

Evaluation of modern day kitchen knives: An ergonomic and biomechanical approach to design

by

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ABSTRACT

The focus of this study was to evaluate how different knife characteristics affect the consumer's ability to slice vegetables. There are many variables to a knife and there are beliefs about what makes for a better knife. There are two common multipurpose knives used for slicing vegetables, the chef knife and the santoku knife. The aim of the first portion of the study was to investigate if there is a difference in cutting between a chef knife and a santoku knife, a ceramic knife and a stainless steel knife, and a sharp and dull knife in terms of muscle activation, body part discomfort, time, and slice performance. In order to test these variables, four different knives were used. 50 participants sliced two pounds of vegetables with two knives each, each on a different day. The results show that for the consumer, the type of knife, material, and level of sharpness do not affect the user's muscle activation, discomfort, time, or slice performance. In the second portion of the study the Pinch Cinch grip was designed to be placed on the knife to create an affordance for users to hold the knife in a pinch grip. This grip aligns the wrist and forearm and decreases fatigue and increases stability and control while cutting. The designed grip, the Pinch Cinch, is to be used as a training mechanism for the consumer to easily adjust to using the pinch grip. The grip was tested with 16 participants against a previously tested knife to ensure it did not require more muscle activation, time, discomfort, or cause lower slice performance. The results showed this grip did not have any significant difference from the knife with out the grip. The Pinch Cinch did not have any negative effect on the task compares to the other knife tested. The Pinch Cinch can ensure the consumer is maintaining the pinch grip, and allows them to become accustomed to it by having the affordance present. With the use of the Pinch Cinch, the consumer will feel the pinch grip is natural and retain the benefits of more control and stability.

CHAPTER 1

INTRODUCTION

Lillian Gilbreth, one of the founders of industrial engineering, was a leader in making advances in the kitchen. In the 1920s she sold her own books sharing with housewives how they could use engineering principles to make kitchen work easier and more efficient (Graham, 1999). One of the things Lillian focused on was the movement around the kitchen. She developed “continuous” floor plans but left the layout up for customization. She provided flow diagrams and charts for housewives to be able to make the kitchen work for their own habits (Bell, 2002). Over the course of her research she interviewed more than 4000 women to design the heights for different kitchen appliances (Mitchell, n.d.) One key thing she reminded housewives of was the counter height has to be adjusted to the person. Frederick Taylor, another person playing a key role is the development of efficiency, said “it is the wrong idea that many women have of making their kitchen look like other rooms, with tools tucked out of sight. A kitchen is a workshop, where efficiency should rule over mere looks.” In the early 1900s the schedule of a family had to keep at home in order to keep food on the table and a clean house, left them with very little time to relax. With the introduction of labor saving devices, women were able to start to free themselves from having only doing their domestic duties (Bell, 2002). Lillian Gilbreth patented three well known kitchen appliances, the electric mixer, the trash can with a foot pedal, and the shelves in the refrigerator door, among many others. Many of her ideas are still in today’s kitchen designs (Mitchell, n.d.). In the 1940s the kitchen work triangle was developed as a metric for how efficient a kitchen layout it. This is the distance between the sink to the stove to

the refrigerator and back to the sink. The design principle is the perimeter should be less than 23 feet (Fisher, 1989).

In 1970, Joan Ward argued being a housewife was a job and that it was worth looking at the ergonomics of the home. The caloric impact was calculated for a variety of home tasks, and all were relatively low. Even though the activities are low impact, the muscle strain can be taxing on the individual. It's mentioned that the way kitchen work needs to be studied is through electromyography, especially for looking at different working heights and its effect on the muscle activation levels. Ward mentions two studies done for the posture during ironing and depth and height of kitchen sinks that were based on the subject's preferences. The argument is that people might prefer what they are used to, not what is optimal for their stature. This paper fights that the home is worthy of more ergonomic studies (Ward, 1970). Ward did go on to use electromyography, anthropometry, and preference to determine heights for different kitchen activities that fit 95% of the female population (Ward, 1971).

Since the huge advancements in the 1920s, there have been few studies to follow. Much of the recent focus has been on commercial kitchen operations and the ergonomics for the workers. 11 working kitchens were studied for the muscular and skeletal load. From a health questionnaire and ergonomic assessment, it was found that issues in the neck and shoulder regions were results from work surfaces being too high. Adjustable work tables would be able to reduce the effects seen (Pekkarinen & Anttonen, 1988). A study done in 2007 looked at municipal kitchens, and was looking at the ergonomics, and how the musculoskeletal workload could be optimized. The only research data collected was through diaries, questionnaires, and focus groups. Time and resources were reasons for implementation challenges (Pehkonen et al., 2007). Another study looking at the musculoskeletal load through a video based observation

method. The video was analyzed by looking at postures, time, and force requirements (Pehkonen et al., 2009, A). Another study was done in a hospital kitchen to see the work intensity. They found the workers were averaging 101 beats per minute and 24-41% of VO₂peak (Smolander, 1999). One of the few studies using electromyography was looking at the posture while washing dishes and if adding an aid or leaning against the sink would be effective in reducing the leg muscle activates (Iwakiri, 2007).

There have been a few studies looking at the domestic tasks. A study focusing on how to make the kitchen safer for the elderly, suggested shelves within reach, windows should slide up for easy without having to use a chair or stool, and tables being fixed firmly to the ground (Pinto et al., 2000). A study was done in 2003 to compare the energy used when doing a task by hand versus with a machine. Washing both clothes and dishes by hand required significantly more energy than using the dishwasher or washing machine (Lanningham-Foster, 2003). One more specific study investigated the spatula, one of the most used kitchen tools in Asia. The design of the spatula was studied in terms of cooking performance and perceived exertion. The study found the optimal length and angle for frying food, turning food, and shoveling food (Wu & Hsieh, 2002).

While there have been many developments in the kitchen and new time saving devices implemented, there are few studies done for the consumer on a biomechanical basis. Biomechanics is the study of the forces and the mechanical system of the body (Fung, 2013). When looking at the human body during an activity it is important to look at it from a biomechanical perspective because it gives insight into how the different parts of the body move and the effects experienced in different muscles (Fung, 2013). Biomechanics is also instrumental in ergonomics, for determine what is optimal for the body.

One way of looking at the biomechanical model of the body is through the use of surface electromyography (EMG). EMG provides insight into the process that cause the muscles to move and to create forces. EMG is best used for three different applications, as an indicator of muscle activation levels, the relationship to the force produced from a muscle, and as an index for quantifying muscle fatigue (De Luca, 1997).

A few studies have utilized EMG since Ward conducted kitchen height research. In a study focusing for professional deboners, EMG was used on multiple arm muscles. Their objective was to see how using a sharp knife compares to a dull knife affected the muscle activation in the arm (Claudon & Marsot, 2006). Another study was done in a poultry processing plant using EMG to look at the forces the workers were experiencing in three different types of jobs (Bao, 2001). A study was using a reaching device to move a soup can from the cupboard to the counter and used EMG as a metric. It was found that the length of the reaching device did not have an effect on the amount of muscle strength required (Pinkston, 2005).

There are many kitchen tasks and only a handful have been researched in terms of a biomechanical approach. There are countless kitchen gadgets and tools out there, but no published research to back up if it makes a significant difference to the consumer's muscles. One of the most widely known kitchenware companies is OXO. Their focus is on universal design, so everyone is able to comfortably use the same product (Coleman, 2007). The look and feel of kitchen products is important, but knowing the mechanics behind the movement for the design is crucial to see if the product makes a difference to the human action. It's time to go back to what Ward was saying and use physical metrics to evaluate kitchen tasks. There needs to be focus put back on the home consumer, and see how their tasks can be made easier. Especially with the

downwards trend in time spent cooking, it is important to make kitchen task as easy and efficient as possible (Ferdman, 2015).

CHAPTER 2

LITERATURE REVIEW

Cooking Population

Every day, millions of Americans spend time at home preparing food to eat or to serve to their household. In 2014 the US Department of Labor reported that 56.3 percent of the population engaged in food preparation and cleanup (Bureau of Labor Statistics, 2014). For the participating population the average time per day spent on this activity was 1.04 hours (Bureau of Labor Statistics, 2014). There are many different types of people preparing food, and some tasks are difficult to complete because of the strength required, or the position it needs to be done in (Kelsheimer & Hawkins, 2000).

While the younger population might have no trouble completing kitchen tasks, those who are aging or have other disabilities might have problems using certain kitchen tools to prepare food the way they want to (Gustafsson, 2002). Cooking in the kitchen is a necessity for many people, and making tools and tasks easier or less time consuming can have a significant effect on the person's ability to complete them (Ritzel & Donelson, 2001 & Bowers, 2000).

Old Age Effects

Arthritis and old age can greatly affect the task of food preparation (Reisine, Goodenow, & Grady, 1987 & U, 1996). One study interviewed 48 people between the ages of 60 and 90 about food preparation. Of the participants, 19% had trouble completing tasks related to food preparation, or had modifications for ways they could accomplish tasks. 2% of the participants felt pain while peeling and chopping, and another 2% said she didn't have enough strength in her

hands to be able to do certain food preparation tasks. An alternative suggestion was buying prepared meals or pre-sliced vegetables instead of doing the work yourself (Maguire et al., 2014). This is an unfortunate substitute when being able to keep cooking in one's own kitchen with the familiar routine is something the elderly find very rewarding (Maguire et al., 2014). When aging, cooking is the last thing a person wants to give up (Shanas, 1968).

Much of past human factors and ergonomics work in the kitchen has focused on the layout and creating universally designed kitchen tools (Mitchell, n.d.). Sam Farber started OXO in 1990, when his wife suffering from arthritis found kitchen tools increasingly harder to use. He did not want to make a special needs product, so universal design became the philosophy of OXO (Coleman, 2007). OXO is now one of the leading companies in kitchen tools and their approach has been identifying what tools hurt to use and how can they be made more comfortable (Simply better design," 2008). Many of their products feature a comfortable power grip. A power grip wraps the finger and thumb around the tool, and gives the user strength to perform the task (Konz, 1974). While it is important to create tools for essentially everyone to use, there are other areas of food preparation to study (Williamson, 2012). Slicing vegetables is one task a power grip cannot easily be applied to.

Key Muscles

The key muscles involved in the slicing action are in the arms. The focus of the cutting action is in the lower and upper arm muscles. The four muscles of interest in this study are the extensor digitorum, carpi radialis, biceps brachii, and triceps brachii, and the location of each can be seen in Figure 1. These four muscles are the most involved in the cutting action, and more importantly are optimal for the use of surface electromyography. These are large muscles and are

located close to the surface of the skin. While there are many smaller and deeper muscles involved in the cutting action, it would be expected they would behave similar to the monitored muscles in that area (Grant, K. A, 1997). The two lower arm muscles are the extensor digitorum and carpi radialis. The extensor digitorum is located on the backside of the forearm. This muscle is pivotal in the movement of the wrist and elbow. The extensor digitorum also is responsible for the extension of the four fingers (Keen, 2003). In a study focusing on poultry processing, there were high muscle loads in the forearm extensor and flexor muscles (Bao, 2001). The carpi radialis is located on the inside of the forearm. This muscle is very close the wrist and is one of the primary muscles that produced torque around the wrist (Buchanan et al., 1993). The biceps brachii is located on the inside of the upper arm and the triceps brachii is located on the outside of the upper arm. The biceps brachii and triceps brachii work together to control the elbow and the shoulder (Healthline Medical Team, 2014).

