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Using digital photogrammetry to conduct an anthropometric analysis of wheelchair users

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Abstract. This study deals with using digital photogrammetry to make an anthropometric analysis of wheelchair users. To analyse the data, Digita software was used, which was made available by means of the agreement of the Design Department of the Federal University of Pernambuco - Brazil - with the Department of Ergonomics of the Technical University of Lisbon - Portugal. Data collection involved a random sample of 18 subjects and occurred in the Biomechanics Laboratory of the Maurice of Nassau Faculty, located in Recife, Pernambuco. The methodology applied comprises the steps of Ergonomic Assessment, Configuration of the Data Base, Taking Digital Photographs, Digitalising the Coordinates and Presentation of Results. 15 structural variables related to static anthropometry were analysed, and 4 functional range variables relating to dynamic anthropometry. The results were presented by analysing personal data, classified by gender, ethnicity and age; by functional analysis of the sample, classified by clinical diagnosis, results of assessing the joints, results of the evaluation through motion and postural evaluation; and of the analysis of the anthropometric sample, which indicated for each variable the number of people, the mean, the standard deviation, and the minimum, median and maximum values.

Keywords: anthropometry, photogrammetry, disable people

1. Introduction

Dissatisfaction with the usability of the interface between a disabled person with their physical environment has been described by authors from the areas of Rehabilitation, Design and Ergonomics [2-4, 6, 8, 13].

From this perspective, Ergonomics is presented as an essential tool that argues for a product design that considers various users and meets their real needs [16-18].

The ergonomic quality of a product obligatorily undergoes being made anthropometrically suitable [5, 15]. However, few studies have been published on the anthropometrical data of the population in Brazil. When one thinks of people with disabilities, this shortfall becomes even greater. Data on persons with disabilities are seldom available and urgently needed [11, 15].

The paucity of anthropometric data on wheelchair users limits projects to creating environments and products that may be used effectively and safely, and this covers the concept of inclusive design [3, 4, 13].

There are no data, on a large scale, on the anthropometry of wheelchair users [12]. One must create an extensive database about disabled people that includes information on the strength, balance and stability of segments of the body, as well as on ranges, limits and capabilities of motion [9, 10].

Many authors claim that the difficulty of conducting an anthropometric analysis on wheelchair users is to do with the variables involved, such as the type and extent of the injury, the body segments affected, the degree of dysfunction presented by the individual and the cumulative effect on global mobility due to constant use of a wheelchair. Thus, this study set out to make a prior functional assessment of the individuals so as then to conduct the anthropometric survey of a sample.

The overall objective was to evaluate and test the advantages and disadvantages of using photogram-

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metry – the Digita system – to gather data on disabled people who use wheelchairs for locomotion.

It should be made clear that this study aimed to evaluate a tool for digital photogrammetry, and did not intend by so doing to carry out a significant anthropometric survey of the population.

2. Methods and techniques

To gather data, the Digita System, developed in the Department of Ergonomics at the Technical University of Lisbon, Portugal was used. This system enabled the recording of reference points by using photogrammetric techniques. This study pioneered the use of Digita for disabled people.

Thus, it is important to clarify that an adaptation of the methodological procedures of the Digita System was made so that wheelchair users could be evaluated.

2.1. Planning and selection of the sample

The survey was conducted on a random sample of 18 individuals, who use a wheelchair as a constant form of locomotion, aged between 18 and 65. The individuals were selected with the help of FCD – the Christian Fraternity for the Sick and Disabled - an association that serves people with disabilities in the city of Recife.

Data collection took place in the Biomechanics Laboratory of the Maurício de Nassau Faculty, Recife, Pernambuco, which kindly donated the space for this research.

2.2. Application of the Digita System

2.2.1. Personal Data

This stage began with obtaining the profile of the sample, in which their age, gender, ethnicity and place of birth were recorded.

Then, the functional evaluation began. The perception of preserved functionality acts as an important guide to understanding the user's real needs.

