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Development and examination of pop-top can openers and how they improve accessibility for an aging population

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Development and examination of pop-top can openers and how they improve accessibility for an aging population

By

Zach Sobczak

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Industrial Engineering

Program of Study Committee:
Richard Stone, Major Professor
Gary Mirka
Jason Gillette

Iowa State University

Ames, IA

2012

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Most of all, I thank my parents Karen and Gregory Sobczak. You have always believed in me and because of your love and support, I am able to accomplish all of my dreams. I dedicate this thesis to you.

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Abstract

The primary function of consumer packaging, specifically pop top cans, is to protect the contents of the container and ensure it is safe and functional for the buyer to use. As packaging has evolved, greater focus is placed on increasing the convenience of products. Pop-top cans are simpler to use because they do not require tools but bring inherent problems with opening primarily for the older population. The development of different opening devices aims to improve accessibility for the older population by reducing the frustrations and discomforts associated with this style of packaging. A study of 24 individuals, showed different preferences in opening methods between older and younger individuals. Furthermore, determining time to open, EMG muscle activation, and wrist angle revealed that some objective measures related the subjective preferences. Younger individuals believed that the increased convenience of a pop top, greatly outweighed any pain they had to endure. The elderly however, preferred to use a simple opening device to transfer the movement away from the fingers to the wrist. Because of the reduction of precision movements, the elderly preferred to use the J-popper opening device. The difference in preferred opening methods between age groups shows that packaging designers must consider the needs of all members of the population when designing products to insure accessibility to all consumers.

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Chapter 1:

Introduction

1.1 Pinch grip and pain sensing in the elderly

The degradation of human physical ability with age has been well-documented. Two types of deterioration that are especially trying are a reduction of pinch grip strength and an increase in pain sensitivity. Pinch grip strength involves the ability to grasp objects between the thumb and distal ends of the fingers.[1] Pain sensitivity is the perceived pain experienced and tolerance threshold of an individual given a stimulus.[2] The reduction of strength and increase in sensitivity can make it difficult for otherwise healthy elderly individuals to perform everyday tasks.

Over time, muscle fibers break down, reducing the strength capabilities of the muscles. A 42% decrease in grip strength was documented in the research of Viitasalo et al. between the youngest and oldest group of participants.[3] Furthermore, there is a decrease in active motor units, defined as the motoneuron and the connected muscle fibers, which reduces the ability for muscle fibers to activate. As a result, strength is further reduced.[4]

Beyond to the degeneration of muscle strength, the orientation of the hand and wrist can greatly affect pinch grip. When the wrist is at extreme angles, the force produced by the hand can be reduced by as much as 60% from the maximum capabilities.[5] Furthermore, there is a reduction in the wrist range of motion for an elderly person. A study of workers in Taiwan indicated a reduction in range of motion of about 20% between the oldest and youngest age group.[6] This reduced range results in lower extreme angles, creating a more restricted range for optimal grip strength.

In addition to the reduction in strength, the threshold of pressure pain tolerance also decreases with age. A study by Lautenbacher et al. showed that pressure pain sensitivity in the fingers of the elderly increases with age.[7] Consequently, everyday tasks that provide minor discomfort in younger individuals can lead to almost unbearable pain in the elderly. However, the type of stimulus and the duration also affects the pain sensitivity in the elderly.

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For shorter durations, the elderly are found to have higher tolerances to pain then younger individuals.[8] As a result, many assistive technologies aid the elderly in these ordinary tasks by maintaining or improving their quality of life through their advanced years.

1.2 Design of consumer packaging

It is widely accepted that advances in healthcare lead to an increase in life expectancy, resulting in an aging population. The aging population with diminished physical abilities requires greater consideration in the design of products. One major area of opportunity is consumer packaging, especially for grocery products. Packaging in food manufacturing serves four main functions: to contain, protect, convenience, and communicate.[9] The primary focus in food packaging has long been to protect the contents of the packaging. Changes in society have resulted in a shift of this focus. In the fast-paced Western culture, there is an increased demand for food products that provide greater convenience for the consumer. As a result, many advances in consumer packaging have focused on reducing the kitchen accessories required by making the product easier to open.[10] Some examples of this include the evolution of microwavable containers for frozen entrees, development of cost-effective oven-safe containers for packaging, and the utilization of a ring pull on canned goods.

Despite the major advances in convenience for opening and preparing food products, accessibility is often an afterthought in the design process. A New Zealand survey of elderly consumers found that a majority of participants had problems opening many different kinds of packaging.[11] Additionally, a study aimed to increase the accessibility of consumer packaging found that a large percentage of young adults cannot comfortably apply the necessary forces to open packaging; specifically glass jars.[12] Many research studies have focused on the problem of opening glass jars, but neglect more modern packaging techniques. Contemporary packaging utilizes plastic films and ring pull cans which are easily disposable. Conversely, they create much smaller grips, requiring high forces exerted by smaller muscles.

In the consumer packaging survey by Duizer et al, ring pull cans were identified as a highly problematic style of packaging for the aging population.[13] The most common issue

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listed was that the small size of the ring pull made it difficult to get under and pull back because of the finite grip required. As a result, the design of the ring pull has evolved into new shapes and sizes. The two most common designs are the tab with the small, rounded shape on the lifting end (see Figure 1.1) or the larger tab with a flat edge on the lifting end (found in Figure 1.2).

Figure 1.1: Rounded tab

Figure 1.2: Flat tab

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There are two main steps involved in opening a ring pull can. The first step is lifting the tab to break the initial seal (see Figure 1.3) of the can and provide a handle for pulling the lid back. A preliminary study by the authors indicated that this first step is difficult because of the small space between the tabs and can lids preventing easy lifting. Once the tab is raised, the next step is to peel the lib back across the can by the tab to remove it from the can (see Figure 1.4). This step is difficult because the size of the pulls require a pinch grip. Furthermore, there is a danger from sharp edges of the lid cutting the user. Finally, when removing the lid from the can completely, there is a tension created in the metal that causes the lid to spring back when released often resulting in a small amount of the can contents splashing out.

Figure 1.3: Lifting ring pull

Figure 1.4: Peeling back ring pull and lid

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1.3 Can opener designs

To combat the issues associated with ring pull style can, various opener designs have appeared on the market. The first of these designs is a device called the J-popper, made by Brix Design in Stege, Denmark and shown in Figure 1.5. The J-popper utilizes a thin edge to get under the tab of the can. The user then rocks the device back across the lid, pulling on the tab and peeling back the top of the can. The simple design appears to address the main issues indicated by creating a larger extension of the tab for lifting and pulling.

Figure 1.5: J-Popper

1.4 Hypothesis

As of today, no scientific study examines the physical ergonomics of ring pull cans and the assistive openers currently available for them. For this purpose, the authors developed a can opener that attempts to exploit physiological advantages, such as improving hand grip and moving exertion to larger muscle groups. The device tries to create greater ease in opening ring pull cans especially in the elderly population.

