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ORIGINAL ARTICLE

Evaluating Inappropriate Tool Application Damages for Left-Handers

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ABSTRACT

15% of world population are Left-handed people. Dominance of right brain hemisphere causes dominance of left side of their bodies also known as left handedness as a minority group. This group differs in some of their motor attributes compared to right-handed majority. This issue is more tangible when it comes to working with tools that requires reasonable degree of precision or power. It is essential to prevent permanent damages with aid of ergonomics principles. The purpose of this research was to examine and highlight the extra stress imposed on the left handers using the tools designs solely designed for right handers and further to come up with suggested solutions. The research was conducted based on user-centered methodology utilizing questionnaire, field observation and interview with users as well as extensive laboratory experiments on left-handed individuals. At first, left-handed samples were selected by Edinburgh “Hand Dominance” survey and then in second survey, a can opener and scissors were identified as the most challenging kitchen tools. The fatigue and tension in the muscles were measured via Electromyography (EMG) tests on the sampled left-handed and right-handed users working with scissors and can openers within the established experiment setting. Finally, the top three proposed design for future can openers were evaluated using AHP methodology and the best design concept was selected. This research highlights significance of considering left-handed people as a minority group of users that demands particular attention in design process of products.

KEYWORDS: Left-Handed, Ergonomics, Design of Tools, User Centered Methodology, Electromyography

INTRODUCTION

Prior to design a product, the importance of customer requirements should be taken into account. People are born with different mental and physical attributes and these differences include so many fields. One of these differences is left handedness or right handedness that is a result of dominance in left or right hemisphere of brain. Eighty to ninety percent of world population are right handed. Certainly, there is more awareness regarding the needs of right handed but mostly ignoring the fact that there is a noticeable increase in population of left handed in world. This makes it crucial to get to know the attributes, weakness and strengths of left-handed in both developed and developing societies. One of the common theories in twentieth century is functionalism that did not

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consider user and their needs at all. This theory puts performance and function first [1]. As a result, minorities had no choice but to use products designed for the majority and this is the system that adversely impacted portion of world population.

The aim of this research was to study damages of using inappropriately designed tools by left handed users and to come up with proper solutions on how to address the issue. Left handed individuals have difficulty in using tools and especially tools that are sharp or require more power or precision. Having analyzed left handed people, we will then examine tools especially the ones that are mostly known as kitchen tools.

There are some questions on how currently designed tools impact on the left handers physically and operationally or whether any adverse impact can be addressed by better design.

First hypothesis was that there is a significant difference between the muscle tension of the left forearm muscle when using the left hand device with the left hand and the left hand using the right hand device. Second hypothesis was that there is a significant difference between the muscle tension of the left arm biceps when using the left-hand device with the left hand and the left-hand arm using the right-hand device with their right hand. Finally, as third hypothesis, there is a significant difference between the muscle tension of the left arm triceps when using the left-hand device with the left hand and the left-hand arm using the right-hand device with their right hand.

If right hemisphere of brain, which controls left side of the body, grow more compared to left hemisphere, dominant hand is the left hand and vice versa. In other words, hand dominance is the result of growth in left or right hemisphere of the brain [2]. Talking about left handedness is not just more ability to use left hand compared to right handed people but it is meaning a complete different function system than those right handed people which requires education and training [3]. Left handedness has pushed more work pressure of left handed people compared to right handed person due to the inappropriate design of workplace, machines and tools force where eventually lead them to use their right hand way more than left hand. Important point is that difference in power of left and right arm is 4.5% in right handed women and 9.3% in right handed men while the difference of power in left and right arm of left handed people is hardly noticeable or even measurable. Equal strength in both arms of left handed people shows that a world designed for right handed people forced them to use their right hand as much as right handed people [4].

In a research, Nalkasi et al. investigted 310 male and female medical students' motor skillsusing Chapman hand dominance questionnaire. The results proved that there was a meaningful relation between hand speed and hand dominance especially in left handed people while women had more preference in asymmetric movement [5]. Furthermore, Insell et al. measured grip power and tension relationship by a dynamometer among 128 right handed and 21 left handed individuals. The results showed that there is a meaningful difference between power of the dominant hand and the non-dominant hand. In addition, participants with more grip power in their non-dominant hand were 33.33% left handed and 10.39% right handed. In squeezing batter there was a less meaningful difference between the results of dominant and non-dominant left handed and right handed people 27.57% and 28.12% [5].

As a place that includes quite many tools with big variety, kitchen is the most challenging environment for left-handed people. Tools such as peeler, knives, scissors, can opener, grater and ice cream scoops are the most important examples. Left-handed people that have to work constantly in the kitchen are physically and emotionally engaged with kitchen and its tools [6]. This can cause many damages to their bones and muscles such as tennis elbow, hand wrist syndrome, tendon and pod inflammation and also psychologically it can bring them stress and sense of disability. These challenges can be seen in many other situations ranging from settings of watches designed for right-handed people to door knobs, or picking objects from the dining table or cutting with knives and scissors or use of camera and classroom chairs which are just few examples of many products and activities that are all and all designed for right-handed users. According to a research, the percentage of house wives with bone-muscle disorder in waist, neck and shoulders were 49.5%, 24.1% and 21.2%, respectively [7]. According to the reports of health care organization on wellness of women in Iran, distribution of some disorders is higher among women in spinal column and upper and lower organs [8].

