Ergonomic Analysis of Modern Day Kitchen Knives

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Abstract
The focus of this study was on how different knife characteristics affect the consumer's ability to slice vegetables. The aim of this 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. The results show for the consumer that knife characteristics do not affect the user's performance.

Disciplines
Ergonomics | Operational Research

Comments
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**INTRODUCTION**

Every day, millions of Americans spend time at home preparing food to eat or to serve their household. In 2014, the US Department of labor reported 56.3% of the population engaged in food preparation and cleanup, averaging 1.04 hours daily spent on this activity (Bureau of Labor Statistics, 2014). While the younger population might have no trouble completing kitchen tasks, those who are aging or have other physical 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 interviews 48 older people between the ages of 60 and 90 about food preparation. Of the participants, 19 percent had trouble completing tasks related to food preparation, or had modifications for ways they could accomplish tasks. One of the participants felt pain while peeling and chopping, and another 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 “older people often find it personally rewarding to continue with familiar kitchen routines and skills known throughout their lives” (Maguire et al., 2014, p. 77). 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 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.

**BACKGROUND**

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, will not be using 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 food. This knife is “wide enough to give you plenty of knuckle clearance when you’re working on a cutting board; long enough to cut large items efficiently and small items precisely; and curved enough to let you rock the blade as you chop” (Jay & Sur La Table, 2008, p. 21). 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 tip of the knife for fine work, the cutting edge for general duty, and the heel of the knife for heavy-duty chopping” (Ward & Regan, 2008, p. 49). 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. 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 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). 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 de-boners that there were significantly less muscle activation for the flexor digitorum superficialis, biceps brachii, triceps brachii, anterior deltoids, and the upper trapezius muscles (Claudon & Marsot, 2006).

In this study, the hypotheses being tested were: (1) 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. (2) 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. (3) 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.

METHODS AND MATERIALS

There were 50 participants comprised of 11 females and 39 males. The average female age was 21 years old with a range from 19 to 28. The average male age was 21 years old with a range from 19 to 32.

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 and a dull JA Henckels International chef knife. The knives were the same, but one was dulled. The second pair was a sharp JA Henckels International santoku knife and a sharp KitchenAid ceramic chef knife. 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.

To maintain the same level of sharpness an EST K100 Knife Edge Sharpness Tester 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.).

EMG was used to capture the muscle activity during the study. 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 muscle activity 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 participants were 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 change in discomfort was recorded for each body part.

Figure 1: (a) Chef knife, (b) Santoku knife, (c) Ceramic chef knife

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 slices was tested for size. For carrots, ten slices were tested on the tolerance zone of +/- 1/8” on the 1/2” slice. For potatoes, five slices were tested to see if they met the tolerance zone of +/- 1/8” on the 1/2” slice.

There were two different procedures followed for the two vegetables sliced. Both carrots and potatoes 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 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 they would be using and the carrots or potatoes they would be slicing. 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. 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 was stopped and saved. The participant was given another body part discomfort survey to fill out. The time taken was noted from the EMG file.

RESULTS

Electromyography

The results for the average percent of MVC reached for the extensor digitorum, carpi radialis, biceps branchii, and triceps branchii are shown in Figures 2-5. A series of inferential statistical test was performed for each muscle. With the large amounts of variation between participants, there was no statistical significance for any of the muscles while cutting either carrots or potatoes. The type of knife, material of the knife, and the sharpness of the knife, did not affect the percent of the MVC reached or the amount of energy required to complete the slicing.

Body Part Discomfort

Participants found the most discomfort in the fingers and lower arms, while they felt minimal discomfort in the shoulder. A series of inferential statistical tests were performed, and there was no statistical significance between the different knives tested. The type of knife, material of the knife, and the sharpness of the knife, did not affect the discomfort the participants felt from the task of slicing carrots or potatoes.
Slicing Performance

A series of inferential statistical tests were performed and there was no statistical difference between the knives for slicing performance. The type of knife, material of the knife, and the sharpness of the knife, did not affect slicing performance for either the carrots or potatoes.

Time

A series of inferential statistical test were performed and there was no statistically significant difference in the time it took to complete the task for the four knives. The type of knife, material of the knife, and the sharpness of the knife, did not affect the time it took to complete the task for either the carrots of potatoes.

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 a statically significant difference resulted in there being no 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. Since there was no statistically significant difference between the two, the results show these knives require the same muscle activation level.

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 that the ceramic would result in less than the stainless steel, and the chef would result in less than the santoku.

The last two metrics, slice performance and time also proves 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.

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.

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. These results show for the consumer it does not make a difference what knife they use for a short cutting task. This lead to the conversation of what would make a difference to the consumer cutting task. 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.

LIMITATIONS AND ASSUMPTIONS

One limitation for this study was it only consisted of cutting carrots and potatoes. These foods are similar in 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. The participants were all from the college population and not older adults were used as participants. If the duration of the task had been longer, there might have been more time for a difference to appear, but it was decided to keep the task to be realistic for the consumer. Another limitation was the grip of the ceramic knife was different than the handles of the other knives.

REFERENCES
