Original Article

Comparison of frequently used, unexplored and newly designed indices for the assessment of segmental and whole body constituents

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Many constitutional indices, used as screening parameters in public health, have been explored (*in-vivo*) and applied for many years, but as yet there is no consensus on a universal index. This reflects confusion, or at least lack of agreement, about what a constitutional index should represent. The aim of this study was to explore the direct relationship of frequently used, unexplored and newly designed indices with adipose tissue masses and trunk adipose tissue distribution, on an anatomical 5-component model. Whole body and trunk composition, of 28 white Caucasian cadavers (aged 78.4±6.9 years), were determined at the anatomical tissue-system level by direct dissection. In the male group, the body mass index, the height/$^3\sqrt{}$body volume index and the weight/height-waist circumference-depth index showed good to excellent significant correlations with all adipose tissue masses (r-values between 0.75 and 0.92) and with the internal adipose tissue/adipose tissue ratio (r-values between 0.59 and 0.78). In the female group, the body mass index, the height/$^3\sqrt{}$body volume index and the weight/height-waist circumference index showed moderate to excellent significant correlations with all adipose tissue masses (r-values between 0.58 and 0.87) and with the internal adipose tissue/adipose tissue ratio (r-values between 0.52 and 0.80) and the internal adipose tissue/subcutaneous adipose tissue ratio (r-values between 0.48 and 0.78). The findings suggest that the newly designed indices (e.g. weight to height-waist circumference-depth index in males and weight to height-waist circumference index in females) are better correlates of whole body adipose tissue masses and trunk adipose tissue distribution than the frequently used indices.

Key Words: adipose tissue, body composition, health status indicators, indices, (tissue) dissection

INTRODUCTION

Since the beginning of anthropometry, as soon as attention was given to body dimensions and their biological and medical implications, the need for a constitutional index was recognised.[1]

It was Quetelet in 1832 who described the possible relation between the weight of individuals of different heights "equal to about the squared sizes".[2] The results of his research marked the beginning of the exploration on relative weight indices.[3,4] The comparisons of efficiency between weight (W) – height (H) indices [W/H, W/H^2, W/H^3 and $H/^3\sqrt{W}$ (the ponderal index)] were studied much later.[5-9]

Judged by the criteria of correlation with height and to measures of body fatness the Quetelet index, called body mass index (BMI) by Keys et al (1972), seems preferable over other indices.[1,10-13] The BMI developed into the most popular index, with believers and criticizers, and it became a parameter used in the screening and classification of underweight, overweight and obesity in adult individuals, based on its correlation with total body adiposity.[14]

Recent studies indicate that excess deposition of adipose tissue in the abdominal region is more strongly associated with the metabolic disturbances than is total body adiposity suggested by BMI.[15] These metabolic disturbances are thought to underlie many of the obesity-related health problems, such as: hypertension, hypercholesterolemia, diabetes mellitus, coronary artery heart disease, and other chronic diseases.[16,17] Several indicators of abdominal obesity are available, but recent reports suggest waist circumference (WC), the sagittal abdominal diameter (SAD) and the waist-to-hip ratio (WHR) as the most practical and accurate measures of abdominal obesity for use in many public health situations.[15,18] The WC, WHR and SAD pretend to measure intra-abdominal adiposity which plays a major role in the association with the metabolic syndrome entailing an increased morbidity and cardiovascular mortality.[19,20]

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Manuscript received 9 November 2010. Initial review completed 1 March 2011. Revision accepted 28 March 2011.

The relationship of BMI, WC and WHR with total body and intra-abdominal adiposity is based on indirect estimations of adiposity and/or other prediction values.[21-23] The criterion methods used for the validation of these anthropometric measures are based on a constant tissue distribution and ad hoc densities and hydration. Their tissue mass predicting capacities might be acceptable in groups; in individuals they are at least debatable, if not doubtful. Elderly persons with similar BMI and/or WC values do not necessarily present similar tissue mass proportion, limiting their use when comparing individual body composition (BC).[23]