Tools must be designed to increase power and performance of human body in specific tasks. In other words, main goal of using a tool is to transfer force from human body to an object in order to get a job done. Tools must fulfill not only the needs that they are designed for also to be usable for majority of the users as much as possible [9]. In general, comfort parameters of a tool are different according to their usage. Different impact on skin and muscle tissue can be expected regarding physical attributes and the difficulty level of tools [10]. Tools play crucial role in different industries. In some professions such as carpenter, surgeons, chefs and mechanic workers nothing can be done without tools [11].

A wrist that is tilted more than its optimal angle cannot use tools. According to the fact that most of the times, tilt of the handgrip of a tool determines angle of the wrist, thus prior to purchasing or designing a tool it should be clarified that "what will be position of wrist while gripping the tool?" [12]. Rotation axis of forearm starts from extension of elbow to a point where second finger (Ring finger) begins. If function of a tool is similar to rotation, prior fact must be considered and if possible handgrip must have 120 degrees angle according to length axis that is 100 degrees. As a result, every tool that rotates clockwise by a right handed with force and power must have a 120 degrees angle with their elbow. Optimal axis to transfer force is extension of opened index finger to elbow [12].

The results of a research on comfort of 4 tools showed that comfort primary is related to elegance, performance and physical interaction after using a tool for a short period of time [13]. Another study was done on 12 participants while working with tools having seven different handgrips and different diameters, average maximum torque was 3.034 newton meter and optimum grip diameter to maximize user comfort and maximum hand torque was 38 millimeters [14].

Disability is defined as "lack of ability to do a certain task" and can be measured comparatively. Thus, a left-handed while working with tools can be compared to a right handed that most of tools are designed for their usage as they include majority of the population. In this comparison a left-handed has much less ability in using exactly the same tools. One of the most important reasons to assess and apply ergonomics and human factors in interactions is to make effective changes in to achieve more satisfaction, productivity, and consumer mental health improvement [15]. Human factors have two ultimate goals. First, increasing performance and efficiency in working environment and; the second one is to empower optimal human values. Minimizing error, maximizing efficiency, elevating ease of work are the results of achieving first goal and better safety, more job satisfaction and less fatigue and tension caused by work are the result second goal [16]. A relationship between ergonomics and affiliated factors has been shown in Figure 1.

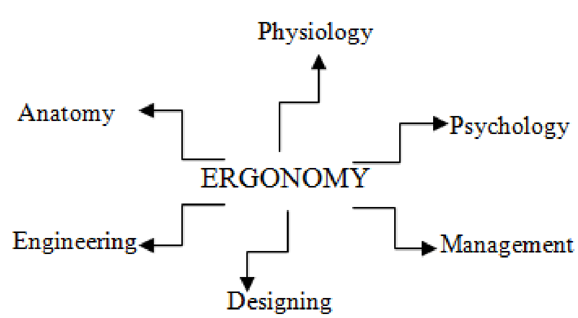

Fig 1. A relationship between Ergonomics and Affiliated Factors [1]

MATERIAL AND METHODS

This research is based on user-centered design (UCD) approach with its design principles. This method was designed based on interview, questionnaire, observation and experiment to evaluate ergonomics factors and its harmful impacts on left handed people. Qualitative and quantitative results consist of practical product and solutions for a better kitchenware design that can easily and comprehensibly fulfill the needs of both left handed and right handed individuals. In UCD philosophy, designers should always consider two main elements in their designs. First, having correct understanding of user's needs, and the second is to design and translate these understandings to the language of products in such a way that final product is satisfactory according to fundamental needs as identified in the first step.

A first stage in UCD is to understand users' requirements and how the work is done. In this stage, research team studies routine issues of users by placing themselves in situation of users and observing their behavior. Thus, for our research, in order to understand usage situation, the target group were identified with hand Edinburgh hand dominance survey with help of Iranian left handed association. The Edinburgh Handedness Inventory is a measurement scale used to assess the dominance of right or left hand in everyday activities, sometimes referred to as laterality. Then, kitchenware's problems were identified. In the current study, participants were selected among men and women in the range of 18 to 40 years old. 104 out of 115 participants were left handed (this survey included 10 activities that requires using the dominant hand and according to personal preference dominant hand and side of the body will be recognized). After target group selection, second questionnaire was designed based on frequently used and problematic tools by target group. The second questionnaire was focused on parameters such as type of usage, intensity, duration, abundance and required energy and force. Both questionnaires were sent to participants via email.

In the second stage of the research, electromyography (EMG) assessment was used in order to study damages resulted from inappropriate tools usage by left handed people. EMG examines muscle performance by analyzing electrical signals generated during muscle contractions. Electromyography is a laboratory technique of musculature and it helps ergonomists to study the work environment, tool design and work process timing based on tests such as muscle load (stationary and stimulus), positional muscle fatigue due to overload, timing and coordination of muscle and improvement pattern of stimulus unit, explaining the fatigue of low-level muscle and mental pressure.

