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Improvement of a cutting flowers tool by using ergonomic design
Desarrollo de una herramienta de corte de flores, mediante requerimientos ergonómicos de diseño

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Abstract

The risk factors for developing the Carpal Tunnel Syndrome include the required strength to perform the apprehension gesture and the wrist posture; where the Colombian flowers sector has the highest rates. The objective of this study is the development and validation of manual tool to cut flowers, maintaining the same grip diameter on the fingers while it is being used, with the aim of improving the mechanical advantage and mitigate the strength factor. For this, two phases were developed: proposal of a functional model of the cutting tool and its laboratory validation. The research found that tool type is associated with finger strength, and that the tool proposed presented the smallest strength value, reducing the necessary strength to make the cut. This research showed that it is necessary to develop tools with specific requirements for the Colombian population and thus mitigate occupational diseases that can leave life-long injuries and generate disability.

Keywords: apprehension gesture; carpal tunnel syndrome; cutting tool; finger strength.

Resumen

La fuerza de la mano y la postura de la muñeca son los factores de riesgo para el desarrollo del síndrome del túnel carpiano, y las tasas más altas de esta patología las presenta el sector floricultor colombiano. Este estudio tiene como objetivo el desarrollo y la validación de una herramienta manual de corte de flores, que permita mantener el diámetro de aprehensión, mejorando la ventaja mecánica y mitigando el factor de fuerza. Esto se desarrolló en dos fases: primera, la propuesta de un modelo funcional de la herramienta de corte, y, segunda, su validación en laboratorio. Se encontró que el tipo de herramienta tiene asociación con la fuerza de los dedos y que la herramienta propuesta presenta el menor valor de fuerza necesaria para realizar el corte. Se concluye que es necesario desarrollar las herramientas con requerimientos de la población colombiana para mitigar enfermedades ocupacionales que puedan dejar lesiones de por vida a los trabajadores.

Palabras clave: fuerza en los dedos; gesto de aprehensión; herramienta de corte; síndrome del túnel carpiano.

1. Introduction

Colombia is the second largest exporter of cut flowers on a world-wide scale and the cut flower production is the fourth largest productive sector at national level, resulting in high revenue of dollars [1]. This sector generates 80.000 direct and 50.000 indirect jobs, mainly employing women in Colombia rural areas [2], and they occupy their jobs primarily in cut area and post-harvest [3]. Accordingly, this productive sector is one of the most important in the country.

According to some authors [4] [5] [6], during the flower harvest and post-harvest, cutting the flower stem means a need to hold the same postures of hand and arm for extended periods of time with repetitive movements.

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Physical demands in these workers is increased due to the high demand in productive levels, this producing direct consequences in their bodies and psychosocial well-being [2].

Other researches had confirmed these analyses. The administrators of the subsidized health Regime (ARS SURA), Pontificia Universidad Javeriana and Escuela Colombiana de Ingeniería, showed that the task with highest mechanic demand is the cut in the harvest area. The employee works between 8 and 12 hours with high demand [4]; and cuts the stems a rate of 380 or 400 stems per hour. Furthermore, the stems diameter can be a half centimeter to two. That gives some idea of the impact that produces the cutting task and strain involved in the use of the cutter, which requires thrust up to 16,6 Kgf, equivalent to 183% of strain more than those recommended on international literature [7]. This is why, in the short term, it is evidenced the worker's fatigue when undertaking their work and in the long-term it is possible to arise occupational illness which may adversely affect the work quality, and more important, impair their quality of life [8][9]. In this sense, loss of mobility and loss of strength in the hand is a logic consequence of workers who specialize in one task [3].

It has also been found that the tool to cut flowers is unsuitable due to hand anthropometry in Colombia compared with workers for other parts of the world where these tools are produced [10]. It is important to understand the relationship between tool, person and its right use according to the task [11] to prevent possible diseases generated by the work.

It is a fact that highest incidence in occupational illness, such as carpal tunnel in floriculture, has increased substantially. In 2012, this was the disease with the highest prevalence per economic activity in Colombia [12], and in cut flower production it had the more detected cases with 19% the sum of the records [13]. In fact, there is a consensus between authors that the upper limb musculoskeletal pathology is the major disease in this productive sector, in combination with different factors such as repetitive movement with muscular tension, forces postures in wrist, excessive manual strength and insufficient rest, higher repeatability and effort [14].