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It is hypothesized that the mechanical advantage created with opening-devices will reduce the discomfort experienced when opening ring pull cans. The mechanical devices will reduce the movement of the wrist as well as decrease the muscle exertion resulting in a subjective preference toward the device. Furthermore, between older and younger individuals, there is a difference in tool preference based on the specific needs of the two groups. Older individuals will prefer to use an opening device to reduce pain while younger individuals will endure the discomfort of not using an opener because of the added convenience.

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Chapter 2:
Methodology

2.1 Development of locking opener device

Many researchers have explored different grip designs for tools.[14,15] The continued work of ergonomists tries to apply this research to many everyday tools. These concepts were applied to the design of this opener, aiming to move muscle exertions from the small muscles of the hand to the larger muscles of the arm as stated in the second hypothesis. The grip of the tool featured a rounded handle, removing the need for a pinch grip or any pressure on the fingers. The handle shape can be seen in Figure 2.1.

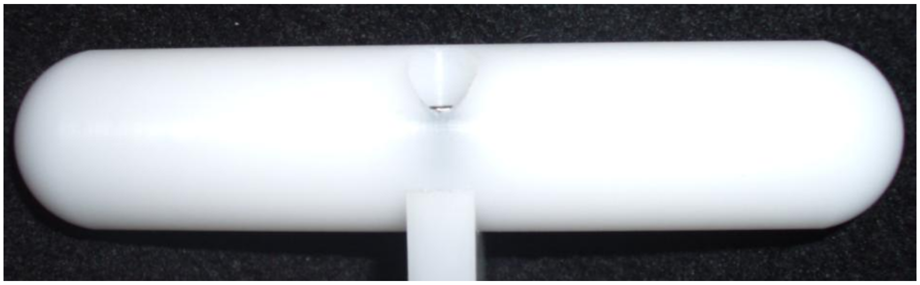

Figure 2.1: Locking opener handle

Furthermore, one of the major problems with the openers currently available on the market is they do not lock onto the tab, allowing the lid to fly off the can, resulting in a mess and increased potential for injury on the sharp edges of the lid. As a result, this opener features a lock mechanism (see Figure 2.2) for the tab creating greater control and reduced risk of injury.

Additionally, preliminary indications showed that initially lifting the tab is an issue for many individuals. Therefore, the locking mechanism also features an incline to easily get under the tab and break the seal of the can (see Figure 2.2). This reduces pain on the fingertips leading to a subjective preference toward using the device. The incline is made of aluminum to allow a thin edge to get under the tab and the strength for repeated use of the opener. In addition, the aluminum provides weight at the end of the opener to improve stability. The weighted end helps to counter essential tremor, which is common condition in individuals over 65.[16]

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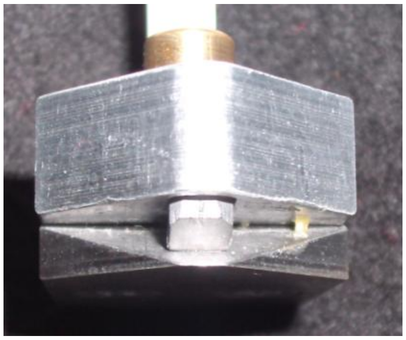

Figure 2.2: Locking mechanism with incline

Finally, the handle is attached to the base in a “T” fashion, seen in Figure 2.3, to encourage use of the muscles in the arm rather than the hand when opening. The length of the handle provides a small amount of leverage for lifting the tab, but is still short enough to maintain control with the weighted end. The handle is made from a white plastic with a smooth finish for comfort and easy cleaning.

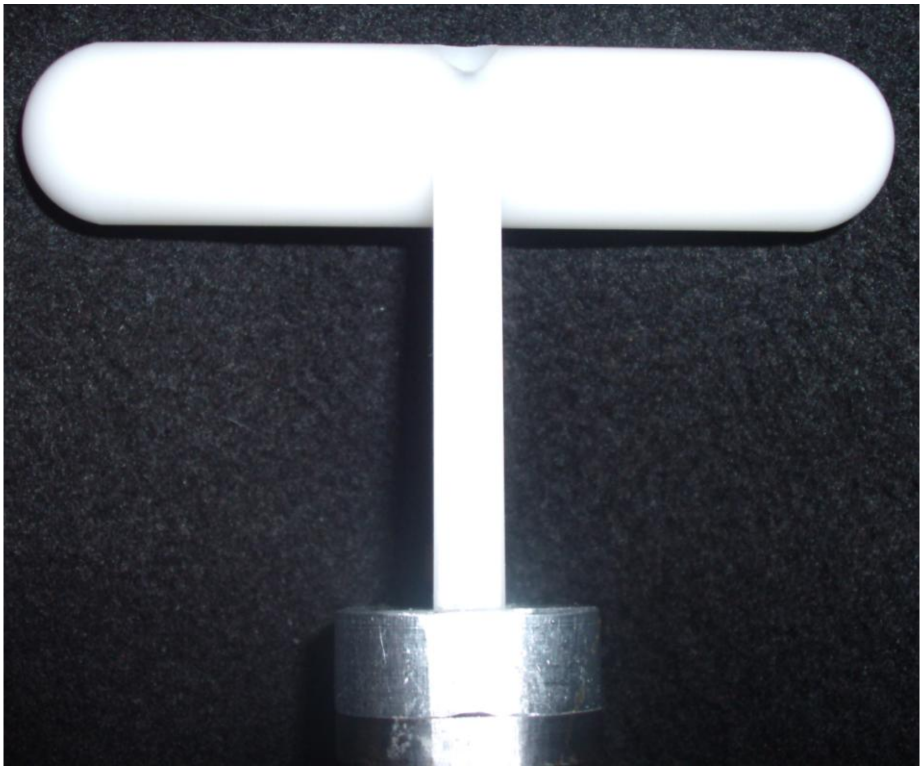

Figure 2.3: T-Handle attachment

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2.2 Participants

Twenty-four individuals participated in this study. The participants were divided into two groups. A control group consisted of twelve university students between the ages of 18 and 24. There were three males and nine females in this group. The experimental group consisted of twelve elderly individuals over the age of 65. There were five males and seven females within this group. Each participant opened three different styles of cans with three different opening methods used for each style.

2.3 Variables

The independent variables for this study are the different opening method for the pop-top cans and the different styles of tab and can design. Three different opening methods were used: 1) No opener, 2) J-popper, and 3) Locking opener. There were also three different designs for the cans: 1) short can with a rounded tab, 2) tall can with a rounded tab, and 3) tall can with a large flat tab.