The functional state of the individuals was assessed in accordance with the following items:

- Clinical diagnosis, as set out in the International Classification of Diseases - 10^{th}. Revision (ICD-10), proposed by WHO;
- History of the Current Illness: research into the time since the disease appeared, because the longer it has been since the lesion, the greater the risk of muscular hypotrophy. The reduction in muscle volume leads to a reduction in the static anthropometric measurements;
- Past Pathological History: a check was made on the incidence of postural and respiratory function alterations, which may generate new design needs;
- Articular examination: evaluating the range of motion (ROM) is a basic technique used to examine all periarticular tissues [7]. Since wheelchair users have significant loss of voluntary motor function, they need to be monitored by health teams who undertake passive movements. However, when these individuals are not included in the rehabilitation process, states of restriction of joints set in. As digital photogrammetry is a two-dimensional tool, there is need to position body segments at angles of 90° or 180°, because the adoption of intermediate angles causes the segment to be positioned diagonally, which precludes recording the measurements. The restriction on the range of motion, arising only from the deficit of muscular strength, precludes making an anthropometric analysis of dynamic variables. While the structural limitation, with shortening of soft tissues and periarticular calcification, prevents the evaluation of the static and dynamic anthropometric variables. Moreover, there is a need to identify the limitation imposed as <u>active</u> or <u>passive</u>. To facilitate the functional evaluation, the ranges of motion were described only as <u>complete</u> or <u>incomplete</u>, with the precise degrees of joint limitation not being defined. These considerations relate to the use of digital photogrammetry with only one camera, which characterizes it as a two-dimensional technique;
- Assessment Through Motion: a motor examination was performed of the upper limbs and trunk. To each motion, a mark was attributed, ranging from 0 to 5: 0 being total paralysis, 1. Palpable or visible contraction, 2. Active motion with arc of motion complete with gravity eliminated, 3. Active motion with full range of motion against gravity, 4. Active motion with full range of motion against moderate resistance, 5. Complete arc of active motion against resistance (normal);
- Posture Review: variations in the central axis of the human body were evaluated, since all postural positions that generate diagonal posi-

tions of the vertebrate spine preclude anthropometric analysis with two-dimensional techniques. When the trunk is inclined, the digital photograph captures an image showing the markers of the anatomical points closest to reality. Thus, the insistence on data collection generates unreliable measurements.

2.2.2. Anthropometric Data

For the total verification of the selected anthropometric variables, 11 photos were taken.

The 15 static anthropometric variables selected in this study were collected in four photos. The variables relating to heights were first evaluated in a simple chair and then in a wheelchair, it being considered that the interference of the dimensions of the wheelchair generate new design needs

The dynamic anthropometric variables were collected in 7 photographs.

To better describe the standardization of the collection, the anatomical points, used to reference each anthropometric variable, will be presented in the following table.

Table 1

Anthropometric Variables

	Anthropometric variables	Points of Reference
Estáticas	Height do top of the head	Top of the head – floor
	Height of the level of the eyes	External corner of the eyes – floor
	Height of the shoulder	Acromion – floor
	Height of the knee	Anterior side of the knee – floor
	Height of the popliteal cavity	Popliteal cavity – floor
	Maximum depth of the thorax	Dorsal side of the trunk – anterior side of the thorax
	Maximum abdominal depth	Dorsal side of the trunk – anterior side of the abdomen
	Depth buttock – knee	Dorsal side of the buttocks – anterior side of the knee
	Depth buttock – popliteal cavity	Dorsal side of the buttocks – articular line of the popliteal cavity
	Length of upper member	Acrômio – extremidade do dedo médio
	Length of arm	Acromion – olecranon
	Length forearm – hand	Olecranon – tip of the middle finger
	Width of the thighs	Greater trochanter of the femur do femur right to left
	Width of the arms	Greater tubercle of the humerus right to left
	Width of the thorax	Axillary line right to left
	Anthropometric variables	Points of Reference
Dinâmicas	Anterior Reach	A.1. Protraction of the shoulder
		A.2. Protraction of the shoulder + scapula-humeral flexion to 90º
		A.3. Protraction of the shoulder + scapula-humeral flexion to 90º + flexion of the trunk
	Lower Reach	I.1. Upper member extended , positioned along the body
		I.2. Upper member extended + depression of the shoulder
		I.3. Upper member extended + depression of the shoulder + inclination of the trunk
	Upper Reach	S.1. Elevation of the shoulder
		S.2. Elevation of the shoulder + scapula-humeral flexion ta 180º
		S.3. Elevation of the shoulder + scapula-humeral flexion to 180º + maximum extension of the trunk
	Lateral Reach	L.1. Lateral rotation of the scapula
		L.2. Lateral rotation of the scapula + scapula-humeral abduction
		L.3. Lateral rotation of the scapula + scapula-humeral abduction + inclination of the trunk

2.2.3. Environment for collection

A 6.4 megapixel NIKON D70S, which complies with the requirement of the Digita System, was used to take photographs [14].

The camera was positioned six metres away from the subject, face on to the midline of his/her body and at a height of approximately half the height of the subject in a sitting position, thus avoiding the parallax error.