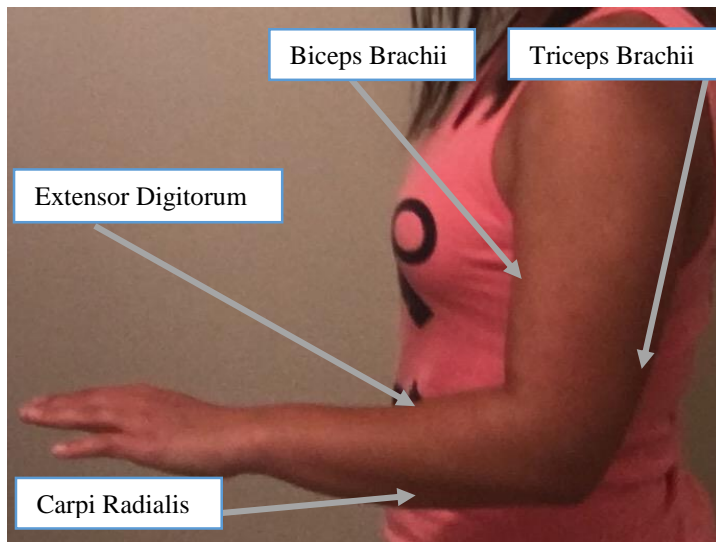


Figure 1: Muscle Locations

In the action of slicing carrots, there are two main movements in the body. For slicing carrots, the recommended way is to keep your knife tip on the board (Jay & Sur La Table, 2008).

When approaching the carrot to make the first slice, you have your knife tip on the board with the knife angled up. In this position the wrist is in the flexed position, meaning the palm bends towards the arm (Gonzales, 1997). This position is shown in Figure 2. To begin slicing through the carrot, the muscles in the upper arm produce the movement of the elbow down. As the elbow continues to move down, the wrist also needs to adjust in order to slice the carrot. At the completion of the slice the wrist moves to a neutral position, which is inline with the forearm. This final position is shown in Figure 3. To make the next slice, the elbow is brought up and the wrist once again becomes flexed. In order to produce these movements, many of the arm muscles are used. The movement in the elbow is mainly controlled by the biceps brachii and the triceps brachii. The flexion of the wrist is controlled by the forearm muscles.



Figure 2: Arm position before slicing



Figure 3: Arm position after the slice

The action of slicing is repetitive, and repetitive tasks can cause cumulative trauma over time (Kroemer, 1989). For an action being studied it is important to know the activation levels of each muscle involved. A way to quantify how much each muscle is being used is through surface electromyography (EMG). The optimal muscle to apply EMG sensors to is a large one close to the surface (De Luca, 1997). Since the biceps brachii and triceps brachii control the elbow

movement, and are large muscles close to the surface, both were chosen to represent the muscles in the upper arm. The wrist extension is the other important movement, and the easiest muscles read by EMG in the lower arm are the carpi radialis and extensor digitorum.

Being able to see the muscles activation levels through EMG, gives a biomechanical model of the arm. If a certain type of knife characteristic creates a different arm movement, it would be captured through the change in activation levels of the muscles. EMG also provides insight into the forces produced by the muscles (De Luca, 1997). If one knife requires more force to slice through the carrots, it should be reflected in the EMG data.

Slicing Vegetables

Slicing vegetables with a knife is a tiring activity, and there are no easy short cuts or ways to complete the task (Lang, 2000). Although there are many different variables in the knife market-type of knife, material, and sharpness being the three main ones-there is no research done on the consumer level to see if these variables affect the user's ability, in terms of comfort, muscle activation, forces, precision, and time. This study concentrates on the kitchen task of slicing vegetables, specifically carrots and potatoes, in the home setting. Commercial operations have workers cutting for extended lengths of time. Studies have been done to examine fields such as meatpacking, where the risk of cumulative trauma is 30 times greater than the average for all other industries (McGorry, Dowd, & Dempsey, 2005). Professional chefs spend years learning the skills that give them the precision and expertise they need (Trotter, Wareing, Hill, & Hall, 2008). Consumers, on the other hand, do not use a knife for a long length of time when preparing a meal and most are not going to dedicate years of time to learning the proper way to cut each type of food with accuracy. The focus of this study was on how different types of knives, materials, and levels of sharpness affect the user while slicing carrots and potatoes.

Types of Knives

There are many types of knives serving different purposes. There are two multipurpose knives recommended for slicing vegetables, the chef knife and the santoku knife. The chef knife is the all-purpose knife most people know and use. It's used for chopping, slicing, dicing, and mincing most any food. This knife lets the consumer use the rocking motions when cutting and its length allows to cut both large and small items. The knife also given the consumer plenty of room for their hands to comfortably stay above the cutting board (Jay & Sur La Table, 2008). Another knife that has gained popularity in recent years is the santoku knife. This is a Japanese utility knife and translates to the "knife of three virtues." There are three different theories for what the three virtues are. The first is the ability to cut fish, vegetables, and meat. The second is that the knife excels in slicing, mincing, and chopping. And the final theory is the ability to use the three parts of the knife for different purposes. The tip of the knife can be used for precision, the main part of the blade for typical slicing, and the heel of the knife for heavy-duty cutting (Ward & Regan, 2008).

Knife Material

One debate about knives is what material is better to use, stainless steel or ceramic. Stainless steel knives have been around for a long time. They're strong, durable, and easily sharpened. These days, new metals are being used and mixed to optimize the knife; for instance, sharp brittle carbon steel is placed between flexible stainless steel, giving the user the sharp brittle metal in the middle, and softer metal surrounding it to keep it in good condition. In the last 25 years, ceramic knives have entered the market. The ceramic blade is 50% stronger than steel, it's sharp, and stays sharp. It makes for a light knife, but it is brittle and cannot be sharpened at

home. This knife can do most of the daily tasks, but with hard foods it might not stand up to the challenge (Jay & Sur La Table, 2008).

Sharpness

Sharp knives are believed to be safer to use than dull knives. A butcher explained that when you have a dull knife it takes more cuts to cut through than with a sharp knife. The more cuts made, the more likely it is to have the knife slip and have the person cut themselves (Christensen, 2011). Dull knives are also stated to require more force to cut through the food (Henry, n.d.). In a study focusing on commercially cutting meat it was found that sharper blades required significantly less cutting moments and grip forces than the dull blade (McGorry, Dowd, & Dempsey, 2003). For commercial operations, high grip forces are a good indication of where injuries occur. Identifying the high risk areas and decreasing the forces experienced, helps to prevent musculoskeletal disorders (McGorry, Dowd, & Dempsey, 2003). Another study found for professional deboners that there were significantly lower EMGs for the biceps brachii and the triceps brachii, but did not find a significant difference for the extensor digitorum (Claudon & Marsot, 2006).

Pinch Grip

Knife skill books recommend the pinch grip for slicing vegetables (Jay & Sur La Table, 2008 & Ward, 2008 & Lumb, 2009 & Trotter, Wareing, Hill, & Hall, 2008). The author, along with most consumers, have always held the knife with their fingers around the handle (later referred to as the handle grip) (BDL, 2010). This is the way the knife affords to be held so people intuitively hold it in this manner (Riggio, Patteri, Oppo, Buccino, & Umiltà, 2006). It was

intriguing to find the the knife skill books recommend a pinch grip instead (Jay & Sur La Table, 2008 & Ward, 2008 & Lumb, 2009 & Trotter, Wareing, Hill, & Hall, 2008). It was evident to the author that this grip needed to be investigated further because it is the recommended grip and the average consumer does not know about it. This grip has you place your thumb on the knife blade, which is demonstrated in Figure 4, have your index finger curl around the other side of the blade, which is shown in Figure 5, and have your remaining three fingers wrap around the bottom of the handle (Jay & Sur La Table, 2008). The pinch grip is an example of a precision grip. This grip is able to support the tool to reduce any tremble in the tool, increasing the stability and control the user has (Konz, 1974).



Figure 4: Thumb placement for the pinch grip



Figure 5: Index finger placement for the pinch grip

An analogy from *Cutting Edge Knives* is the handle grip is like typing with the end of a pencil (Cutting Edge Knives, n.d.). It is possible, but you have much less control and is harder to do. The pinch grip allows for better control of the knife, and you are able to utilize the length of the knife (Cutting Edge Knives, n.d.). There are two major advantages to using the pinch grip. The first advantage is the arm becomes aligned with the wrist and the knife. This gives the knife more stability, more leverage, and reduces fatigue. The second advantage is the grip prevents the knife from moving precariously when coming across an unforeseen wobble or bone (Ward, 2008).

Consumers like the pinch grip, but the challenge is getting used to it (Carter, 2011). One consumer acknowledged that most likely the way you have always held the knife is wrapping your fingers around the knife handle, and it's awkward to try to switch to a pinch grip. It is not an intuitive grip and takes time to get used to; this consumer thought it would take a few months (BDL, 2010). Another user thought it felt unnatural to have their fingers on the blade, but with time it became, and they achieved more power and control with this grip (I'm Not a Cook, 2012). So why, if this grip gives you more control, is there no easier way to become accustomed to it? There is one kickstarter started by FINI Cutlery to make knives with short handles. This knife would make the pinch grip mandatory because there was no handle to grasp (Knife News, 2015).

CHAPTER 3

THE EVALUATION OF MODERN DAY KITCHEN KNIVES: AN ERGONOMIC AND BIOMECHANICAL APPROACH

Olivia Janusz and Richard Stone

Abstract

The focus of this study was to evaluate how different knife characteristics affect the consumer's ability to slice vegetables. There are many variables to a knife and there are beliefs about what makes for a better knife. There are two common multipurpose knives used for slicing vegetables, the chef knife and the santoku knife. The aim of the first portion of the study was to investigate if there is a difference in cutting between a chef knife and a santoku knife, a ceramic knife and a stainless steel knife, and a sharp and dull knife in terms of muscle activation, body part discomfort, time, and slice performance. In order to test these variables, four different knives were used. 50 participants sliced two pounds of vegetables with two knives each, each on a different day. The results show that for the consumer, the type of knife, material, and level of sharpness do not affect the user's muscle activation, discomfort, time, or slice performance. In the second portion of the study the Pinch Cinch grip was designed to be placed on the knife to create an affordance for users to hold the knife in a pinch grip. This grip aligns the wrist and forearm and decreases fatigue and increases stability and control while cutting. The designed grip, the Pinch Cinch, is to be used as a training mechanism for the consumer to easily adjust to using the pinch grip. The grip was tested with 16 participants against a previously tested knife to ensure it did not require more muscle activation, time, discomfort, or cause lower slice performance. The results showed this grip did not have any significant difference from the knife

with out the grip. The Pinch Cinch did not have any negative effect on the task compares to the other knife tested. The Pinch Cinch can ensure the consumer is maintaining the pinch grip, and allows them to become accustomed to it by having the affordance present. With the use of the Pinch Cinch, the consumer will feel the pinch grip is natural and retain the benefits of more control and stability.

Introduction

Every day, millions of Americans spend time at home preparing food to eat or to serve to their household. In 2014 the US Department of Labor reported that 56.3 percent of the population engaged in food preparation and cleanup (Bureau of Labor Statistics, 2014). For the participating population the average time per day spent on this activity was 1.04 hours (Bureau of Labor Statistics, 2014). There are many different types of people preparing food, and some tasks are difficult to complete because of the strength required, or the position it needs to be done in (Kelsheimer & Hawkins, 2000).

While the younger population might have no trouble completing kitchen tasks, those who are aging or have other disabilities might have problems using certain kitchen tools to prepare food the way they want to (Gustafsson, 2002). Cooking in the kitchen is a necessity for many people, and making tools and tasks easier or less time consuming can have a significant effect on the person's ability to complete them (Ritzel & Donelson, 2001& Bowers, 2000).

Arthritis and old age can greatly affect the task of food preparation (Reisine, Goodenow, & Grady, 1987 & U, 1996). One study interviewed 48 people between the ages of 60 and 90 about food preparation. Of the participants, 19% had trouble completing tasks related to food preparation, or had modifications for ways they could accomplish tasks. 2% of the participants

felt pain while peeling and chopping, and another 2% said they didn't have enough strength in their hands to be able to do certain food preparation tasks. An alternative suggestion was buying prepared meals or pre-sliced vegetables instead of doing the work yourself (Maguire et al., 2014). This is an unfortunate substitute when being able to keep cooking in one's own kitchen with the familiar routine is something the elderly find very rewarding (Maguire et al., 2014). When aging, cooking is the last thing a person wants to give up (Shanas, 1968).