An advanced semiconductor technology is required to display important signal information collected while mixed with noise. In most cases, EMGs have also been used to measure this complete change with external load measurements, body postures, or joint movements. EMG recordings are made either through needle electrodes inserted into the muscle or by surface electrodes closed on the skin of the target muscle [17].

The two main reasons for using electromyography in this research were to examine the level of the fatigue and the amount of stress applied to the muscle to identify whether a greater or lower amount of stress and fatigue due to the use of disproportionate left-handed tools compared to right-handed use can be seen. According to what was obtained from the EMG used experiment and the results of the questionnaire, left handed individual have experienced more fatigue and stress when working with right handed tools.

In order to record EMG, circular Ag/Agcl surface electrodes with gel shape were used. Initially, 3 points of the Palmaris, Biceps and Triceps were identified and connected, and two ground references were placed on the wrists of both hands. The electrodes are placed in the center of the muscle tissue because the center of the muscle produces the most signal. A g /USB Amp bio potential amplifier was used to record EMG signals with sampling frequency pf 1200 Hz and online band pass filtering of 2-250 Hz was chosen as anti-aliasing filter, and also online notch filter of 50Hz was activated for canceling the power line noise. A pattern of muscle activity is extracted by electromyography signals, as when the muscle contracts, the result of potentials action create ionic currents, which are transmitted by the post-conductor tissue and can be recorded from the skin surface by electrodes. The electromyography signal indicates muscle contraction, and therefore the frequency of this signal and how the muscle contract is visible in terms of strength and form. The data of this research has been processed using MATLAB software version 2016. The higher the intensity of the muscle tension, the more strength the muscle has expended and can be considered as more fatigue. Figures 2 and 3 show the selected muscles and the sample of raw signals, respectively.

Proper test design and recording protocol is one of the most important parts of signal evaluation. The better and more accurately this step is implemented, the more controlled the signal and the processing procedures needed to make the simpler decision and the results.

In the current study, three left-handed women and one right-handed woman were selected.

The tasks definition for experiments:

Task 1: Opening a can with tin can (right hand tool) with the left hand and right hand for all 4 participants.

Task 2: Cutting paper with scissors (left-handed tool) with left and right hand in all 4 participants.

Task 3: Cutting paper with scissors (right hand tool) with left hand and right hand Doors 4 participants.

Fig 2. Selected muscles

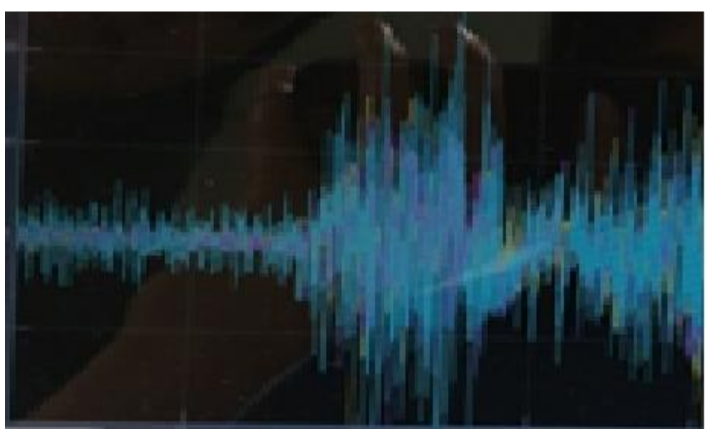

Fig 3. Sample of raw signals

The length of the test interval in each task is divided into four different motion intervals, and each of these four parts is divided into 4 motion intervals in order to increase the accuracy of the data. To prepare the skin, a layer of the skin surface is removed with a soft sandpaper to transmit the signal better by the electrodes.

In first task, participants were asked to open the can at regular intervals, all four participants gradually reduced the speed and accuracy of their work at intervals. First, the right-handed subject opened the can with a can opener (right-hand tool), starting with the right hand, and then with the left hand, in four time intervals. Then, three left-handed subjects performed the can open operation in the same way.

In second task, they were asked to cut a large number of pieces of paper at regular intervals, all four participants gradually reduced the speed and accuracy of their work at intervals. First, the right-handed subject with scissors (left-handed tool) at the beginning performed the operation with the right hand and then the left hand in four time intervals, and then three left-handed subjects performed the scissors operation in the same way.

In order to perform the third task, the same process was done with scissors designed for the right hand.

In the third and fourth steps of UCD philosophy, based on the instructions obtained in the previous steps, several examples of hand tool design were performed. The three selected designs were proposed then analyzed and evaluated based on 4 factors (i.e., performance, ergonomics, aesthetic and price) using Analytic Hierarchy Process (AHP) method.

RESULTS

Table 1 shows open propositions and coded concepts that summarize the positive and negative experiences of left-handers when using inappropriate hand tools. Some of answers with no positive experiences or repetitive answers in negative experiences are summarized and mentioned in Table 1.