The dependant variables are 1) surface electromyography (EMG) of muscles in lower arm, 2) wrist angle, 3) subjective pain and usability measures, and 4) time to open. The use of EMG is well-documented for illustrating the level of work being produced in a muscle group. Through a review of the literature followed by preliminary studies, it was determined that most useful muscles to follow in this study were the flexor carpi radialis and the extensor digitorum.[17,18] The level of exertion in these muscles was recorded in each trial to determine the level of effort required to use each opening style. Wrist angle is measured to determine the range of motion a participant traveled though when using the different methods. Methods that require less wrist movement are believed to have a subjective preference as previously stated. The pain and usability information was administered in the form of a survey. Participants would rate the level of pain experienced as well as if they felt an opener was easy to use, if it improved opening ability, and how frequently they would use the opener to uncover cans. Finally, the time to open was measured from the instant that contact was made with the tab until the lid was peeled back past ¾ the distance of the diameter as this is an opening large enough to get the contents out of the can.

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2.4 Experimental design

Participants first provide written informed consent to participate in the study. Once all of their questions are answered, triode EMG sensors were attached to the participant's dominate arm as seen in Figure 2.4and Figure 2.5. Bend sensors connected to a Velcro strap are then attached to the arm and taped to the hand, allowing the sensors to cross the wrist. The sensors are positioned on the top of the wrist to measure flexion and extension as well as on the outside of the wrist for radial and ulnar deviations. The setup on the arm can be seen in Figure 2.6

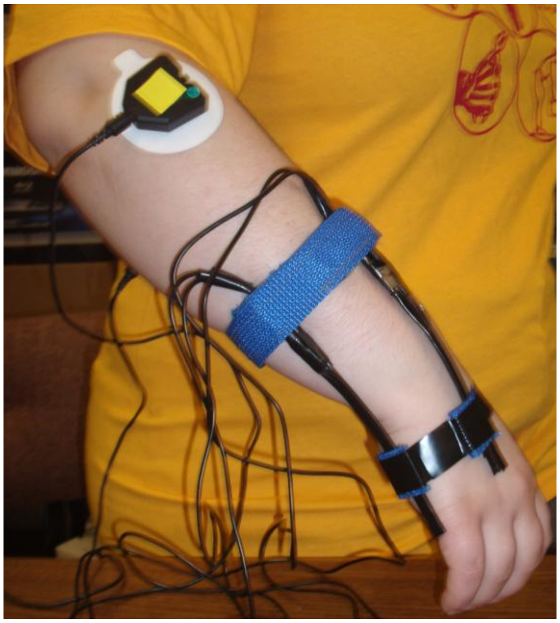

Figure 2.4: Extensor digitorum EMG sensor placement

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Figure 2.5: Flexor carpi EMG sensor placement

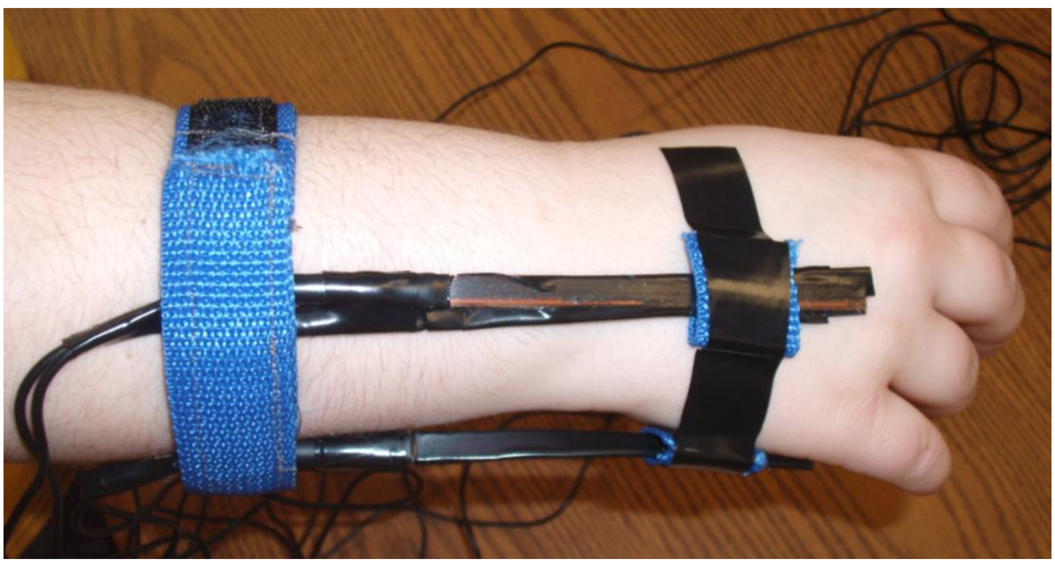

Figure 2.6: Bend sensor setup

All the sensors connect to a FlexComp Infinity encoder produced by Thought Technology Ltd in West Chazy, New York. The encoder records information at 2048Hz and saves it to a computer running BioGraph Infinity Software, also developed by Thought Technology. The sensors, encoder, and software have the ability to filter and rectify raw data. After being rectified, the EMG data passes through two filters: a notch filter and an IIR filter. The notch

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filter removes the 60 Hz frequency noise caused by electronic devices. The data then passes through a high pass Infinite Impulse Response (IIR) filter with a cutoff of 20 Hz to remove additional artifacts from the data such as heart rate and wire movement.

Four bend sensors were also utilized and connected to the FlexiComp encoder. The bend sensors were taped in pairs back to back to increase precision in one direction. As a result, there was one sensor for each direction of movement: radial, ulnar, flexion, and extension. The sensor data is put through a linear transformation to correlate the maximum and minimum input to a 100-point scale, allowing for greater ease in data analysis.

After attaching all the sensors and confirming they function properly, maximum voluntary contractions (MVC's) are obtained. The MVC value is used to normalize the data in the trial runs to determine the level of exertion of the muscles. To obtain the MVC value for the extensor digitorum, participants are asked to stand with their arm held out in front of them and extend the wrist back as far as they can for duration of 5 seconds. Participants are then given a brief resting period, before the flexor carpi radialis MVC value was obtained. Again, individuals held the arm in front, but flexed the wrist forward as far as possible for duration of 5 seconds. After another resting period, a maximum range of motion for the bend sensors is obtained. Participants were asked to move their hand in all directions as far as they could. This information normalized the trial run data for the bend sensors.

After all the maximum output data is obtained, the participants began opening cans. Each participant used the three opening styles on each of the three cans. The order of the opening was randomized using Microsoft Excel's random number generator. After opening each can, participants are asked to rate the level of pain experienced. Using a scale from 0 to 10 with 0 being no pain and 10 being the worst possible pain, participants describe how much pain they experienced overall, in their fingers, in their wrist, and in any additional parts of the body. Likewise, participants evaluated the opening styles. They are questioned about the usability of the opener and the ease of opening the can. They can describe in detail what qualities they liked and disliked about the openers. Finally, there were asked how frequently, if at all, they would use the specific opening style again.