Much of past human factors and ergonomics work in the kitchen has focused on the layout and creating universally designed kitchen tools (Mitchell, n.d.). Sam Farber started OXO in 1990, when his wife suffering from arthritis found kitchen tools increasingly harder to use. He did not want to make a special needs product, so universal design became the philosophy of OXO (Coleman, 2007). OXO is now one of the leading companies in kitchen tools and their approach has been identifying what tools hurt to use and how can they be made more comfortable (Simply better design," 2008). Many of their products feature a comfortable power grip. A power grip wraps the finger and thumb around the tool, and gives the user strength to perform the task (Konz, 1974). While it is important to create tools for essentially everyone to use, there are other areas of food preparation to study (Williamson, 2012). Slicing vegetables is one task a power grip cannot easily be applied to.

Slicing vegetables with a knife is a tiring activity, and there are no easy short cuts or ways to complete the task (Lang, 2000). Although there are many different variables in the knife market-type of knife, material, and sharpness being the three main ones-there is no research done on the consumer level to see if these variables affect the user's ability. This study concentrates on the kitchen task of slicing vegetables, specifically carrots and potatoes, in the home setting. Commercial operations have workers cutting for extended lengths of time. Studies have been

done to examine fields such as meatpacking, where the risk of cumulative trauma is 30 times greater than the average for all other industries (McGorry, Dowd, & Dempsey, 2005).

Professional chefs spend years learning the skills that give them the precision and expertise they need (Trotter, Wareing, Hill, & Hall, 2008). Consumers, on the other hand, do not use a knife for a long length of time when preparing a meal and are not going to dedicate a period of time to learning the proper way to cut each type of food with accuracy. The focus of this study was on how different types of knives, materials, and levels of sharpness affect the user while slicing carrots and potatoes. The user was outfitted with electromyography (EMG) sensors, and the percent of their maximum voluntary contraction (MVC) was used as a metric. The other dependent variables were body part discomfort, the duration of the task, and slice performance, tested from a sampling of their vegetable slices.

There are many types of knives serving different purposes. There are two multipurpose knives recommended for slicing vegetables, the chef knife and the santoku knife. The chef knife is the all-purpose knife most people know and use. It's used for chopping, slicing, dicing, and mincing most any food. This knife lets the consumer use the rocking motions when cutting and its length allows to cut both large and small items. The knife also given the consumer plenty of room for their hands to comfortable stay above the cutting board (Jay & Sur La Table, 2008). Another knife that has gained popularity in recent years is the santoku knife. This is a Japanese utility knife and translates to the "knife of three virtues." There are three different theories for what the three virtues are. The first is the ability to cut fish, vegetables, and meat. The second is that the knife excels in slicing, mincing, and chopping. And the final theory is the ability to use the three parts of the knife for different purposes. The tip of the knife can be used for precision, the main part of the blade for typical slicing, and the heel of the knife for heavy-duty cutting

(Ward & Regan, 2008). These two knives were selected for this study due to their wide range of uses and popularity in the home. Most home cooks are likely to own versatile knives and not ones for specific uses.

One debate about knives is what material is better to use, stainless steel or ceramic. Stainless steel knives have been around for a long time. They're strong, durable, and easily sharpened. These days, new metals are being used and mixed to optimize the knife; for instance, sharp brittle carbon steel is placed between flexible stainless steel, giving the user the sharp brittle metal in the middle, and softer metal surrounding it to keep it in good condition. In the last 25 years, ceramic knives have entered the market. The ceramic blade is 50% stronger than steel, it's sharp, and stays sharp. It makes for a light knife, but it is brittle and cannot be sharpened at home. This knife can do most of the daily tasks, but with hard foods it might not stand up to the challenge (Jay & Sur La Table, 2008).

The third knife variable investigated was how sharpness affects the user. Sharp knives are believed to be safer to use than dull knives. A butcher explained that when you have a dull knife it takes more cuts to cut through than with a sharp knife. The more cuts made, the more likely it is to have the knife slip and have the person cut themselves (Christensen, 2011). Dull knives are also stated to require more force to cut through the food (Henry, n.d.). In a study focusing on commercially cutting meat it was found that sharper blades required significantly less cutting moments and grip forces than the dull blade (McGorry, Dowd, & Dempsey, 2003). Another study found for professional deboners that there were significantly lower EMGs for the flexor digitorum superficialis, biceps brachii, triceps brachii, anterior deltoids, and the upper trapezius muscles (Claudon & Marsot, 2006).

After the completion of the knife comparison study, the author decided to look into what other variables could affect the performance with a knife. After looking through knife skill books, the most interesting thing found was the grip the professionals suggest for slicing vegetables (Jay & Sur La Table, 2008 & Ward, 2008 & Lumb, 2009 & Trotter, Wareing, Hill, & Hall, 2008). The author, along with most consumers, have always held the knife with their fingers around the handle (later referred to as the handle grip) (BDL, 2010). This is the way the knife affords to be held so people intuitively hold it in this manner (Riggio, Patteri, Oppo, Buccino, & Umiltà, 2006). It was intriguing to find the the knife skill books recommend a pinch grip instead (Jay & Sur La Table, 2008 & Ward, 2008 & Lumb, 2009 & Trotter, Wareing, Hill, & Hall, 2008). It was evident to the author that this grip needed to be investigated further because it is the recommended grip and the average consumer does not know about it. This grip has you place your thumb on the knife blade, which is demonstrated in Figure 6, have your index finger curl around the other side of the blade, which is shown in Figure 7, and have your remaining three fingers wrap around the bottom of the handle (Jay & Sur La Table, 2008). The pinch grip is an example of a precision grip. This grip is able to support the tool to reduce any tremble in the tool, increasing the stability and control the user has (Konz, 1974).



Figure 6: Thumb placement for the pinch grip



Figure 7: Index finger placement for the pinch grip

An analogy from *Cutting Edge Knives* is the handle grip is like typing with the end of a pencil (Cutting Edge Knives, n.d.). It is possible, but you have much less control and is harder to do. The pinch grip allows for better control of the knife, and you are able to utilize the length of the knife (Cutting Edge Knives, n.d). There are two major advantages to using the pinch grip. The first advantage is the arm becomes aligned with the wrist and the knife. This gives the knife more stability, more leverage, and reduces fatigue. The second advantage is the grip prevents the knife from moving precariously when coming across an unforeseen wobble or bone (Ward, 2008).

Consumers like the pinch grip, but the challenge is getting used to it (Carter, 2011). One consumer acknowledged that most likely the way you have always held the knife is wrapping your fingers around the knife handle, and it's awkward to to try to switch to a pinch grip. It is not an intuitive grip and takes time to get used to; this consumer thought it would take a few months (BDL, 2010). Another user thought it felt unnatural to have their fingers on the blade, but with time it became, and they achieved more power and control with this grip (I'm Not a Cook, 2012). So why, if this grip gives you more control, is there no easier way to become accustomed to it?

This was the point the authors decided they wanted to make a training tool for consumers to use to learn the pinch grip. This grip would allow the pinch grip to feel natural and remind the consumer of how to hold the knife. In order for it to be viable, the authors wanted to create a grip that would be easily attached and removed from the knife, would be able to be used on any knife, be easily cleaned, and have a universal design. Around the same time as this grip was being developed, FINI Cutlery started a Kickstarter for making knives with short handles. This knife would make the pinch grip mandatory because there was no handle to grasp (Knife News, 2015). While this idea enforces the pinch grip, the authors wanted to create something that could be added to existing knives (Knife News, 2015). This way the consumer could purchase a small add-on that could be moved from knife to knife.

The focus of this study was to create the grip and test it against the findings using the sharp chef knife in the first portion of the study. From the various knife skill books, and user testimonies, it was decided the pinch grip did have advantages, but it was not going to be the focus of the study (Ward, 2008). Instead the focus of the second portion of the study was on the designed grip.

Methods

Grip Development

For the focus of the second portion of the study a grip was designed. In order to promote the pinch grip to knife users, the goal was to create an affordance to add to the knife. The initial step was to do inkings of the grip on the knife for two hand sizes; where the thumb and finger made contact with the blade was documented for a small female hand and a large male hand. From there clay was placed on the blade and formed by holding the knife with a pinch grip. The

thumb grip was made to be a rounded out area big enough to ensure it could fit large thumbs.

The index finger grip was created with two different pathways. There was a separate channel for a small and large index finger. This way people with smaller hands can wrap their finger closer to the blade, and those with larger hands have an option further away. Once the clay models were formed and dried, they were removed from the knife blade. The clay models were laser scanned to create the surface of the grips. 3D models of the grips were made and printed in ABS plastic. This technology made it possible to create one grip to be able to test its effect. The method of creating a mold for one piece would not be a viable option for testing purposes.

In order to satisfy the requirement of easy attachment and removal, and attaching it to any knife, different methods of attachment were considered. Due the criteria, any permanent attachment mechanism was ruled out. The grip needed to stick to the knife, but still be removable. The only option that was able to meet the criteria was to use magnets. Any use of adhesive would be too permanent, and modifying the knife to have an insert for the grip would make it impossible to attach to any knife at home.

Magnets would attach easily to the metal knife, but would make this grip unusable for ceramic knives. In order to allow for a downward force on the grip while cutting, there needed to be a connecting piece over the top of the knife. Magnet sheets were the chosen option. The grips were glued to a magnetic sheet that bent over the spine of the knife. Magnetic sheets are readily available, and would be a practical option if the grip were to be manufactured. The grip was named the Pinch Cinch, and is shown in Figure 8. Figures 9, and 10 show the Pinch Cinch on the knife.

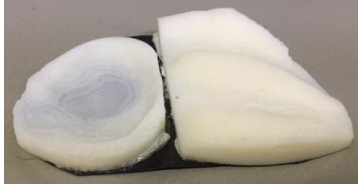


Figure 8: The Pinch Cinch

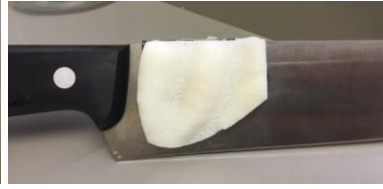


Figure 9: The right side of the Pinch Cinch for the index finger



Figure 10: The left side of the Pinch Cinch for the thumb

Objectives

The first objective of this study was to determine if the type of knife, the knife material, and the knife sharpness affects the user's ability to slice vegetables in terms of muscle activation, body part discomfort, time, and slice performance. The second objective was to see if adding the Pinch Cinch to enforce the pinch grip on the knife would negatively affect the user in terms of muscle activation, body part discomfort, time, and slice performance.

Hypotheses

The hypotheses for both portions of the study were:

- The ceramic knife will result in a lower amount of muscle activation, lower task time, higher slice performance, and lower body part discomfort than the stainless steel knife.
- The sharp knife will result in a lower amount of muscle activation, lower task time, higher slice performance, and lower body part discomfort than the dull knife.
- The chef knife will result in a lower amount of muscle activation, lower task time, higher slice performance, and lower body part discomfort than the santoku knife.
- Using the Pinch Cinch will not increase muscle activation, body part discomfort scores, time, or decrease slice performance compared to the knives used in Project 1.

Participants

For the first portion of the study participants were recruited from an undergraduate engineering course and earned extra credit from their participation. There were 50 participants. There were 11 females and 39 males. The average age was 21 years old, with a range from 19 to 32. For the second portion of the study, participants were recruited from a graduate level engineering course and earned extra credit for their participation. There were 16 participants. There were four females and 12 males. The average age was 25 years old with a range from 20 to 36. Only right handed participants were included in the second portion, due to the way the Pinch Cinch was designed. Both studies were done under approval from the Human Subject IRB, and the IRB approval can be seen in Appendix A.

Independent Variable

There were three independent variables tested, as shown in Table 1.