Table 1. Open Propositions and Coded Concepts

Proposition	Open coding concepts	Axial coding concepts	Practical concepts in design
1. It allows me to use with my right hand	- Ability to use both hands -Increase mental and physical ability and skills	Psychological effects Performance effects	- Can be used for both groups of consumers - Check how to interact
2. Subconsciously learn to adapt to all the tools and facilities designed for the right hand; Because almost nothing special is designed for us.	-Increase skills in using non-superior hand - Frustration - Unconscious adaptation	Performance effects Physical effects Workplace effects	- Evaluate left-handers in design - Easy to use for both groups - Adjustable - how it is placed in hand
3. I always make the family laugh, especially when using knives and scissors	- Feeling unable to do - Decreased skill - Creating stress - Impact on how it works	Psychological effects Performance effects Workplace effects	- Observance of anthropometric dimensions - Simplicity in design - Familiar appearance for the user
4.I do not have a positive experience, I am always annoyed by kitchen utensils	- Feeling unable to do - Boredom - Psychological effects -Feeling pain	Psychological effects Performance effects Physical effects	- Maintaining safety in the product - Communicating with the consumer - Observance of anthropometric dimensions
5. Over time, I have become accustomed to these devices and have been able to cope with this problem.	- Increase skills - Boredom - Ability to use both hands	Performance effects Physical effects	- Observe the dimensions for both - Fit to the environment and conditions
6.Negative hand-cutting experience	- Feeling of pain - Injure yourself - Impact on how it works -Dissatisfaction with the environment	Psychological effects Performance effects Physical effects Workplace effects	- Prevent hand cuts - Observe and maintain the angle of the wrist - Fit dimensions - Creating satisfaction from the activity - Product safety
7.Being hard and looking for an alternative	- Impact on how it works -Dissatisfaction with the environment	Performance effects	- Meet the needs of the user - Ease of use

The following Figures (4, 5, 6, 7, and 8) have been drawn to show the problems of users with hand tools and the prioritization of tools.

Factors and variables such as the type of tool used (personal experience of use), strength, age, awareness, etc. were considered as effective resulting from the questionnaire survey. Based on the results, can openers and kitchen scissors were considered and based on other parameters such as the intensity and type of interaction with the tool and the type of problem, one of them was concluded. The type of tool's problem can be examined in three categories before use, during use, and after use. The tool's problems at work were evaluated in 5 aspects including usage period, interaction intensity, usage time, accuracy, and required force.

