive hours for distances

exceeding 11 kilometers per day typically for 1 or 2-3 day trips (Lobb, 2004). The effect of load carriage for these recreational backpackers can vary on different terrain, in different seasons, and for different durations (Simpson, Munro, & Steele, 2011).

Given that recreational backpackers are traveling long distances while carrying a heavy load, it makes sense that recreational backpacks are designed with comfort in mind and are often equipped with complex frames and suspension systems. Recreational backpacks can be characterized partially by their wide, padded straps and hip belts as well as their adjustability (Legg, Perko & Campbell, 1997). Well-padded hip belts reduce the weight placed on the shoulders, which can reduce overall strain leading to fewer injuries. Recreational backpacks can be adjusted to fit the size of the person and many of these adjustments can be made while the user is walking. These adjustments help to reduce strain by shifting the location of where the pressure of the load is being applied (Knapik, Harmann, & Reynolds, 1996). The combination of internal frame and curved shape allows the bag to be brought close to the carrier's body to minimize biomechanical strain (Legg, Perko & Campbell, 1997).

Travel backpacks are designed for travel and specifically a type of travel referred to as “travel backpacking." Travel backpacking can be distinguished from other forms of traveling by characteristics including the length of the trip, the rigidity of the itinerary, and the budget. Backpackers generally travel for weeks to months at a time and tend to have more flexible itineraries. In order to accommodate the longer trip, backpackers tend towards cheaper accommodations and transportation (Uriely, Yonay, & Simchai, 2002; Hecht & Martin, 2006; O’Reilly, 2006; Riley, 1988). When looking at Cohen's classification of travelers, backpackers can be classified as noninstitutionalized tourists. Noninstitutionalized tourists are characterized as one who travels with the intent to experience a place rather than see it. The

noninstitutionalized traveler will sacrifice lush accommodations in order to understand the people and the culture of the place they are traveling (Cohen, 1972). These travel backpackers are generally young, middle class tourists (Hyde & Olesen, 2011).

Travel backpacks generally place less emphasis on backpack fit compared to recreational backpacks. The emphasis is instead on features of convenience like front panel loading, hideaways suspension straps, additional organizational pockets, and a removal daypack (Hostetter, 1997). *Backpacker* magazine classifies travel packs into five categories: backpackable luggage, hybrid luggage, luggable backpack, duffel bag, and padded duffel. Backpackable luggage generally refers to a pack that resembles a soft suitcase with attached backpack straps. The focus of these backpacks is to function as luggage and they are not designed for recreational activities like hiking due to their less advanced suspension system. Hybrid luggage has the same travel focus of the backpackable luggage, but with padding and stabilizers that are much more similar to recreational backpacks. The luggable backpack is a backpack designed for both travel and recreational usage. This includes having the traditional features of a recreational backpack – size specific, frame, suspension system – while having travel features including a front panel loading style as opposed to the top loading style that is common for recreational packs. Duffel bags and padded duffels are other travel pack options, but they are not backpacks so will not be considered for this research (Prichard, 1996). According to Osprey, the backpack brand that was the focus of this study, travel packs continue to be popular because they target a specific user just as women's packs and children's packs target specific users (Siber, 2010).

Backpacker magazine also defined several features that consumers should look for when buying a travel pack. These include a side carry handle, detachable shoulder sling, hideaway

suspension, organizer pockets, zip-off daypack and zip-off fanny pack, internal cinch straps, lockable zipper pull, wet storage, and interchangeable suspension (Prichard, 1996).

In order to better understand the feature differences between backpacks designed for recreation and backpacks designed for travel, a product analysis was conducted. Initial analysis was completed by examining the variety and availability of both travel and recreation backpacks at REI.com, the Recreational Equipment Inc. (REI) website. REI is a cooperative that sells outdoor equipment and apparel. Table 4 below outlines some general differences between the backpacks advertised for travel and recreation applications.

Table 4: Differences in features, variety, and availability between backpacks designed for travel and backpacks designed for recreation.

	Travel	**Recreation**
Advertised Features	Laptop compartment Adjustable torso Carry-on size iPad/tablet compartment Removable daypack Checkpoint-friendly Wheeled	Adjustable torso Sleeping bag compartment Raincover Suspended mesh back panel Ultralight Removable daypack
Capacity	Range: 18-85 L • 11-20 (1) • 21-35 (3) • 36-50 (8) • 51-75 (9) • 76-100 (5)	Range: 20-105 L • 11-20 (2) • 21-35 (22) • 36-50 (63) • 51-75 (90) • 76-100 (18) • 101-150 (4)
Number of Options	26	182
Brands	Deuter(5) Eagle Creek (2) Osprey (8) Pacsafe(1) REI (5) Timbuk2 (4) Zoot (1)	Arc'teryx(5) Black Diamond (1) Deuter(19) Granite Gear (14) Gregory (50) JanSport(3) Kelty(9) Mammut(1) MountainHardwear(3) Mountainsmith(3) Osprey (36)

Table 4 (continued)

		Patagonia (2) REI (15) Sierra Designs (1) The North Face (20)
Price	$50.00-$99.99 (4) $100.00-$199.99 (18) $200.000-$499.99 (4)	$20.00-$49.99 (1) $50.00-$99.99 (17) $100.00-$199.99 (104) $200.00-$499.99 (64)

There are significantly more options for recreational backpacks than for travel backpacks (182 compared to 26). Additionally, there is a wider price range, a wider capacity range, and more brand variety for recreational backpacks. The three brands highlighted in yellow produce both travel and recreational backpacks.

The next step in the analysis was identifying specific features that vary between the two types of backpacks. This study is intended to determine whether there is an advantage or disadvantage to using one of the two types of backpacks for travel applications. Because of this, the features identified focused on those that would be valuable for travel. For example, having a backpack that is security lock compatible would be desired for travel applications, but having a loop for an ice pick is likely not as desirable. A list of features was compiled by looking through the advertised features for backpacks as well as by examining the physical characteristics of the backpacks.

This feature list was then used as a checklist to compare the top 15 best selling travel backpacks and the top 15 best-selling recreational backpacks. Two of the top 15 best-selling recreational backpacks were excluded because they were designed for children so the 16th and 17th best selling recreational backpacks were added to the analysis.

From this data, it was concluded that one distinguishable feature difference between travel and recreational backpacks is how they open. 93% of backpacks designed for travel had a

front panel opening similar to the one shown below in Figure 11 compared to 20% of backpacks designed for recreational activities.

Figure 11: Example of a front panel opening backpack

The alternative to this front panel is typically a top-loading design as seen below in Figure 12. These top opening compartments are secured with a drawstring. This feature lends itself to another distinguishable difference between travel and recreational backpacks. 80% of travel backpacks examined were security lock compatible while none of the recreational backpacks had this feature. This goes hand in hand with the loading style because only bags with zipper openings have the potential to be luggage lock compatible.

Figure 12: Example of a top-loading backpack

Another difference is the handles available. While all backpacks examined in both categories had top carrying handles, 60% of travel backpack top handles were padded whereas none of the recreational backpacks had padded handles (examples shown in Figure 13 and Figure 14). Additionally, 86.7% of travel backpacks had an additional side handle as shown below in Figure 15. None of the recreational backpacks had this feature. These padded and additional handles on travel backpacks are logical, as travelers might be more likely to carry their backpack in their hands than hikers because travelers are generally walking a shorter distance with their bags.

Figure 13: Backpack with a non-padded top carrying handle

Figure 14: Backpack with a padded top carrying handle

Another feature to suggest that travelers are more likely to carry their backpacks somewhere other than on their back is the duffel strap option. 60% of travel backpacks examined had the option to attach a strap to the side of the bag to carry it as a duffel bag over the user's shoulder as shown in Figure 15 below. None of the recreational backpacks examined had that feature.

Figure 15: Backpack with a side carrying handle

Figure 16: Backpack with a duffel strap option

Another feature unique to the travel backpack is the option to zip-away the backpack straps. This feature can be used in conjunction with the duffle strap option or the padded top/side handles. 73.33% of travel backpacks had this feature and none of the recreation backpacks had this feature. Figure 17 and Figure 18 below show an example of zip-away straps.

