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Design of a measuring device for the establishment of anthropometric dimensions of the Ecuadorian hand in older adults

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ABSTRACT: *Product design requires a research base focused on the human factor to effectively contribute to the generation of new proposals. Ecuador has few anthropometric studies, and the existing tangible applications are based on anthropometric tables from other countries to fill this absence.*

This research work aims to support the collection of anthropometric data of the population of older adults (over 65 years) of the female gender. It was established a data compilation with the different foreign anthropometric studies that are related to the topic to describe essential requirements in the configuration of the device, then it was proceeded to design the device by using a 3D model with which a validation was made, besides the presentation of the device by an analysis of finite elements (studies of buckling, fall and fatigue).

***KEYWORDS** -Anthropometry, anthropometric measurements, Ecuador, hand, industrial design*

I. INTRODUCTION

Anthropometric research on Latin American populations is scarce, and when research from other countries is taken into account for the configuration of a system, human variability (genetic inheritance, sex, age, socioeconomic conditions, occupation, generations) makes regional data unsuitable for the population, representing a conflict for the Ecuadorian population. (Chaurand, León y Muñoz, 2007)

Ecuadorian women from 65 years old are more susceptible to suffer pathologies that influence in limiting the mobility of the hand (osteoporosis, sarcopenia), this causes difficulties now of obtaining the anthropometric measures and becomes the main factor of study. (Betancourt Ortiz, 2014)(Santamaria y Tapia ,2018)

1.1. Related investigations

Summary table of research on the method used in different studies, determination of requirements for the generation of the proposal.

Table1. Related investigations(Source: Own Elaboration, 2020).

References	Instrument used	Description
Anthropometric hand evaluation in students of the physical therapy career at PUCE for the elaboration of an anthropometric hand database applied in the redesign of an exoskeleton.		
(Ortiz andTonato, 2018)	Stanley brand measuring tape of 8 meters and accuracy of 2 mm, the Stanley Dual Caliper model 78 - 201 with an accuracy of	Measurements involved: The length, diameter and perimeter of the hand, wrist, palm, interphalangeal joints, and phalanges. Anthropometric position: Lengths of the palm and hand in supination and with the fingers in extension. Perimeters with the hand in pronation. The diameters will be measured with the caliper. The width of the hand will be measured by joining

	0.02 mm and finally the tape measure of 1, 52 cm.	all the fingers together and resting the hand on the table, finally the bistyloid diameter is measured with the hand in pronation.
Obtaining the range of motion of the index, middle, ring and little fingers		
(Barrera, Merchán, Rodríguez, Hernández D. and Hernández G., 2017)	Vernier and marks on the hand that served as a frame of reference.	Measures involved: Palm height, height of hand, palm width, hand width, proximal phalanx, middle phalanx, distal phalanx, finger width; flexing, abduction, and adduction movements. Metacarpophalangeal (MCF), Interphalangeal proximal, Interphalangeal distal. Measurement method: To determine this, the kinematic problem is solved whose objective is to analyze the geometry, position and movement of the solids that make up the system, with respect to a coordinated reference system.
Anthropometry, comparative analysis of technologies for capturing anthropometric dimensions.		
(Lescay, Becerra and González, 2016)	Stadiometer, anthropometer, anthropometric compass, tape measure, anthropometric chair	Measurement methods: (Lasers) Infrared thermography SYMCAD BodyScanner, Measurement with a photograph, Kinect, Android application for anthropometric measurement from mobiles. (First version)
Anthropometric variables and their relationship with hand force-grip, for the ergonomic use of hand tools in a group of workers in the construction sector in Bogotá.		
(Piñeda, Osorio, Sabogal, Corre and González, 2016)	Vernier of short branches from 0 to 200 millimeters, tape measure, hydraulic hand dynamometer up to 90 kilograms.	Measurements involved: Hand Length, Palm Length, Maximum Palm Width, Maximum Thumb Width, Hand Thickness, Hand Grip Diameter, Hand Biomechanics
Manual of anthropometric measurements.		
(Carmenate, Moncada and Borjas, 2014)	Thickness calibrator.	Measures involved: Hand length, Palm length, Palm width. Anthropometric position: Right side of body, hand and fingers extended.
Biometric Aspects of the Hand of Chilean Individuals		
(Binvignat, Almagiá, Lizana, andOlave, 2012)	Calyper Mitutoyo of 0.05 mm accuracy.	Measurements involved: Hand length, hand width, finger length, length of the phalangeal sector. Anthropometric position: hand length was considered from the distal fold of the wrist to the distal end of the middle finger; hand width from the lateral margin of the palm, before the palmar finger fold of the indicator finger, to the medial margin of the palm, before the palmar finger fold of the middle finger; length of the fingers on their dorsal side, from the metacarpal joint to the distal end of the fingers.
Mobility range and descriptive function of the index finger		
(Velázquez, Merchán, Hernández, and Urriolagoitia, 2012)	*	Measures involved: Finger flexion and extension at the MCF joints. Flexion and extension of the fingers at the IF joints Abduction and adduction of the fingers at the MCF joints. Flexion and extension of the thumb at the MCF joint and the IF joint (transpalmar abduction and radial abduction) Thumb abduction and adduction at the carpometacarpal joint (palmar abduction) Method of measurement: Position sensors, which are placed directly on the interphalangeal joints and the open kinematic chain covering the finger structure (Exoskeleton).