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Following the opening of the cans and collection of subjective survey data, the participants are asked a final set of questions. The questions were designed based on the method outlined by Flynn and Goldsmith.[19] Participants ranked in order what opening method they preferred, and what can style they preferred. They also ranked in order which methods and can styles are least painful to use. This concluded all of the data collection.

2.1 Analysis

All of the objective data points and subjective data are entered into Microsoft Excel documents for each individual. Within these documents, all data from the EMG sensors and bend sensors are normalized. To normalize the EMG data, a highest value from the initial MVC measurement is taken. Then, an average is taken across 100 points, the 50 points before and after the highest value. This average is recorded as the MVC value that all trial EMG data points are divided by, allowing a comparison across individuals. The wrist angle data is also normalized in the same fashion using the maximum values from the range of motion trial.

Once all of the data is normalized, preliminary analysis took place. For each trial run, the maximum value, the average value, and the standard deviation of each normalized set of data were calculated. All of this information was put into a summary table, which contained the time each trial took and all of the subjective data. All of this summary data is put into JMP 9.0 statistical software created by SAS Institute, where the data can easily be organized and analyzed. Two main tactics were applied for analyzing the data. The first was an overall evaluation of the data. However, because of the way the data are categorized, the numbers lack randomness that would represent a general population. Therefore, a secondary analysis was performed that looks specifically at each identical trial for variable correlations allowing for a more accurate representation of the experimental group from the general population. A Person product-moment correlation is performed for to determine if any correlations exists between the subjective and objective data. This is similar to a study used to correlate a subjective health survey to an individual's gait cycle.[20] The program returns correlation coefficients as well as values for statistical significance to determine if the measurable variables are statically related. For the pairs of variables that are statistically significant, an

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analysis of variance (ANOVA) is performed to determine how those variables changed in the trials. The threshold used for determining statistical significance was $P<0.05$. This gives insight into how the objective measures affect what people experience and prefer when dealing with consumer packaging.

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Chapter 3:
Results

3.1 Overall opening preference

In the final survey, participants were asked to rank the opening method they most preferred. Across all participants, the J-popper was the most preferred method, receiving 11 first-place rankings and 11 second-place rankings. Using no opener was a close second, with 11 first-place and 7 second-place rankings. However, when looking at the two groups separately, the older individuals preferred to use the J-popper with 7 first-place votes and no third-place rankings. On the contrary, the younger individuals preferred no opener with 7 first-place votes. Both groups did agree that that the least-preferred opening method was the newly designed locking opener, with only one person in each group giving it a first place vote. These results are summarized in Figure 3.1.

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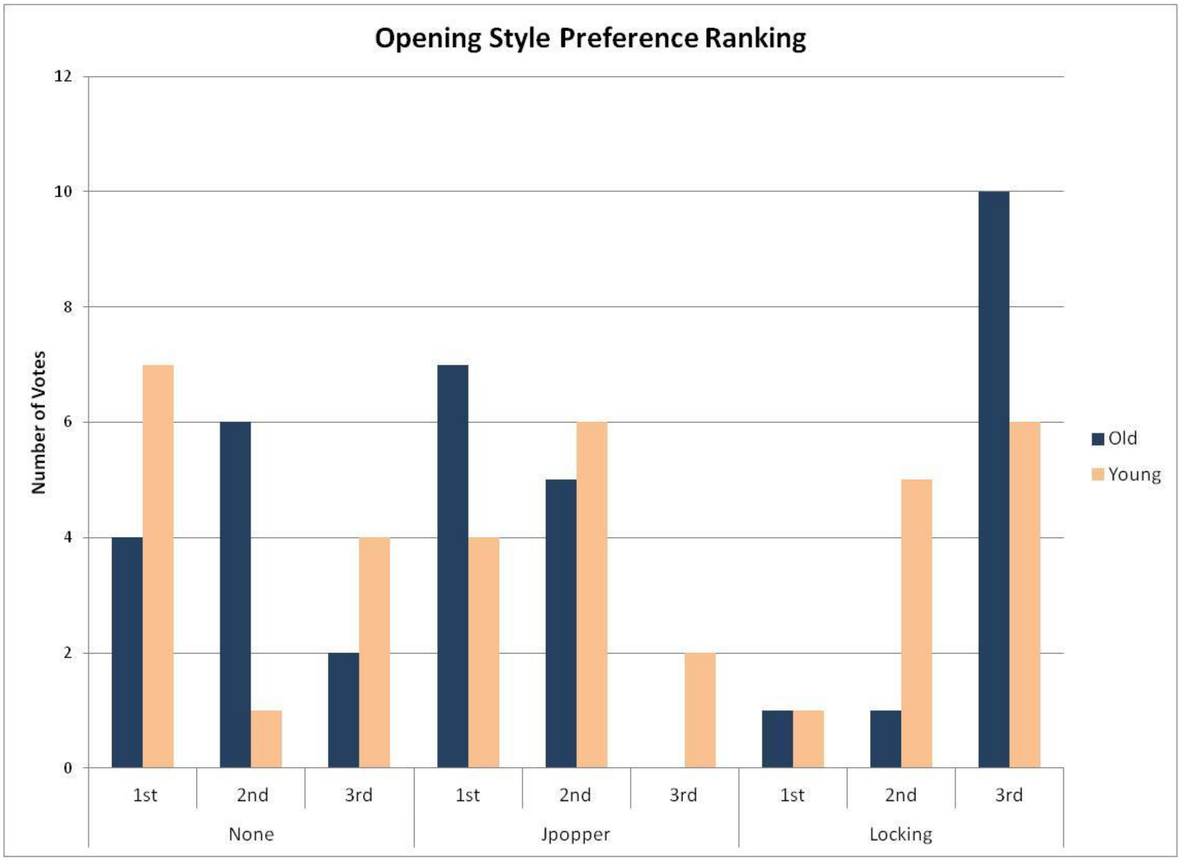

Figure 3.1: Preference ranks based on opening style and age group

In addition to rating the opening method, participants also rated the style of can and tab that they most preferred. Overall, the preferred opening style with the most first-place votes was the large can with a flat tab. When looking at the two sets separately, the group of younger individuals did not show any large preference of can design. The older cluster significantly preferred the flat tab and large cans in general as summarized in Figure 3.2