Figure 17: Example of a backpack with zip-away backpack straps (before)

Figure 18: Example of a backpack with zip-away backpack straps (after)

As emphasized by the preceding features, travel backpacks are designed for carriage over shorter distances. This fact becomes clear when looking at how travel backpacks are designed to fit the user. 20% of travel backpacks are designed to be gender specific while 60% of recreation backpacks are gender specific. Similarly, only 20% of travel backpacks are available in multiple sizes as opposed to "one-size fits all," while 93.33% of recreation backpacks are available in multiple sizes.

Given that the travel backpack appears to be designed for shorter distance travel, an emerging feature of travel backpacks is the removable daypack. This is a small backpack attached to the main pack that can be removed and carried on its own. An example of a removable daypack is shown below in Figure 19 and Figure 20. 46.67% of travel backpacks examined had removable daypacks while only 6.67% of recreation backpacks had removable daypacks.

Figure 19: Example of a removable daypack attached to the front of the main pack

Figure 20: Example of a removable daypack removed from the main pack

While all recreational backpacks examined have a built in frame, only 66.67% of travel backpacks had a frame. This fact emphasizes further the idea that travel backpacks are designed with less emphasis on the load carrying and ergonomic design when compared to recreational backpacks. This is also noticed more qualitatively when looking at the suspension system of recreational backpacks compared to travel backpacks. There are generally more components and more padding on the recreational suspension system than the travel suspension system.

Airplane carry-on capability is a desirable feature when considering the travel application. Whether a recreational backpack is carry-on compatible or not is not specified in the detailed product descriptions. Additionally, height-length-depth measurements are not provided for recreational backpacks so it is difficult to determine if a bag will in fact meet the 9 by 14 by 22 inch bag requirement of most airlines. However, when comparing recreational and travel backpacks visually, hiking backpacks generally seem to be designed taller and less wide than travel backpacks which can restrict the carry-on compatibility. 40% of travel backpacks were identified as carry-on compatible, whereas carry-on compatibility was not specified for any recreational backpacks.

An additional usability feature to consider when traveling is storage space for electronic devices. A user is more likely to need a laptop or tablet when traveling than during a recreational activity where access to electricity is limited. 66.67% of travel backpacks are designed with laptop compartments and 46.67% are designed with tablet compartments, while none of the recreational backpacks have either of these features. Table 5 shows a summary of these feature differences.

Table 5: Percentage of backpacks that have a given feature

	Travel	**Recreation**
Front panel open	93.33%	20%
Security Lock Compatible	80%	0%
Top Carrying Handles	100%	100%
Padded Handles	60%	0%
Side Handles	86.67%	0%
Duffel Strap Option	60%	0%
Zip Away Straps	73.33%	0%
Gender Specific	20%	60%
Multiple Sizes Available	20%	93.33%
Frame	66.67%	100%
Removable Daypack	46.67%	6.67%
Carry-on Compatible	40%	--
Laptop/iPad Compartment	66.67%/46.67%	0%/0%

While similar capacity (average 56.33 L vs. 57.73 L) and weight (3 lbs 11.8 oz vs. 4 lbs 1.72 oz) are seen for travel and recreational backpacks, other features seem to be quite variable. For example, recreational backpacks tend to have more exterior features such as number of exterior straps (6.67 compared to 3.2) and number of exterior pockets (7.13 compared to 4.8). The price tag is also quite different with the average recreational backpack costing $234.24 and the average travel backpack costing $164.73. This is summarized in Table 6 below.

Table 6: Metrics for each type of backpack

	Travel	**Recreation**
Number of Exterior Straps	3.2	6.67
Number of Exterior Pockets	4.8	7.13
Capacity (L)	56.33	57.73
Price (Full Price)	$164.73	$234.24
Weight	3lbs11.8oz	4lbs1.72oz

One of the primary usability factors considered in this research is packability. One feature that has a large effect on packability of a backpack is how it can be loaded. Recreational backpacks tend to be top loading. This means that an opening at the top of the bag is the primary

way to access the contents of the main pocket. This can be beneficial when performing recreational activities because the lack of zippers makes the bag more durable. Loading from the top also allows for more compression. Most travel backpacks have a front panel for loading. This means that there is a horseshoe-shaped zipper on the front face of the backpack that allows you to pull the face of the bag out of the way displaying the whole contents of the main pocket of the bag. This allows for easier packing and organization of personal items (Nelson, 2001).

Given that travel backpackers are traveling for extended periods of time and recreational backpackers tend to travel for just a few days, it makes sense that the features of travel bags lend themselves to ease of packability while possibly sacrificing ergonomic design. Because of this, the two usability factors this research focuses on are packability, defined as the ease of packing quickly and efficiently, and ergonomic design as it relates to comfort/discomfort for the user.

Based on the preceding information regarding design and usage of recreational and travel backpacks, it is predicted that, for the travel application, backpacks designed for travel will be more efficient when it comes to packability. That is, packing a travel backpack as well as finding an item in a packed travel backpack will be quicker when compared to performing the same tasks with a recreational backpack. Additionally, it is predicted that users will indicate more discomfort when carrying a loaded travel backpack as opposed to a loaded recreational backpack and will also exhibit reduced stability and increased exertion.

Methods

Research Objectives

The purpose of this is study is to determine if there is an identifiable and significant difference between backpacks designed for recreation and backpacks designed for travel and to ultimately determine if there is an advantage to using either type specifically for the travel application. These differences/advantages will be determined based on the design features, the packability, and the ergonomic load-carrying design.

Hypothesis

The differences between backpacks designed for recreation and backpacks designed for travel were assessed through testing the following hypotheses.

- H1: Travel backpacks will allow for improved packability as measured by a shorter amount of time required to pack the backpack as well as a shorter amount of time to find items in the packed backpack.
- H2: Travel backpacks will have higher perceived discomfort than recreational backpacks as measured by discomfort survey assessment.
- H3: Travel backpacks will require higher exertion compared to recreational backpacks when performing a walking task.
- H4: Travel backpacks will result in reduced postural stability when compared to recreational backpacks as measured by force plate data.

Participants

Participants were recruited from Iowa State University. Participants were required to be over 18 years old, weigh at least 105 pounds, could not use a heart pacemaker or automatic defibrillator, and could not have pre-existing back, knee, or hip injuries that would put them at risk. 24 participants were included in this experiment, 12 males and 12 females. The average age of the participants was 22.333 years (SD = 2.353).

Task/Scenarios

Participants were assigned to one of four archetypal backpacks identified (details on backpack selection can be seen in the following subsection). They were then asked to pack the backpack with provided items representative of a travel packing list. This packing list was taken from travel expert Rick Steves (Steves). Once the backpack was packed, participants put the backpack on and walked on a treadmill at a slow pace (2 miles/hour) for 30 minutes. After walking on the treadmill, participants were asked to find three items in their bags.

Backpack Selection

For ease of comparison, bags were selected from brands that make both travel and recreational backpacks. The backpacks selected needed to have close to the average number of straps, number of exterior pockets, capacity, price, and weight for their type as shown in Table 8.

Once the first backpack was selected for a given type, the features that were not in line with the representative features were highlighted as in Table 7 below. For example, travel bag 1, the Osprey Farpoint 55, did not have a duffel strap option even though 60% of travel backpacks have the duffel strap option compared to 0% of recreational bags. Because of this, it was desired

for the second travel backpack selected to have the duffel strap option. Similarly, travel bag 1 had a frame, but only 66.67% of travel backpacks have a frame compared to 100% of recreational backpacks, so it was desired for the second backpack selected to not have a frame.

While it was initially desired to have two brands represented (one of each brand for each backpack type) in order to have all of the type-specific features represented for travel backpacks this was not possible. Only one brand is represented for the four sample backpacks and that brand is Osprey.

Table 7: Features considered when selecting representative travel backpacks

	Travel	**Osprey Farpoint 55**	**Osprey Porter 46**
Front panel open	93.33%	Yes	Yes
Security Lock Compatible	80%	Yes	Yes
Top Carrying Handles	100%	Yes	Yes
Padded Handles	60%	Yes	Yes
Side Handles	86.67%	Yes	Yes
Duffel Strap Option	60%	No	Yes
Zip Away Straps	73.33%	Yes	Yes
Gender Specific	20%	No	No
Multiple Sizes Available	20%	Yes	No
Frame	66.67%	Yes	No
Removable Daypack	46.67%	Yes	No
Carry-on Compatible	40%	No	Yes
Laptop/iPad Compartment	66.67%/46.67%	Yes	Yes

Table 8: Metrics considered when selecting representative travel backpacks

	Travel	**Osprey Farpoint 55**	**Osprey Porter 46**
Number of Exterior Straps	3.2	4	2
Number of Exterior Pockets	4.8	4	4
Capacity (L)	56.33	55	46
Price (Full Price)	$164.73	$180	$130
Weight	3lbs11.8oz	3lbs12oz	3lbs4oz

Selecting recreational backpacks was simpler given that there were strong feature trends. Most of the chosen features described close to 100% or close to 0% of recreational backpacks.

