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PHYSIOLOGY & REHABILITATION | RESEARCH ARTICLE

On the importance of the theoretical computation of the human body segments' masses

Francisco-J Renero-C[1*]

Abstract: In this work, statistical formulae, with depend on anthropometric measurement and the age, are used to estimate the weight of the lower limb of 20 young, healthy, adults. Then, four clinical characteristics, the body mass index (BMI), the blood volume (BV), basal metabolic rate (BMR) and skin surface, also based on statistical formulae, are estimated for this sample population. Furthermore, the four clinical characteristics are estimated for 20 fictitious patients, with one lower limb amputated. From the sample population, the averaged results are the lower limb mass is 12.05 ± 2.79 kg, the BMI 22.89 ± 3.93 kg/m^2, BV 3.99 ± 0.82 l, BMR 1,543.32 ± 236.98 kCal and body surface (BS) 1.66 ± 0.20 m^2. While for the fictitious patients, the results are the BMI of 18.42 ± 3.17 kg/m^2, BV of 3.60 ± 0.74 l, BMR of 1,399.07 ± 183.38 kCal and BS of 1.51 ± 0.18 m^2. The clinic characteristics of the sample population, healthy-young adults showed, for instance, that the BV vary from 2.84 l and up to 5.67 l. The lower limb mass is approximately 20% of the total mass of the individual, while the BV, after the amputation, decreased by an amount of 10%. By having equations, depending on anthropometric measurements and age provides valuable information on the clinical characteristics of the patient. Thus, the clinicians, adding their experience to these results, may be more confident to the treatment and the evolution of the patient.

Subjects: Biophysics; Orthopedics; Prosthetics & Orthotics; Physiology

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PUBLIC INTEREST STATEMENT

The knowing of the body segments masses may be helpful to the health professional to evaluate the patient condition, to calculate the drug doses (particularly those depending of the patient weight), to establish a physical therapy, etc. In this work, the height and mass of 20 young individuals are used to compute, based on statistical formulae, the body mass index (BMI), the blood volume (BV), the basal metabolic rate (BMR) and the body surface (BS). This data is used, to estimate the four clinical parameters of 20 fictitious patients who were amputated from one lower limb. Thus, the average mass of the one lower limb is 10.22 ± 1.92 and 13.88 ± 2.3 kg for women and men, respectively. Then, the loss of the BMI and the BS is about 20% and 9%, respectively, while the BV and BMR may be reduced by an amount of 11% and 9%, respectively.

Keywords: mass of the lower limb; body mass index; blood volume; basal metabolic rate; body surface

1. Introduction

In the clinical practice, the health professional follows several kinds of protocols (signs and symptoms scheme for a given sickness, questioning and filling questionaries for the given pathology, etc.), in different professional aspects (the rights of the health professional, administrative protocols to attend a patient, etc.), some of them are difficult to quantify, some others have to be applied depending on the situation. For instance, to estimate the BV for a programed amputation is not easy task for the clinician, because several variable come out (Christian, Peter, & Morten et al., 2017), and some clinical characteristics should be approached like the BMI (Eckard, Pruziner, Sanchez, & Andrews, 2012; Himes, 1995; Miller et al., 2008). Thus, it seems to be important to know the mass of the body segments, which of course had been an old research topic (Clausser, McConville, & Young, 1969; Pearsall & Reid, 1994; Zartsioky, 1982). Another example, in which the knowing of the human body segments may be useful, is when assessing the muscular force, for a particular muscle group, here the health professional have to apply the "minimum" or the "maximum" force (Hislop & Montgomery, 1995), which is human depending. Thus, the importance of knowing the mass of the body segment has several applications in the clinic, just to compute the BMI or up to compute the blood requirements after an amputation.