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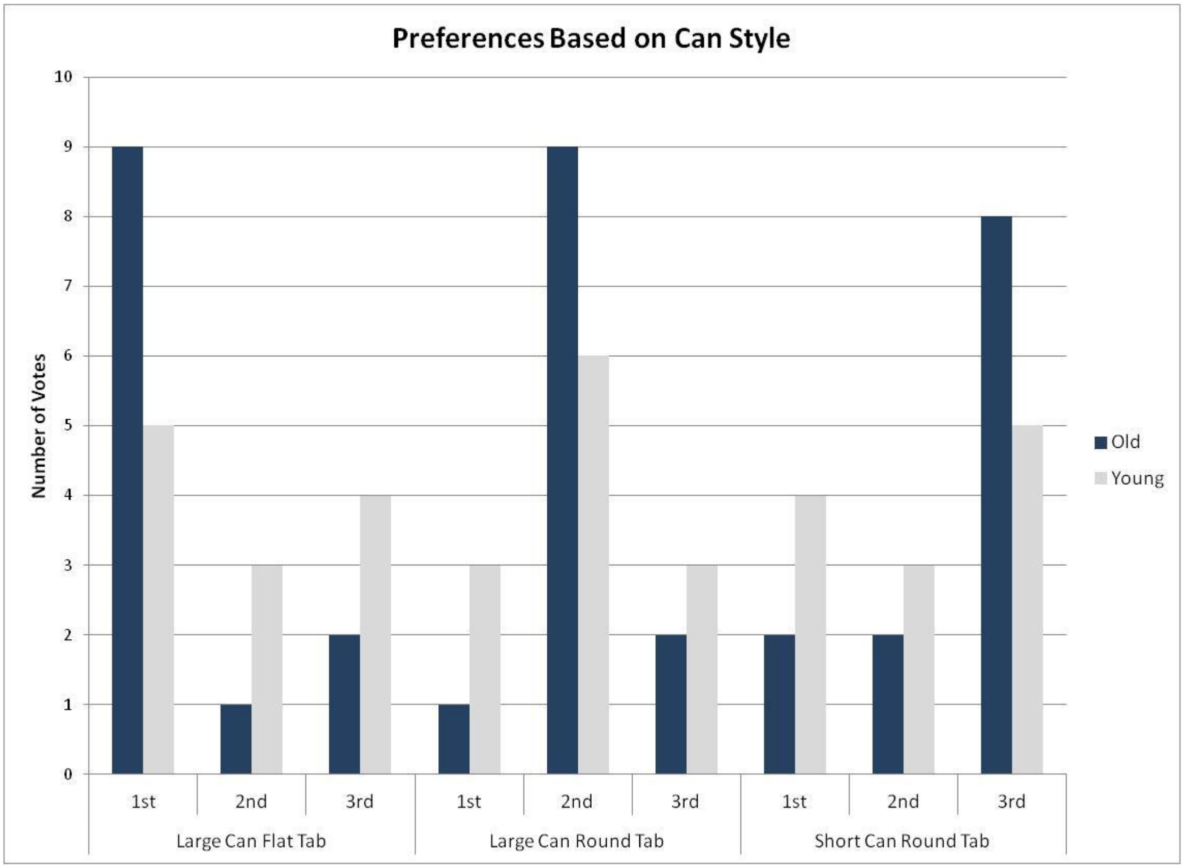

Figure 3.2: Preference ranking based on can style

In addition to counting the number of votes, values for each ranking were assigned and summed to determine a score for each opening method and style. First place votes received a score of 3, second received a score of 2 and third received a score of 1. These scores were summed and are shown in Table 3.1.

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Table 3.1: Summed preference ranking score

	None	J-popper	Locking	Large Can Flat Tab	Large Can Round Tab	Short Can Round Tab
Young	27	26	19	25	24	23
Old	26	31	15	31	23	18
Total	53	57	34	56	47	41

3.2 Overall pain experienced

Similar to the ranking of opening style preference, the overall level of pain experienced with each opening method and can design was evaluated. Participants gave the highest rankings to the choice that was the least painful to use. Some individuals did not experience any pain when performing the experiment and could not rank any of the options. In this case, all choices were given a ranking of one because no pain was experienced. In terms of pain, the J-popper had the lowest pain ranking by receiving 17 first-place votes. There was not a major difference between no-opener and the locking opener in terms of pain. The pain rankings are summarized in Figure 3.3

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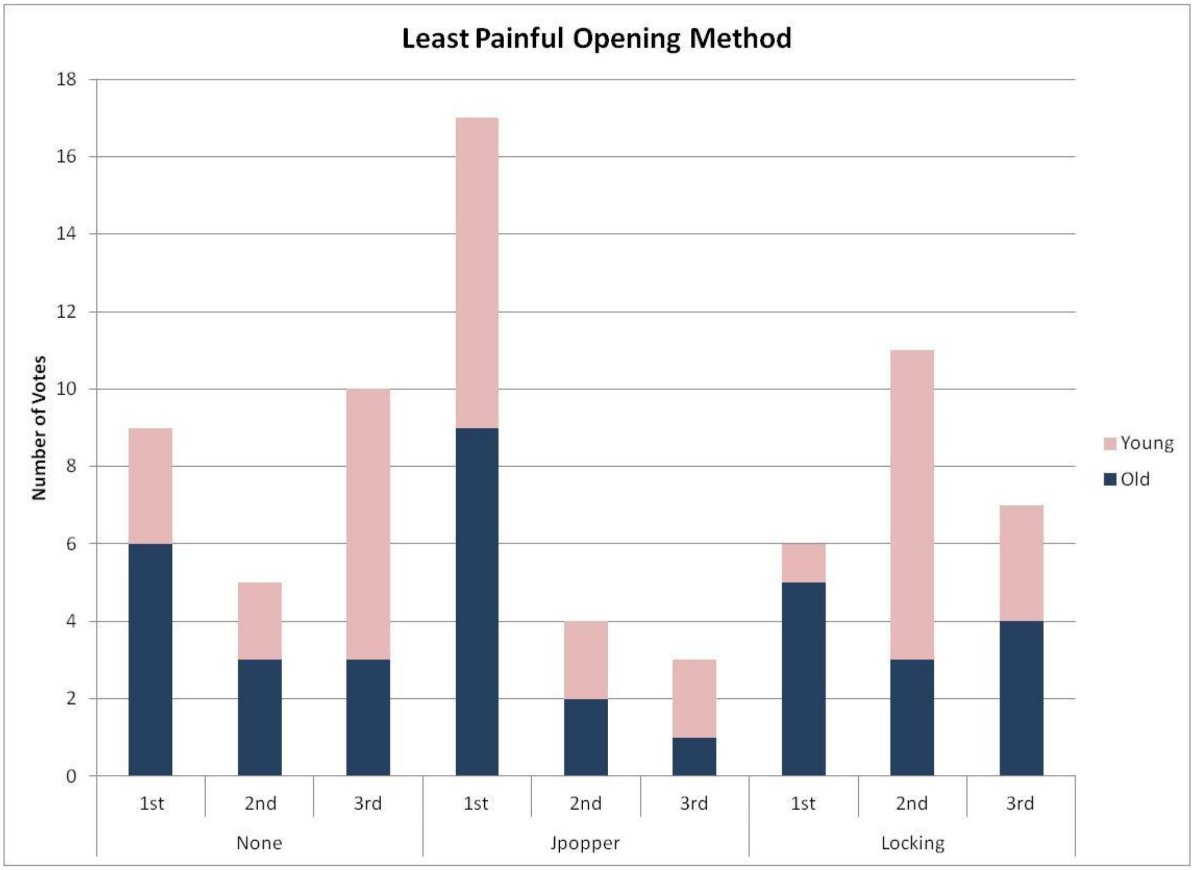

Figure 3.3: Least painful opening method rankings

The can design rankings showed that the large can with a flat tab was the least painful design receiving, 16 first-place votes. The large can with rounded tab was second, with 14 second-place votes. Surprisingly, the young group gave this can style no first place votes. The small can received the most third place votes for pain with 11 but also received an equal number of first-place votes. These results are summarized in Figure 3.4.