These frequently used indices have been explored (*in-vivo*) and applied for many years but as yet there is no consensus on a universal index. This reflects confusion, or at least lack of agreement, about what an index should represent. The combination of different W-H indices and anthropometric measures in relation to direct obtained values for BC assessment is unedited and renewed. Not only newly designed but also unexplored dimensionless indices, derived from hydrodynamic research in the shipbuilding industry, can give some new insights from another point of view. In hydrodynamics a number of indices are morphology related as indicators of respectively frictional, wave-making and eddy resistance of bodies moving through the water. The length/surface ratio, e.g. the square of body height/body surface area (H^2/BSA) is an indicator of frictional resistance. The Slenderness index, e.g. body height/$\sqrt[3]{}$body volume ($H/\sqrt[3]{BV}$) is an indicator of wave-making resistance. The length/depth and length/ breadth ratios, e.g. body height/thorax xiphoïd depth (H/T) and body height/biacromial breadth (H/B) give information of the streamline while the breadth/depth ratio, e.g. biacromial breadth/thorax xiphoïd depth (B/T) predicts eddy or rest resistance.[24,25] Abstraction made that these non-dimensional form indices are part of a complex (hydrodynamical) description of the human body movement in water, these indices are constitutional, call it, morphological in nature, but where never related to body constituents as such.

The aim of this study was to measure an extensive battery of anthropometric dimensions prior to a full dissection of tissues according to an anatomical 5-component model in order to calculate well known BC indices as well as unknown and newly designed indices.[21,22,26]

MATERIALS AND METHODS

Subjects

Twenty-eight (11 male aged 75.9±6.3 years and 17 female aged 79.9±7.1 years) well-preserved white Caucasian cadavers were used in this study (Table 1). By means of a will system, adult Belgian citizens can donate their bodies for medical and scientific research purposes to the university of their choice. All data were collected in the Department of Anatomy at the Vrije Universiteit Brussel (Brussels, Belgium) during separate whole-body dissection projects known as the Brussels Cadaver Analysis Studies (BCAS).[21,26,27] The most common cause of death of the subjects was heart disease (Table 2). All cadavers were embalmed within 48 hours after decease. All applicable institutional, governmental and legal regulations concerning the ethical approval of human volunteers were followed during the study.

Anthropometry

To create an *in-vivo* measurement situation, the cadaver was suspended by an adapted orthopedic head harness. Hip circumference (HC, at the level of the greatest poste-

Table 1. Physical characteristics and body composition of the subjects

	Males (n = 11) Mean ± SD (range)	Females (n = 17) Mean ± SD (range)
Physical characteristics		
Age (years)	75.9±6.3 (65.0-87.0)	79.9±7.1 (68.0-94.0)
Weight (kg)	59.6±13.5 (38.5-85.1)	58.8±11.6 (32.0-75.4)
Height (cm)	166±5 (160-178)	159±7 (146-173)**
Biacromial breadth (cm)	36.4±1.8 (32.9-39.3)	34.3±2.5 (29.1-38.6)*
A-P Chest depth (cm)	21.9±1.5 (19.7-24.2)	19.3±1.3 (16.7-21.3)***
Hip circumference (cm)	88.8±5.1 (81.5-99.2)	94.5 ±7.4 (79.5-106)*
Body surface area (m²)	1.67±0.14 (1.46-1.88)	1.63±0.25 (1.25-2.18)
Body volume (dm³)	56.6±13.4 (35.1-82.2)	56.9±11.67 (30.9-72.9)
BMI (kg/m^2)	21.5±4.3 (14.7-28.4)	23.4±4.6 (12.9-30.9)
WC (cm)	81.9±7.3 (70.9-94.3)	79.2±8.4 (58.8-94.0)
WHR	0.92±0.05 (0.86-1.01)	0.84±0.06 (0.74-0.98)***
Body composition		
AT (kg)	15.9±6.8 (5.7-25.7)	23.2±8.9 (4.6-40.1)*
TAT (kg)	8.0±3.8 (3.2-14.2)	10.7±4.6 (2.7-19.2)
SAT (kg)	4.9±2.3 (2.6-9.4)	7.6±3.1 (2.5-13.4)*
IAT (kg)	3.1±1.7 (0.5-5.3)	3.1±1.7 (0.3-5.8)
Skin (kg)	3.4±0.7 (2.5-4.7)	3.2±0.6 (1.7-4.1)
Muscle (kg)	22.0±6.2 (14.0-34.8)	17.1±3.2 (12.3-23.4)*
Bone (kg)	9.3±1.2 (7.4-11.8)	7.7±0.8 (6.7-10.0)***
Viscera (kg)	8.9±1.6 (6.3-10.9)	7.5±1.4 (5.8-10.7)*
IAT/AT (%)	18.1±5.2 (9.1-24.8)	12.6±3.5 (5.3-17.6)**
IAT/SAT (%)	62.1±26.9 (18.8-117)	40.5±15.5 (10.9-73.9)*

n: total number of subjects, SD: standard deviation, BMI: body mass index, WC: waist circumference, WHR: waist-to-hip ratio, A-P: anterior-posterior, AT: total body adipose tissue, TAT: trunk adipose tissue, IAT: trunk internal adipose tissue, SAT: trunk subcutaneous adipose tissue. *p<0.05, **p<0.01, ***p<0.001.