Table 1: Independent Variables and Levels

Independent Variable	Level 1	Level 2
Type of Knife	Chef	Santoku
Knife Material	Stainless Steel	Ceramic
Sharpness	Sharp	Dull

For the study, the participants were required to test two knives, each on a different day. The study had four different knives, with two paired together. The first pair was a sharp JA Henckels International chef knife acquired from Amazon.com and a dull JA Henckels International chef knife. The knives were the same, but one was dulled. The chef's knife is shown in Figure 11. The second pair was a sharp JA Henckels International santoku knife

acquired from Amazon.com, shown in Figure 12, and a sharp KitchenAid ceramic chef knife purchased from Target in Ames, IA, shown in Figure 13. Both JA Henckels International chef knives and the JA Henckels International santoku knife had the same handle. A ceramic knife with the same grip was not available, so another brand and design was used. This knife has a soft grip to it, while the JA Henckels brand knives were hard. The order of the paired knives was balanced among the participants. Table 2 shows the knife characteristic combinations tested, where there are three comparisons, stainless steel chef knife sharp and dull, stainless steel chef knife sharp and ceramic chef knife sharp, and stainless steel chef knife sharp and stainless steel santoku knife sharp.

In order to maintain the same level of sharpness, an EST K100 Knife Edge Sharpness Tester, obtained from Amazon.com, was used. A tolerance zone was developed to ensure the sharp knife remained at the same sharpness, and the dull knife remained at the same dullness (Edge On Up, n.d.). The sharp knives had to be in the 350-450 range, which represent high end cutlery. The dull knives were in the range of 1200-1300, where a knife at 650 is at need to sharpening.



Figure 11: JA Henckels International chef knife



Figure 12: JA Henckels International santoku knife



Figure 13: KitchenAid ceramic chef knife

Table 2: Knife Comparison Study Setup

	Stainless Steel	Ceramic
Chef Knife	Sharp Dull	Sharp
Santoku Knife	Sharp	

For the second study only the sharp chef knife was used with the Pinch Cinch. Table 3 shows the set up for the knife comparison for the second portion of the study.

Table 3: Grip Effect Study Comparison

Knife Characteristic	Knife	Reference
Effect of the Grip	JA Henckels International Chef Knife- Sharp with the grip	JA Henckels International Chef Knife- Sharp

Procedure

For the first portion of the study there were two different procedures followed for the two vegetables sliced. Both carrots, whole and packaged in two pound bags, and potatoes, russet potatoes from a 10-pound bag were chosen to cut because they provide resistance and required a certain amount of strength to cut through.

When the participant arrived, they were given the informed consent and an overview of the study. Having given their consent, the participant was shown a video on either how to slice carrots or potatoes. The video “How to Slice a Carrot” shared the key point of keeping your knife tip on the cutting board (mahalodotcom, 2011). The video “How to Slice Potatoes” showed the participant how to effectively slice a potato (MonkeySee, n.d.). After watching the video and confirming their understanding, the participant was given a body part discomfort form to fill out.

EMG sensors were placed on the participant and MVCs were collected. Participants were given verbal feedback to encourage them to put in their maximal effort (Jung & Hallbeck, 2004).

The participant was introduced to the testing environment, consisting of a counter top at the standard height of 36" and a cutting board (Crews & Zavotka, 2006). The participant was given the knife to use and the carrots or potatoes to slice. Each participant was given two pounds of carrots to slice, which represents the upper end of a recipe one might follow at home ("Apricot Glazed Carrots Recipe," n.d.). They were told to cut the carrots in 1/2" slices using only their dominant hand on the knife. The participants slicing the potatoes were given two pounds of potatoes to slice into 1/2" slices using only their dominant hand (O'Sullivan, n.d.). There was a diagram given to them to show the desired size of the slices, which is shown in Appendix D. They were given a bin to move the slices into. With no further questions, the participant started and the EMG recording software was started. Once the participant sliced all the carrots or potatoes, the EMG data collection was stopped and saved. The participant was given another body part discomfort survey to fill out. The time taken was noted from the EMG software, which recorded the time along with all the EMG data for the duration of the task. The procedure can be seen in Figure 14.

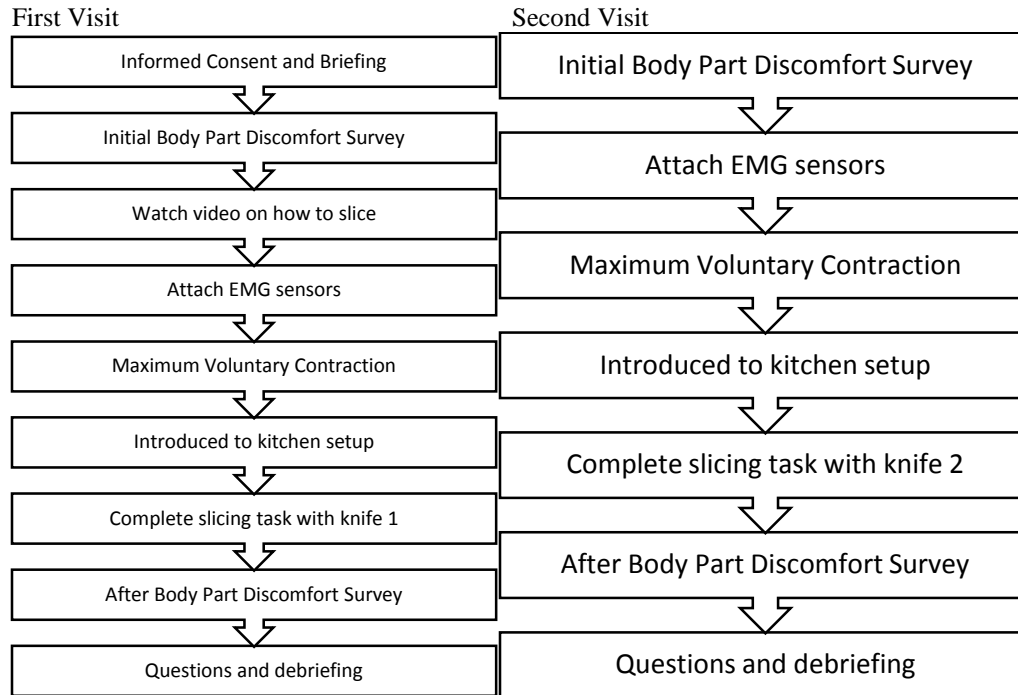


Figure 14: Procedure for the first portion of the study

There were a few minor changes to the procedure for the second portion of the study. The participant only had to come once. They only sliced carrots, and they had to use the Pinch Cinch on the knife. Before they used the Pinch Cinch, it was explained to them how to use it correctly. The procedure is diagramed in Figure 15.

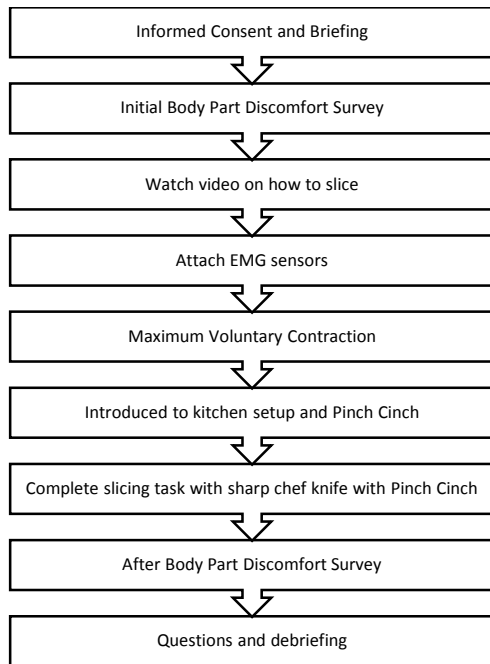


Figure 15: Procedure for the second portion of the study

Metrics

The metrics were the same for both portions of the study, and are outlined in Table 4. EMG was used to capture the muscle activity during the study. This was done using the BioGraph infinity software package from Thought Technology and EMG MyoScan Pro sensors. Graphs of the muscle activation levels were shown throughout the duration of the study, and the raw data was exported at the completion of the task. The activity of four muscles was recorded: the extensor digitorum, carpi radialis, biceps brachii, and triceps brachii. Maximum voluntary contractions (MVC) were found, and the average EMG over the task were used to find the percent MVC reached. Participants were given a body part discomfort survey before and after the study. The participant was asked to rate how much discomfort they were experiencing in their thumb, fingers, lower arm, upper arm, and shoulder for their dominant arm. The scale went

from 1 to 10, 1 being no discomfort and 10 being the maximum discomfort. The survey is shown in Appendix B. The change in discomfort was recorded for each body part.

The time it took to complete the task was recorded from the EMG software. The last metric for the study was the slice performance, where a random sample of large number of slices was tested for size. For the carrots, ten slices were tested on the tolerance zone of $\pm 1/8$ " on the $1/2$ " slice. For the potatoes, five slices were tested to see if they met the tolerance zone of $\pm 1/8$ " on the $1/2$ " slice. Each slice either met the criteria or did not. The device created for testing the size is shown in Appendix C.

Table 4: Dependent Variables

Variable	Metric	Unit	How?
Muscle Activation	Electromyography	% MVC reached	Average EMG over the task/MVC
Body Part Discomfort	Change in discomfort	Likert scale	Before and after surveys
Slice Performance	How many sliced fit the thickness criteria	% Good	Sample of slices tested for a tolerance zone
Time	How long to complete the task	Minutes	Times using the EMG software

Data Analysis Plan

In order to test each individual hypothesis, about the type of knife, material, and sharpness, the two knives will be compared using a paired t-test using a p value of 0.05. The knives to be compared on each characteristic are shown in Table 5. This portions of the analysis will show if there was a significant difference in type of knife, material, and sharpness for any of the metrics used. After each knife characteristic has been analyzed, all four knives will be compared to see if there were any significant differences between them. This will be done

through an ANOVA, and will allow the knives to be compared not just according to the characteristic they were tested for. For the second portion of the study, the use of the Pinch Cinch will only be compared to the sharp chef knife data. This will be analyzed using a paired t-test with a p value of .05. This will show if adding the Pinch Cinch significantly affects any of the metrics.

Table 5: Knife Characteristics for paired t-tests

Knife Characteristic	Knife #1	Knife #2
Type of Knife	JA Henckels International Chef Knife- Sharp	JA Henckels International Santoku Knife
Knife Material	JA Henckels International Chef Knife- Sharp	KitchenAid Ceramic Chef Knife
Sharpness	JA Henckels International Chef Knife- Sharp	JA Henckels International Chef Knife-Dull
Effect of the Grip	JA Henckels International Chef Knife- Sharp with the Pinch Cinch	JA Henckels International Chef Knife- Sharp

Results

Electromyography- Knife Comparison

The results for the average % MVC for the extensor digitorum are shown in Figure 16. For both vegetables and for all four knives, the variability was high and the standard deviation overlapped. A series of ANOVA and paired t-tests were completed to confirm there was no statistically significant difference between the knives for the average % MVC for the extensor digitorum.

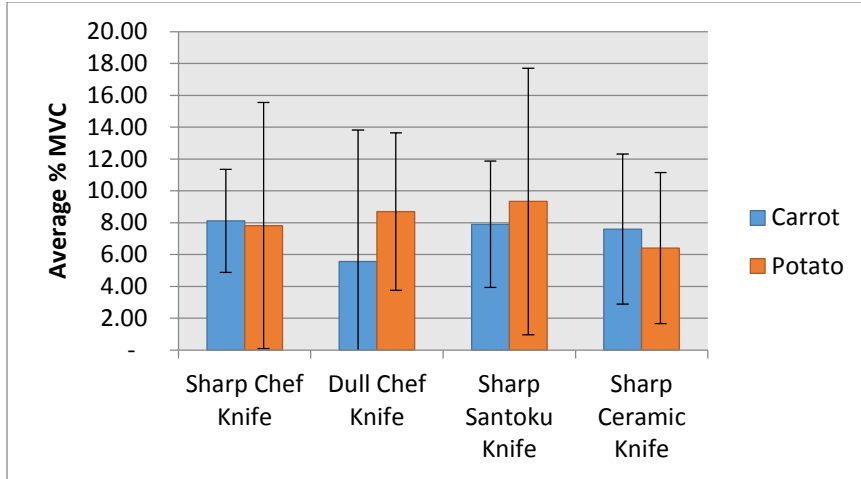


Figure 16: % MVC for the Extensor Digitorum with standard deviation (n=50; $p > 0.05$)

The results for the average % MVC for the carpi radialis are shown in Figure 17. A series of ANOVA and paired t-tests were completed to confirm there was no statistical significance between the knives for the average % MVC for the carpi radialis.