This was because the features selected for analysis were chosen to be those desirable for travelers not for the variety of tasks that may be required of recreational backpacks. Because of this, it was decided that all recreational bag-specific features must be represented by both backpacks and one backpack needed to be designed for males and one designed for females. This is reasonable given that 60% of recreational backpacks are designed to be gender specific while only 20% of travel backpacks are designed to be gender specific.

Additionally, when selecting recreational backpacks, it was important to note that some brands create backpacks that have male and female counterparts. This means that the bags are essentially the same in terms of features, but have been only slightly modified to fit the male or female body. The two bags selected could not be counterparts to ensure the necessary variety between the two bags. Selection criteria for recreational backpacks can be seen below in Table 9 and Table 10.

Table 9: Features considered when selecting representative recreational backpacks

	Recreation	**Osprey Atmos 50 (Men's)**	**Osprey Kyte 46 (Women's)**
Front panel open	20%	No	No
Security Lock Compatible	0%	No	No
Top Carrying Handles	100%	Yes	Yes
Padded Handles	0%	No	No
Side Handles	0%	No	No
Duffel Strap Option	0%	No	No
Zip Away Straps	0%	No	No
Gender Specific	60%	Yes	Yes
Multiple Sizes Available	93.33%	Yes	Yes
Frame	100%	Yes	Yes
Removable Daypack	6.67%	No	No
Carry-on Compatible	--	--	--
Laptop/iPad Compartment	0%/0%	No	No

Table 10: Metrics considered when selecting representative recreational backpacks

	Recreation	**Osprey Atmos50 (Men's)**	**OspreyKyte46 (Women's)**
Number of Exterior Straps	6.67	6	8
Number of Exterior Pockets	7.13	7	4
Capacity (L)	57.73	50	46
Price (Full Price)	$234.24	$229.95	$179.95
Weight	4lbs1.72oz	4lbs	3lbs8.8oz

Independent Variables

The independent variable in this study was backpack type: recreational backpack or travel backpack. Two backpacks of each type were used in this study. For the recreational backpack, one male and one female bag were used. For the travel backpack, two gender neutral bags were used. Because of this, the number of participants per backpack varies, but the number of participants per type of backpack is consistent as detailed in Table 11 below.

Table 11: Distribution of participants assigned to backpacks

Backpack	**Number of Male Participants**	**Number of Female Participants**	**Total Number of Participants**	
Travel 1	3	3	6	12
Travel 2	3	3	6	
Recreational Male	6	-	6	12
Recreational Female	-	6	6	

Dependent Variables/Metrics

Table 12: Dependent variables and associated metrics

Dependent Variable	Metric	Unit	Measurement Frequency	Data Collection Method
Packability	Time to pack	Min:sec	Once: Before walking	Timing
Exertion	Heart rate	Beats/min	Twice: Resting heart	Heart rate monitor

Table 12 (continued)

			rate before backpack, active heart rate while walking with backpack	
Discomfort	Survey	Likert Scale	Twice: Before backpack is introduced, after walking with backpack	Discomfort Survey
Stability	Variance of Center of Pressure attributed to backpack	Center of Pressure	Twice: Before backpack is introduced, after walking with backpack	Forceplate
Packability	Time to find	Min:sec	Once: After walking	Timing

Packability was assessed by two different metrics: time to pack and time to find. Packability and "time to pack" or "time to find" have a negative relationship. That is, the less time it takes to pack the bag or find items, the higher the packability of the bag.

Exertion was assessed using heart rate. Data was collected before the treadmill trial as resting heart rate and again during the treadmill trial as active heart rate. The difference between the active heart rate and resting heart rate for a participant describes his or her exertion. Higher exertion is indicated by a larger difference between active and resting heart rate.

A discomfort survey was complete before receiving the backpack and after walking on the treadmill with the backpack. This discomfort survey was a basic Likert scale and asked the participant to consider different parts of his or her body and record the corresponding level of discomfort.

Stability was measured by having the participant stand on a Bertec FP4060-07-1000 force plate connected to an AM6504 analog to digital converter/amplifier (with gain set to 1) for five minutes before the backpack was introduced and for five minutes after walking on the treadmill with the backpack. The backpack was still on the participant when final force plate data was collected. Force and moment data for the X, Y, and Z direction was collected. The center of

pressure (CoP) was then calculated from these values and the change in the variance of CoP from baseline to final was used as a metric to assess the change in postural stability caused by the two types of backpacks. The use of standard deviation of center of pressure is a previously defined method used to assess stability where an increase in standard deviation indicates reduced stability (Ross, Guskiewicz, Gross, & Yu, 2009; Zumbrunn, Macwilliams, & Johnson, 2011).

Experimental Design

The study conducted was a single factor, two level design with data collected between participants. Participants were randomly assigned to one of the three applicable backpacks (travel backpack 1, travel backpack 2, or gender-appropriate recreational backpack). The number of participants were divided evenly between recreational backpacks and travel backpacks (12 and 12) as well as between the two travel backpacks (6 and 6). Gender was considered when assigning backpacks to allow for this even distribution.

Procedure

Participants were asked to wear athletic clothes and shoes to the study. Tank tops were not allowed. The study took place indoors behind a closed door in a temperature-controlled environment. The first thing participants did when arriving to the study was to sign the consent form. After signing the consent form, participants were asked to complete a questionnaire asking for general demographic information as well as general information about the participants' experience with both backpacks designed for travel and backpacks designed for recreation. Height and weight measurements were then collected. Once paperwork was completed, participants were equipped with a Bioharness heart rate monitor.

Once a participant was equipped with a heart rate monitor, baseline data was collected. This data included level of discomfort as assessed by a Likert scale discomfort survey, stability as assessed by standing still on a force plate for five minutes, and resting heart rate as assessed by having the participant sit quietly for five minutes.

Following baseline data collection, participants were given their pre-assigned backpack. Participants were then given five minutes to familiarize themselves with the features of their backpack. Once the five minutes had elapsed, participants were instructed to pack the provided items into the backpack as though they were going on a trip, not as though they were simply trying to fit everything into the bag. Provided items were representative of what one might take on a travel trip according to travel expert Rick Steves's packing list (Steves). The total weight of the items to be packed into the backpack was 17.1 lbs. The time it took for the participant to pack all of the items into the backpack and place it on his or her back was measured and recorded.

Once the backpack was packed, participants were instructed how to properly adjust their backpacks. Once properly adjusted, participants walked on a treadmill at a 0% incline at a slow pace (2 miles/hour) for 30 minutes. Participants were instructed not to use the rails on the treadmill to help them support their weight. Heart rate data was collected while participants were walking on the treadmill.

When the treadmill task was completed, participants kept the backpack on as final data was collected. Final data collection included level of discomfort as assessed by the same Likert scale discomfort survey and stability as assessed by standing still on the force plate for five minutes. Once completed, participants were asked to find three items that they had previously packed into their backpacks. They were instructed to remove their backpack, remove the three

items from it, repack the backpack with everything except for those three items, and place it back on their backs. The time it took to find the three items and place the bag back on their backs was measured and recorded. Following this task, participants were allowed to remove their backpack and heart rate monitor and an informal interview regarding the experiment was conducted. Below is an outline of the experimental procedure.

Paperwork

- Sign consent form
- Complete questionnaire
- Collect height and weight measurements

Sensors

- Equip with heart rate monitor

Baseline data collection

- Discomfort survey
- Force plate
- Resting heart rate

Packing the backpack

- Receive the backpack
- Familiarize with backpack
- Pack backpack
- Properly adjust backpack

Walk on treadmill for 30 minutes

- Record heart rate

Final data collection

- Discomfort survey
- Force plate

Finding items in backpack

- Record time to find

Remove backpack and sensors

Informal interview

Debrief

Results

Data was collected to assess packability, perceived discomfort, exertion, and stability. A summary of the data collected can be seen below.

Packability

Time to Pack

The time it took participants to pack their backpacks with the provided items was measured. This time was then compared for the two types of backpacks as well as for each individual backpack. A Shapiro-Wilk Test was conducted to assess the normality of the data collected for “time to pack.” With a p-value of 0.1951, the assumption of normality was not rejected.

