Model for Prediction of the Weight and Height Measurements of Patients with Disabilities for Diagnosis and Therapy

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Abstract: *Background: Accurate measurement of a patient's height and weight is an essential part of diagnosis and therapy, but there is some controversy as to how to calculate the height and weight of patients with disabilities. Objective: This study aims to use anthropometric measurements (arm span, length of leg, chest circumference, and waist circumference) to find a model (alternatives) that can allow the calculation of the height and the body weight of patients with disabilities. Additionally, a model for the prediction of weight and height measurements of patients with disabilities was established. Method: Four hander patients aged 20-80 years were enrolled in this study and divided into two groups, 210 (52.5%) male and 190 (47.5%) female. Result: A significant correlation was noted between body height and arm span, as well as between body height and length of leg in all study groups. The body weight and the ratio of arm span or leg length to the sum of chest and waist circumferences were found to have a negative significant correlation. Model equations were derived to estimate the height and body weight according to anthropometric measurements. Conclusion: Anthropometric measurements can be used to create a model for calculating the body height and body weight of patients with disabilities and which can be considered an alternative to measurements that can be made on otherwise healthy subjects.*

Keywords: *Therapy, Diagnosis, Anthropometric measurements, Iraq.*

Introduction

Accurate results are extremely important in medical examinations, which require that patient information is recorded to high accuracy. Age and gender can be determined directly from the patient, but height and weight must be carefully measured.

Height and body weight data play an essential role in the medical field, for instance, in determining the amount of anaesthetic when preparing for surgery and the amount of contrast medium required for medical imaging, as well as in determining the amount of radioactive material to use in radiotherapy and radiodiagnosis. Also, height and body weight data are important for the lung function test and bone density measurements. In addition, patient weight has an essential effect on the distribution of medicine within the body and is taken into account when determining medicine dosage. A mistake in recording a patient's weight or using inaccurate weighing equipment may lead to an increased risk of errors in diagnosis, therapy, and anaesthesia or pharmaceutical dosage [5].

Height and weight have an essential role in all the equations of the pulmonary function test [17]. Although the prediction of normal pulmonary function test values requires a measurement of the patient's height when standing upright, many patients taking the lung function test suffer from axial skeletal abnormalities or physical disabilities that prevent them from standing as normal. These conditions can lead to a body height measurement that is inaccurate due to the associated difficulties in establishing them [8]. Therefore, the arm span was used to directly estimate the height of a patient instead of the 'deformed' body height [1, 18].

Several studies have stated that determining the requirements for therapy and diagnosis is dependent on equations which, in turn, depend on age, gender, height, and weight [22]. Age and gender can be gained directly from the patient, but there is problem with the height and weight of the body, they must be calculated; it is thus important to know how they are calculated. Parameters (gender, age, height, and weight) have a significant effect on normal heart size. Therefore, these parameters should be taken into consideration when determining the cut-off that indicates the need for therapy or surgery [20].

In medical imaging, the amount of contrast medium (CM) injected, which is related to the patient's weight, will greatly influence the degree of contrast in the final image [13]. The patient cross-sectional area can represents a challenge when determining the dose required for computerized tomography (CT) for abdominal imaging [15, 16, 25]. It has been shown that bone mineral density measurements in the vertebrae and hip can be affected by body mass index (BMI) and body weight, with the two showing a positive correlation [14]. For example, [10] reported that there is an inverse relationship between patient body weight and improvement in vascular contrast in abdominal CT. At the same time, there is a positive correlation between patient body weight and the amount of anaesthesia used in surgery [19].

In chemotherapy, maintaining the patient's body weight during the first stages of treatment is an essential indicator by which one can ensure the completion of the treatment without risking the patient's life, such as for patients suffering from bile duct cancer [11]. Barras and Legg [4] stated that a higher dose of medication should be given to obese individuals compared to thinner individuals with the same condition because increased body weight and body mass index leads to an increase in the extent to which the medication can be distributed in the body.

In radiotherapy and diagnosis, the patient's body weight has a significant effect on radiation exposure, where overweight patients will need to be exposed to higher doses of ionizing radiation, such as patients undergoing invasive cardiac procedures [15].

In this paper we will focus on alternatives to directly measuring the height and weight of patients with disabilities or in emergency cases, which will help to reduce the mistakes that might otherwise be associated with their diagnosis and therapy. Therefore, in cases of disability (the patient is unable to stand) and emergency cases, there are obvious difficulties in measuring the height and weight. The main objective of the current study is to find a model (alternative) by which to calculate the height of disabled patients by measuring arm span and leg length, as well as estimating body weight by measuring the ratio of arm span or leg length to the circumferences of the chest and waist in the population of Baghdad, Iraq.