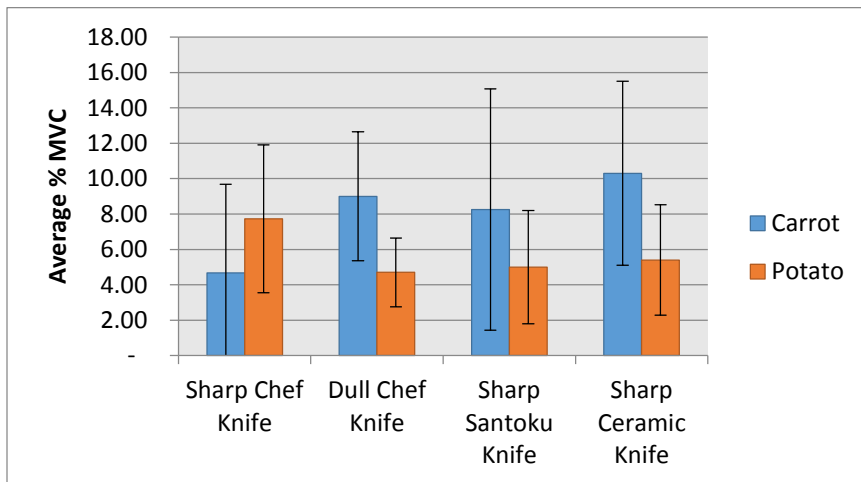


Figure 17: % MVC for the Carpi Radialis with standard deviation (n=50; $p > 0.05$)

The results for the average % MVC for the biceps brachii are shown in Figure 18. The differences between the knives were confirmed to be statistically insignificant by completing a series of ANOVA and paired t-tests.

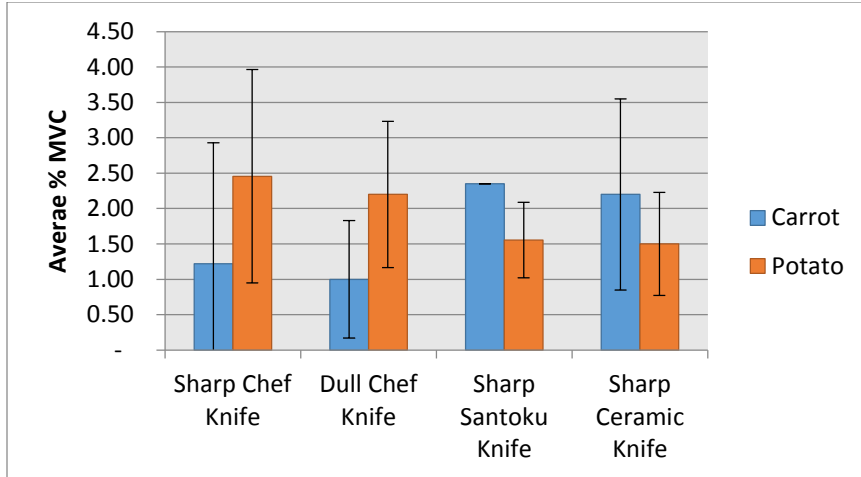


Figure 18: % MVC for the Biceps Brachii with standard deviation (n=50; $p > 0.05$)

The average % MVC results for the triceps brachii are shown in Figure 19. The standard deviations overlapped and a series of ANOVA and paired t-tests were conducted to confirm there were no statistically significant differences between the knives.

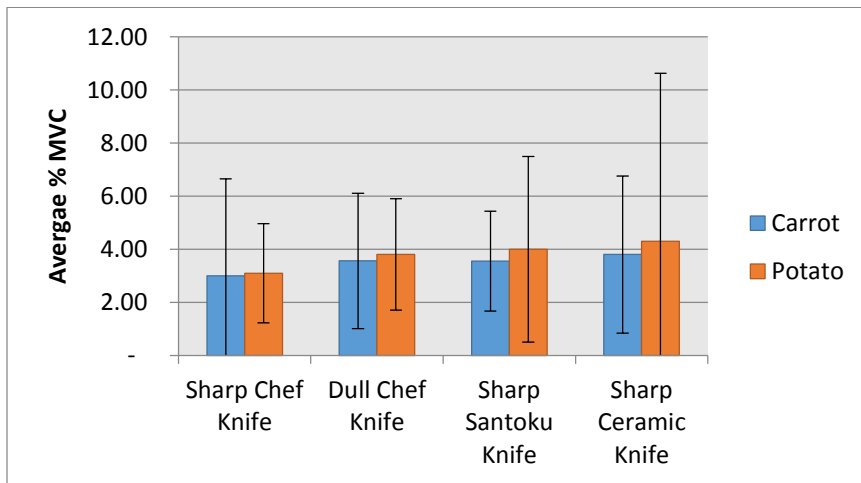


Figure 19: % MVC for the Triceps Brachii with standard deviation (n=50; $p > 0.05$)

Body Part Discomfort- Knife Comparison

The results for the change in body part discomfort for the fingers are shown in Figure 20. The results were statically insignificant by a series of ANOVA and paired t-tests.

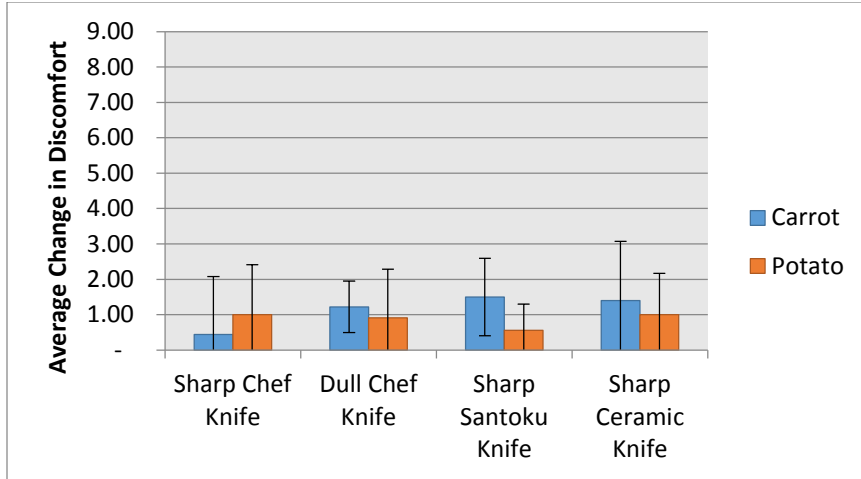


Figure 20: Change in Finger Discomfort with standard deviation (n=50; $p > 0.05$)

The results for the average change in body part discomfort for the thumb are shown in Figure 21. The large standard deviations as well as the performed series of ANOVA and paired t-tests showed there was no statistical significance between any of the knives.

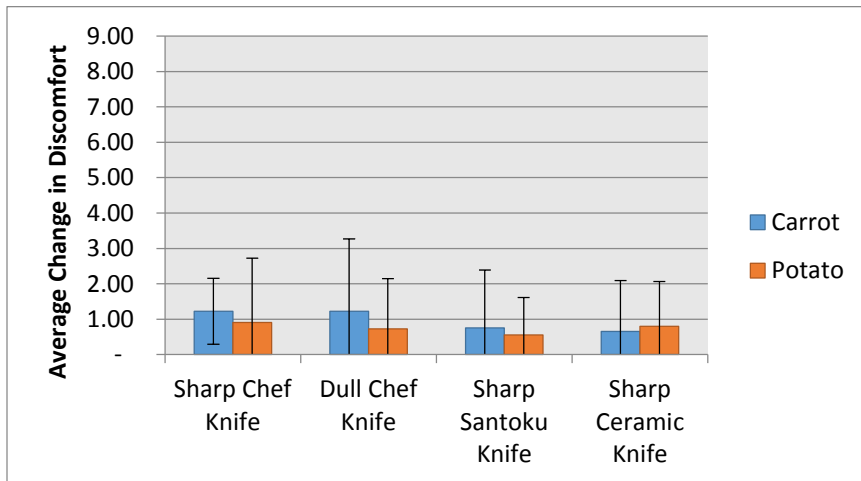


Figure 21: Change in Thumb Discomfort with standard deviation (n=50; $p > 0.05$)

For the lower arm body part discomfort the results are shown in Figure 22. A series of ANOVA and paired t-tests were performed and resulted in no statistical significance.

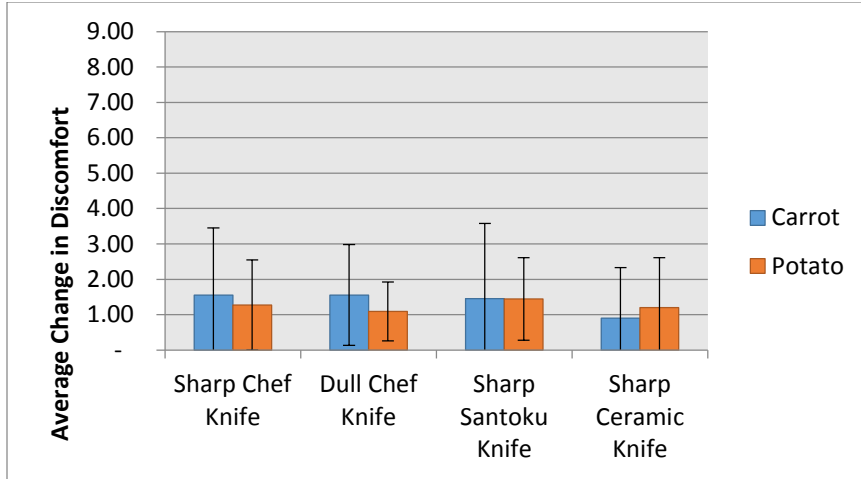


Figure 22: Change in Lower Arm Discomfort with standard deviation (n=50; $p > 0.05$)

The results for the average change in discomfort for the upper arm are shown in Figure 23. The large amount of standard deviation showed little chance of significance, and the difference was confirmed to be statistically insignificant through a series of ANOVA and paired t-tests.

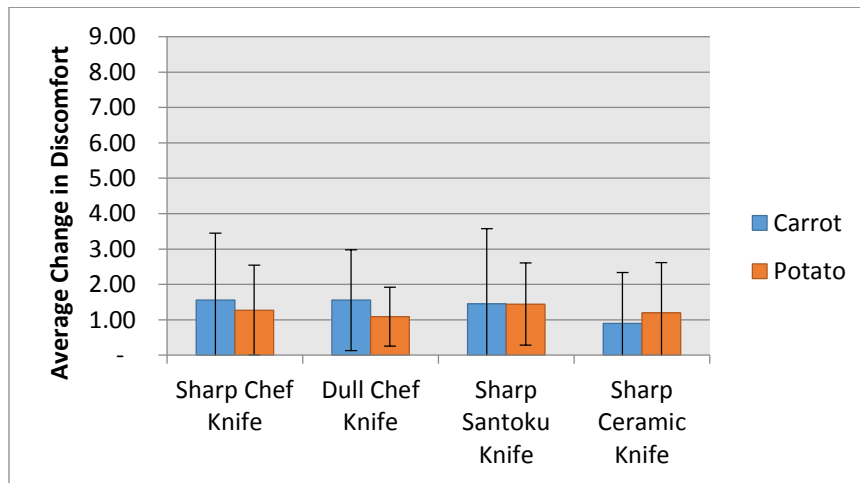


Figure 23: Change in Upper Arm Discomfort with standard deviation (n=50; $p > 0.05$)

The shoulder was the last body part to be surveyed for discomfort and the results are shown in Figure 12. A series of ANOVA and paired t-tests were performed and it was concluded the differences between the knives were statistically insignificant.