		Anthropometric position: Abduction and adduction are measured from the axial line of the hand, all fingers are separated in arcs of approximately 20°, while in adduction they are joined and touch each other.
Pilot study of anthropometric hand measurements and gripping forces, applicable to the design of hand tools		
(Díaz, Mariángel, Silva and Herrera, 2010)	Dinatronics brand hydraulic handheld dynamometer, for measuring full palmar grasp force (grip) and flexible tape measure, for measuring anthropometric dimensions.	Measures involved: hand length, palm length, hand width, maximum hand width, grip diameter, it is also important to consider the length of the phalanges, hand thickness, hand circumference and maximum hand circumference. Anthropometric position: Evaluation of 3 grips with your dominant hand with rest periods of 2 minutes between each grip. Then the measurement of the required anthropometric dimensions was carried out: The evaluator asked the patient to remain seated with the hand to be measured in front of him and the measurements corresponding to the required anthropometric dimensions were taken through a flexible tape measure.
Anthropometric dimensions of Latin American population		
(Chaurand, León, and Muñoz, 2007)	Caliper	Measurements involved: Hand width without thumb, hand width with thumb, hand length, hand height, handle diameter, maximum hand diameter, index finger diameter. Anthropometric position: Subject sitting with right arm extended in front with palm facing upward.

*Not available data is represented with an asterisk.

The proposal of measurement resulting from the investigation has as purpose to base the configuration of the device for the survey of anthropometric data of the Ecuadorian hand that will benefit directly to investigations and professionals within related disciplinary areas.

II. MATERIALS AND METHODS

A device is proposed that contributes to the collection of anthropometric measurements of the hand of Ecuadorian women from 65 years of age. Within the development, measures were proposed for the configuration of the device, followed by an analysis of direct competition and thus determine the specific requirements and materials in the proposal.

The most relevant anthropometric measurements of the hand for the configuration of systems or products are: length of the hand, length of the palm of the hand, maximum width of the palm of the hand, maximum width of the palm of the hand with the thumb, and lengths of each finger so, the device will help to take such measures.

In order to establish the measurement method, the instruments used in the related research were analyzed, determining the caliper as direct competition, so it proceeds to analyze its operation by means of reverse engineering for the selection of the most appropriate components in based on its strengths and weaknesses, as this device is not designed to measure human dimensions.The precision offered by the digital vernier caliper is based on its capacitive sensors, so through a study on these sensors, the use of these sensors is established for the configuration of the device due to their precision in adverse situations and the ability to detect different objects. However, due to its short detection range (depending on the material it varies between

30mm to 80mm), the measurement of the end of the device is considered until the beginning of the measurement to obtain the real measurement by means of subtraction.