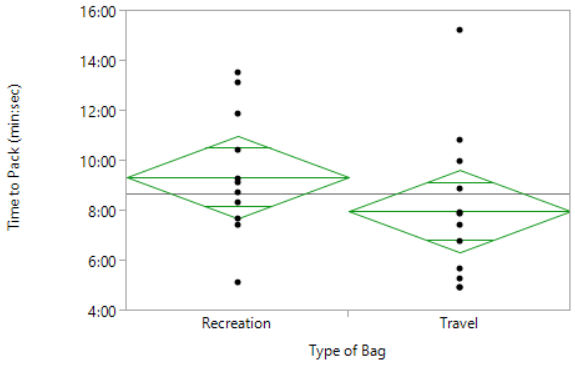

Figure 21: Time to pack for each type of bag

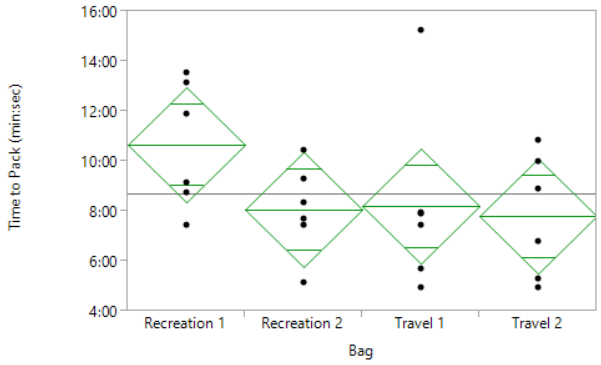

Figure 22: Time to pack for each individual bag

A t-test was performed to evaluate the difference in mean packing time for each type of backpack (travel versus recreation) with H_o: $\mu_{travel} - \mu_{recreation=} 0$ and H_a: $\mu_{travel} - \mu_{recreation} < 0$ and $\alpha=.05$, that is, it was predicted that it would take less time to pack for travel backpacks compared to recreational backpacks. The results of this t-test can be seen below in Table 13. With a p-value of .1200, the null hypothesis cannot be rejected, indicating there is no significant difference between the mean time to pack for recreational and travel backpacks.

Table 13: Results of T-test to evaluate difference in mean packing time for each type of bag

Difference	-81.58	T Ratio	-1.20876
Std Err Dif	67.49	DF	21.33734
Upper CL Dif	58.64	Prob > |t|	0.2400
Lower CL Dif	-221.81	Prob > t	0.8800
Confidence	0.95	Prob < t	0.1200

In order to evaluate the difference in mean packing time for each individual backpack, Tukey's HSD test was performed. The results of this test can be seen below in Table 14. For each combination, the p-value is greater than 0.05, indicating there is no significant difference in mean packing time for any pair of individual backpacks.

Table 14: Ordered differences report from Tukey's HSD test to evaluate difference in mean packing time for each individual bag

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Recreation 1	**Travel 2**	171.3333	93.72266	-90.99	433.6571	0.2899
Recreation 1	**Recreation 2**	155.5000	93.72266	-106.824	417.8238	0.3702
Recreation 1	**Travel 1**	147.3333	93.72266	-114.99	409.6571	0.4161
Travel 1	**Travel 2**	24.0000	93.72266	-238.324	286.3238	0.9939
Recreation 2	**Travel 2**	15.8333	93.72266	-246.49	278.1571	0.9982
Travel 1	**Recreation 2**	8.1667	93.72266	-254.157	270.4905	0.9998

Time to Find

The time it took participants to find the three items and repack the backpack was measured. This time was then compared for the two types of backpacks as well as each individual backpack. A Shapiro-Wilk Test was conducted to assess the normality of the data collected for "time to find." With a p-value of 0.0004, the assumption of normality was rejected. A Levene test was conducted to test that the variances for recreational and travel backpacks were equal. With a p-value of 0.8812 the assumption of equal variances was not rejected.

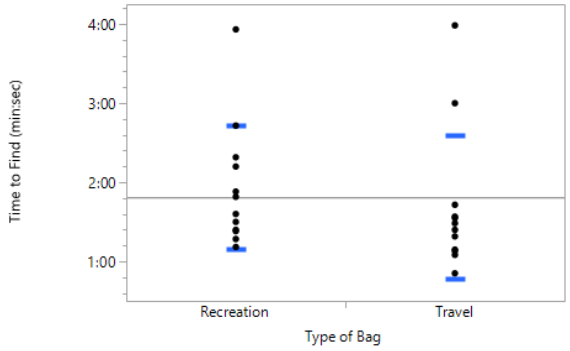

Figure 23: Time to find for each type of bag

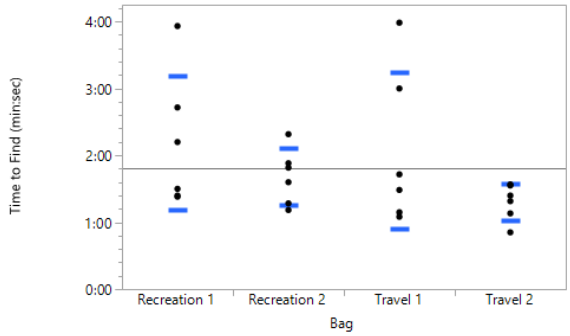

Figure 24: Time to find for each individual bag

A Mann-Whitney test was performed to evaluate the difference in the distributions for the two types of backpacks. It was hypothesized that the recreational distribution would have higher values for "time to find." The results of this test can be seen below in Table 15. With a p-value of

.0921, the null hypothesis cannot be rejected, indicating there is no significant difference between the two distributions for "time to find" for recreational and travel backpacks.

Table 15: Results of Mann-Whitney test to evaluate difference in distributions of "time to find" for each type of bag

Z-value	-1.32819	Prob > |Z|	0.1841
		Prob > Z	0.9080
		Prob < Z	0.0921

In order to evaluate the difference in mean packing time for each individual backpack, the Wilcoxon method was used. The results of this test can be seen below in Table 16. For each combination, the p-value is greater than 0.05, indicating there is no significant difference in mean packing time for any pair of individual backpacks.

Table 16: Report from Wilcoxon method to evaluate difference in time to find for each individual bag

Level	- Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann
Travel 1	**Recreation 2**	-0.16667	2.081666	-0.08006	0.9362	-4.0000
Travel 1	**Recreation 1**	-0.50000	2.081666	-0.24019	0.8102	-14.5000
Recreation 2	**Recreation 1**	-1.50000	2.081666	-0.72058	0.4712	-16.0000
Travel 2	**Travel 1**	-2.16667	2.081666	-1.04083	0.2980	-18.5000
Travel 2	**Recreation 2**	-3.16667	2.081666	-1.52122	0.1282	-20.0000
Travel 2	**Recreation 1**	-3.33333	2.078024	-1.60409	0.1087	-38.5000

Perceived Discomfort

Perceived discomfort was measured using a Likert scale discomfort survey that asked participants to quantify the discomfort of various body parts. Participants completed this discomfort survey before packing and putting on the backpack and after walking with the packed backpack on for 30 minutes. The change in perceived discomfort was then calculated and analyzed.

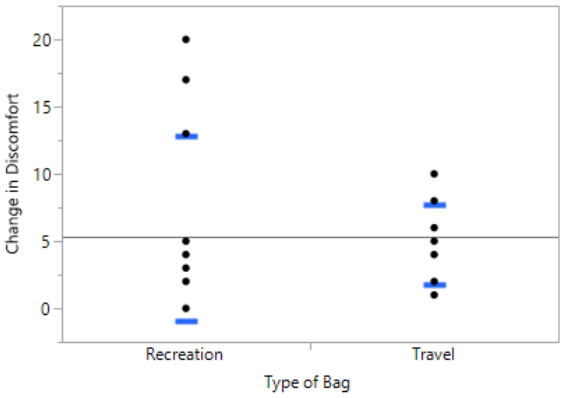

Figure 25: Change in perceived discomfort for each type of bag

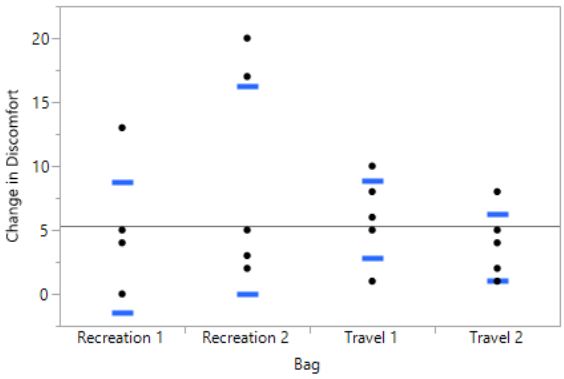

Figure 26: Change in perceived discomfort for each individual bag

A Shapiro-Wilk Test was conducted to assess the normality of the data collected for perceived discomfort data. With a p-value of 0.0014, the assumption of normality was rejected. A Levene test was conducted to test that the variances were equal. With a p-value of 0.0217 the assumption of equal variances for recreational and travel backpacks was rejected. The results for perceived discomfort, as can be seen in Figure 25 and Figure 26, do not indicate a statistically significant difference with regards to change in perceived discomfort between recreational and travel backpacks.