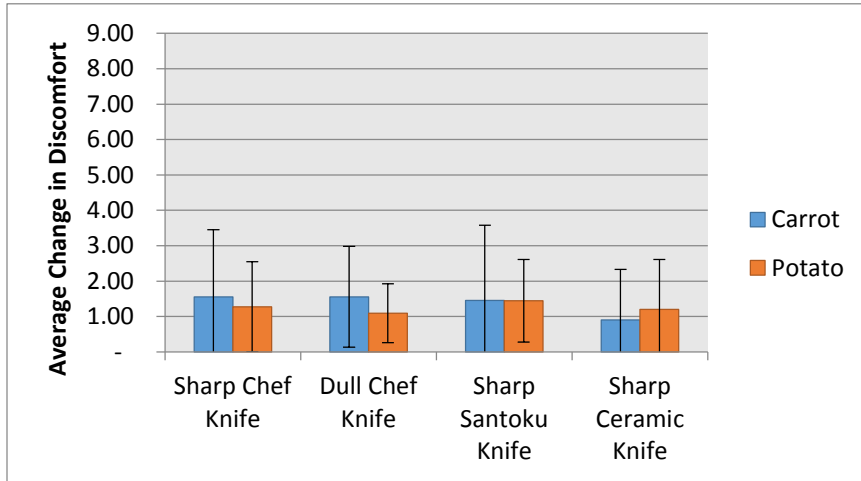


Figure 24: Change in Shoulder Discomfort with standard deviation (n=50; $p > 0.05$)

Slicing Performance- Knife Comparison

The results for slice performance are shown in Figure 25. The results showed no significant difference through running a series of ANOVA and paired t-tests.

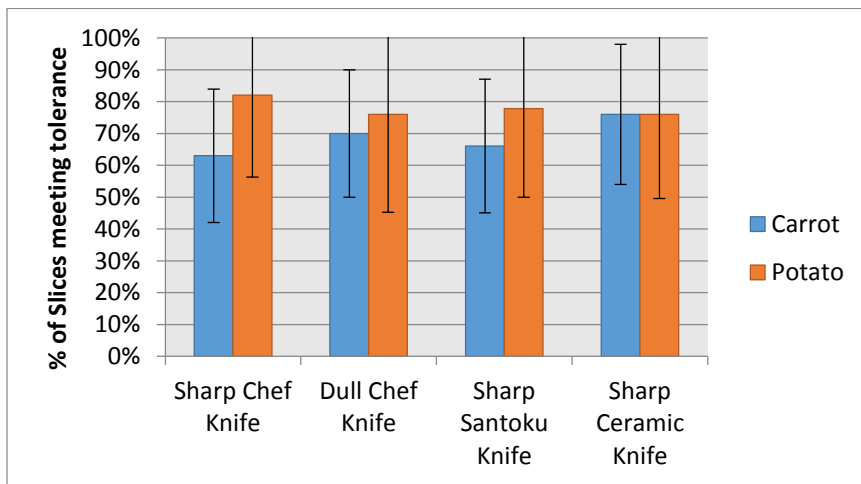


Figure 25: Performance Ratings of Carrot Slices with standard deviation (n=50; $p > 0.05$)

Time- Knife Comparison

The results for time are shown in Figure 26. A series of ANOVA and paired t-tests were conducted and the time difference between the knives was not statically significant.

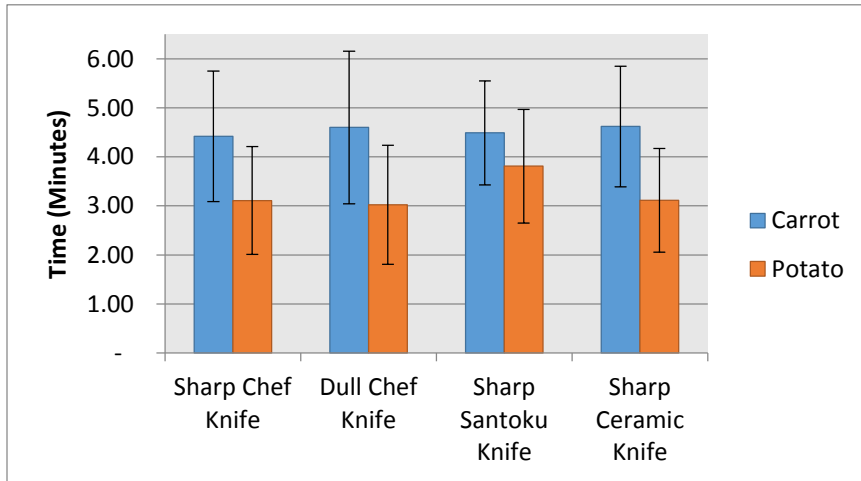


Figure 26: Time of task with standard deviation (n=50; p > 0.05)

Electromyography- Pinch Cinch

The results for the average extensor digitorum % MVC for the Pinch Cinch in comparison to the sharp chef knife are shown in Figure 27. The Pinch Cinch did not have any statistically significant differences from sharp chef knife, and did not negatively impact the cutting operation on the extensor digitorum. This was tested through a paired t-tests.

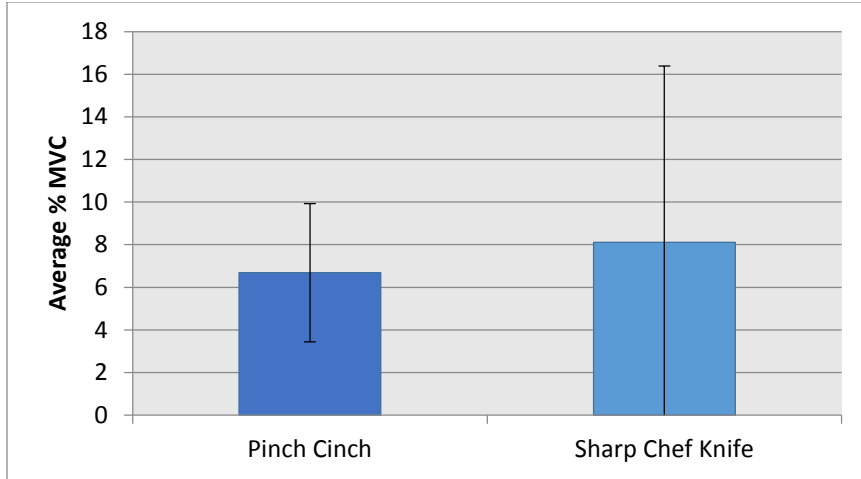


Figure 27: % MVC for the Extensor Digitorum with the Pinch Cinch with standard deviation (n=16; $p > 0.05$)

The results for the Pinch Cinch for the average %MVC for the carpi radialis are shown in Figure 28. A paired t-test was performed, and there was no statistically significant difference found between the Pinch Cinch and sharp chef knife. The Pinch Cinch did not negatively impact the muscle activation for the carpi radialis.

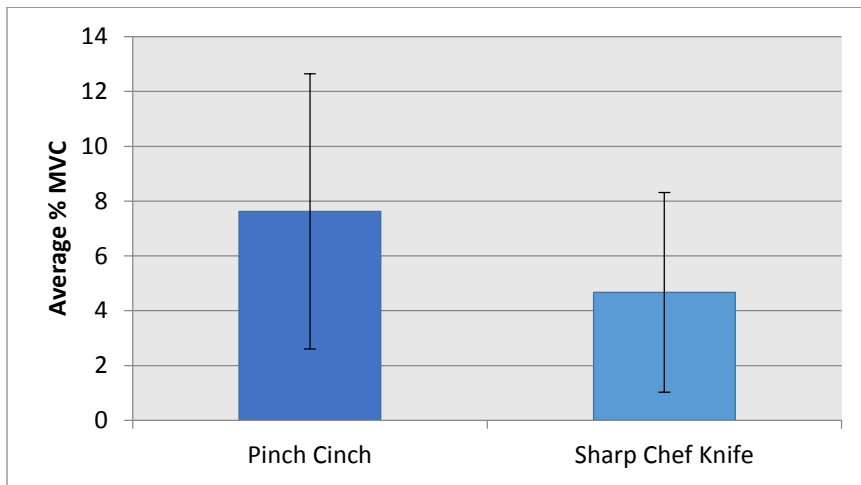


Figure 28: % MVC for the Carpi Radialis with the Pinch Cinch with standard deviation (n=16; $p > 0.05$)

The results for the average muscle activation for the biceps brachii are shown in Figure 29 for the Pinch Cinch. The Pinch Cinch was found to have no statistically significant difference through a paired t-test. This added grip did not affect the average % MVC for the biceps brachii.

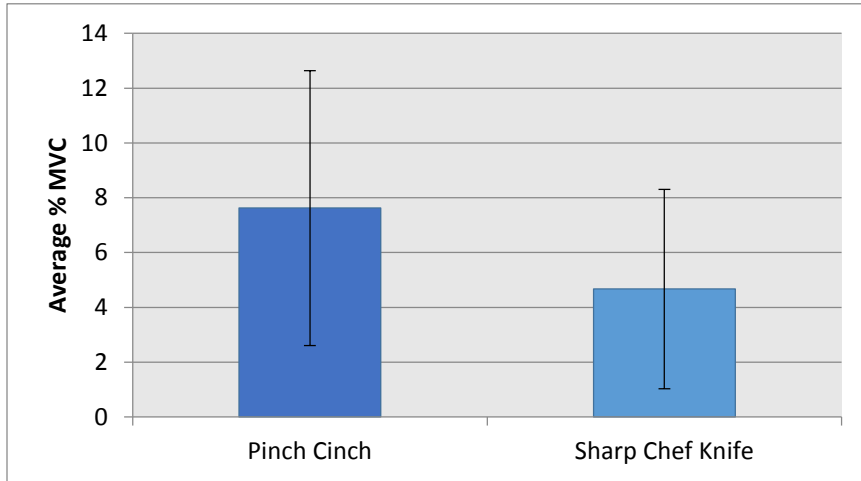


Figure 29: % MVC for the Biceps Brachii with the Pinch Cinch with standard deviation (n=16; $p > 0.05$)

The results for the average % MVC for the triceps brachii when using the Pinch Cinch are shown in Figure 30. While the % MVC was higher, it was not statistically significant because of the high amounts of variability. This was tested through a paired t-test, and it was concluded the Pinch Cinch did not negatively affect the triceps brachii for this task.

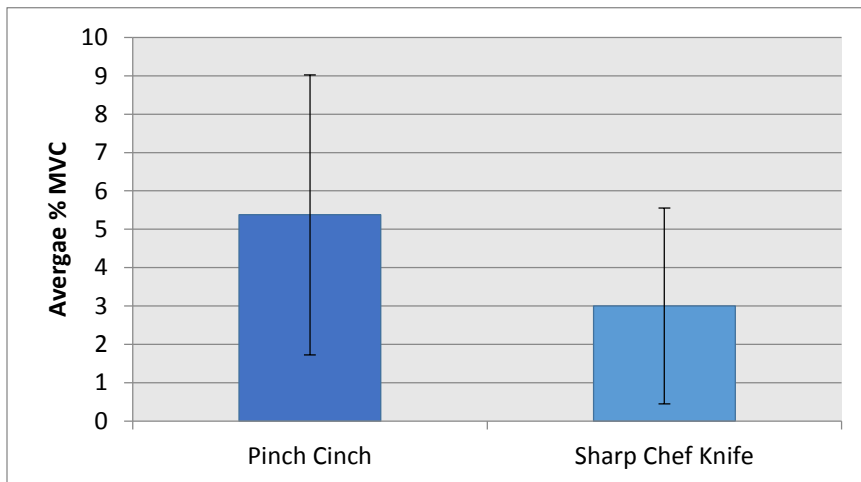


Figure 30: % MVC for the Biceps Brachii with the Pinch Cinch with standard deviation (n=16; $p > 0.05$)

Body Part Discomfort- Pinch Cinch

The results for body part discomfort for the fingers while using the Pinch Cinch are shown in Figure 31. A paired t-test was performed and it was found that there was not a statistically significant difference between the Pinch Cinch and the sharp chef knife. The Pinch Cinch did not have a different effect on the discomfort on the fingers than the sharp chef knife.