The main requirements of the device are based on the need to ensure the position of the hand while taking measurements, in related investigations it is performed on the right hand and requires that it be supported on a flat surface, the fingers must be straight and together, palm up, and at the moment of measuring the tissues should not be compressed. In addition, for a better comfort of both the person who performs the measurement and the person to be measured, taking into account the deficiency of the digital caliper, additional requirements are established: it must be light to facilitate its manipulation, it must reduce the measurement time, ensure good visibility for the evaluator and must be intuitive to reduce errors in the investigation; likewise, to ensure reliability, the precision of the data must have an approximation of two decimal places.

Altogether, all that has been mentioned converges in the proposal of a device with a rigid base, elastic bands to flatten the hand, thirteen capacitive sensors at the ends and movable plates for their determination. The base will allow to support the right hand (palm up) in such a way that the fingers are stretched and together, with the help of the elastics (on the wrist and phalanges so as not to compress the tissues of the thenar and hypothenar regions).

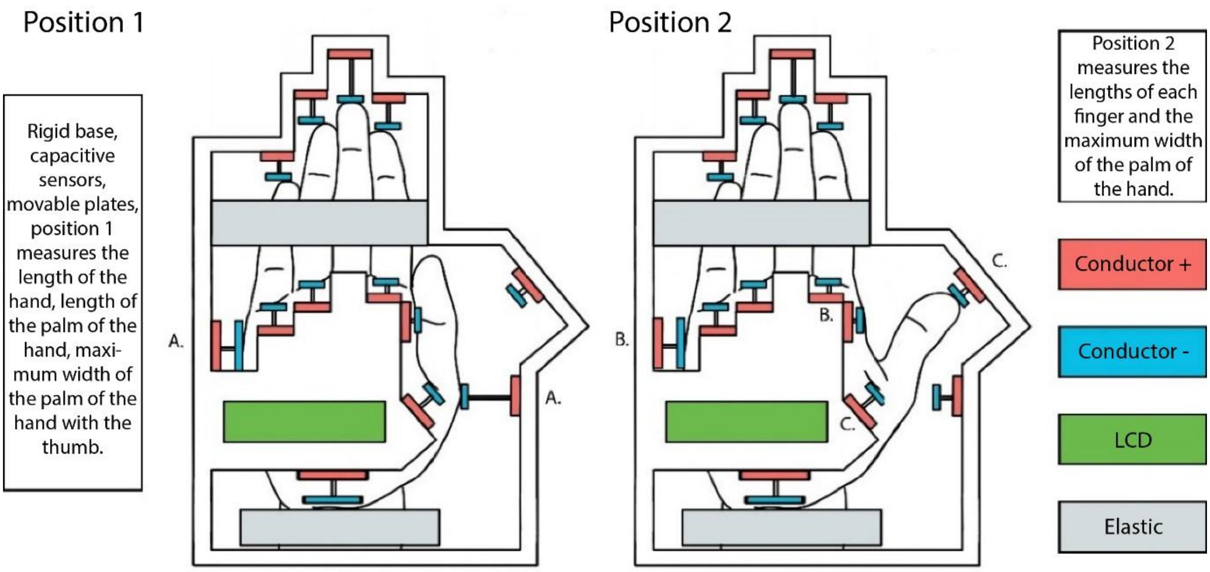


Figure1. Conceptual sketch (relationship components, positions and anthropometric measurements to be measured)(Source: Own Elaboration, 2020).

2.1. Device simulation

A simulation of the device was carried out using a 1: 1 scale model, six individuals and three different heights of the support surface (70cm, 74cm and 78cm). The six individuals were asked to support the elbow of their right arm on a table and extend their hand to enter the model of the device, they were held on the fingers and wrist by the pressure of a support hand simulating the elastics and questions were asked to determine their comfort.