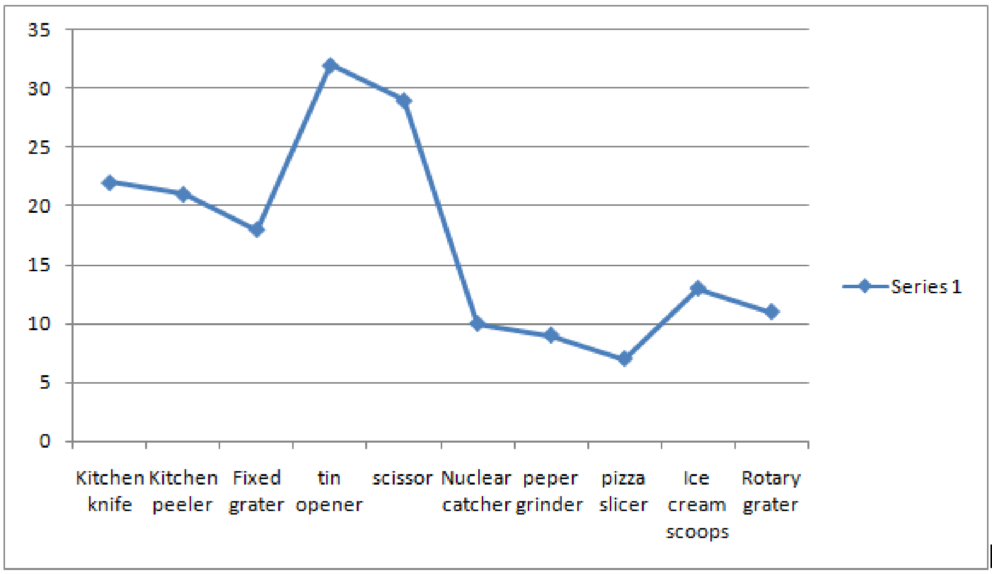

Fig 4. Difficulty degree while working with device

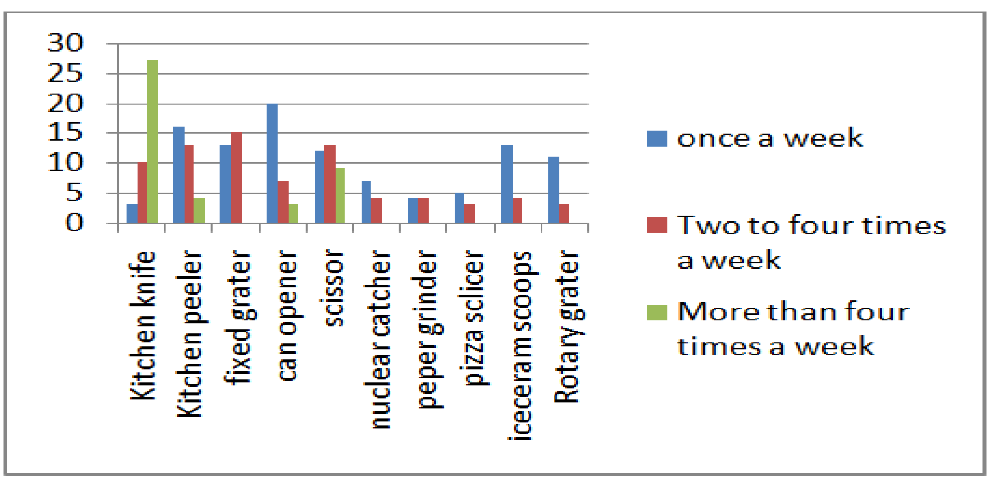

Fig 5. Intensity check chart

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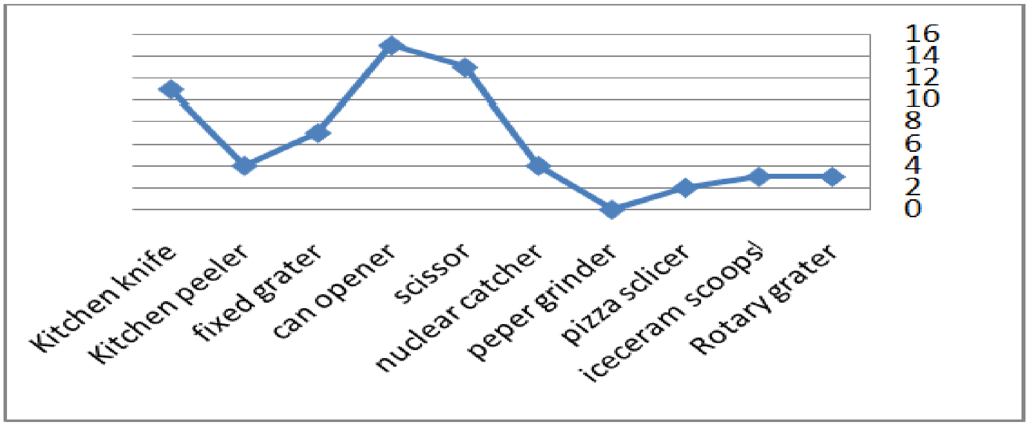

Fig 6. Accuracy check chart

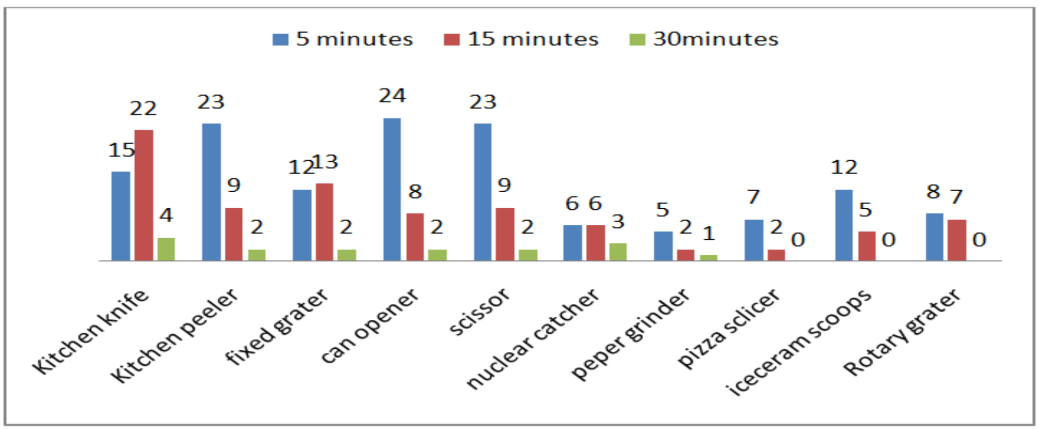

Fig 7. Weekly usage chart

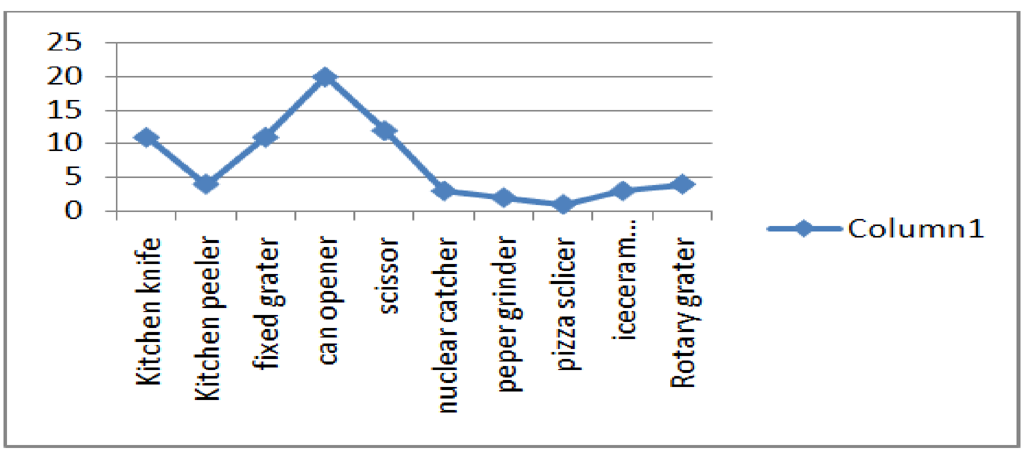

Fig 8. Required force chart

Figures 4 to 8 show 5 important and influential factors in the study of kitchen tools that are evaluated based on the conceptual framework as proposed in Figure 12. Based on this, as shown in Table 2, can opener was selected as a case study sample.