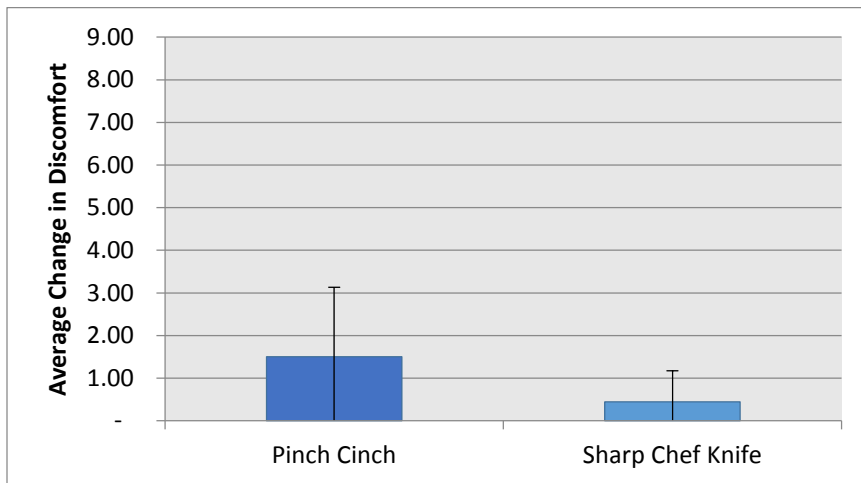


Figure 31: Change in Finger Discomfort with the Pinch Cinch with standard deviation (n=16; $p > 0.05$)

The results for the discomfort experienced in the thumb are shown in Figure 32. The statistical significance was tested through a paired t-test. The Pinch Cinch did not impact the discomfort experienced in the fingers, as there was no statistical differences between it and the sharp chef knife.

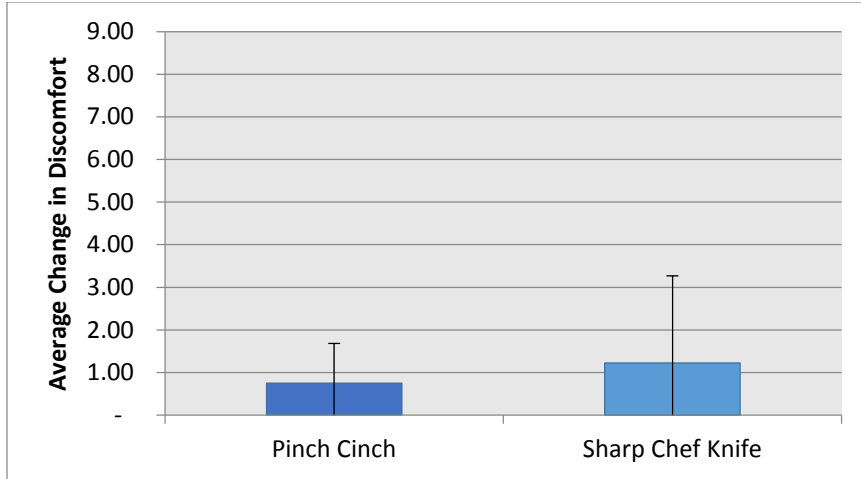


Figure 32: Change in Thumb Discomfort with the Pinch Cinch with standard deviation (n=16; $p > 0.05$)

The discomfort experienced in the lower arm for the Pinch Cinch is shown in Figure 33. The statistical significance was tested through a paired t-test. There was no statistically significant difference found, meaning the Pinch Cinch did not negatively affect the task.

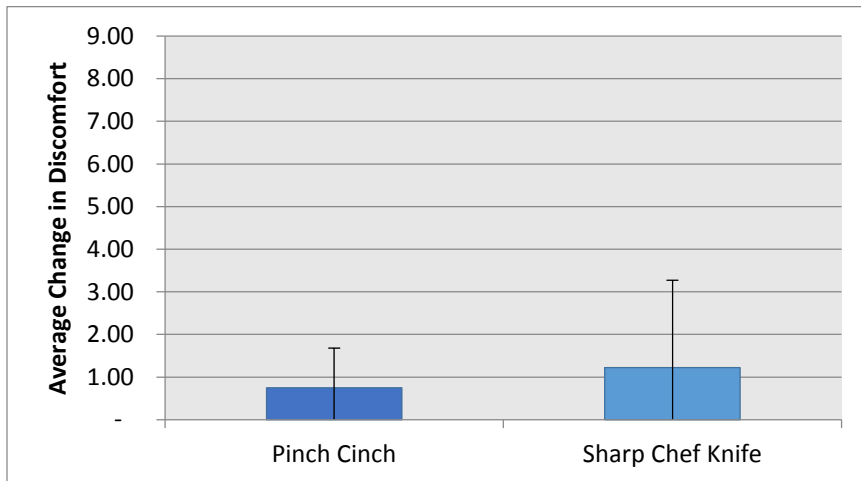


Figure 33: Change in Lower Arm Discomfort with the Pinch Cinch with standard deviation (n=16; $p > 0.05$)

Figure 34 shows the results for the average discomfort felt in the upper arm from the Pinch Cinch. A paired t-test was completed and there was no statistically significant difference

between the Pinch Cinch and sharp chef knife. The Pinch Cinch did not affect the user in a negative way.

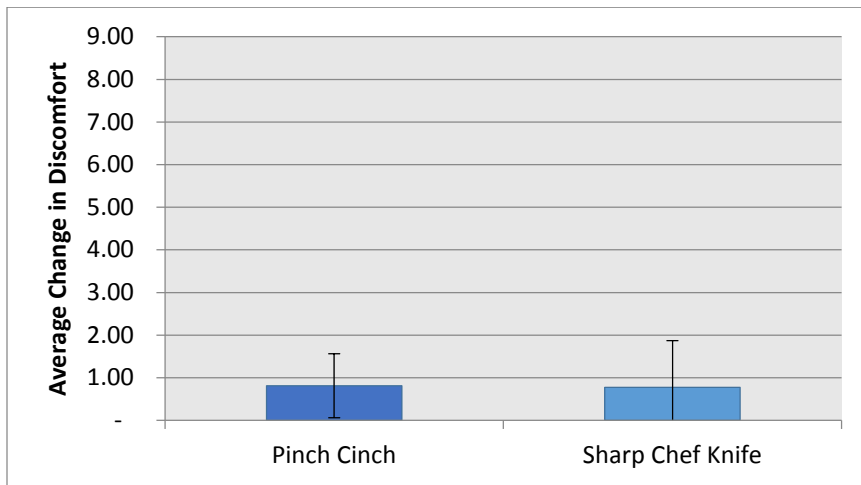


Figure 34: Change in Upper Arm Discomfort with the Pinch Cinch with standard deviation (n=16; $p > 0.05$)

The result for the discomfort in the shoulder are shown in Figure 35. A paired t-test resulted in no statistically significant differences between the Pinch Cinch and sharp chef knife. The Pinch Cinch did not affect the discomfort of the shoulder any differently than sharp chef knife.

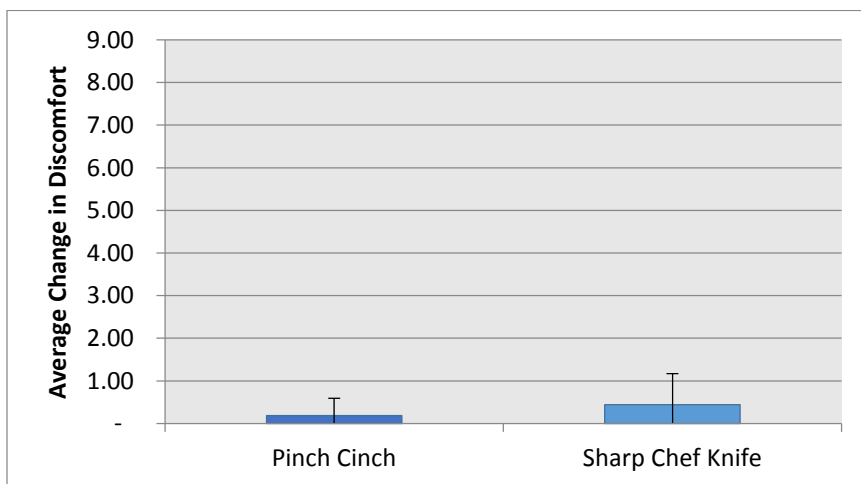


Figure 35: Change in Shoulder Discomfort with the Pinch Cinch with standard deviation (n=16; $p > 0.05$)

Slice Performance- Pinch Cinch

The results for slice performance with the Pinch Cinch were compared to the sharp chef knife are shown in Figure 36. A paired t-test was performed and it was determined that there was no statistically significant differences between the Pinch Cinch and the sharp chef knife. The Pinch Cinch did not positively or negatively affect the slice performance of the task.

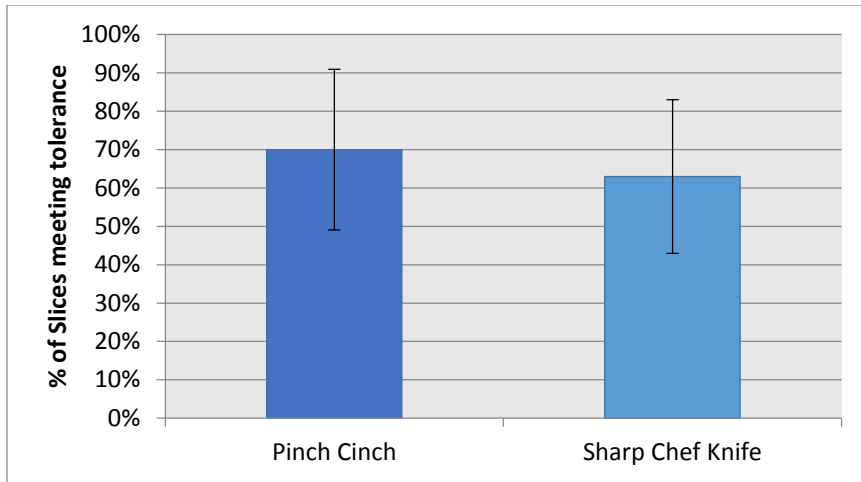


Figure 36: Performance Ratings of Carrot Slices with Grip with standard deviation (n=16; $p > 0.05$)

Time- Pinch Cinch

The results for time for the task when using the Pinch Cinch were compared to sharp chef knife and are shown in Figure 37. A paired t-test was performed and there were no statistically significant differences between the time it took with the Pinch Cinch and the sharp chef knife. The Pinch Cinch did not have an effect on the time it took to complete the task.