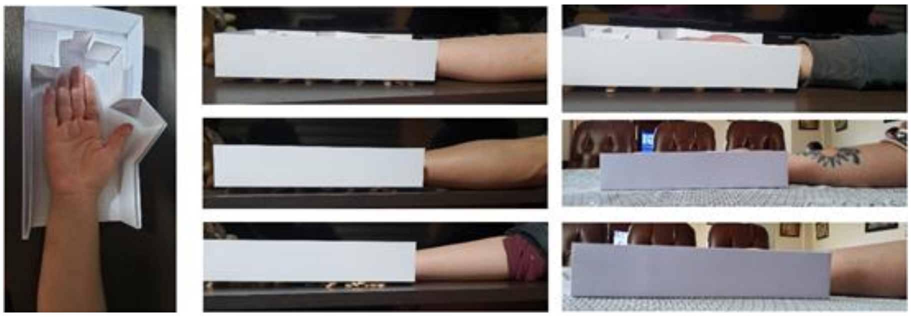


Figure2. Simulation of the device in six individuals(Source: Own Elaboration, 2020).

As a conclusion, it was determined that regardless of the height of the support surface, the participants did not express any discomfort in terms of the position of their arm, thanks to the support of the elbow on the table and the ease of moving the measuring device depending on armlength.

Once the validation was carried out using the model, a selection of materials was made using the database method, where the use of: polyvinyl chloride (PVC), acrylic and polyester elastic was determined.

Next, the relevant properties of polyvinyl chloride (PVC) and Polymethylmethacrylate (acrylic) will be presented, based on the MatWeb database(MatWeb, 2016), in order to determine the parameters necessary to perform a finite element analysis as validation.

Table 2. Material properties (Source: Own Elaboration, 2020).

Property	PVC	Acrylic	Units
Elastic modulus	2 800	2900	N/m^2
Poisson's ratio	0,47	0,4	N/D
Density	1,4	1,18	g/cm^3
Traction limit	45	69	N/m^2
Compression limit	60	100	N/m^2
Coefficient of thermal expansion	$75x10^{-6}$	$77\ x10^{-6}$	/K

Polyester elastic is stretched by the type of fabric, since it is not particularly elastic, and as it has different properties from its fibers, it is not found in the databases, so the choice of this material was made using a traditional method focused on experience.

Taking into account the variables to be measured, the requirements of the measurement taking and the requirements of the users, the final device is configured in such a way that it supplies the needs established with the application of product design and all the analysis that it entails.

III. RESULTS

For the development of the proposal we started with a digital modeling created by solids in SolidWorks™, followed by a finite element analysis with simulation tools provided by the software to validate its reliability, sensitivity, and feasibility.

The modeling consists of: a base to support the hand, which is removable for regular cleaning; a lid with walls that contain the positive conductors of the sensors; a transparent acrylic lid that allows the visualization of the hand and has rails for the movement of the negative conductor of the sensor; a device that carries and protects the negative conductor of the sensor, besides allowing the movement in a more comfortable way; on the side there are two Arduino R3 internally, besides two power buttons under each liquid crystal display (LCD), each one reflects the data taken in a position.

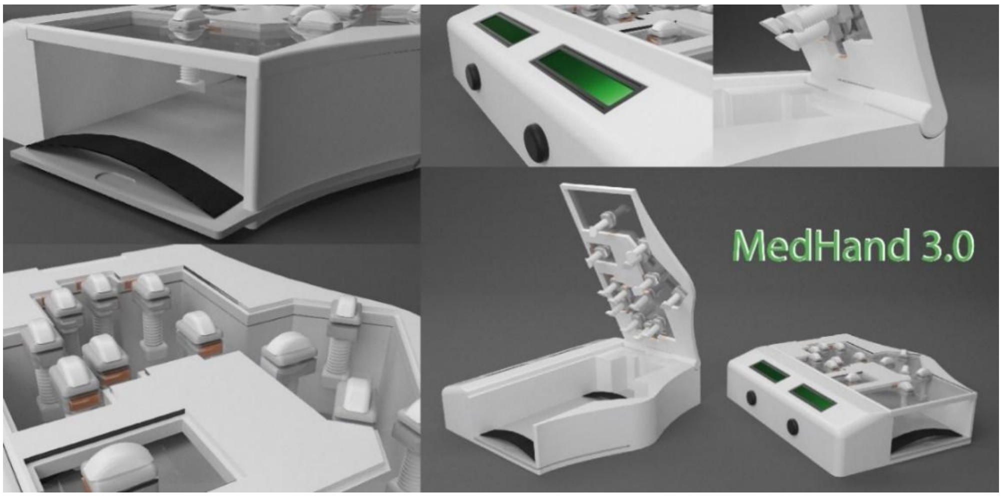


Figure3. Proposal developed in SolidWorksTM(Source: Own Elaboration, 2020).