The site selected had good artificial lighting which remained the same at any time of day. The environment also had walls of a white ice color, which created a good contrast with the red color of the volumetric markers.

The image calibrator was used at 50cm and positioned next to the subject, so it can be visualised in all the photos.

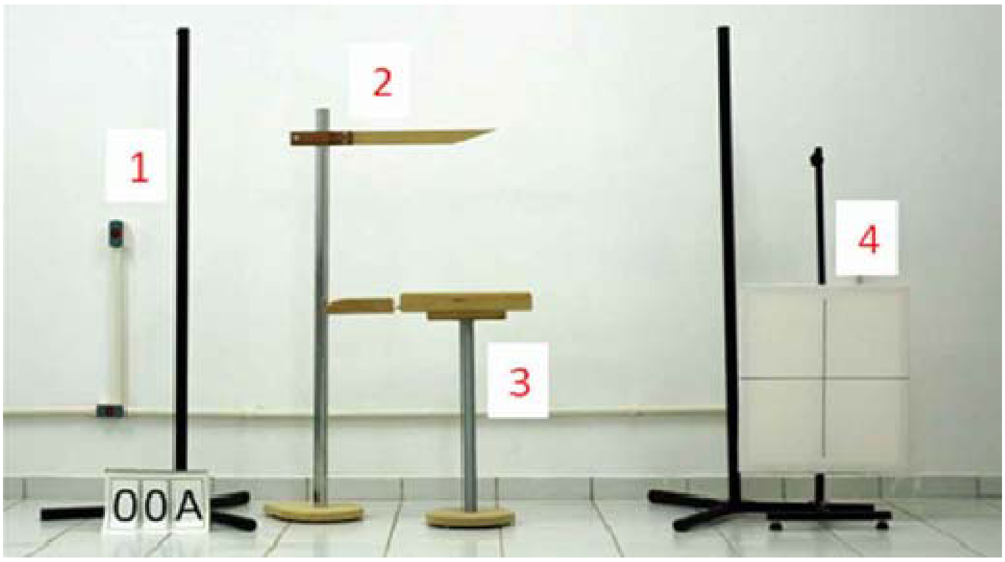
The two wall bar guides were also placed next to the subject and assisted in correctly positioning him/her.

In addition to these two pieces of equipment, intended for the anthropometric analysis of people deemed non-disabled, two other instruments were made. The first was developed for static analysis, being a support to position the subject´s arm at 90º. It was used whenever the individual did not have the muscular strength to be able to keep their arms open.

The second was developed for dynamic analysis and is a rod which was positioned at the starting position of the subjects. Before the subjects voluntarily moved so as to analyse their reach, the tip of the rod was positioned next to the acromion of the scapula. Both instruments have adjustable heights and can be used for individuals of all percentiles.

Figure 1

Sructure required to take digital photographs
1. Parallel guide bars; 2. Mobile rod; 3. Support for upper members; 4. Image calibrator.



3. Results

3.1. Analysis of the personal data

The sample size was 18 individuals of whom 12 were female and six were male.

With respect to ethnicity, there was an equal distribution of the sample. Data show there were 33.33% people for each ethnic group.

Regarding age, there was a predominance of the 35 to 39 age group, who formed 33.33% of the total population. None of the volunteers were aged between 50 and 65.

With regard to the clinical diagnosis reported by the respondents, there was a predominance of child paralysis, with 12 such cases in the total population.

With regard to the assessment of the passive range of articular motion, three wheelchair users, 16.6% of the total population showed considerable reduction in the arc of passive motion which precluded the analysis of structural variables with digital photogrammetry. These people were not subjected to static and dynamic anthropometric analyses.

As to assessing the active range of articular motion, the muscular strength of four respondents - 22.2% of the total population – was less than 3. This result was presented to at least one motion. When muscular strength is classified as 0 to 2, the individuals are not able to move their body segments in the desired range to analyse variables of functional range. So these people were not subjected to dynamic anthropometric analysis. There was no impairment of the static analysis because the arc of passive motion was complete.

In Figures 2 and 3, it is observed that the reduction of muscular strength for the motions of the upper limb precludes the adoption of the position required for the analysis of the forms of reach.