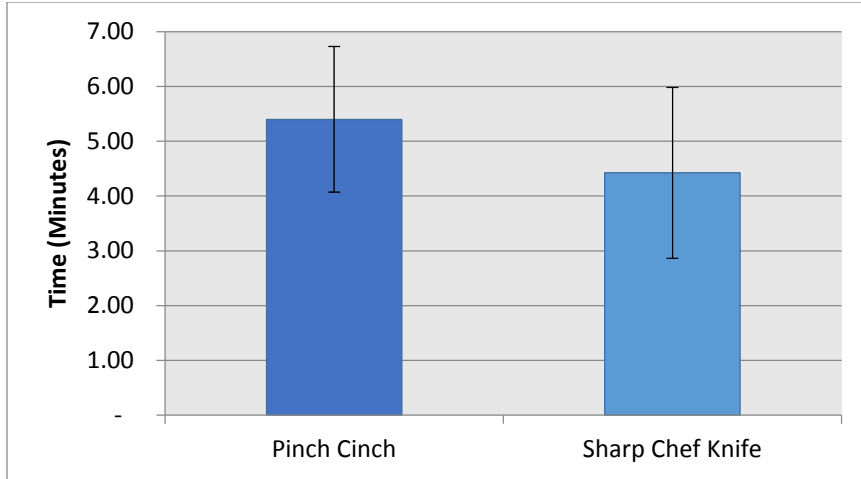


Figure 37: Time of Task with Pinch Cinch with standard deviation (n=16; $p > 0.05$)

Discussion

From the electromyography results it was shown that for the four muscles tested: the extensor digitorum, carpi radialis, biceps brachii, and triceps brachii, there were no statistically significant differences between the knife characteristics tested. It was expected that the dull chef knife would require more muscle activation to complete the task that using the sharp chef knife. This did not prove true; there was no trend or significant difference between the sharp and dull knife for either vegetable sliced. The difference between the chef and santoku knife was hypothesized to be that the chef knife would require less muscle activation. The lack of difference resulted in no statically significant difference in muscle activation between the two types of knives. The last expectation was that the ceramic knife would perform better than the stainless steel knife. Again there was no statistically significant difference between the two. The lack of difference could most likely be attributed to the time it took to complete the task. The duration of the study lasted around five minutes, and might not have been long enough to see a change in muscle activation levels. While more time might have shown a change in EMG, it would also veer towards not being a realistic consumer task.

The body part discomfort survey covered five different body parts: the fingers, thumb, lower arm, upper arm, and shoulder. For each of these body parts there were no statistically significant differences between the different knife characteristics tested. The hypothesis the dull chef knife would result in less body part discomfort than the sharp chef knife was rejected, along with the other two hypotheses being the ceramic would result in less than the stainless steel, and the chef would result in less than the santoku. Again the short cutting time could have impacted the change is discomfort. Also since the participant did not have a definite baseline for what degree of discomfort they were feeling, the results might not have portrayed a difference in discomfort.

The last two metrics, slice performance and time also proved to be statistically insignificant for the different knives. All three hypotheses were rejected that said the dull knife would take longer and have worse slice performance than the sharp knife, the stainless knife would take longer and have worse slice performance than the ceramic knife, and the santoku knife would take longer and have worse slice performance than the chef knife. Different users performed the task at different speeds, and causes a high amount of variability in the time it took to complete the study. Also even though users were given a template of the size desired for the slices, the participants did not always focus on cutting that size. Some participants were very precise, and had all their slice very similar in size, but were not very accurate in their slices, and had a low amount of accepted slices.

All the results showed there was no statistically significant differences between the knife characteristics. This means that for the short time a consumer is cooking at home it does not matter what type of knife they use in terms of muscle activation, body part discomfort, time, and slice performance. There could have also been a floor effect with the metrics collected. The %

MVC reached and the change in body part discomfort were all small numbers. Since the numbers were so small it would have been difficult to see a difference between the knives.

Since there were no differences experienced between the knives tested, it brought about the question if anything would make a significant difference in cutting. Options brainstormed for future work were cutting other types of food, using a different grip on the knife, picking a different type of knife task, trying other knife materials, and redesigning the knife blade. The grip was chosen to explore.

The Pinch Cinch was tested against the sharp chef knife in order to determine if it hindered the performance of the task in terms of muscle activation, body part discomfort, time, and slice performance. The muscle activation results showed there was no effect of using the Pinch Cinch over the sharp chef knife during the slicing task. For the body parts tested for discomfort, there were no statistically significant differences between the discomfort experienced with the Pinch Cinch and the discomfort experienced with sharp chef knife. The slice performance for the Pinch Cinch did not yield any significant differences from the sharp chef knife. The time it took to complete the task with the Pinch Cinch was not statistically significant and therefore did not affect the time. For each metric the Pinch Cinch did not have any effect on the task. In this study the Pinch Cinch did meet the objective of the design, the participants were able to hold the knife in the pinch grip, and experienced the same amount of muscle activation and discomfort, took the same amount of time, and had the same level of slice performance. This tool can be utilized to learn the pinch grip and become accustomed to it without it hindering the user in any way. The pinch grip allows for more control and less slippage, creating a safer cutting environment.

The purpose of creating the Pinch Cinch was to be used as a training tool to get the consumer to remember how to hold the knife and to get comfortable with the pinch grip. When this grip becomes natural for the consumer, they can start using the knife without the Pinch Cinch. The Pinch Cinch has no negative effects on slicing vegetables and getting the consumer to get accustomed to the pinch grip is the biggest obstacle to using the pinch grip. The challenge the Pinch Cinch is made to overcome is making the pinch grip feel natural. The bare knife has no affordances to show the pinch grip. With the use of the Pinch Cinch the user knows where to place their fingers. With this device the consumer has the advantages of having their knife, wrist, and forearm aligned, decreasing fatigue, and increasing control and stability. The Pinch Cinch was not tested for training effects, but that could be a next step to see how the users feel about using it.

There were a few other factors that could have impacted the study. One limitation for this study was it only consisted of cutting carrots and potatoes. These foods are similar in the cutting style, and are only two examples of foods that are sliced with a knife. Different foods require different forces, and meat might be a food that having a sharp knife is important (Brown, James, & Purnell, 2005). For this study it was not economical to cut meat, and it would also have been a biohazard in the lab to have raw meat. Again the time could have had an impact, if the participants had cut for a longer time, they might have experienced more fatigue and discomfort. Another option would have been to slice for a specific amount of time instead of an amount. This was not chosen because the participant might not have put as much effort in if they had to cut for an amount of time, instead of get through the vegetables they had in front of them. The participants were all from the college population and no older adults were used as participants. Another limitation was the grip of the ceramic knife was different than the handles of the other

knives. One assumption for the second portion of the study was that the participant would not experience a learning curve when using the Pinch Cinch with the knife. Only one Pinch Cinch was designed, and it was made for right handed people, so only right handed people were able to participate in the second portion of the study.

Conclusion

For all of the metrics tested: electromyography, body part discomfort, time, and slice performance, there were no significant differences between the different knives tested for slicing carrots or potatoes. The Pinch Cinch did not have any statistically significant impact on EMG, body part discomfort, time, or slice performance compared to the sharp chef knife. To a consumer cooking in the kitchen, the characteristics of their knife are not influential in their performance of small cooking tasks and the addition of the Pinch Cinch did not have any negative impact on the task, in terms of muscle activation, body part discomfort, time, and slice performance. The Pinch Cinch is designed to overcome the challenge of becoming used to the pinch grip. The Pinch Cinch gives the consumer the advantages of the pinch grip, less fatigue, more stability and control, while having an intuitive and easy to use grip.

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CHAPTER 4

OVERALL CONCLUSIONS

In this study two different things were tested. The first portion of the study investigated the impact of knife characteristics on muscle activation, body part discomfort, time, and slice performance. The type of knife, santoku or chef, the material of the knife, stainless steel or ceramic, and the sharpness of the knife, sharp or dull, did not have a significant effect on the metrics tested. The lack of significant differences, means for the common consumer the knife they chose to use for a short kitchen task will not affect their performance. For the second portion of the study a grip was designed to enforce the pinch grip. The pinch grip is the recommended grip because it gives the user more control and stability due to having the knife, wrist, and forearm aligned. This grip is also less fatiguing for the user. The designed grip provided to user the affordance to hold the knife in a pinch grip and was tested to see if it caused any negative effects. There were no statistically significant differences between muscle activation, body part discomfort, time, and slice performance for the knife tested with the grip and with the sharp chef knife tested in the first portion of the study. This added grip gives the user the benefits of the pinch grip, which include more stability, more control, and less fatigue, without hindering performance.

CHAPTER 5

FUTURE WORK

This study has focused on the cumulative trauma risk involved with repetitive actions, such as slicing and has paved the way for more interesting studies to follow. With the results having no significant difference, the focus on knives could transition from cumulative trauma to acute trauma, meaning the results of a single event such as a slip of the knife. This study could be repeated with metrics focused on the control of the knife and if more acute trauma would occur with one type of knife characteristic over another. One way this could be tested would be through purposely introducing unexpected events to the participant, such as a carrot wobbling. Through this action, the amount of control and the slippage of the knife could be quantified. Carrots are just one example of a food that consumers slice in their home. This study could be replicated with other foods, to see if the grip would make a difference with a food with a different texture. Meat for instance has a very different consistency, and might show different results. Another study could be designed to test precision. The ½” carrot slices were chosen initially before the pinch grip was a focus. With the pinch grip consumers should have an easier time making precise slices. By making the intended size of the carrot much smaller, the results might yield a difference in the slice performance of using the Pinch Cinch and using a knife without the pinch grip. Extending the task time could also have a significant effect on the study. With a longer task duration, participants would likely feel more muscle fatigue and more discomfort. The Pinch Cinch could also be tested as a training device to see how effective it is, as well as collect participant's thoughts and feelings about it. This would be a vital step forward, if this product were to be commercially produced.

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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: 11/16/2015

To: Olivia Janusz
119 Stanton Avenue Apt. 426, Ames, IA 50014

CC: Dr. Richard T Stone
3004 Black Engineering

From: Office for Responsible Research

Title: Evaluation of Modern Day Cooking Utensils: an ergonomic and biomedical approach to design

IRB ID: 14-256

Approval Date: 11/16/2015 **Date for Continuing Review:** 6/30/2016

Submission Type: Modification **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, 1138 Pearson Hall, 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
BODY PART DISCOMFORT SURVEY

On a scale 1-10. 1 being no discomfort, 10 being maximum discomfort rate the following body parts

Dominant hand fingers

1 2 3 4 5 6 7 8 9 10

Dominant Hand Thumb

1 2 3 4 5 6 7 8 9 10

Dominant Lower arm

1 2 3 4 5 6 7 8 9 10

Dominant Upper arm

1 2 3 4 5 6 7 8 9 10

Dominant Shoulder

1 2 3 4 5 6 7 8 9 10

APPENDIX C

CARROT SLICE DIAGRAM

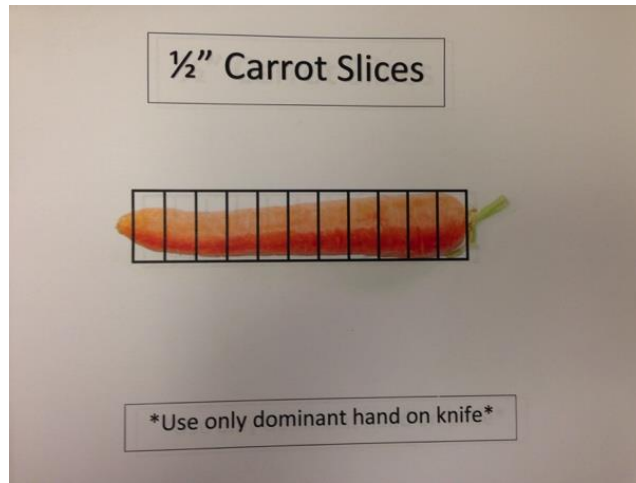


Figure 38: Size diagram given for carrot slices

APPENDIX D

SLICE TOLERANCE ZONES

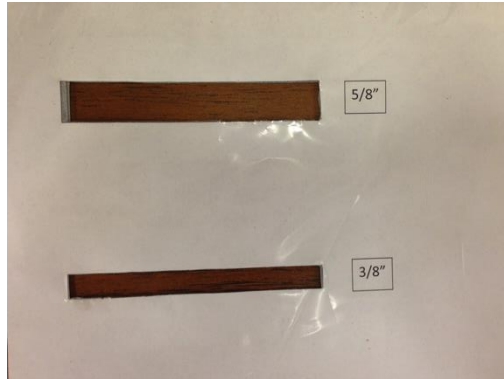


Figure 39: Go No-Go gauge for slices