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Weight for Height during Growth, Useful Formulas to Insert into the Pediatrician's Smart Phone

Pierre M Braillon*

Department of Pediatric Imaging, University Claude Bernard, France

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***Corresponding author:** Pierre M Braillon, PhD, MD, Department of Pediatric Imaging, Hospital "Femme-Mère-Enfant" and University Claude Bernard – Lyon, France, Tel: +33-672-725-880; Fax : +33-427-869-262; Email: pb7169@gmail.com

Abstract

The objective of this work was to define simple formulas to calculate the ideal weight (W) for height (H) of children and adolescents aged 2 to 18 years. Using data from 12 countries, two formulas of the form W=A * exp (B*H) have been established (W in kg, H in m). The values for A and B were 2.120±0.112 kg and 1.993±0.05 m^{-1}, respectively, in girls, and 2.379±0.130 kg and 1.895±0.060 m^{-1} in boys. The relevance of these formulas has been controlled by comparing the calculated weight to the measured weight, for children living in 20 other countries, and with various ranges of age. The formulas can be easily introduced into a computer or a smartphone. They appear useful for pediatricians to follow the growth of children, especially those with disease that affects their body weight, the rule being that a gain in H of 5 cm would lead to a weight gain of 10% and a gain of 35 cm a doubling of the body weight.

Key words: Pediatrics; Growth; Weight; Height; Nutrition; Anorexia; Obesity

Introduction

In pediatrics, height (H) and weight (W) are the two most commonly used anthropometric indicators of growth. Usually, the measured H and W values in a given subject are then compared to the mean values for age read on two separate specific growth charts, for H and W, in order to define the so-called "Z scores". They are also used to calculate the body mass index (BMI). However, in many situations, none of these parameters are sufficiently informative, and their interpretation can be misleading. This is especially the cases in abnormal growth velocity, or when comparing the growth of children at the time of puberty as H can be significantly different for the same age. This is also the case for children from different ethnic origins or those for whom the age is not precisely known.

Therefore the relationship between W and H is of real interest to the pediatrician. However, most of the relationships between H and W were established for adults. They are usually linear and are not applicable in pediatrics. Broca [1] was the first to define such a relationship. Years later Devine [2], Robinson et al. [3], Miller et al. [4], and Hamwi [5] published alterations to the Broca's formula. However, these corrections were still not adapted to studies in children. Finally, few practical data W(H) to be used in pediatrics can be found. They are usually given as growth charts established for a limited range of ages, rather than the entire growth period of time.

The aims of this work were

(i) to calculate the best correlations between H and W during growth by using data published in countries from diverse geographical regions, and given as numerical data from ages 2 to 18 years,

(ii) to estimate the possible differences between the mean W values calculated on this range of ages in these different populations,

(iii) to define general formulae for W against H which can be easily inserted in a computer, and

(iv) to test the validity of the general W(H) formula in populations for whom W and H data are given on a much limited range of ages than 2-18 years or from specific limited populations.

The results obtained here should be considered only as practical tools for daily practice in pediatrics. No attempt was made to consider this work as a statistical study.

Materials and Methods

Anthropometric data from different countries giving H and W in numerical values (and not as graphical charts) for children and adolescents aged 2 to 18 years were used. Data from 12 countries were selected, namely: China [6], France [7], Germany [8], Italy

[9], Korea [10], Netherlands [11], Norway [12], Spain [13], Sweden [14], Turkey [15], United Kingdom [16], and USA [17].

The mean data values given in these studies for W (kg) were plotted against the mean corresponding values for H (m) in each male and female population, and they were fitted with the best correlation. A Kruskal-Wallis one way analysis of variance on ranks was then performed (SigmaStat 3.5; Systat Software, Inc. GmbH) to compare the different groups. Finally, general formulae, W (H), for W against H, that might be used in all these male and female populations were defined.

In order to test the pertinence of these formulae, data from 20 other countries or limited populations, were used. These data were given in studies from Argentina [18], Australia [19], Brazil [20], Cyprus [21], Denmark [22], Finland [23], Paris-France [24], Jena-Germany [25], Hungary [26], India [27], Iran [28, 29], Japan [30-32], Malaysia [33], Mexico [34], Pakistan [35], Poland [36], Serbia [37], Seychelles [38], South Africa [39], and Taiwan [40]. They covered a limited range of ages during the growth period of time. Also were included data from 2 populations with specific anthropomorphic characteristics or way of life and nutrition, namely Pygmies [41], and Aboriginal communities [42].