Thus, it is necessary to find solutions that allow to maintain the relation between handles distance and apprehension strength in every finger, in accordance to hand anthropometry [15] of Colombian female workers and minimize unnecessary effort when the flower is cut, taking advantage of biomechanics and physiologic characteristics. In short, the aim of this project is answer the question: How much improvement the grip strength and therefore reduce the effort required to make the cut, when the new tool to cut flowers, is used?

2. Materials and methods

This study is approved by the Universidad Industrial de Santander Ethics Committee CEINCI by means of a written informed consent for the participants. In addition, the study was classified without risk.

2.1. Participants

Participation in this study was voluntary among the Universidad Industrial de Santander community. To take a homogeneous sample (N=33), women with ages between 21 and 31 years old, hand width from 6,4 to 8 cm, hand length from 14 to 24 cm and with right hand dominant were considered. Moreover, the participants had no pain and inflammation in shoulders, elbows, forearm and fingers of the right hand. Likewise, they had not cysts around the hand joints or have been diagnosed with rotator cuff syndrome, epicondylitis, epitrochleitis, carpal tunnel syndrome or trigger finger.

Table 1. Test procedure

Test	Kind of tool	Arm position	$\bar{t}$ in min (time)	Comments
1	H1 H2 H3	45° flexion 	1	• Position of the hand and tool respect to the cut, in pronation. • 3 cuts in each task
Rest			2	Promote the muscle physiologic recovery and avoid fatigue
2	H1 H2 H3	100° flexion 	1	• Position of the hand and tool respect to the cut, in pronation. • 3 cuts in each task
Rest			2	

** For each treatment H1, H2 and H3 applied 2 tests and the corresponding rest.*

2.2. Variables and equipment

An arrangement of two factors called "arm position" and "kind of tool" were used. Hence, it was considered two arm positions (45° and 100° arm flexion) and three treatments for tool kind, as can be seen in Table 1 and 2.

Finally, the study used the pronation, because it was the ideal flower-cutting posture since it involves less effort to perform such task [15].

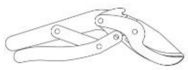
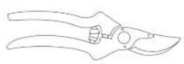
Kind of tool	Maximum diameter*	Minimum diameter*	Handgri p length**
H1 (new cutting flower tool) 	8 cm	5 cm	14 cm
H2 (the cutting flower of the market) 	14 cm	5 cm	15 cm
H3 (the cutting flower of the market) 	13,6 cm	6 cm	13,5 cm
* The maximum diameter refers to maximum opening of the tool and minimum diameter in minimum opening of the tool. ** Handgrip length measured from the fulcrum.			

Table 2. Treatments

For this study, the following informatics systems were used to capture information: 5 strength sensors Biometric ltd for collecting the strength data in each finger, and a hand goniometer SG65 Biometric ltd with a Biometrics minidatalog for collecting the wrist angles and deviations of the right hand. The data was collected with the Biometric Datalog Software, in which the strength sensors have been calibrated in sensibility channel 1mV, 1200 mV output, minimum value zero and maximum 180°.

The strength sensors were adhered to the skin with surgical tape micropore on the index, middle, third and little finger (S1, S2, S3, S4 respectively), specifically in the finger´s middle joint. In the thumb finger, the sensor was adhering in the thenar eminence (S5) as shown in Figure 1.

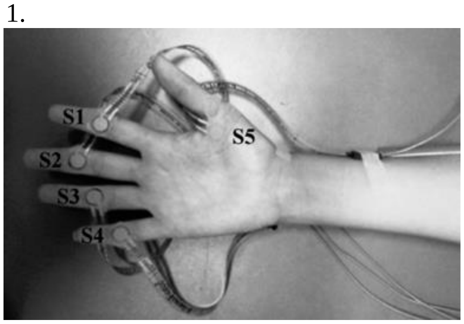


Figure 1. Sensors straight.

2.3. Characteristic of experimental procedure

- The Chrysanthemum was the flower species selected, because it is in the 1st and 3rd position of Colombian exports in the last years [16]. This project tried to keep the same flower characteristics, with stems diameter between 10 and 14 mm, and before the beginning of testing the flowers were immersed in water for 2 hours; the study did considerer this period of time appropriate for keeping the flower fresh.
- In general, laboratory space had free access as not to interfere with the procedure such as cables, chairs or persons. For that reason, the only participants at the moment of experiment were the investigator in charge, support staff, witnesses and the participant.