Exertion

Exertion was measured using heart rate. Resting heart rate data was collected by having the participant sit quietly for five minutes. The participant's heart rate at time T=5 minutes was used as the resting heart rate. Task heart rate data was collected while the participant was walking on the treadmill with the backpack on for 30 minutes. The participant's heart rate at time T=30 minutes was used as the task heart rate. The change in heart rate from resting to task was calculated and analyzed. Heart rate data from 23 participants was collected (12 recreational, 11

travel). A Shapiro-Wilk Test was conducted to assess the normality of the data collected for exertion. With a p-value of 0.1719, the assumption of normality was not rejected.

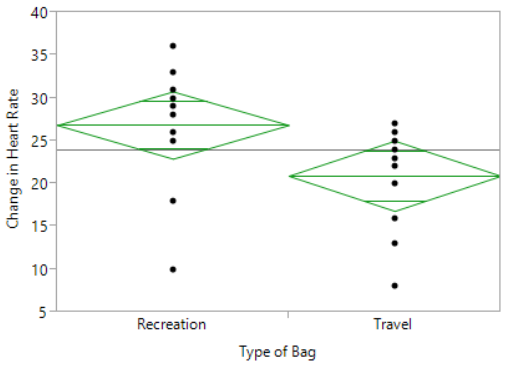

Figure 27: Change in heart rate for each type of bag

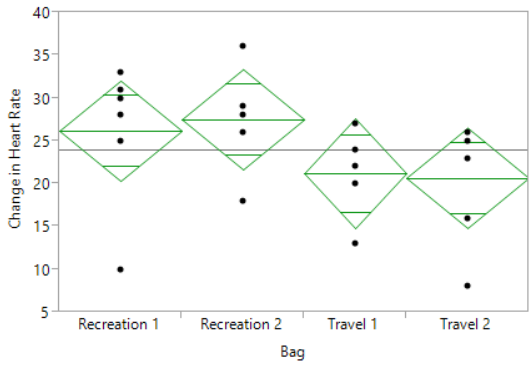

Figure 28: Change in heart rate for each individual bag

A t-test was performed to evaluate the difference in the mean change in heart rate for each type of backpack (travel versus recreation) with H_o: $\mu_{travel} - \mu_{recreation=} 0$ and H_a: $\mu_{travel} - \mu_{recreation} > 0$ and α=.05, that is, it was predicted there would be a larger change in heart rate for travel backpacks compared to recreational backpacks. The results of this t-test can be seen below in Table 17. The results show that there is a statistically significant difference between mean change in heart rate, however, it is the opposite of what was expected. With a p-value of 0.0203, there is evidence that recreational backpacks have a larger change in heart rate than travel backpacks.

Table 17: Results of T-test to evaluate difference in change in heart rate for each type of bag

Difference	-5.924	t Ratio	-2.18142
Std Err Dif	2.716	DF	20.98332
Upper CL Dif	-0.276	Prob > |t|	0.0407
Lower CL Dif	-11.572	Prob > t	0.9797
Confidence	0.95	Prob < t	0.0203

Stability

Stability was measured by having the participant stand on a force plate for five minutes before the backpack was introduced and for five minutes after walking on the treadmill with the backpack. The backpack was still on the participant when final force plate data was collected. Force and moment data for the X, Y, and Z direction was collected. The center of pressure (CoP) was then calculated from these values and the change in the variance of CoP from baseline to final was used as a metric to assess the change in stability caused by the two types of backpacks. A larger change in variance is associated with less stability. The equation to calculate center of pressure can be seen below where *h* is the thickness of any material on top of the force plate, *F* is the force, and *M* is the moment.

$$x_p = \frac{-h \times F_x - M_y}{F_z} \qquad y_p = \frac{-h \times F_y + M_x}{F_z}$$

Center of Pressure (CoP) in the X-direction

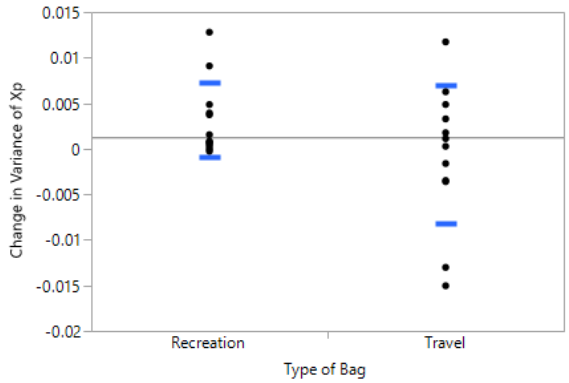

Figure 29: Change in the variance of Xp for each type of bag

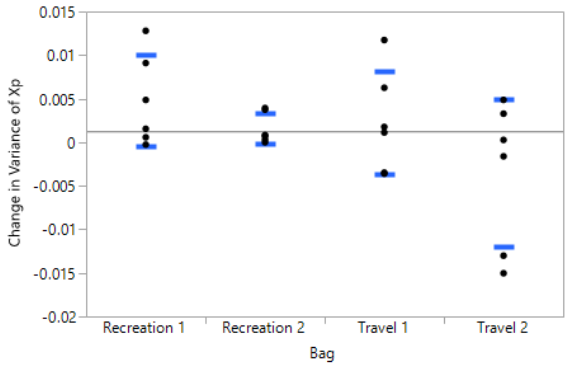

Figure 30: Change in the variance of Xp for each individual bag

A Shapiro-Wilk Test was conducted to assess the normality of the data collected for change in variance of Xp. With a p-value < 0.0309, the assumption of normality was rejected. A

Levene test was conducted to test that the variances were equal. With a p-value of 0.1225 the assumption of equal variances for recreational and travel backpacks was not rejected.

A Mann-Whitney test was performed to evaluate the difference in the distributions for the two types of backpacks. It was hypothesized that the travel backpacks would have a higher variance in force. The results of this test can be seen below in Table 18. With a p-value of .8573, the null hypothesis cannot be rejected, indicating there is no significant difference between the two distributions for change in variance of Xp for recreational and travel backpacks.

Table 18: Results of Mann-Whitney test to evaluate difference change in variance of Xp for each type of bag

Z-value	-1.06810	Prob > |Z|	0.2855
		Prob > Z	0.8573
		Prob < Z	0.1428

In order to evaluate the difference in change in variance of force in the x-direction for each individual backpack, the Wilcoxon method was used. The results of this test can be seen below in Table 19. For each combination, the p-value is greater than 0.05, indicating there is no significant difference in variance of Xp for any pair of individual backpacks.