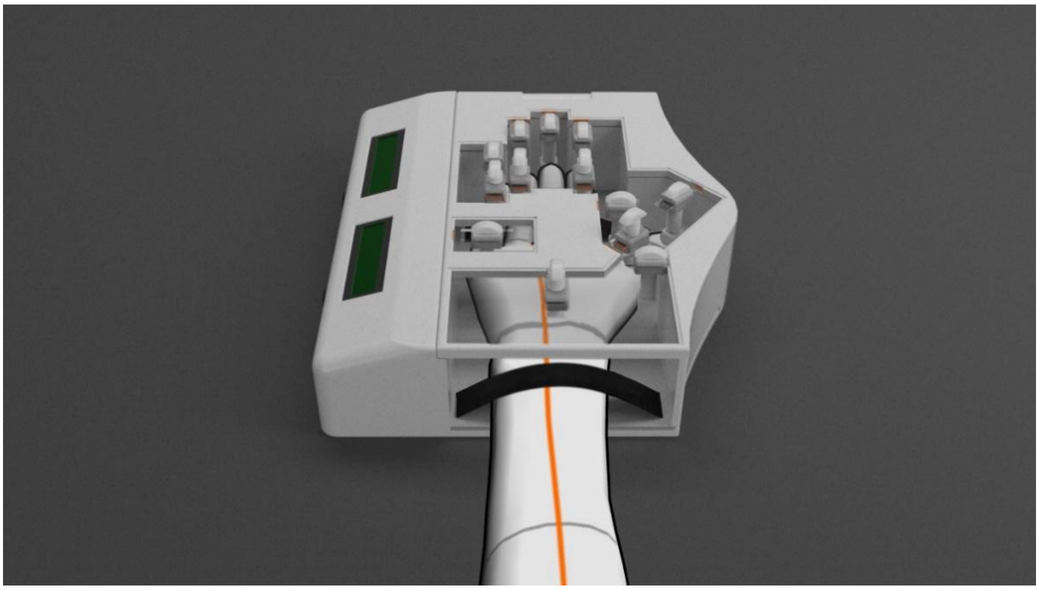


Figure 4. Context of use MedHand 3.0(Source: Own Elaboration, 2020).

The structure is founded on a mesh based on combination curvature, composed of tetrahedra automatically generated by the software, this separation of the structure serves to apply the simulations that in this case are: static, fatigue and fall. To perform the simulation, assumptions are made based on the context of use of the person willing to perform the measurement, to recreate the environment where certain external loads that are insignificant are ignored. Within the static analysis, the individual could apply a force of 26.8 N/m2 to the Cover and the Acrylic when applying pressure to the meters; with the thumb and index finger could apply a pressure of 3.37 N/m2 to the meter when adjusting the measurement distance; finally, when removing the Removable Base for cleaning and reinserting it, the individual could apply a pressure of 26.8 N/m2 to the Base piece. For the fatigue analysis, the repetitive cycles of the loads applied to the Meter and Removable Base parts that are generated in each individual when being measured are considered. The fall analysis assumes that the device will fall to the floor from a height of 80 cm (above the height established for a table) and that the affected parts will mainly be the Base on the side face where the electronic components are located, since when it falls it tends to do so towards this zone due to the weight it has; and the Cover on a face parallel to the impact zone established on the Base part.

The results provided by the simulation can be seen in a color map and in the report generated by the software. The piece has a color map on the right side that explains the distribution of efforts, deformations, safety factor and load (depending on the study applied) in the model.

3.1. Static Analysis

Table3 Static Analysis Report developed in SolidWorksTM(Source: Own Elaboration, 2020).