2.4. Subject procedure

- Objective and measured equipment's explanation.
- Reading and signature of informed consent.
- Data acquisition: measures of hand, weight and size. Assignment of corresponding participant code for confidentiality.
- Participant´s approximation to H1, H2 and H3 treatments, strength sensors and goniometers.
- Adhere the equipment to participants and calibrate it as shown in Figure 2.

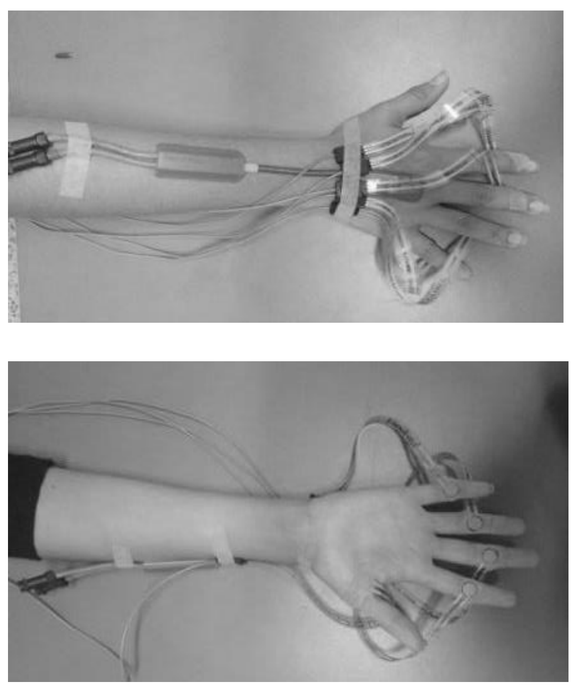


Figure 2. Location of sensors in the participants.

First, adhere the goniometer on the dorsal surface of the hand where one end of the goniometer adheres on third metacarpal and the other on middle line of dorsal side forearm with the wrist in neutral position. Finally, the strength sensors were adhered. All devices were connected to Minidatalog located in the participant hip.

2.5. Test Procedure

- Explanation of the cutting posture with right hand in pronation, in the air without support the upper limb on surface, as is done in normal labor of work [15]. See table 1.
- Maintain stable standing participant´s position and take the arm-bending angle (45° and 100°) before collecting the data to indicate the exact cut position.
- Execution of the test with each treatments and randomized tasks. Each participant in each arm position (45° and 100°) should do 3 cuts every 5 seconds.

2.6. Data Analysis

Appropriate descriptive statistics were computed for strength and posture variable. The results were analyzed using the ANOVA for continuous data and chi-square test for ordinals data. Thus, for strength results in the 5 fingers and treatments, were considered 3 range: 0 to 0,1 [N] low strength, 0,1 to 0,2 [N] middle strength and 0,2 to 0,95 [N] high strength. Data were analyzed using SPSS 22.0. For all statistical tests, significance was set at $p<0,05$.

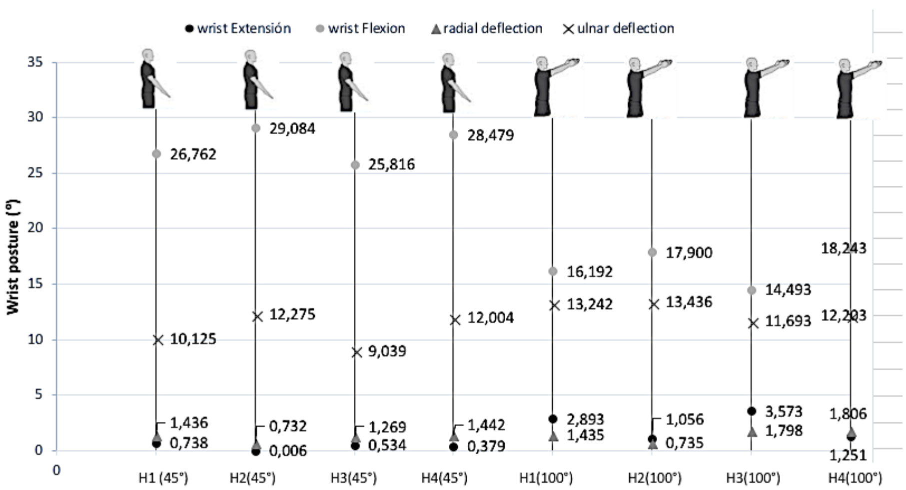


Figure 3. Mean wrist posture and arm bending while the tools are used.