Table 2. Selection of a case sample for tool

Basic parameters	Open coding	Can opener	Kitchen scissors
Problem type	- Side effects - Efficacy effects - Psychological effects - Work environment	✓	
Intensity check	-Physical effects - Work environment - Side effects - Product		✓
Accuracy check	- Physical effects - Effects of performance - Psychological effects - Work environment		✓
Weekly usage	-Effects of efficiency - Psychological effects - the product	✓	
Required force	- Physical effects - Side effects - Product - Psychological effects	✓	

After identifying the subject tool, EMG method was used to examine the position of left hand muscles in the face of right hand instruments more accurately. According to the EMG results, left-handers experienced less difficulty and fatigue, when using their non-dominant hand (right hand) to open the can than the right-hand sample, when using their non-dominant hand (left hand), when performing the same action. This may indicate strengthening the opposite hand of the left hand over time in a world full of right-handed tools. This result is applicable for scissors too. The highest satisfaction based on the results is related to the time of left-handed use of the left hand and the use of left-handed scissors. The descriptive results of muscle tension have been presented in Table3.

In the final step, based on the results of the research, design criteria for kitchenware have been shown in Table 4.

Table 3. Descriptive results of muscle tension

Muscle	group	Average	The standard deviation
Palmaris	Left hand	83.25	25.82
	Right hand	147.31	16.99
Biceps	Left hand	83.75	16.69
	Right hand	146.16	14.31
Triceps	Left hand	86.08	15.50
	Right hand	171.17	31.39
Total muscle tension of the hand	Left hand	84.19	18.37
	Right hand	155.06	20.72

Table 4. Kitchenware design criteria

Main criterion	Sub-criteria	Criterion description
Function	Usage	- Easy and simple operation - Left-handed and right-handed use a device at the same time - Easy mechanism - Buildable mechanism
	Material	- Be strong - Washable - Easy to maintain - The product is durable
	Safety	- There is no sharp and winning edge - Creating a sense of security during use
Aesthetics	Appearance	- Have a beautiful appearance - Fits other kitchen utensils - Appearance is directly related to performance - The texture of the handle is appropriate
Ergonomics	Ergonomics	- Proportional grip - High effective force level - Observe the angles of the wrist and forearm - Not heavy - Observance of anthropometric dimensions
Price	Price	- Easy to build - Easy assembly - Proportional price

In Figure 9 three design concepts which named from left to right (left, middle and right) were proposed as illustrated below to address the issue for left-handed based on the above-mentioned criteria. These designs were evaluated using the AHP method, which can be seen in Table 5.

Considering the acquired data in Table 5, the right hand site concept (blue one) can be the best design for can opener.

Fig 9. Can opener concept design (Red, Green and Blue)

Table 5. AHP result

	Function	Ergonomics	Aesthetics	Price	Total
Red Concept (Image in Left)	0.33	0.27	0.16	0.16	1.52
Green Concept (Image in Middle)	1.4	0.75	0.46	0.19	2.8
Blue Concept (Image in Right)	1.54	1.41	0.87	0.37	4.19

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DISCUSSION

It was assumed, based on the first hypothesis that there is a significant difference between the muscle tension of the left forearm muscle when using the left hand device with the left hand and the left hand using the right hand device. In order to test this hypothesis and make the desired comparison, the independent t-test was used, the results have been shown in Table 6.

Table 6. Difference between muscle tensions for Palmaris muscle

Variable	group	Average	T	df	P
Palmaris Muscle tension	Left hand	83.25	3.59	4	0.023*
	Right hand	147.31			

P<0.05*

Using independent t-test, the difference between forearm muscle tension has been reported. Accordingly, based on the value of t-statistic (3.59) at the level of significance of the test (p = 0.023), it can be concluded that there is a significant relationship between muscle tension of the left forearm muscle when using the left-handed tool with the left hand. There was a significant difference between left-handed and right-handed devices when left-handed people use it, and the muscle tension created for the left hand was less than the right hand (P<0.05). Second hypothesis was that there is a significant difference between the muscle tension of the left arm biceps when using the left-hand device with the left hand and the left-hand arm using the right-hand device with their right hand. In order to test this hypothesis and make the desired comparison, the independent t-test was used, the related results have been presented in Table 7.

Table 7. Difference between muscle tension for Biceps muscle

Variable	Group	Average	t	df	P
Biceps Muscle tension	Left hand	83.75	4.95	4	0.008*
	Right hand	146.16			

P<0.05*

Using independent t-test, the difference between biceps muscle tension has been reported. Accordingly, based on the value of t-statistic (4.95) at the level of significance of the test (p = 0.023), it can be concluded that there is a significant relationship between muscle tension of the left biceps when using the left-handed device with the left hand. A significant difference between left-handed and right-handed devices is witnessed when left-handed individuals use them, and the muscle tension created in the biceps muscle for the left hand was less than the right hand (P<0.05).