Results

When plotted against H, W values showed similar and regular growth shape for each population studied. They were best fitted by exponential curves (in all cases $r^2 > 0.99$) with equations computed as W= A * exp (B*H).

A and B characteristics and pertinence

Table 1: W=A*exp (B*H), A and B values calculated from the data given in papers ref. 6 to 17.

W=A*exp (B*H)					
	Males		Females		
Country	**Ref**	**A**	**B**	**A**	**B**
China	6	2.283	1.909	2.049	1.981
France	7	2.427	1.861	2.208	1.936
Germany	8	2.480	1.823	2.091	1.961
Italy (North)	9	2.405	1.907	2.127	2.007
Italy (South)	9	2.296	1.950	1.980	2.079
Korea (2005)	10	2.249	1.983	2.013	2.059
Netherlands	11	2.615	1.790	2.252	1.92
Norway	12	2.493	1.844	2.314	1.916
Spain	13	2.310	1.937	2.034	2.041
Sweden	14	2.491	1.870	2.227	1.963
Turkey	15	2.121	1.989	1.952	2.059
UK	16	2.422	1.864	2.141	1.99
USA	17	2.335	1.911	2.166	1.991
m		*2.379*	*1.895*	*2.120*	*1.993*
SD		*0.130*	*0,060*	*0,112*	*0,054*
Median		*2.405*	*1.907*	*2.127*	*1.990*
Range		*2.121-2.615*	*1.790-1.989*	*1.952-2.314*	*1.916-2.079*
CV (%)		*5.5*	*3.2*	*5.3*	*2.7*

(W and A in kg, H in m and B in m^{-1}).

CV (%): Coefficient of Variation in percent.

Values for the coefficients A and B are given in Table 1. In their range of data, A and B values were inversely and similarly correlated together (B=- 0.437 * A + 2.935; r^2=0.89 in males, and B=– 0.438 * A + 2.920; r^2=0.81 in females). The mean values for the product A.B, a main parameter in the change of W with H gain (e.g. ΔW/ΔH), were 4.502±0.122 in males, and 4.218±0.128 in females, showing low differences between the studied populations (coefficients of variation: 2.7% and 3.0%, respectively). A Kruskall-Wallis is one way analysis of variance on ranks indicated that no statistically significant difference was found in the 12 groups of W values calculated with their own equation for H from 80 cm to 170 cm in females, and from 80 cm to 180 cm in males (p=0.999). Therefore two general equations were defined by using A and B mean values (±1 standard deviation): A=2.120±0.112 kg, B=1.993±0,054 m^{-1} in girls and A=2.379±0.130 kg, B=1.895±0.060 m^{-1} in boys (1), H and W being expressed in meters and kilograms, respectively (H given with 3 digits).

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The relevance of these equations was tested by comparing W data given in 20 more studies to the calculated mean weight for the same corresponding height (Wcalc). This is illustrated by the results given in table 2. Values close to 1 were found for Wcalc/W in most cases or they allow to estimate the anthropomorphic differences between populations or sub-populations when they differ significantly from 1 (see, for example, South Africa, Table 2).

Table 2: Ratios of the calculated mean weight for height (Wcalc) to the mean measured weight (W) for children in 20 different world countries (South Africa: LSES & HSES= lower & higher socio-economic status, respectively).

Country	Ref.	Range of ages (y)	Wcalc/W Males	Wcalc/W Females
Argentina	18	3 - 13	0.98±0.01	1.00±0.02
Australia	19	10 - 17	0.94±0.03	0.92±0.03
Brazil	20	8 - 16	1.00±0.02	0.99±0.03
Cyprus	21	6 - 16	0.98±0.02	1.00±0.03
Denmark	22	6.6 – 18.2	1.04±0.05	1.00±0.07
Finland	23	12 - 18	0.99±0.02	1.01±0.02
France (Paris)	24	2 - 18	1.01±0.02	1.02±0.02
Germany (Jena)	25	7 - 14	1.01±0.02	1.03±0.01
Hungary	26	2 -14	0.99±0.02	1.01±0.01
India	27	5-18	1.03±0.03	1.03±0.05
Iran	28, 29	6 - 18	1.06±0.04	1.02±0.05
Malaysia	30	6.5 - 17	1.00±0.04	1.03±0.04
Mexico	31	10 - 18	0.95±0.02	0.91±0.05
Japan 2002	32	5 – 17	0.98±0.08	0.95±0.03
Japan 2004	33	6 – 14	0.98±0.02	0.99±0.01
Japan 2010	34	7 – 14	0.96±0.02	0.95±0.02
Pakistan	35	6 – 12	1.02±0.03	1.05±0.04
Poland	36	7 – 18	1.03±0.02	1.04±0.02
Serbia	37	3 – 11	0.99±0.01	1.00±0.01
Seychelles	38	6 – 19	1.07±0.03	1.01±0.05
South Africa	39	5 – 19 (LSES)	1.08±0.03	1.03±0.08
		5 – 20 (HSES)	1.01±0.03	0.96±0.05
Taiwan	40	6.5 – 18.5	0.95±0.04	0.98±0.03