In this work, the mass of the lower limbs are computed from a statistical formula, which depend on the weight and the size of the patient (Zartsioky, 1982). The sample is 20 young healthy adults, 10 women and 10 men. Then, four clinic characteristics, the BMI (Center for Disease Control and Prevention, 2017; World Health Organization, 2017), the BV (Nadler, Hidalgo, & Bloch, 1962), the BMR (Harris & Benedict, 1918) and the BS (Du Bois & Du Bois, 1989) are computed for the sample population and for 20 hypothetical patients who have lost one lower limb. From the sample population, the averaged lower limb mass is 12.05 ± 2.79 kg. The averaged clinical characteristics are BMI of 22.89 ± 3.93 kg/m^2, BV of 3.99 ± 0.82 l, BMR of 1,543.32 ± 236.98 kCal and BS of 1.66 ± 0.20 m^2. While for the fictitious patients the averaged clinical characteristics are BMI of 18.42 ± 3.17 kg/m^2, BV of 3.60 ± 0.74 l, BMR of 1,399.07 ± 183.38 kCal and BS of 151 ± 0.18 m^2. These are raw results, which may lead to misunderstanding in a real patient. However, the computed mass of a lower limb fluctuates between 7.43 kg and up to 18.30 kg. Then, for instance, the computed BV varies between 2.84 l and up to 5.67 l. Thus, the importance of these results resides on the fact that any clinical characteristics, that can be computed, should be done for the individual, and avoid the use of the averaged values.

Furthermore, once the mass of a body segment is known, the minimum and maximum force can be defined in terms of a weight, attached to the center of gravity of the body segment that is proportional to the mass of that body segment.

2. Method

2.1. Procedure

The weight, height and age of 20 young healthy[1] adult were obtained so as to compute the human body segments, and the four clinics characteristics (the BMI, the BV, the BMR and the BS) which formulae depend on the mass, weight and the age of the individual. Tables 1 and 2 resume the measured data, the computed clinic characteristics and the mass of a lower limb for women and men, respectively. The columns, on the both tables, represent the identification of the volunteer (W and M stand for woman and male, respectively), height, weight, age, BMI, BV, BMR, BS and the mass of one lower limb according to the formula of Zatsiorsky (Clausser et al., 1969; Eckard et al., 2012; Himes, 1995; Pearsall & Reid, 1994; Zartsioky, 1982).

Table 1. The data of the women volunteers: height, weight and age. Blood volume (BV), basal metabolic rate (BMR), body surface (BS) and mass of a lower limb (Zartsioky, 1982)

Volunteer	Height (cm)	Weight (kg)	Age (years)	BMI (kg/m^2)	BV (liters)	BMR (kCal)	BS (m^2)	Mass of one lower limb (kg)
W01	165	56	22	20.57	3.64	1,393.01	1.61	11.0
W02	157	68	22	27.59	3.81	1,492.96	1.69	13.10
W03	150	60	20	26.67	3.37	1,412.86	1.55	11.30
W04	150	44	20	19.56	2.84	1,259.85	1.36	8.30
W05	152	46	21	19.91	2.96	1,278.00	1.40	8.70
W06	162	51	20	19.43	3.38	1,348.99	1.53	10.00
W07	153	45	19	19.22	2.95	1,274.97	1.39	8.60
W08	156	47	27	19.31	3.09	1,266.91	1.44	9.00
W09	156	45	24	18.49	3.02	1,261.91	1.41	8.70
W10	159	70	19	27.69	3.93	1,529.82	1.72	13.50
Average	156.00	53.20	21.40	21.84	3.30	1,351.93	1.51	10.22
Standard deviation	4.99	9.83	2.50	3.82	0.39	101.18	0.13	1.92

Note: Body mass index (BMI).

Table 2. The data of the men volunteers: height, weight and age. Blood volume (BV), basal metabolic rate (BMR), body surface (BS) and mass of a lower limb (Zartsioky, 1982)

Volunteer	Height (cm)	Weight (kg)	Age (years)	BMI (kg/m^2)	BV (liters)	BMR (kCal)	BS (m^2)	Mass of one lower limb (kg)
M01	179	92	24	28.71	5.67	2,064.92	2.11	18.30
M02	173	68	21	22.72	4.69	1,725.16	1.81	13.60
M03	178	55	19	17.36	4.44	1,584.94	1.69	11.30
M04	170	60	19	20.76	4.34	1,613.67	1.69	12.00
M05	172	80	22	27.04	5.05	1,878.41	1.93	15.80
M06	169	67	21	23.46	4.53	1,691.40	1.77	13.30
M07	166	63	22	22.86	4.31	1,614.64	1.70	12.40
M08	167	86	24	30.84	5.08	1,922.38	1.95	16.80
M09	165	64	23	23.51	4.31	1,616.63	1.70	12.60
M10	170	64	24	22.15	4.47	1,634.89	1.74	12.7
Average	170.90	69.90	21.90	23.94	4.69	1,734.70	1.81	13.88
Standard deviation	4.72	12.01	1.91	3.94	0.45	164.07	0.14	2.30

Note: Body mass index (BMI).