3. Results

3.1. The wrist and the arm posture

When comparing the mean wrist posture (extension, flexion, radial-ulnar deflection) with the arm bending while the tools are used; without taking account the kind of tools (H1, H2 and H3), the study found that the extension and radial-ulnar deflection have the same posture behavior when the cut is done in 45° and 100°, as show in Figure 3. Wrist flexion was the unique posture in which there is variation, stating that in the measure in which the cut is getting higher, wrist flexion is lower; these values are the lowest in H1 and H3 treatments. Further, the study found that statistically, tools have no effect in wrist flexion, on the contrary the arm bending has effect in the wrist flexion ($p=0,000$).

3.2. Grip Strength

Index and middle finger show the strength with highest values, independently of the kind of tool, therefore these fingers were considered as statistical evaluation axis. According to the tools average value and the arm bending, it was found that, generally the height of cut the flower no have effect on the strength in each fingers. Furthermore, the kind of tool has association with the finger strength; the arm bending in 100° affect the index strength (p-value = 0,037) and middle strength (p-value = 0,01).

The strength in the fingers, according to kind of tools, showed that tools H1 and H3 use less force, as shown in Figure 4. In this specific case, H1 presented the smallest value of strength. In terms of the scale of strength of this specific study, H1 mean values are in the range of "middle strength (between 0,1 to 0,2), however H2 and H3 are in the range of "high strength".

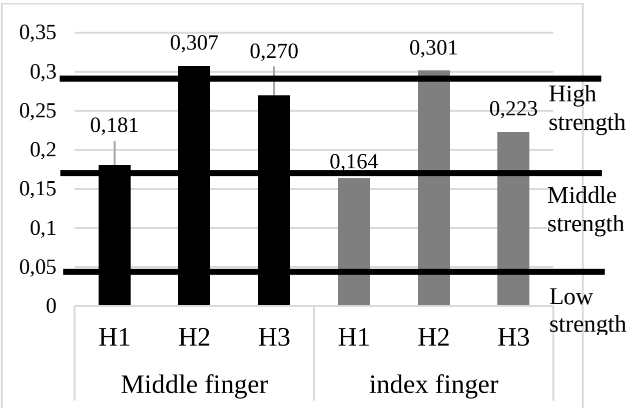


Figure 4. Strength in the fingers (N) according to kind of tools.

4. Discussion

In this study, a cutting flower tool was developed that established a maximum diameter of 8 cm, decrease it in a 57,14% in relation with the traditional tools on the international and national market. Thus, this study is consistent with Greenberg and Chaffin [17]; the ideal maximum diameter, for both men and women, ranges between 6.4 cm and 8.9 cm. The traditional tools used in this study to be compared with the proposed tool, have diameters between 13 and 14 cm which makes difficult the manipulation and cut for the Colombian workers, because this tools are designed in other countries with different anthropometric measures [18][10].

In accordance with posture, the ulnar and radial deviations of the wrist, especially in the flower cutting and classification task, shown that were not sustained beyond extreme angles in a study conducted by Barrero et al [4]. The same applies to this study, where the flexion- extension afford 27,53° to 0,41°, is still well within the bounds of normal angles [19].

On the other hand, related to the research question, strength is also an important factor in the cutting flower task, because is one of the risk factors associated with appearance of musculoskeletal disorders that affect workers in this sector. In this sense, it is proposed to improve mechanical advantage during the manual operation of the cutting flower tool to benefit the health of workers. The studies show that the external force requirement using different types of tool to cut flowers have a range between 3,3 and 15, 4Kgf [4], the proposed tool in this study, compared to those traditionally used in floriculture (H2 and H3), succeeded in increasing the mechanical advantage without cutting the biomechanical advantage in 180% [20]. Therefore, this can have an impact in the health and work activity for the workers.
As a result, the tool designed by the Research Group GEPS of Universidad Industrial de Santander, decreases the grip strength and maintains neutral posture while the tool is used, thus reducing the ergonomics risk. The studies show that posture, strength, repetition and vibration are the factors that can cause Carpal Tunnel Syndrome [10], therefore it is necessary that the future research development of new tools take thiese factors into account.

5. Conclusions

A mechanic system that increases the mechanical advantages and potentiates biomechanics advantage was developed. This new tool reduces the strength in the principal fingers, middle and index, contribute to mitigate the force risk factor. Nonetheless, it is necessary to validate the strength in all hand phalanges and thus find more evidence of possible benefits of this hand tool. This validate should be in real work space with real workers to evaluate the characteristics and possible effects in them.

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