Figure 2
Lower Reach Precluded

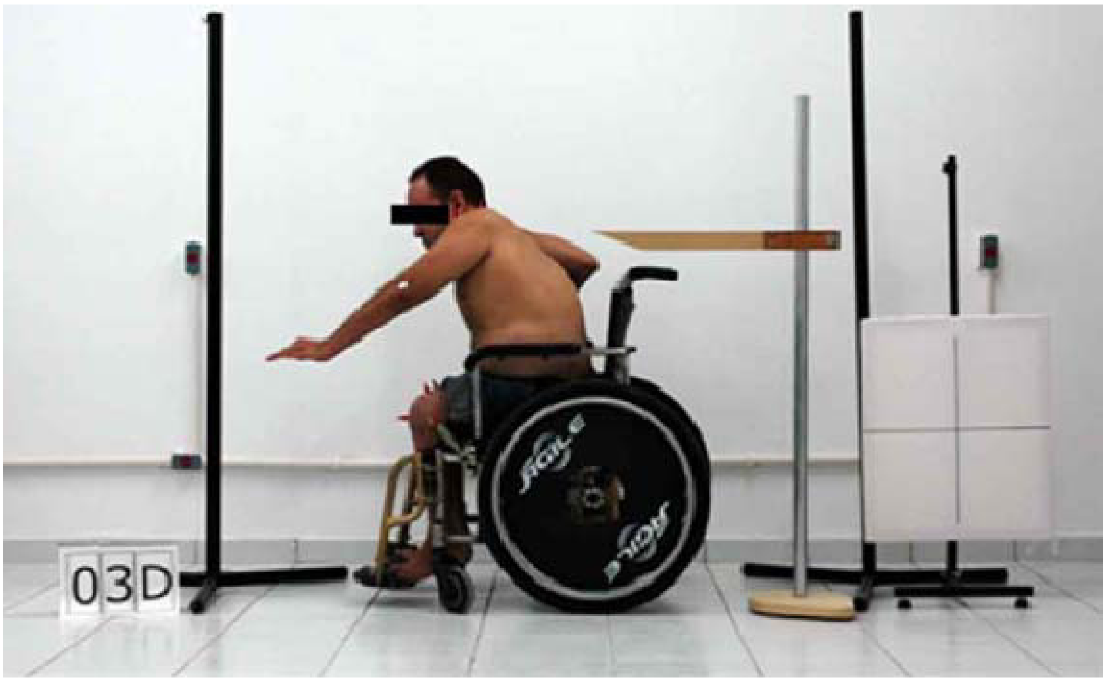


Figure 3
Upper Reach Precluded

Regarding postural assessment, four subjects - 22.2% of the total population - had advanced scoliosis. This deviation of the vertebral spine causes improper positioning of various body segments and, consequently, of the anatomical reference points. Thus, these people were not subjected to static and dynamic anthropometric analysis.

At the end of the functional assessment, only 11 wheelchair users were placed in the sample of the static anthropometric analysis. And only 6 were included in the dynamic anthropometric analysis. The other participants were excluded due to the reduction in muscular strength and/or the presence of scoliosis.

3.2. Analysis of the Anthropometric Data

After analysing the digital photographs in the Digita system, statistical analysis of the anthropometric data was made using Epi Info 2002. The results were shown so as to provide for each variable the number of people, the mean, the standard deviation, and the minimum, median and maximum values.

Tables 2 and 3 show the general statistics of the anthropometric variables.

Table 2

Functional Anthropometric Variables

Total No. of people assessed: 6 wheelchair users					
Functional variables	Average	Standard Deviation	Mimimum value	Median	Maximum Value
Right anterior reach	1024.6	157.3	717.0	1063.0	1164.0
Left anterior reach	930.8	91.9	767.0	960.5	1023.0
Right lower reach	920.5	193.7	647.0	954.0	1152.0
Left lower reach	969.0	221.6	697.0	968.5	1289.0
Right upper reach	669.0	75.9	571.0	701.0	744.0
Left upper reach	671.3	129.1	447.0	697.5	830.0
Right lateral reach	728.8	107.1	615.0	720.0	859.0
Left lateral reach	779.3	132.0	640.0	785.0	969.0