2.2. Results

From Tables 1 and 2, the average measured height and weight were 156 ± 4.99 cm and 53.20 ± 9.83 kg for the women, while 170.90 ± 4.72 cm and 69.90 ± 12.01 kg for men, respectively.

The computed clinical characteristics for the women varies from healthy individuals (18.5 ≤ BMI (kg/m^2) ≤ 24.9) and up to some individuals with overweight (BMI ≥ 25 kg/m^2). The other three clinical characteristics showed widely fluctuations, for the BV from 2.84 to 3.93 l, the BMR from 1,259.85 to 1,529.82 kCal and for the BS from 1.36 to 1.72 m^2, respectively. The weight of one lower limb varies from 8.30 to 13.50 kg.

While for the men, the clinical characteristics varies from underweight individuals (BMI ≤ 18.5 kg/m^2) and up to individuals with obesity (BMI ≥ 30 kg/m^2). Then, the other three clinical characteristics widely fluctuate for the BV from 4.31 (does not correspond to the underweight individual) to 5.67 l, the BMR from 1,584.94 to 2,064.92 kCal and for the BS from 1.69 to 2.11 m^2, respectively. The weight of the one lower limb varies from 11.30 to 18.30 kg.

Tables 3 and 4 show the clinics characteristics of the fictitious patients who lost one lower limb. The clinics characteristics were evaluated by subtracting the mass of the lower limbs from the total mass of the individual.

Most of the fictitious women patients show BMI<18.5, that is, they are underweight. Just, three of them show 18.5 ≤ BMI (kg/m^2) ≤ 24.9. The BV fluctuates from 2.57 to 3.48 l, the BMR from 1,179.08 to 1,400.68 kCal and for the BS from 1.24 to 1.57 m^2, respectively.

While, half of the fictitious men patients belong to the underweight group, that is, BMI < 18.5 kg/m^2, the other half patients show up in the normal group, that is 18.5 ≤ BMI (kg/m^2) ≤ 24.9. The BV fluctuates from 3.91 to 5.08 l, the BMR from 1,429.83 to 1,812.61 kCal and for the BS from 1.53 to 1.92 m^2, respectively.

3. Discussion

The sample population, young healthy adults, is chosen arbitrary with only one inclusion criteria, that is, the volunteers were not sick at the time of the interview. The sample is divided in women and men. The equations, used to compute lower limb weight and the clinical characteristics, depend on two

Table 3. The BMI, BV, BMR and BS for the fictitious women patients, who were amputated for one lower limb. The four characteristics were computed by subtracting the mass of the lower limb from the total mass of the patient

Volunteer	BMI (kg/m^2)	BV (l)	BMR (kCal)	BS (m^2)
W01	16.53	2.57	1,287.43	1.47
W02	22.27	2.66	1,368.09	1.54
W03	21.64	2.67	1,304.75	1.42
W04	15.87	2.74	1,180.84	1.24
W05	16.14	2.79	1,194.72	1.28
W06	15.62	3.00	1,253.46	1.39
W07	15.55	3.05	1,193.19	1.27
W08	15.61	3.27	1,180.54	1.31
W09	14.92	3.38	1,179.08	1.29
W10	22.35	3.48	1,400.68	1.57
	17.65	2.96	1,254.28	1.38
	3.10	0.33	82.86	0.12

Note: Body mass index (BMI); blood volume (BV); basal metabolic rate (BMR); body surface (BS).

Table 4. The BMI, BV, BMR and BS for the fictitious men patients, who were amputated for one lower limb. The four characteristics were computed by subtracting the mass of the lower limb from the total mass of the patient

Volunteer	BMI (kg/m^2)	BV (liters)	BMR (kCal)	BS (m^2)
M01	23.00	5.08	1,429.83	1.92
M02	18.18	4.26	1,449.12	1.65
M03	13.79	4.08	1,459.89	1.53
M04	16.61	3.95	1,538.34	1.54
M05	21.70	4.54	1,444.07	1.76
M06	18.80	4.10	1,509.01	1.61
M07	18.36	3.91	1,443.91	1.55
M08	24.81	4.54	1,660.66	1.78
M09	18.88	3.91	1,812.61	1.55
M10	17.75	4.06	1,691.22	1.59
	19.19	4.24	1,543.87	1.65
	3.20	0.37	132.42	0.13

Note: Body mass index (BMI); blood volume (BV); basal metabolic rate (BMR); body surface (BS).

anthropometric measurements and the age, that is, can be filled up easily. A disadvantage, in these calculations, is the use of recurrent equations: one to compute the weight of human body segments and the other to compute the clinical characteristics. Thus, to simplify the calculations the body weight segments can be estimated as a percentage of the total body mass (Gowitzke & Milner, 1999). However, both approaches can be easily programmed in the different programing platforms.