Table 19: Report from Wilcoxon method to evaluate differences in change in variance of Xp for each individual bag

Level	- Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann
Travel 1	**Recreation 2**	0.50000	2.081666	0.24019	0.8102	0.000607
Travel 1	**Recreation 1**	-1.16667	2.081666	-0.56045	0.5752	-0.003151
Recreation 2	**Recreation 1**	-1.83333	2.081666	-0.88070	0.3785	-0.001176
Travel 2	**Travel 1**	-1.83333	2.081666	-0.88070	0.3785	-0.004686
Travel 2	**Recreation 2**	-2.16667	2.081666	-1.04083	0.2980	-0.002132
Travel 2	**Recreation 1**	-3.16667	2.081666	-1.52122	0.1282	-0.007202

Center of Pressure (CoP) in the Y-direction

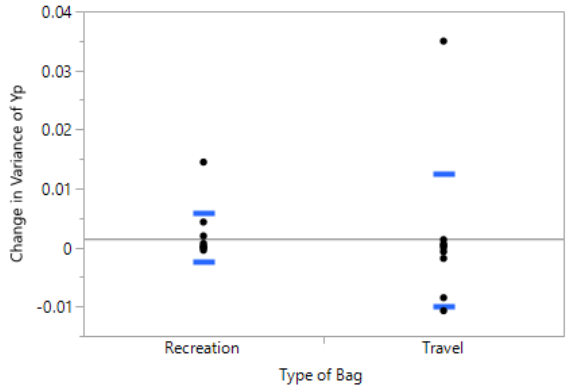

Figure 31: Change in the variance of Yp for each type of bag

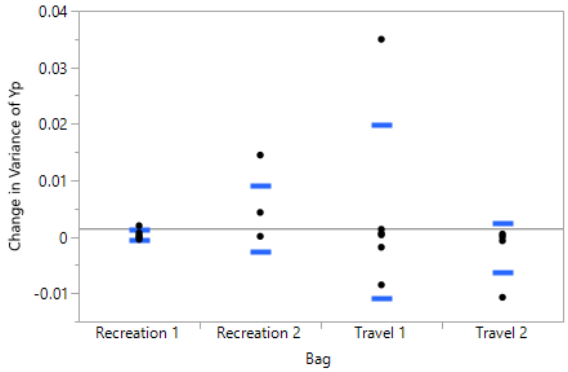

Figure 32: Change in the variance of Yp for each individual bag

A Shapiro-Wilk Test was conducted to assess the normality of the data collected for change in variance of Yp. With a p-value < 0.0001, the assumption of normality was rejected. A Levene test was conducted to test that the variances were equal. With a p-value of 0.3117, the assumption of equal variances for recreational and travel bags was not rejected.

A Mann-Whitney test was performed to evaluate the difference in the distributions for the two types of backpacks. It was hypothesized that the travel backpacks would have a higher variance in force. The results of this test can be seen below in Table 20. With a p-value of .8573 the null hypothesis cannot be rejected, indicating there is no significant difference between the two distributions for change in variance of Yp for recreational and travel backpacks.

Table 20: Results of Mann-Whitney test to evaluate difference change in variance of Yp for each type of bag

Z-value	-1.1.18357	Prob > |Z|	0.2366
		Prob > Z	0.8817
		Prob < Z	0.1183

In order to evaluate the difference in change in variance of force in the y-direction for each individual backpack, the Wilcoxon method was used. The results of this test can be seen below in Table 21. For each combination, the p-value is greater than 0.05, except when comparing travel bag 2 to recreational bag 2 where there is evidence that recreational bag 2 resulted in a higher variance in Yp indicating less stability when compared to travel bag 2 (p-value = 0.0306).

Table 21:Report from Wilcoxon method to evaluate differences in change in variance of Yp for each individual bag

Level	- Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann
Recreation 2	**Recreation 1**	1.83333	2.081666	0.88070	0.3785	0.000518
Travel 1	**Recreation 1**	0.16667	2.081666	0.08006	0.9362	0.000257
Travel 1	**Recreation 2**	0.00000	2.081666	0.00000	1.0000	-0.000798
Travel 2	**Travel 1**	-2.16667	2.081666	-1.04083	0.2980	-0.001066
Travel 2	**Recreation 1**	-2.50000	2.081666	-1.20096	0.2298	-0.000663
Travel 2	**Recreation 2**	-4.50000	2.081666	-2.16173	0.0306*	-0.000808

Discussion

"Time to pack" and "time to find" were both metrics used to assess packability. It was predicted that it would take longer to pack and find items when using a recreational backpack due to the higher number of external features (straps and pockets) and the top loading design. The results show a trend for both metrics supporting the hypothesis, however, there was no significant difference in "time to pack" or "time to find" for the two types of backpacks. When looking at the time to pack and find for each individual backpack (Figure 22 and Figure 24), it becomes visually clear that there is variability within the two backpack types, though this variability was not statistically significant. The lack of difference for "time to find" could be due to the types of items participants were asked to find. The three items participants were asked to find were the travel guidebook, ibuprofen pain reliever, and the rain jacket. Because of the nature

of these three items, many participants packed them in highly accessible pockets or positions. Had the participants been asked to find the pair of blue jeans (an item many participants packed at the bottom), the results may have been different. However, changing the items to be found could also make the task less realistic.

The discomfort survey collected information regarding 17 different parts of the body. The results of the survey show no statistically significant difference between the two types of backpacks when considering perceived discomfort. It was hypothesized that travel backpacks would cause more perceived discomfort because of the limited suspension system and padding when compared to recreational backpacks. This lack of difference could be due to the amount of weight packed into each backpack (17.1 pounds), the duration of time participants walked with the backpack (30 minutes), or a combination of these two factors. If either of these were increased, this could have resulted in an identifiable difference between backpack types.

It was predicted that carrying travel backpacks would require more exertion compared to recreational backpacks because travel backpacks have a limited suspension systems. The results indicated the opposite to be true. Exertion was measured as the increase in heart rate and, on average, the recreational backpacks resulted in a larger increase in heart rate with statistical significance (p-value = 0.0203). These unexpected results could be attributed to the padding of each type of backpack. One characteristic of recreational backpacks is the increased padding along the back panel of the bag compared to travel backpacks. Figure 33 and Figure 34 show the padding on recreational backpacks 1 and 2 used in this experiment. Recreational backpack 1 has a mesh panel along the back that is suspended from the part of the backpack that actually carries the load. The user's back does not actually come into contact with the weight. This allows for a secure fit between the user and mesh panel, but also distances the weight of the backpack from

the user. Recreational backpack 2 has a padded mesh panel along the back of the backpack. While the distance between the weight of the backpack and the user is not as severe for this backpack, it still exists. Comparing this with travel backpacks 1 and 2 in Figure 35 and Figure 36, the difference in the amount of padding is visible.

Figure 33: Back-panel padding on recreational backpack 1

Figure 34: Back-panel padding on recreational backpack 2

Figure 35: Back-panel padding on travel backpack 1

Figure 36: Back-panel padding on travel backpack 2

When carrying a load on the torso, one of the most important factors when trying to reduce energy consumption is positioning the load as close to the center of mass of the body as possible (Knapik, Harmann, & Reynolds, 1996; Obusek, Harman, Frykman, Palmer, & Billis, 1997). This means that, while the additionally padding in recreational backpacks is intended to lead to increased comfort, it may cause in increase in exertion as evident by the increase in heart rate.

Stability was analyzed using the variance of center of pressure (CoP). It was predicted that travel bags would result in larger variance because of the limited suspension system. The results showed no statistically significant difference between the two types of backpacks with regards to stability. This lack of difference could be due to the relatively low weight of the packed bags. If the weight of the load were increased, it's possible that an identifiable difference between backpacks would have been seen. There was a trend in the data suggesting that recreational backpacks actually resulted in a larger variance in CoP, indicating less postural stability. This unexpected result could be attributed to the design and intended use of recreational backpacks. When a load is applied to a person's back, the person leans forward to compensate for this and ensure the system (user and backpack) center of mass remains stable by rebalancing the moments around the hips (Pascoe, 1997; Goh, Thambyah, & Bose, 1998; Attwells, Birrell, Hooper, & Mansfield, 2006). Recreational backpacks are designed to be taller and narrower than travel backpacks and this taller design moves the center of mass of the backpack higher on the user's back. A study conducted by Qu and Nussbaum showed that as loads were placed higher on the back, balance control decreased when considering parameters such as CoP (2009). The findings of Rugelj and Sevsek also supported this idea (2011). Recreational backpacks are designed for use when traversing uneven surfaces such as when hiking or mountaineering. In

these activities, walking at inclines or declines, the body is naturally leaning forward or backward to improve stability (Leroux, Fung, & Barbeau, 2002). While this design might not affect stability when hiking, it could result in a reduction in stability when walking on a level surface, as was the case during this experiment.

Overall, the only variable that showed statistical significance was exertion. The objective of this study was to determine if there are significant differences between backpacks designed for recreation and backpacks designed for travel and to ultimately determine if there is an advantage to using either type for a travel application. If one was to choose a backpack for a travel application solely based off of this study, they should select a travel backpack because of the lower exertion required when walking at a slow pace over level surfaces for up to 30 minutes. However, there were some limitations with this study.