Table 3

Structural Anhtropometric Variables

Total No. of people assessed: 11 wheelchair users					
Strucrural variables	Average	Standard Deviation	Mimimum value	Median	Maximum Value
Height seated – in the simple chair	1226.4	74.3	1088.0	1240..0	1327.0
Height of the eyes – in the simple chair	1109.2	72.7	987.0	1121.0	1233.0
Height of the shoulder – in the simple chair	1005.7	67.5	866.0	1006.0	1109.0
Height of the knee – in the simple chair	494.3	80.5	288.0	515.0	603.0
Popliteal height – in the simple chair	390.6	75.5	199.0	422.0	455.0
Width netween the thighs	361.8	35.4	294.0	362.0	409.0
Width between the arms	336.6	46.9	248.0	344.0	397.0
Width of the thorax	330.2	42.5	253.0	346.0	375.0
Depth of the trunk	256.3	48.0	170.0	252.0	332.0
Abdominal depth	289.8	66.1	188.0	302.0	402.0
Depth of the thigh	536.0	80.9	399.0	521.0	678.0
Popliteal depth	443.9	74.7	337.0	453.0	587.0
Length of the upper member	663.0	81.4	543.0	676.0	761,0
Length of the arm	260.7	29.2	211.0	261.0	312.0
Length forearm – hand	400.9	58.8	301.0	418.0	470.0
Height seated – in the wheelchair	1288.5	71.6	1124.0	1311.0	1376.0
Height of the eyes – in the wheelchair	1172.9	63.7	1069.0	1189.0	1248.0
Height of the shoulder – in the wheelchair	1055.6	56.9	969.0	1050.0	1142.0
Height of the knee – in the wheelchair	534.5	93.9	301.0	563.0	629.0
Popliteal Height – in the wheelchair	406.5	72.3	229.0	425.0	486.0

4. Final Considerations

4.1. Discussion

It was observed that factors such as: time of appearance of the disease, associated diseases and the monitoring of a rehabilitation team directly interfere with anthropometric measurements. Thus, to measure the influences of these factors, analyses of the range of motion and muscular strength were made.

As digital photogrammetry – the Digita System - is a two-dimensional tool, the body segments must be positioned at angles of 90º or 180º, since the adoption of intermediate angles generates the diagonal positioning of the segment, which makes it impossible to record the action. Unfortunately, it is extremely common for disabled people to have restrictions on their range of articular motion, forcing the assumption of postures in rotation and tilting of the upper limbs and trunk.

If the restriction of the range of motion is due only to lack of muscular strength, it will be impossible to conduct the anthropometric analysis of dynamic variables. If there is a structural limitation, with shortening of soft tissues and periarticular calcification, it will be impossible to evaluate static and dynamic anthropometric variables. Therefore, it is still necessary to identify the limitation as active or passive.

The result classified only as incomplete active indicates a restriction for analysing functional reaches. The individual did not possess muscular strength capable of moving the body segment to the angle of 90º or 180º needed to conduct digital photography.

The result defined as incomplete passive indicates a restriction on analysing structural variables and functional range. The changes of the periarticular structures preclude the passive positioning of body segments, even when there is muscular strength.

Finally, those results identified as complete can be analyzed without restriction. To this end, the motions need to be classified as 3 to 5. Otherwise, they will not present sufficient muscular strength to adopt the positions needed to make an analysis that uses digital photogrammetry, thus making dynamic anthropometric analysis impossible.

Thus, we conclude that:

- The results classified as the arc of active incomplete motion indicate a restriction for dynamic anthropometric analysis;
- The results defined as incomplete passive indicate a restriction on static and dynamic anthropometric analysis.

Moreover, the postural alterations classified as scoliosis limit the subjects that can be assessed with two-dimensional techniques. This occurs because, in cases of scoliosis, some vertebrae are rotated, causing the trunk of the individuals to be positioned diagonally in relation to the main planes of movement of the human body.

The trunk forms a perpendicular angle to the digital camera. When the trunk is inclined, the digital photograph captures an image showing the markers of the anatomical points much closer than the real one. Thus, insistence on data collection will result in obtaining unreliable measures.

5. Conclusion

The main advantage of using digital photogrammetry is to reduce the time that the individual must be present in the process of data acquisition, thereby reducing the fatigue consequent on maintaining specific and necessary positions and postures when using conventional anthropometers.

In addition, the use of the Digita system has enabled the cost of technical material to be reduced and results to be obtained in a very much shorter period, since this reduces the time spent on lining up the equipment and analysing and cross-checking data. The structure used to collect images also becomes an advantage, because all the devices are portable.

The main drawback is the inadequacy of the tool for a significant portion of the population of wheelchair users. As the use of digital photogrammetry is presented in this study as a two-dimensional technique, it is restricted to disabled people who have a full range of motion, muscle strength greater than or equal to three, and unchanged postural alignment. In short, it is limited to a set of disabled people whose motor behavior is very close to that considered normal in the sitting position.

As a recommendation for future studies, it is suggested that the standardization of data collection, defined in this study, be applied to three-dimensional systems.

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