The statistic of the computed clinical characteristics is given in Table 5. Depending on how familiar is the clinician with these clinical characteristics, then it may not be impressive for some them, but very interesting for others, and it may be more interesting for those young clinicians and for students of different fields. The differences, between the maximum and the minimum computed value are 1.09 l

Table 5. The computed clinical characteristics of the sample data (20 young, healthy, adults), the minimum and maximum values and the averages values with the standard variances

	Clinical characteristic	Minimum	Maximum	Average
Women				
	BMI (kg/m^2)	18.49	27.69	21.84 ± 3.82
	BV (l)	2.84	3.93	3.30 ± 0.39
	BMR (Kcal)	1,259.85	1,529.82	1,351.93 ± 101.18
	BS (m^2)	1.36	1.72	1.51 ± 0.13
	Mass of lower limb (kg)	8.30	13.50	10.22 ± 1.92
Men				
	BMI (kg/m^2)	17.36	30.44	23.94 ± 3.94
	BV (liters)	4.31	5.67	4.69 ± 0.45
	BMR (Kcal)	1,584.94	2,064.92	1,734 ± 164.07
	BS (m^2)	1.69	2.11	1.81 ± 0.14
	Mass of lower limb (kg)	11.30	18.30	13.88 ± 2.30

Note: Body mass index (BMI); blood volume (BV); basal metabolic rate (BMR); body surface (BS).

and 1.36 l (BV), 269.97 kCal and 479.98 kCal (BMR), 0.36 m^2 and 0.42 (BS) and 5.02 and 7.0 kg (mass of a lower limb) for women and men, respectively. This wide variation in the clinical characteristics shows the importance of not using the median or the average to estimate them.

Another useful application from knowing the masses of the body segments is when assessing the muscle force of specific group. For instance, in a transtibial amputation, the hamstring muscles are still functioning. Then, after the amputation surgery and without any risk of injury, these muscles can be stretched by attaching an object on the stump with an equivalent mass to the leg and the foot. Because of, before the amputation, the hamstring muscles could flexed, at least, a weight composed of the leg and foot, against the gravity force.

Furthermore, the minimum and maximum force, in the muscle force assessment (Hislop & Montgomery, 1995), may be defined in terms of a weight proportional to that of the body segment mass to be assessed. It is known that when a muscle group can move the body segment against gravity, the next assessment is to apply the minimum force. Thus, this force may be evaluated by attaching to the center of gravity of the body segment to be assessed, a weight proportional to the mass of the body segment. That is, if *Mbs* designates the mass of the body segment, then the mass to be attached to the center of gravity may be 1/4 *Mbs*, 1/2 *Mbs*, 1 *Mbs*, 2 *Mbs*, etc. The same strategy can be applied to define the maximum force.

The knowing of the body mass segment is useful to estimate clinics characteristics of the patient to assess muscle force for a given muscle group, and those pathologies where the limbs of the human body are affected, like bone cancers, lymphomas, peripheral neuropathies, peripheral artery disease, etc.

4. Conclusions

By means of a sample population of young healthy adults, it was shown the importance to compute the clinical characteristics for the patient in front of the clinician. The weight of the lower limbs and the BMI, BV, BMR and BS showed a wide variation within the sample population.

By using a linear equation, which in function of the weight and height of the patient, the mass of lower limbs were computed and used to estimate the clinics characteristics of 20 fictitious patients who lost one lower limb. These, clinics characteristics showed that the patients have different requirements than before the amputation.

The knowing of the mass of the body segments allow to estimate the minimum and maximum force to be applied to the assessments of a muscular force. Furthermore, the patient, in the rehabilitation process, may be referred in terms of the weight, attached to the center of gravity of the body segment, moved by the muscles in rehabilitation against gravity force.

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Declaration of interest
There are no known conflicts of interest.

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Note

1. This means that the volunteer, according to their knowledge, was in good health condition. Then, it is the only inclusion criteria.

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