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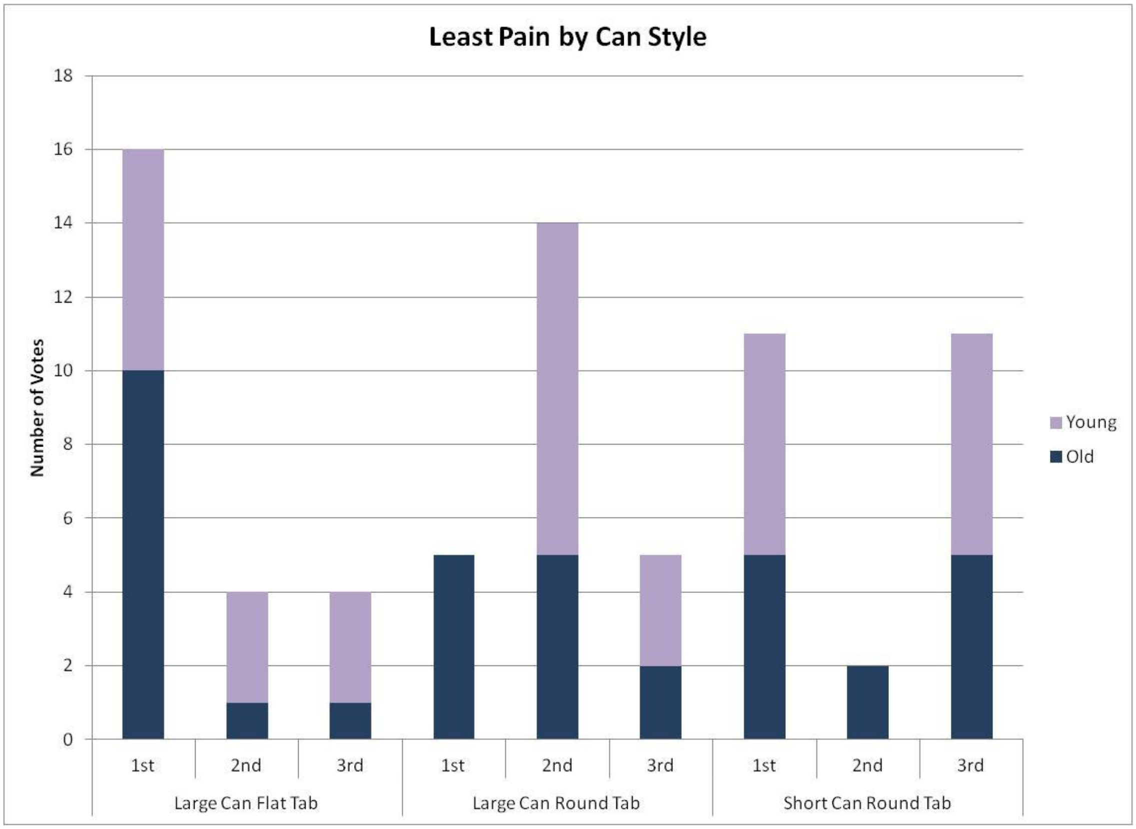

Figure 3.4: Least pain ranking by can style

The pain data was also assigned a score based on the ranking. The scoring system was the same as the preference scale with a first place vote receiving a 3, second receiving a 2, and third receiving a 1. These scores were summed for each opening method and can design as shown in Table 3.2.

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Table 3.2: Least painful ranking scores

	None	J-popper	Locking	Large Can Flat Tab	Large Can Round Tab	Short Can Round Tab
Young	20	30	22	27	21	24
Old	27	32	25	33	27	24
Total	47	62	47	60	48	48

3.3 Overall correlation analysis

The results from the correlation analysis showed that there is a strong positive correlation in the evaluation of opening preference. If participants found that an opening style was easy and aided their opening of the can, they were inclined to use it again. When looking at the normalized objective data, there were strong correlations between the average wrist angle and the maximum wrist angle. As a result, only the average values for wrist angle were examined. All of these correlations had a P-value below 0.05 with most falling below 0.01, indicating a strong statistical significance. This information was used to simplify the analysis by reducing the number of factors examined for potential correlations.

Significant correlations were also found between the objective and subjective data. The average extension of the wrist was negatively correlated with more than one subjective measure. Similarly, time was also an objective measures that correlated with more than one of the subjective measures. In addition, overall pain was a subjective measure that appeared to have a very strong correlation with all other subjective measures. All of these measures became the primary focus for further study. The correlation coefficients and P-values are summarized in Table 3.3.

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Table 3.3: Summary of correlations between variables

Factor X	Factor Y	Correlation Coefficient	P-value
Overall Pain	Average Extension	-0.1683	0.0132
Finger Pain	Time	0.2081	0.0021
	Average Extension	-0.1593	0.0192
Usability of Opener Design	Time	-0.4292	<0.0001
	Average Extension	0.278	<0.0001
	Overall Pain	-0.3478	<0.0001
Improved Ability to Open Can	Time	-0.4014	<0.0001
	Average Extension	0.2452	0.0003
Use the Opener Again	Time	-0.2994	<0.0001
	Average Extension	0.33262	<0.0001
	Overall Pain	-0.1494	0.0282

When examining the older and younger groups separately, the overall pain measure no longer has a P-value below the 0.05 threshold. The measure of time and average wrist extension both remained as strong correlations with P-values well below 0.05.

3.4 Overall analysis of variance

The JMP software was used to perform one-way analysis of variance focused on the target variables identified in the correlation analysis. Comparing the different opening styles, there was a statistical difference for all of the variables with a P-value less than 0.0001 based largely on the high number of observations. As a result, there are large standard deviations but still a strong statistical significance. The overall pain experienced when opening the cans

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had the lowest mean value for the J-popper opening style at 0.2847. The time it took to open the can also listed the J-popper as having the lowest mean value at 8.038 seconds. However, the no opener style had a very similar time to open with a mean of 8.227 seconds. The locking opener was the slowest opening style with a mean value of 16.55 seconds. The average wrist extension measurements showed the J-popper as having the highest extension amount. The normalized mean for the J-popper was 0.2459, which was much higher than the other opening styles. The values are shown for comparison in Table 3.4.