One limitation was the fact that only two backpacks of each type were considered. While effort was made to ensure the bags were representative of their corresponding type, it is possible that including more backpacks could help to emphasize trends. Another limitation was the weight of the backpack. If the backpack were heavier, it's possible that trends in the data would have become more obvious. Similarly, time spent walking was a limitation and if participants were to walk for a longer period of time, results may have been different. Given these limitations and the results found, future work could focus on the differences between the two types of backpacks when weight of the backpack is increased or when duration of the walking task is increased. Additionally, an assessment using electromyography could be conducted to compare muscle activation associated with carrying each type of backpack.

Conclusion

The objective of this study was to determine if there are significant differences between backpacks designed for recreation and backpacks designed for travel and to ultimately determine if there is an advantage to using either type for a travel application. The results of this study indicate that recreational backpacks require additional exertion when compared to travel backpacks when walking at a slow pace for 30 minutes across even terrain. The results also indicate a trend that travel backpacks require less time to pack, require less time to find items in the bag, and result in increased postural stability when compared to recreational backpacks.

References

Attwells, Renee L., Birrell, Stewart A., Hooper, Robin H., & Mansfield, Neil J. (2006). Influence of carrying heavy loads on soldiers' posture, movements and gait. Ergonomics, 49(14), 1527-1537.

Birrell, Hooper, & Haslam. (2007). The effect of military load carriage on ground reaction forces. *Gait & Posture, 26*(4), 611-614.

Cohen, E. (1972). TOWARD A SOCIOLOGY OF INTERNATIONAL TOURISM. *Social Research, 39*(1), 164-182.

Dominelli, P.B., Sheel, A.W. & Foster, G.E. Eur J Appl Physiol (2012) 112: 2001. doi:10.1007/s00421-011-2177-8

Hecht, Jo-Anne & Martin, David. (2006). Backpacking and hostel-picking: An analysis from Canada. *International Journal of Contemporary Hospitality Management, 18*(1), 69-77.

Heller, Challis, & Sharkey. (2009). Changes in postural sway as a consequence of wearing a military backpack. Gait & Posture, 30(1), 115-117.

Hostetter, Kristin. (1997). Odds 'n' ends. (backpacking accessories)(Buyers Guide). *Backpacker, 25*(2), 229.

Hyde, Kenneth F., & Olesen, Karin. (2011). Packing for touristic performances. *Annals of Tourism Research, 38*(3), 900.

Goh, Thambyah, & Bose. (1998). Effects of varying backpack loads on peak forces in the lumbosacral spine during walking. Clinical Biomechanics, 13(1), S26-S31.

Keren, G., Epstein, Y., Magazanik, A., & Sohar, E. (1981). The energy cost of walking and running with and without a backpack load. *European Journal of Applied Physiology and Occupational Physiology, 46*(3), 317-324.

Knapik, Joseph, Harmann, Everett, & Reynolds, Katy. (1996). Load carriage using packs: A review of physiological, biomechanical and medical aspects. *Applied Ergonomics, 27*(3), 207.

Leg G, S. J. And Mahanty, A. 1985. Comparison of five modes of carrying a load close to the trunk, Ergonomics, 28, 1653 ± 1660.

Leroux, Alain, Fung, Joyce, & Barbeau, Hugues. (2002). Postural adaptation to walking on inclined surfaces: I. Normal strategies. *Gait & Posture, 15*(1), 64-74.

Lloyd, R., & Cooke, C. (2011). Biomechanical Differences Associated with Two Different Load Carriage Systems and their Relationship to Economy. *Human Movement, 12*(1).

Lobb, B. (2004). Load carriage for fun: A survey of New Zealand trampers, their activities and injuries. *Applied Ergonomics, 35*(6), 541-547.

Martin, P. E. And Nelson , R. C. 1986, The effect of carried loads on the walking patterns of men and women, Ergonomics, 29, 1191 ± 1202.

Nelson, Dan A. (2001). Packs. *Backpacker, 29*(2), 20.

O'Reilly, C. (2006). From drifter to gap year tourist: Mainstreaming Backpacker Travel. *Annals of Tourism Research, 33*(4), 998-1017.

Obusek, J. P., Harman, E. A., Frykman, P. N., Palmer, C. J., & Billis, R. K. (1997). The relationship of backpack center of mass locations to the metabolic cost of load carriage. Medicine and Science in Sports and Exercise, 29, S205.

Pascoe, David D., Pascoe, Donna E., Wang, Yong Tai, Shim, Dong-Ming, & Kim, Chang K. (1997). Influence of carrying book bags on gait cycle and posture of youth. *Ergonomics, 40*(6), 631.

Prichard, Nancy. (1996). Travel packs: You hauls. (includes related article on avoiding luggage problems while traveling)('96 Gear Guide)(Cover Story)(Buyers Guide). *Backpacker, 24*(2), 197.

Qu, Xingda & Nussbaum, Maury A. (2009). Effects of external loads on balance control during upright stance: Experimental results and model-based predictions. *Gait & Posture 29*(1), 23-30.

Qu, & Yeo. (2011). Effects of load carriage and fatigue on gait characteristics. *Journal of Biomechanics, 44*(7), 1259-1263.

Quesada, Mengelkoch, Hale, & Denniston. (1996). Kinetic assessment of marching while wearing military style backpacks. *Gait & Posture, 4*(2), 201-202.

REI.com

Riley, P. (1988). Road culture of international long-term budget travelers. *Annals of Tourism Research,15*(3), 313-328.

Ross, Scott E., Guskiewicz, Kevin M., Gross, Michael T., & Yu, Bing. (2009). Balance measures for discriminating between functionally unstable and stable ankles. *Medicine and Science in Sports and Exercise, 41*(2), 399-407.

Rugelj, Darja & Sevsek, France. (2011). The effect of load mass and its placement on postural sway. *Applied Ergonomics, 42*(6), 860-866.

S. J. Legg , L. Perko & P. Campbell (1997) Subjective perceptual methods for comparing backpacks, Ergonomics, 40:8, 809-817, DOI: 10.1080/001401397187801

Siber, Kate. (2010). Packs with purpose: Whether it's comfort, fit or value, today's consumers are diving into new adventures with backpacks designed to hold the bare essentials. *SGB, 43*(4), 56.

Simpson, Munro, & Steele. (2011). Effect of load mass on posture, heart rate and subjective responses of recreational female hikers to prolonged load carriage. *Applied Ergonomics, 42*(3), 403-410.

Soule, R., & Goldman, R. (1969). Energy cost of loads carried on the head, hands, or feet. *Journal of Applied Physiology, 27*(5), 687-90.

Stevenson, J., Bossi, L., Bryant, J., Reid, S., Pelot, R., & Morin, E. (2004). A suite of objective biomechanical measurement tools for personal load carriage system assessment. *Ergonomics, 47*(11), 1160-1179.

Steves, Rick. (n.d.). *Rick's Packing List.* Retrieved from https://www.ricksteves.com/travel-tips/packing-light/ricks-packing-list.

Uriely, Yonay, & Simchai. (2002). Backpacking experiences: A Type and Form Analysis. *Annals of Tourism Research, 29*(2), 520-538.

Zumbrunn, Macwilliams, & Johnson. (2011). Evaluation of a single leg stance balance test in children. *Gait & Posture, 34*(2), 174-177.

CHAPTER 3: OVERALL CONCLUSIONS

This study aimed to evaluate the differences between backpacks designed for recreational use and backpacks designed for travel and to ultimately determine if there is an advantage to using either type for a travel application. A feature analysis was conducted to determine what features are representative of each backpack type. Based off of this analysis, representative backpacks of each type were selected and evaluated to determine functional differences. These differences were evaluated using metrics of packability, perceived discomfort, exertion, and stability. The results of this study indicate a trend that travel backpacks require less time to pack, require less time to find items in the bag, and result in increased postural stability when compared to recreational backpacks. However, none of these metrics resulted in statistical significance. When considering perceived discomfort, there was not a significant difference between the two backpack types. The results do indicate, with statistical significance, that recreational backpacks require additional exertion when compared to travel backpacks when walking at a slow pace for 30 minutes across even terrain.

REFERENCES

Attwells, Renee L., Birrell, Stewart A., Hooper, Robin H., & Mansfield, Neil J. (2006). Influence of carrying heavy loads on soldiers' posture, movements and gait. Ergonomics, 49(14), 1527-1537.

Birrell, Hooper, & Haslam. (2007). The effect of military load carriage on ground reaction forces. *Gait & Posture, 26*(4), 611-614.