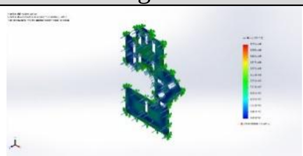
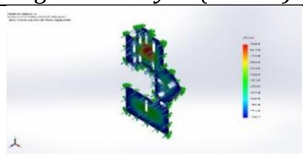
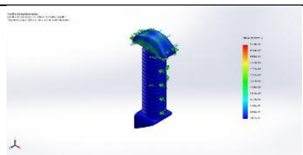
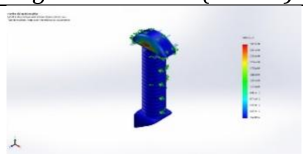
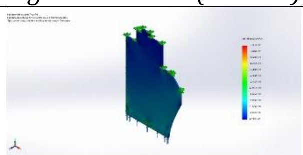
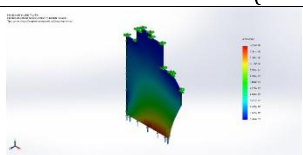
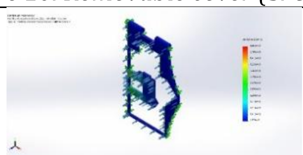
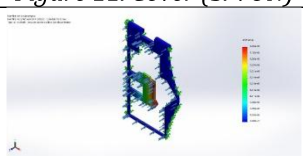
Partname	Kind	Load	Results		Units	Figures
Acrylic	VON	26,8 N/m2	Min	1.660e-06	N/m^2	 *Figure 5. Acrylic (S. VON)*
			Max	1.756e+04	N/m^2	
	URES		Min	0.000e+00	mm	 *Figure 6. Acrylic (S. URES)*
			Max	9.302e-04	mm	
Meter 1	VON	3.37 N/m2	Min	6.442e-08	N/m^2	 *Figure7. Meter 1 (S. VON)*
			Max	5.284e+00	N/m^2	
	URES		Min	0.000e+00	mm	 *Figure8. Meter 1 (S. URES)*
			Max	2.685e-09	mm	
Removablecover	VON	26.8 N/m2	Min	4.132e-01	N/m^2	 *Figure9. Removable cover (S. VON)*
			Max	1.151e+02	N/m^2	
	URES		Min	0.000e+00	mm	 *Figure 10. Removable cover (S. URES)*
			Max	1.491e-06	mm	
Cover	VON	26.8 N/m2	Min	1.378e-01	N/m^2	 *Figure 11. Cover (S. VON)*
			Max	5.652e+04	N/m^2	
	URES		Min	0.000e+00	mm	
			Max	1.203e-02	mm	

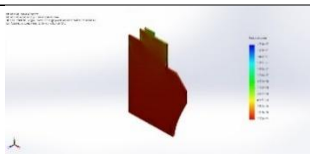
						Figure 12. Cover (S. URES)

*URES (Resulting Displacements), VON (Von Mises Voltage).

With the results reflected in Table 3, the resistance of the parts to deformation was validated considering the theory of maximum distortion energy (von Mises criterion), because the necessary stresses in the critical zones for a deformation are not reachable values taking into account the context of use since the elastic limits are not close to reach the "VON Min" values, moreover the "URES Max" deformations that they reach are not critical because they are elastic deformations.

3.2. Fatigue Analysis

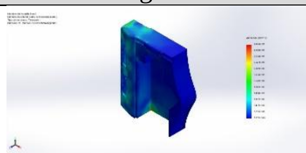
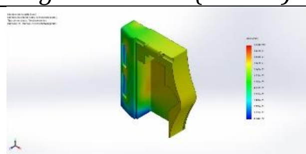
Table4 Fatigue Analysis Report developed in SolidWorksTM(Source: Own Elaboration, 2020).

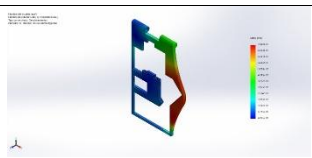
Partname	Kind	Cycles	Results		Figures
Meter 1	Load factor	1000	Min	1.664e+06	 *Figure 13. Meter 1 (F. Load factor)*
			Max	1.502e+16	
Removablecover	Load factor	1000	Min	7.703e+04	 *Figure14. Removable cover (F. Load factor)*
			Max	1.733e+07	

With the previous data from the applied static analysis, we proceeded to determine the fatigue that the parts would suffer with the established repetitive cycles, resulting in a Min load factor of both parts, which far exceeds the factor that indicates the existence of a failure (<1).