Table 3.4: Data summary grouped by opening style

		Mean	Standard Deviation	P-value
Pain	No Opener	1.1667	1.3890	<0.0001
	J-popper	0.2847	0.7498	
	Locking Opener	0.6458	1.1999	
Time	No Opener	8.2265	3.3942	<0.0001
	J-popper	8.0381	4.4727	
	Locking Opener	16.5538	13.4526	
Average Extension	No Opener	0.1394	0.0960	<0.0001
	J-popper	0.2459	0.1278	
	Locking Opener	0.1006	0.0964	

In examining the three different can and tab styles, none of the measured variables showed any statistical significance that would prove a preference between any of the styles. In examining the verbal feedback provided, the participants preferred one design over the other

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was because of the ease of getting under the tab initially. In addition, the ability to establish a firm grip on the can with the stabilizing hand played a role in choosing a preferred can design, but was not measured beyond the verbal feedback received.

In exploring the differences between the younger and older group of participants, a t-test was performed on each focused variable comparing the data from the old and young group. Using an alpha value of 0.05, there is a significant difference between the two groups in time to open and average wrist extension but not in the overall level of pain. The overall level of pain had a P-value of 0.0990, which is greater than the threshold alpha value of 0.05. The older group had the lower mean value of 0.5648 whereas the younger group experienced more pain on average with a mean value of 0.8333. The other two variables had much lower P-values, which fell below 0.01, indicating a strong significance in the difference of variance. In terms of time, the younger group was faster with a mean value of 8.457 seconds. The older group had a mean time of 13.42 seconds. Similarly, when measuring the average wrist extension, the older group also had a larger mean value of 0.1974 or 19.74% of the maximum. The younger group had a mean of 0.1266 or 12.66% of the maximum. These statistics are summarized in Table 3.5.

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Table 3.5: Data summary grouped by age

		Mean	Standard Deviation	P-value
Pain Level	Young	0.8333	1.2697	0.0990
	Old	0.5648	1.1067	
Tine (Seconds)	Young	8.4567	5.5632	<0.0001
	Old	13.4223	11.3770	
Average Extension	Young	0.1266	0.1087	<0.0001
	Old	0.1974	0.1280	

An analysis of variance comparing the results of the EMG data collected showed that can style did not have a statistically significant effect on the level of exertion in the flexor carpi radialis and the extensor digitorum. However, when looking at the opening styles there was decrease in the average level of exertion of the extensor digitorum in the J-Popper as compared to the other two opening styles as seen in Table 3.6. This illustrates that the J-Popper reduced the level of exertion required by the muscle making the can easier to open.

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Table 3.6: Average percent of MVC in extensor digitorum based on opening style

	Mean	Standard Deviation	P-value
No Opener	0.2172	0.2358	0.0088
J-popper	0.1755	0.1356	
Locking Opener	0.2820	0.2335	

Similarly, the EMG data was compared across the young and old individuals. This showed that was an increased level of exertion in the elderly of both muscles measured. Meaning that older individuals had to use the muscles more to open the can than the younger group as seen in Table 3.7.

Table 3.7: Muscle exertion based on age

		Mean	Standard Deviation	P-value
Average % MVC extensor digitorum	Young	0.1598	0.1807	<.0001
	Old	0.2900	0.2190	
Average % MVC flexor carpi radialis	Young	0.1830	0.0835	<0.0001
	Old	0.2442	0.1384	

When examining the data group according to sex there was no statistical difference between any of the measured factors. As a result, any differences that may have occurred based on gender did not cause any measurable effect on this study.

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3.5 Trial specific correlation analysis

There were no pairs of subjective and objective variables that correlated in all opener styles and can styles. However, some interesting correlation trends did occur in different categories. The finding that stuck out the most was that among the older population, there were no sets of variables that correlated when using the locking can opener on the short can. In addition, between the groups of older and younger participants very few objective and subjective pairs correlated in both groups. These pairs are summarized in Table 3.8.

Table 3.8: Correlated pairs found in young and old participants

Can and Opener Style	Factor X	Factor Y
J-Popper Large Can Round Tab	Overall Pain Rating	% Max Radial Bend
	Ease of use	Time
J-Popper Small Can Round Tab	Overall Pain	% Max MVC Ext. Dig.
	Finger Pain	Avg % MVC Ext. Dig
Locking Opener Large Can Round Tab	Ease of use	Average % Radial Bend

Some interesting correlations also occurred within the two groups. In the young group, when not using an opener there was a strong positive correlation for the overall pain experienced and the average percentage of MVC measured in the extensor digitorum muscle. Likewise, when looking at the large can with a rounded tab, there is a negative correlation between how easy to use the opener or tab is and the time it takes to open the can. This correlation was also found in the large can with rounded tab of the older participants' J-popper trial.

There were very few interesting correlation results from the older group, when comparing the use of no opener. There were opposite correlations with the flat tab with large tab and the short can with rounded tab. Individuals felt that the can and tab style had opposite effects on their ability to open the can and the maximum percentage of MVC recorded in the flexor

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carpi radialis muscle group. The flat tab had a positive correlation between the variables and the short can had a negative correlation.

3.6 Summary of verbal feedback

In addition to ratings provided after each trial, participants also provided open-ended feedback about the qualities they liked and disliked about the openers. The most common responses for each opening style and can style are summarized in Table 3.9.

Table 3.9: Verbal feedback summary

Opening Style / Can Style	Qualities liked	Qualities disliked
No Opener	• Convenient • Fast • No additional tools required	• Hard to get under tabs • Fear of cutting hand
J-popper	• Simple • Gets under tab • Fast • Fits into drawer easy	• Lid flies off • Messy • Have to go get opener to use it
Locking Opener	• Locks onto lid	• Awkward • Not intuitive • Hard to hold can with opposite hand • Cannot get good leverage
Large Can With Flat Tab	• Easy to get under this tab style • Can get a good grip on can	• Small radius of can hard to get tools in
Large Can With Round Tab	• Easy to pull lid back	• Hard to get under tab • Tab is small and hard to pull
Small Can With Round Tab	• Easy to pull back lid	• Hard to grip can with opposite hand • Tab is small and hard to pull

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3.7 Broken tabs

One measure observed during the experiment that was not initially identified was the occurrence of broken tabs. The locking can opener was responsible for breaking the tab off five different cans. The tabs broke off from all can styles and in both groups. No other opening style broke tabs preventing the can from opening.

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Chapter 4:
Discussion

The purpose of this study was to develop an improved method for opening pop-top cans to make them more accessible to the aging population. Furthermore, it was proposed that the elderly would prefer devices that give a mechanical advantage over the standard ring pull because of reductions in muscles exertion, wrist angle, and pain experienced. Finally, in comparing younger and older individuals, it is believed that preference of opening style would differ based on convenience rather than reducing discomfort. The first objective was disproved, but the results showed trends supporting the second and third objectives and will be discussed further in this chapter.