Material and methods

This study was conducted on patients attending the AL-Yarmouk Teaching Hospital (Functional Pulmonary Test Unit) and X-ray institute (Bone Mineral Density Unit, (BMDU)) during the period from the middle of June 2019 to the middle of January 2020. Ethical approval was obtained from the University of Baghdad, College of Medicine in cooperation with the Ministry of Health (Al-Yarmouk Hospital and X-ray Institute).

In this study, anthropometric measurements were taken from male and female subjects of various ages. It included 400 patients comprised of 210 (52.5%) males and 190 (47.5%) females with ages ranging between 20 and 80 years. The measurements were conducted when the patient was standing straight upright, with a wall directly behind them whilst barefoot. Height (151-188 cm) was measured from the top of the head to the ground, whilst the arm span (64-80 cm) was considered to be from the shoulder to the end of the middle finger, and leg length (88-109 cm) was measured from the highest point of the pelvic bone to the end of the foot with the ground. Chest circumference (78-130 cm) was measured around the breast, while waist circumference (78-138 cm) was measured around the navel. All these measurements were taken by tape measure with an error of ± 1 cm. The body was weighed using a set of digital scales and was found to range from 52 to 112 kg with an error of ± 2 kg.

Arm span and length of leg were used to estimate the patient's height while arm span / chest circumference and waist circumference ratio and leg length / chest circumference and waist circumference ratio were used to estimate the body weight.

In a statistical analysis, the results were presented as absolute numbers of the mean, median and standard deviation (SD) with the lower and upper limits of the data. For comparison between the measured data and calculated data was used in a two-tailed paired data t-test analysis.

Results

The anthropometric measurements of each of the groups (male and female) mentioned in the method section are summarized in Table 1.

From Table 1, the mean values of the height measurement of patients were 173.67 ± 5.103 cm and 165.45 ± 6.337 cm for males and females, respectively, whereas the mean values of the arm span measurement were 73.78 ± 2.84 cm and 70.588 ± 2.786 cm for males and females, respectively. In addition, the mean value of the leg length was 103.52 ± 3.52 cm and 96.585 ± 4.425 cm for males and females, respectively. A high significant positive correlation between height of patient and arm span ($r = 0.934$, $P < 0.001$) was found for males; a positive significant correlation ($r = 0.943$, $P < 0.001$) was also found for females (Table 2). In addition, the correlation between the height of the patient and leg length for males and females were highly positive and statistically significant ($r = 0.933$, $P < 0.001$ and $r = 0.947$, $P < 0.001$, respectively), as reported in Table 2. The relationships between height with arm span and leg length measurements for males and females, separately, are presented in Fig. 1.

From Table 2, the mean values of the weights of patients were 80.422 ± 11.822 kg and 71.474 ± 9.544 kg for males and females, respectively (see Table 1). For males, the mean values for chest and waist circumferences were 96.213 ± 9.852 cm and 100.479 ± 11.25 cm, respectively, whereas, for females, the mean values of the measured chest and waist circumferences were 99.531 ± 11.447 cm and 100.603 ± 12.03 cm, respectively (Table 1).

Table 1. The characteristics and the anthropometrics
of the two groups (male and female) considered in this study

Characteristics	**Male, (*n* = 210)**		**Female, (*n* = 190)**	
	Mean ± SD	**Median, (Min-Max)**	**Mean ± SD**	**Median, (Min-Max)**
Age, (year)	44 ± 15.85	42 (20-80)	42 ± 142	40 (20-80)
Height, (cm)	173.67 ± 5.103	174 (160-188)	165.45 ± 6.337	165 (151-180)
Arm span (AS), (cm)	73.78 ± 2.84	74 (68-80)	70.558 ±2 .786	71 (64-76)
Length of leg (LL), (cm)	103.52 ± 3.52	105 (94-109)	96.585 ± 4.425	96 (94-109)
Weight, (kg)	80.422 ± 11.822	78 (59-112)	71.474 ± 9.544	70 (52-96)
Chest circumference (CC), (cm)	96.213 ± 9.852	94 (78-126)	99.531 ± 11.447	98 (80-180)
Waist circumference (WC), (cm)	100.479 ± 11.25	98 (82-138)	100.603 ± 12.03	98 (78-137)
Height / (WC + CC)	0.891 ± 0.078	0.909 (0.681-1.036)	0.836 ± 0.0824	0.845 (0.627-1.01)
Arm span / (WC + CC)	0.378 ± 0.032	0.383 (0.296-0.44)	0.357 ± 0.034	0.362 (0.27-0.429)
Length of leg / (WC + CC)	0.531 ± 0.0465	0.54 (0.407-0.623)	0.488 ± 0.048	0.495 (0.363-0.586)

Table 2. Illustration of the correlation between heights with arm span and leg length
as measured, separately, for males and females