As third hypothesis, there is a significant difference between muscle tension of the left arm triceps when using the left-hand device with the left hand and the left-hand arm using the right-hand device with their right hand. The results of comparison independent t-test have been presented in Table 8.

Table 8. Difference between muscle tension for Triceps muscle

Variable	group	Average	t	df	P
Triceps Muscle tension	Left hand	86.08	4.32	4	0.013*
	Right hand	171.71			

P<0.05*

Using independent t-test, the difference between triceps muscle tension has been reported. Accordingly, considering the value of t-statistic (4.23) at the level of significance of the test (p = 0.013), it can be concluded that there is a significant relationship between muscle tension of the triceps muscle of the left hand when the hand is left-handed. There is a significant difference between left-handers and right-handers, and the muscle tension in the triceps muscle is less for the left hand than for the right hand (P<0.05).

As fourth hypothesis, there is a significant difference between the muscle tension of the left hand when using the left hand device with the left hand and the case when the left hand uses the right hand device with the right hand. In order to test this hypothesis and make the desired comparison, the independent t-test was used, the results of difference between hand's muscle tension have been presented in Table 9.

Table 9. Difference between hand's muscle tension

Variable	group	Average	t	df	P
Muscle tension of the hand	Left hand	84.19	4.43	4	0.011*
	Right hand	155.06			

P<0.05*

Using independent t-test, the difference between hand muscle tension was reported. Accordingly, based on the value of t-statistic (4.43) at the level of significance of the test (p = 0.011), it can be concluded that there is a significant relationship between muscle tension of the left hand when using the left hand tool with the left hand. There is a significant difference between left-handed people using the right-hand device and their right-hand device, and the muscle tension created in the left hand is less than the right hand (P<0.05).

In the previous section, top three can opener designs were analyzed and the blue design (right image) was the best design using the AHP evaluation method. The selected design includes a blade and a gear for better grip of can opener. The upper axis movability is an advantage of the proposed design which provides the possibility of simultaneous use of left and right hands of a single tool. Therefore, it can be used along with other tools with at least level of complexity. Figure 10 illustrates four views of the designed can opener named plus, which is named from left to right. Figure 10A shows right-handers user-friendly, Figure 10B shows the close-up view of the blade and the gear, Figure 10C shows left-handers compatibility, and Figure 10D shows the back view of the final design.

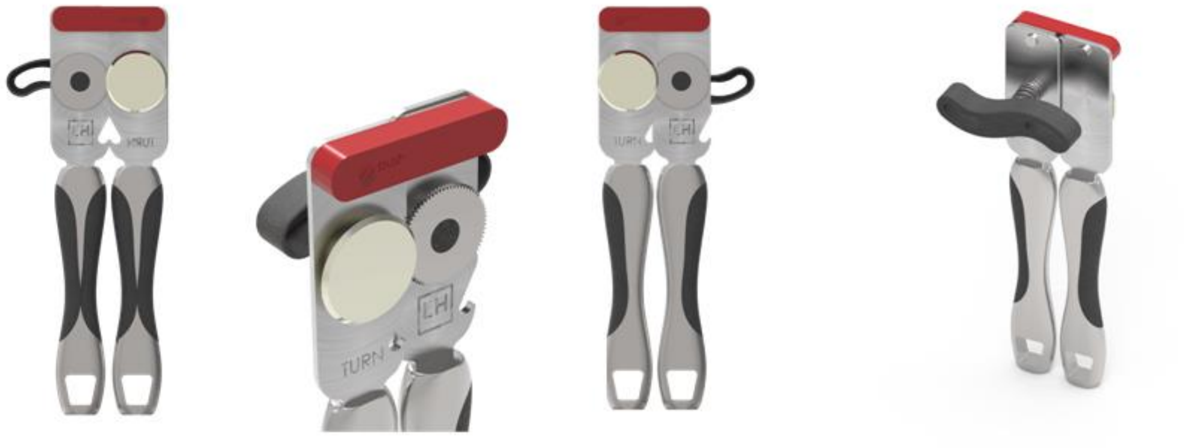

Fig 10. From left to right 10A, 10B, 10C, 10D

The best way to better nurture left-handers and to use their abilities is proposed to educate families on how to avoid forcing children to use their right hand and how to avoid damaging children's confidence and consequently school and the education system.

It is possible that the beginning of education in the right hemisphere in left-handed children, depending on the capabilities of this hemisphere, can lead to the development of special abilities and as a result, the recognition of different aspects of this minority.

The ergonomics characteristics of proposed concept weigh remarkable with regards to the ease and comfort to be grasped due to their handles shape, anti-slippery texture on handles material, ease of operability of rotating knob with fingers, provision of storage and hanging feature, and emotionally distinctive form.

The next proposed solution is to consider an international symbol (Figure 11) for left-handers along with other symbols and labeling such as compliance with standards to indicate that left-handers are considered in products and services.