Cohen, E. (1972). TOWARD A SOCIOLOGY OF INTERNATIONAL TOURISM. *Social Research, 39*(1), 164-182.

Dominelli, P.B., Sheel, A.W. & Foster, G.E. Eur J Appl Physiol (2012) 112: 2001. doi:10.1007/s00421-011-2177-8

Hecht, Jo-Anne & Martin, David. (2006). Backpacking and hostel-picking: An analysis from Canada. *International Journal of Contemporary Hospitality Management, 18*(1), 69-77.

Heller, Challis, & Sharkey. (2009). Changes in postural sway as a consequence of wearing a military backpack. Gait & Posture, 30(1), 115-117.

Hostetter, Kristin. (1997). Odds 'n' ends. (backpacking accessories)(Buyers Guide). *Backpacker, 25*(2), 229.

Hyde, Kenneth F., & Olesen, Karin. (2011). Packing for touristic performances. *Annals of Tourism Research, 38*(3), 900.

Goh, Thambyah, & Bose. (1998). Effects of varying backpack loads on peak forces in the lumbosacral spine during walking. Clinical Biomechanics, 13(1), S26-S31.

Keren, G., Epstein, Y., Magazanik, A., & Sohar, E. (1981). The energy cost of walking and running with and without a backpack load. *European Journal of Applied Physiology and Occupational Physiology, 46*(3), 317-324.

Knapik, Joseph, Harmann, Everett, & Reynolds, Katy. (1996). Load carriage using packs: A review of physiological, biomechanical and medical aspects. *Applied Ergonomics, 27*(3), 207.

Knapik, J., Reynolds, K., & Harman, E. (2004). Soldier load carriage: Historical, physiological, biomechanical, and medical aspects. Military Medicine, 169(1), 45-56.

Legg, S. J. (1985). Comparison of different methods of load carriage. Ergonomics, 28(1), 197-212.

Legg, S. J. And Mahanty, A. (1985). Comparison of five modes of carrying a load close to the trunk, Ergonomics, 28, 1653 ± 1660.

Leroux, Alain, Fung, Joyce, & Barbeau, Hugues. (2002). Postural adaptation to walking on inclined surfaces: I. Normal strategies. *Gait & Posture, 15*(1), 64-74.

Lloyd, R., & Cooke, C. (2011). Biomechanical Differences Associated with Two Different Load Carriage Systems and their Relationship to Economy. *Human Movement, 12*(1).

Lobb, B. (2004). Load carriage for fun: A survey of New Zealand trampers, their activities and injuries. *Applied Ergonomics, 35*(6), 541-547.

Martin, P. E. And Nelson , R. C. 1986, The effect of carried loads on the walking patterns of men and women, Ergonomics, 29, 1191 ± 1202.

Nelson, Dan A. (2001). Packs. *Backpacker, 29*(2), 20.

O'Reilly, C. (2006). From drifter to gap year tourist: Mainstreaming Backpacker Travel. *Annals of Tourism Research, 33*(4), 998-1017.

Obusek, J. P., Harman, E. A., Frykman, P. N., Palmer, C. J., & Billis, R. K. (1997). The relationship of backpack center of mass locations to the metabolic cost of load carriage. Medicine and Science in Sports and Exercise, 29, S205.

Pascoe, David D., Pascoe, Donna E., Wang, Yong Tai, Shim, Dong-Ming, & Kim, Chang K. (1997). Influence of carrying book bags on gait cycle and posture of youth. *Ergonomics, 40*(6), 631.

Prichard, Nancy. (1996). Travel packs: You hauls. (includes related article on avoiding luggage problems while traveling)('96 Gear Guide)(Cover Story)(Buyers Guide). *Backpacker, 24*(2), 197.

Qu, Xingda & Nussbaum, Maury A. (2009). Effects of external loads on balance control during upright stance: Experimental results and model-based predictions. *Gait & Posture 29*(1), 23-30.

Qu, & Yeo. (2011). Effects of load carriage and fatigue on gait characteristics. *Journal of Biomechanics, 44*(7), 1259-1263.

Quesada, Mengelkoch, Hale, & Denniston. (1996). Kinetic assessment of marching while wearing military style backpacks. *Gait & Posture, 4*(2), 201-202.

REI.com

Riley, P. (1988). Road culture of international long-term budget travelers. *Annals of Tourism Research,15*(3), 313-328.

Ross, Scott E., Guskiewicz, Kevin M., Gross, Michael T., & Yu, Bing. (2009). Balance measures for discriminating between functionally unstable and stable ankles. *Medicine and Science in Sports and Exercise, 41*(2), 399-407.

Rugelj, Darja & Sevsek, France. (2011). The effect of load mass and its placement on postural sway. *Applied Ergonomics, 42*(6), 860-866.

S. J. Legg , L. Perko & P. Campbell (1997) Subjective perceptual methods for comparing backpacks, Ergonomics, 40:8, 809-817, DOI: 10.1080/001401397187801

Siber, Kate. (2010). Packs with purpose: Whether it's comfort, fit or value, today's consumers are diving into new adventures with backpacks designed to hold the bare essentials. *SGB, 43*(4), 56.

Simpson, Munro, & Steele. (2011). Effect of load mass on posture, heart rate and subjective responses of recreational female hikers to prolonged load carriage. *Applied Ergonomics, 42*(3), 403-410.

Soule, R., & Goldman, R. (1969). Energy cost of loads carried on the head, hands, or feet. *Journal of Applied Physiology, 27*(5), 687-90.

Stevenson, J., Bossi, L., Bryant, J., Reid, S., Pelot, R., & Morin, E. (2004). A suite of objective biomechanical measurement tools for personal load carriage system assessment. *Ergonomics, 47*(11), 1160-1179.

Steves, Rick. (n.d.). *Rick's Packing List.* Retrieved from https://www.ricksteves.com/travel-tips/packing-light/ricks-packing-list.

Uriely, Yonay, & Simchai. (2002). Backpacking experiences: A Type and Form Analysis. *Annals of Tourism Research, 29*(2), 520-538.

Zumbrunn, Macwilliams, & Johnson. (2011). Evaluation of a single leg stance balance test in children. *Gait & Posture, 34*(2), 174-1

APPENDIX A: IRB APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 9/26/2016

To: Zoe Eagle
PO Box 42306
Urbandale, IA 50323

CC: Dr. Richard T Stone
3004 Black Engineering

From: Office for Responsible Research

Title: Comparison of features, usability, and load carrying design of recreational and travel backpacks when considering travel applications

IRB ID: 16-341

Approval Date:	9/26/2016	**Date for Continuing Review:**	9/25/2018
Submission Type:	New	**Review Type:**	Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp.**
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of** (1) **all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form at least three to four weeks prior to the date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 202 Kingland, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX B: DISCOMFORT SURVEY

APPENDIX C: IMAGE CITATIONS

Figure 1 and Figure 11

- http://answeringoliver.blogspot.com/2012/01/my-rtw-backpack-round-two-osprey.html

Figure 2 and Figure 12

- http://thesavvybackpacker.com/travel-backpack/

Figure 3 and Figure 13

- https://www.rei.com/product/878451/osprey-atmos-65-ag-pack

Figure 4 and Figure 14

- https://www.rei.com/product/870903/osprey-porter-46-travel-pack

Figure 5 and Figure 15

- https://www.rei.com/product/870903/osprey-porter-46-travel-pack

Figure 6 and Figure 16

- https://www.rei.com/product/895849/eagle-creek-load-hauler-exp-travel-pack

Figure 7 and Figure 17

- https://www.rei.com/product/870899/osprey-porter-65-travel-pack

Figure 8 and Figure 18

- https://www.rei.com/product/870899/osprey-porter-65-travel-pack

Figure 9 and Figure 19

- http://www.deuter.com/US/us/travel-packs/transit-50-35209-122.html

Figure 10 and Figure 20

- http://www.deuter.com/US/us/travel-packs/transit-50-35209-122.html

Figure 33

- http://www.ospreypacks.com/my/en/series/technical-packs/atmos-aura-landing

Figure 34

- http://www.ospreypacks.com/ec/en/product/kyte-46-KYTE46.html#pdp-feature-item-1

Figure 35

- https://www.rei.com/product/894563/osprey-farpoint-55-travel-pack

Figure 36

- http://www.ospreypacks.com/us/en/product/porter-46-PORTER46.html#pdp-feature-item-2