3.3. Drop test analysis

Table 5 Drop test analysis report developed in SolidWorksTM(Source: Own Elaboration, 2020).

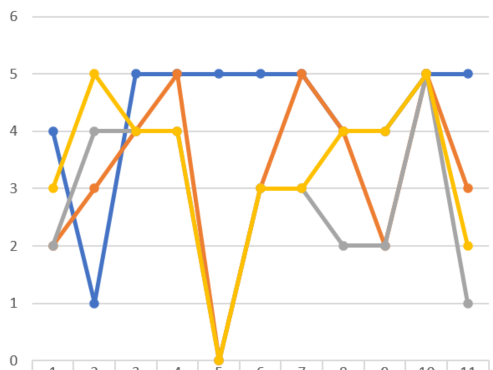
Partname	Kind	Height	Results		Units	Figures
Base	VON	80cm	Min	1.812e+00	N/m^2	 *Figure 15. Base (D. VON)*
			Max	4.483e+07	N/m^2	
	URES		Min	4.244e-02	mm	 *Figure16. Base (D. URES)*
			Max	1.035e+00	mm	
Cover	VON	80cm	Min	1.178e+05	N/m^2	 *Figure 17. Cover (D. VON)*
			Max	2.907e+07	N/m^2	

	URES		Min	4.925e-03	mm	 Figure 18. Cover (D. URES)
			Max	7.504e-01	mm	

*URES (Resulting Displacements), VON (Von Mises Voltage).

The results of the fall analysis described above allowed to validate the resistance to deformation caused by an impact of the pieces from the support surface (table) with a height of 80cm above the floor level. Considering the theory of maximum distortion energy, the necessary stresses in the critical zones are not achievable since the elastic limits are not close to the "VON Min" values, on the other hand, the "URES Max" deformations are not critical since they are elastic.

In addition to the analysis of finite elements, the use of the Quality Function Deployment (QFD) methodology is proposed to determine the relationship of what the user requires with the proposal, taking into account the competition and how it solves those needs. As a result, a graph of the technical analysis of the proposal and its competence is presented, where 11 requirements were established: comfort, lightness, use for the right hand, obtaining of anthropometric variables, assurance of the disposition of the hand, visualization of folds, visualization of results, intuitive use, that does not compress the tissues, measurement in the front face and decrease of time; coded from 1 to 11 respectively. These requirements are weighted from 1 to 5, being 1 a low ratio and 5 a high ratio.



	1	2	3	4	5	6	7	8	9	10	11
MedHand 3.0	4	1	5	5	5	5	5	4	4	5	5
Digital Caliper	2	3	4	5	0	3	5	4	2	5	3
Caliper	2	4	4	4	0	3	3	2	2	5	1
Anthropometric measuring tape	3	5	4	4	0	3	3	4	4	5	2

Figure19. Competitive analysis(Source: Own Elaboration, 2020).

The proposal presents effective results due to the constitution of the design adapting itself to the anthropometry of the hand of the person to be measured, and to the needs of the evaluator, guaranteeing an optimal process in the raising of anthropometric measurements of the hand of the objective public.

IV. DISCUSSION

The device will directly benefit the establishment of a database of Ecuadorian anthropometric dimensions, future studies, research and articles that need such information; likewise, industrial designers or other types of professionals will be able to generate products related to the elderly in a specific way.

From the investigation of the user's pathologies and the formal characteristics of the hand, a better understanding was obtained to be able to transfer this information to the configuration of the device, as well as the foreign studies through the years and the methods used in these constituted an important base for the establishment of a complete measurement protocol.

The impact of the research is proportional to the Ecuadorian user population; however, human variability such as genetic inheritance, socioeconomic conditions, or occupation may impact the usability of the device in extreme cases.

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