No precise numerical data for W and H were found for Pygmies or Aboriginal communities. However, from the estimation that can be made on the graphs related to the growth trajectories in Baka Pygmies [41], it appeared that the mean measured height and weight at age 10 are close to 1.18m and 22.0kg, in both girls and boys, while W was calculated as 22.3Kg in both sexes. At age 18 (H ~1.47 in girls, and 1.49 in boys) the mean weights were calculated as 39.7Kg in girls, and 40.0kg in boys, values approximately 6% lower than the measured mean W values. In Aboriginal populations, from the graphs presented by the authors [42], H and W values can be appreciated at ages 5, 10 and 15 years as: 1.08m, 17,5kg - 1.38m, 32,6kg - 1.62m, 52,4kg in females, and 1,05m, 16.8kg - 1,40m, 33.9kg– 1.68m, 56.4kg in males. The corresponding calculated values for W were: 18.2kg, 33.2kg, 53.5kg, respectively, in females, and 17.4kg, 33.8kg, 57.4kg in males, the differences between W and Wcalc ranging from 0% to 4%.

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Dynamic of weight change during growth

From the equation W=A *exp (B*H), it can be seen that a weight gain of approximately 10% is expected for a gain of height ΔH=0.05m, while a twofold change of W occurs for ΔH=0.35 m (for example, from 1.05 m at age 4-5 years to 1.40 m at the beginning of the puberty spurt).

Discussion

The main goal of this work was to define useful relationships between the weight and height of children aged from 2 years to 18 years [43]. A similar idea was proposed by Ehrenberg to estimate the logarithm weight of children aged from 5 to 13 years. Severe criticism was made by Cole (43) regarding this kind of preoccupation. Clearly, the period of time from birth to age 2 is a period with a particular dynamic of growth (that may be represented by the first stage of a logistic curve) and should be considered separately. It was suggested to use expressions of the form W/Hp, or W=k * Hp. Unfortunately, p value is not constant along the entire growth period of time [30,44,45]. The choice of exponential functions greatly simplifies the computing process.

We used data published in several countries as growth reference, and obtained for most of them by using the Cole & Green [46] LMS method. To calculate mean values from such data, which are still means, is of course a limitation not well accepted in statistics. However, as previously said, the aim of this work was first to define simple tools that can be useful to those in charge of children during their growth, and no attempt to make a precise statistical study was made.

Two equations of the form W=A* exp (B*H) were obtained. These equations, easy to enter in any computer or smartphone, allow pediatricians to estimate the mean ideal weight for height of a boy or girl from age 2 to age 18 with an accuracy sufficient in clinical practice. They could be particularly useful to follow the body weight changes in children with nutrition diseases, especially anorexia or obesity. It is to be note that it is not necessary to precisely know the patient's age, nor his/her Tanner stages [47], and that the changes in growth velocity at puberty are implicitly taken into account in this method of weight assessment. Moreover, the equations obtained here appeared correctly adapted for the analysis of growth whatever the ethnic origin of the subjects was, even in specific pediatric populations, when growth can be considered as possibly related to a particular way of life and nutrition.

Conclusion

To conclude, the ideal weight W for height H could be calculated with a good accuracy in children and adolescents aged from two years to eighteen years, with the formulae W=2.120*exp(1.993*H) in females and W=2.329*exp(1.895*H) in males. These formulae, which are effective in any population can be easily inserted in a computer or a smartphone. They could be of help to the pediatrician to follow the growth of children suffering from diseases that affect their body weight, the regular rule being that an increase in the weight of 10%, and its doubling, are expected for every five and thirty-five centimeters of gain in H, respectively.

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