	Male			**Female**		
	Mean ± SD	**Correlation, *r***	***P*-value**	**Mean ± SD**	**Correlation, *r***	***P*-value**
Height vs arm span	173.67 ± 5.103 vs 73.78 ± 2.84	0.934	< 0.001	165.45 ± 6.337 vs 70.558 ± 2.786	0.979	< 0.001
Height vs length of leg	173.67 ± 5.103 vs 103.52 ± 3.52	0.933	< 0.001	165.45 ± 6.337 vs 96.585 ± 4.425	0.976	< 0.001

P-value represents the comparisons between heights with arm span and leg length, separately, in males and females

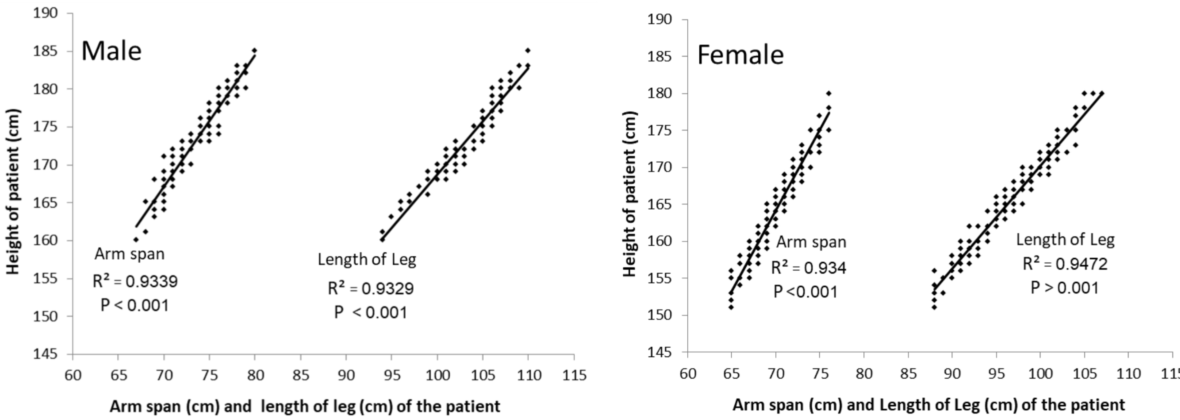

Fig. 1 Graphs showing the relationship between the height of the patient (cm) to arm span (cm) and leg length (cm) for males and females separately

A highly statistically significant reverse correlation between patient body weight and arm span / WC + CC ratio in males ($r = 0.948$, $P < 0.001$) was found, as was a significant reverse correlation ($r = 0.979$, $P < 0.001$) amongst females (Table 3). In addition, patient body weight and leg length / WC + CC ratio represented a significant reverse correlation for both males and females ($r = 0.981$, $P < 0.001$ and $r = 0.976$, $P < 0.001$, respectively), as reported in Table 3.

Table 3. Illustration of the correlation between measured weight with arm span / WC + CC and the leg length / WC + CC as calculated, separately, for males and females

	Male			**Female**		
	Mean ± SD	**Correlation, *r***	***P*-value**	**Mean ± SD**	**Correlation, *r***	***P*-value**
Weight vs arm span / (WC + CC)	80.422 ± 11.82 vs 0.378 ± 0.032	0.984	< 0.001	71.474 ± 9.544 vs 0.537 ± 0.034	0.979	< 0.001
Weight vs length of leg (WC + CC)	80.422 ± 11.82 vs 0.531 ± 0.0466	0.981	< 0.001	71.474 ± 9.544 vs 0.488 ± 0.048	0.976	< 0.001

P-value represents the comparison between body weight with arm span / WC + CC and leg length / WC + CC, separately, for males and females

Fig. 2 shows the results acquired from the analysis of the relationship between patient body weight and arm span / WC + CC ratio, as well as the relationship between patient body weight and leg length / WC + CC ratio for males and females, separately.