4.1 Overall opening performance

The results of the overall opening performance showed that the experimentally-designed mechanical opener was the least-preferred method among the participants. Not only did it underperform in the three main correlated variables, it also was responsible for breaking the tab off the can on five different trials preventing them from being opened. The J-popper was overall the most preferred opening method. The subjective preference is supported by the objective data. The J-popper had the lowest mean measure of pain, shortest average time, and highest average extension value. However, this increased extension value is only valid for a small range. If the extension were to increase to higher percentage it is believed to have a negative effect on performance as discussed in the introduction. Furthermore, the mechanical advantage of the J-Popper was seen in the level of muscle exertion of the extensor digitorum contributing to the subjective preference.

4.2 Overall correlation of objective and subjective data

The many variables measured in this study revealed three main measurements that influenced participants' preference in opening style. First, the time it takes to open a package plays a major role in what a consumer is willing to endure in product packaging. In young participants especially, the amount of time it took to open the can was a deciding factor in the

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preferred opening method. While young individuals experienced greater pain when opening a can without an opening device, they preferred the use of the standard pop-top because of the convenience it provided. While the J-popper took less time in practice, it would require extra steps to find the opener and use it. Many individuals, young and old, felt the extra steps were not necessary. As a result, the standard opening style received more first place votes for young participants, while older individuals preferred the mechanical advantage of the J-popper.

The second correlated variable was the overall pain experienced when opening a can. While this is a subjective measure, it had a strong statistical correlation to all of the other subjective measures as well as the average extension of the hand and wrist. Analysis of pain between younger and older participants revealed that there was no statistical difference between the two groups regarding pain. This implies that perception of pain is an individual experience regardless of age. Pain played an overall role in determining which opening method was preferred. The J-popper had the lowest overall mean pain level. This is because of the mechanical advantage that the device gives the user. It provides increased leverage as well as reduces pain in the fingers by getting under the tab initially to break the seal around the can.

The most interesting of the correlated measures was the correlation between average wrist extension and the ranked preference measures. This could best be explained by the negative correlations between average extension and pain. When there is a smaller wrist movement, it can correspond to increased movement and use of the fingers. As a result, there is an increase in pain experienced in the fingers from the greater work demand. The objective of the experimental opening device was to transfer movement more to the arm then wrist. However, when transferring to those muscles the performance lowered with the locking can opener. Based on this data, it appears that the optimal muscles for opening cans are those of the wrist, which the J-popper utilizes best.

4.3 Trial specific correlation analysis

The most interesting outcome of the trial specific analysis is that there is not one single objective measure that relates to the type of pop top can that individuals prefer. However,

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there are still some measurables that play an important role and aid in the design of further consumer packaging. The lack of correlations in the use of the locking can opener on the short can and small tab showed that another factor must be present in determining what the people prefer. The verbal feedback points to the more complex design making it harder to figure out effectively how to use the opener.

The very few correlation pairs that were found in both the older and younger group help support the claim that the demands of the two groups differ. This shows that the two age groups have different objective measures that effect their subjective preference and use of the tabs. This information supports the claim that the two groups would have different preferences in opener style because of the differences in the factors that affect their fondness.

When looking at only the young group, the correlation between the average MVC in the extensor digitorum and pain shows that the more they use that muscle group the more pain people experienced. Based on muscle function, this shows that the harder the muscle has to work for pulling back the wrist individual experienced more pain. On the contrary, there was a negative correlation between an opener’s ease of use and the time it took to open the can. If the opener took longer to open the can then other methods, individuals felt that it was less useful for them to use to open the can. This simple finding shows that one of the primarily considerations when designing an opening device is to have it improve the time required for opening.

The older group had very few shared correlations between opening styles or can designs. One possible explanation for this could lie in past research about how the elderly respond to problems in consumer products. As summarized in a research paper by Bearden, the elderly are less likely to complain about their dissatisfaction with consumer product.[21] Therefore, the lack of definitive results may stem from their reluctance to complain about the products they are using. The opposite correlations show that depending on the can style, the use of the flexor carpi radialis muscle groups can have opposite effects on peoples preference.

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4.4 Comparison of younger and older participant group preferences

When looking at the preference of opening style, it is evident that younger participants preferred using no opening device. On the contrary, the older subject group preferred the J-popper. The main cause of this is the difference in demands between the two groups. The younger group had a lower average opening time than the older group. Based on this knowledge and the verbal feedback provided, the younger group preferred no opener because of the increased level of convenience. While the j-popper had a lower overall time, it was not enough of an advantage to justify the time required to get the tool in the kitchen. In addition, the younger group experienced a lower overall level of exertion in their muscles when opening cans. This lower exertion shows that the mechanical advantage of the J-Popper is not as beneficial. The stronger muscles in the arm and wrist allow for lower percentages of exertion in the young and do not have the same need for a mechanical advantage of the J-Popper as the older group does. The pain rankings obtained at the end of the study further prove this point. The group indicated that no opener was the most painful opening method but still preferred it to any opening device. Therefore, the advantages of the J-Popper are not as prominent in the younger group. Because there is less of a physical advantage, many younger individuals would rather endure the extra pain of not using an opener to avoid the extra steps required to obtain a device.

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Chapter 5:
Conclusion

The device created by the authors attempted to reduce the wrist movement when opening and muscle exertion of the smaller hand muscles. However, the device lacked intuitive usability and created more of a hindrance than help in opening the cans. As hypothesized, the mechanical advantage created by the J-popper greatly reduced discomfort as well as muscle exertion resulting in a preference amongst older participants. Notably, there was a difference between the older and younger population in preference of opening method. The physical advantages of younger bodies did not benefit from the J-Popper as much as older individuals. Therefore, different objective measures contributed to the preference of opening method in each group. While assistive devices do reduce the amount of discomfort, there is a reduction in convenience because of the added step of getting the necessary tool. Overall, the younger population is willing to tolerate the added stress of not using an opener for the ease of a pop-top can. The older population utilizes different opening devices that are commercially available or around the kitchen, to overcome the physical disadvantage brought on by aging.

5.1 Limitations

The biggest limitation in the research was finding participants who met the age requirements, who were willing to endure the time required for opening the cans, and did not have preexisting musculoskeletal conditions. As a result, a repeatable trial for each subject could not be performed.

5.2 Future work

Studying the reactive forces required in the fixture hand would be a major area of interest for future work. In addition, a comparative study between pop-top and traditional cans would help to identify if any advantage exists beyond the convenience of pop-top cans. Finally, further studies that can relate objective laboratory data to the subjective perceptions that consumers have toward products would allow for an improved understanding of accessibility in consumer packaging.

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Chapter 6:

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