Fig 11. Symbol for Left-Handers

The left-hand label is not a value-added commodity but a sign that the left-handers have been seen. The labeling paves the way that the different physiological characteristics of this minority group are known and are no longer be ignored. This symbol is used when the product can be used by left-handers or in such a way that both left-handers and right-handers can use a single device. Other work environments and stations, as well as technical tools, need to be examined and adapted regarding the physiology of their users, especially if the user is left-handed. The present study's conceptual framework is a logical and developed network of the consequences of using inappropriate tools for left-handers. It has been provided through the processes performed in the research and according to the validation of hypotheses. Figure 12 shows the classification of injuries into groups along psychological effects, performance effects, physical effects, workplace effects, side effects and advancement of technology with how they affect the left hand.

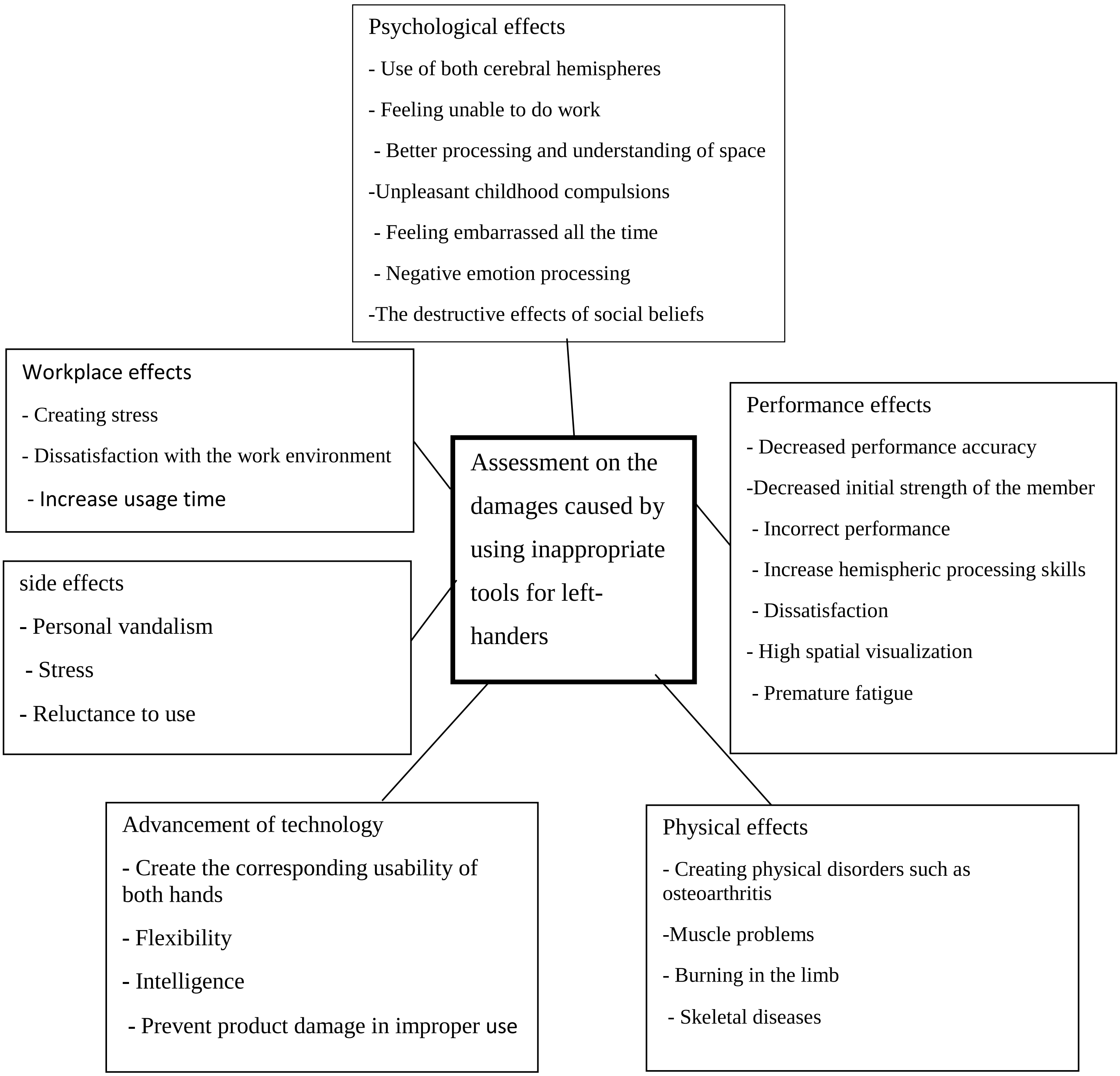

Fig 12. A comprehensive conceptual framework for damages assessment caused using inappropriate tools for the left handers

CONCLUSION

Based on the results and the accepted hypotheses, left-handers' requirements should be taken into consideration in designing products, services, and workstations. This article examined the possible disorder of wrong hand tools' application in the kitchen for left-handers. The initial assessment of harms was done through acquiring the positive and negative experiences of a small community of left-handers. Furthermore, the lefthanders were surveyed and examined qualitatively and quantitatively by a questionnaire and EMG tests. Finally, comprehensive design instructions and suggestions for the enhanced healthy integration of the lefthanders group were provided.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

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