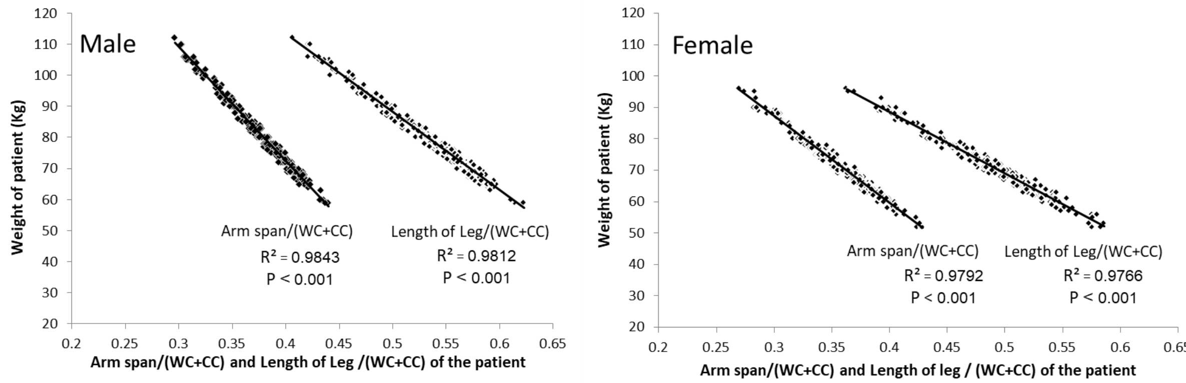

Fig. 2 Graphs showing the relationship between body weight (kg) to arm span / WC + CC and leg length / WC + CC for males and females, separately

Table 4 shows the equations derived from analysing the relationships between patient height to arm span and leg length to estimate patient height from arm span and the leg length, separately. In addition, Table 4 has explained the equations derived from analysing the relationships between body weight and the arm span / WC + CC and leg length / WC + CC in order to estimate patient body weight from arm span / waist circumference + chest circumference and leg length / waist circumference + chest circumference, separately, for males and females.

Table 4. The equations used to derived and calculate the measurements data

Male	**Female**
H = 1.738 × AS + 45.421	H = 2.198 × AS + 10.341
H = 1.420 × LL + 28.542	H = 1.394 × LL + 30.831
W = -366.15 × [AS / (WC + CC)]	W = -277.19 × [AS / (WC + CC)]
W = -251.38 × [LL / (WC + CC)]	W = -195.67 × [LL / (WC + CC)]

H – height, (cm), AS – arm span, (cm), LL – length of leg, (cm), W – weight, (kg), WC – waist circumference, (cm), CC – chest circumference, (cm).

Discussion

The inaccuracy of patient data is one of the main medical issues leading to the inability to diagnosis properly or offer appropriate therapy. Patient weight and height are important indicators on which much is dependent on the medical field.

Various studies have demonstrated the effects of height and weight on the diagnosis and therapy of normal and disabled patients [21], but the particular controversy in this instance is over how to reasonably determine the height and weight of patients with disabilities.

The results of the current study indicated a positive significant correlation between height with arm span and leg length for both genders. The correlation between height and arm span is a highly significant [26]. Two researchers recommended that the height can be substituted with arm span in disability cases to calculate predicted values of pulmonary functions [2, 12], [2]. Therefore, when a person with a disability (cannot be standing) and height cannot be measure, arm span has been suitable parameter to calculate the patient's height. Thus, also leg length can be playing an essential role in measurement patient's height in emergence cases.

Also, in this study, negative significant correlations were between body weight with AS / (WC + CC) ratio and body weight and LL / (WC + CC) ratio. Many researchers stated that the waist circumference is a highly correlation with body weight for males and females [7, 9, 23]. Waist circumference could be used as a supplementary assessment for some medical examination and may be better to BMI, which is body weight / height [6]. Therefore, when a body weight cannot be measured because the patient with a disability or an emergency case, arm span / (WC + CC) or LL / (WC + CC) could be suitable parameters to calculate the patient's body weight.

There are a huge number of studies that have considered how to find a relationship among patient's sitting height, leg length, and the sitting height / leg length ratio [27], whereas another studies emphasis have been placed on reducing the risk and mistakes in diagnosis and therapy that depend on a reasonable estimation of the height and weight of patients with disabilities [24]. Authors in [3] reported that there was low statistically significant differences in arm span and waist circumference between males and females. In our study, the particular focus was on the calculation of patient height by measuring leg length and arm span to support the calculation of height and weight, as well as the measurement of patient body weight by arm span or leg length according to chest circumference and waist circumference. Therefore, a novel method has been developed to create a model using arm span and leg length to calculate body height, and also arm span or leg length with the sum of chest and waist circumference to calculate the body weight of males and females. These calculations are shown in Figs. 1 and 2.

To the best of our knowledge, there are no references illustrating the relationship between body height and the arm span or the leg length, as well as the relationship between body weight and arm span or leg length to the chest and waist circumferences that can allow the direct calculation of the height and weight of the body. Therefore, there is a certain need to carry out complementary studies that use a larger number of patients to allow for fuller statistical analysis and thus more accurate results, both to support the current study and to represent a reliable source in medical examinations. In addition, from our results, we suggest the use of a laser scale for measuring the height, arm span, leg length, chest circumference, and waist circumference instead of using a tape measure in order to get more accurate data.

Conclusion

The arm span, leg length, chest circumference, and waist circumference show promise as alternative parameters in the creation of a model to allow for the determination of body height and weight of patients with disabilities, where our results have could be considered direct alternatives to the body height and weight that can be measured directly for healthy subjects.

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