Table 2. Causes of death§ of the subjects

	Males (n = 11)	Females (n = 17)
Natural	5	5
Heart attack	4	6
Stroke	0	1
Accident	0	1
Cancer	1	2
Renal insufficiency	0	1
Respiratory insufficiency	1	0
Leukemia	0	1

§official diagnose on death certificate

Table 3. Overview of the used indices

Frequently used	Unexplored	Newly designed
BMI	H/B	W/(H×WC)
WC	H/T	W/(H^2×WC)
WHR	H^2/WC	W/(H^3×WC)
	H^2/BSA	H/($^3\sqrt{}$W×WC)
	H/$^3\sqrt{}$BV	W/(H×WC×T)
	B/T	W/(H^2×WC×T)
		W/(H^3×WC×T)
		H/($^3\sqrt{}$W×WC×T)

BMI: body mass index, WC: waist circumference, WHR: waist-to-hip ratio, H: height, B: biacromial breadth, T: anterior-posterior chest depth, BSA: body surface area, BV: body volume, W: weight.

rior protuberance) and WC (the smallest girth between the iliac crest and the costal border) were measured with a flexible steel tape ruler to the nearest 0.1 cm. Waist-to-hip ratio was calculated as WC divided by HC. Anterior-posterior (A-P) chest depth (T, at mesosternale level) was measured with a wide-spreading caliper with recurved branches to the nearest 0.1 cm. Biacromial breadth (B, distance between the most lateral points on the acromion processes) was measured with a large sliding caliper to the nearest 0.1 cm. Supine length was measured with the cadaver on a horizontal surface, using a custom-made anthropometer and using a 90° dorsiflexion support for the feet and head support for a correct approach of the Frankfurter Plane. Both supports allowed for a horizontal anthropometer position. BMI was calculated as weight divided by height squared (kg/m^2). Body surface area (BSA) of the dissected skin was measured with a planimeter on the projected and drawn skin edges on paper. Body volume (BV) was calculated as the difference of weight in air and weight in water (hydrostatic weight).

All measurements were made with the cadaver adapted to ambient temperature (24°C) in order to limit temperature-related differences in texture and mobility of the skin and adipose tissue.[21,28]

Indices

The anthropometric data (as described above), originating from an anthropometric battery as part of a large BC protocol (BCAS projects), were used for the calculation of all well known, unexplored and combined (newly designed) indices (Table 3).The calculation of the combined indices deserves further explanation. The newly designed indices are a combination of several W-H indices with WC. The remaining question is do we put WC in the numerator or in the denominator. Table 4 shows the correlations between each component of the indices and adipose tissue (AT) masses/ratios. Analyzing this table shows that 1/WC is slightly better correlated to the AT masses than WC. Thus WC was placed in the denominator. The addition of T was a tryout because 1/T showed significant correlations with TAT and SAT in the female group.

Dissection

Dissection started in the early morning and continued until completion. Total dissection time varied between 14 and 20 hours, depending of the bodies' constitution.

All cadavers were dissected according the 5-component model and expressed on its tissue-system level i.e. skin, muscle, adipose tissue, viscera and bones; which were weighed to the nearest 0.001 kg with dehydration reduced to a minimum.[29] Detailed methodology of the dissection procedures has been reported elsewhere.[21,22,26,27] The evaporative loss of body fluid during the dissection was calculated as the difference between

Table 4. Pearson correlation coefficients between several index components and AT masses/ratios

	AT	TAT	SAT	IAT	IAT/AT	IAT/SAT
Males (n=11)						
W	0.83**	0.78**	0.74*	0.77**	0.61*	0.45
H	0.38	0.30	0.19	0.41	0.46	0.62*
WC	0.74*	0.75**	0.72*	0.71*	0.48	0.27
T	-0.45	-0.52	-0.45	-0.57	-0.44	-0.31
1/H	-0.33	-0.23	-0.14	-0.34	-0.41	-0.59
1/WC	-0.74*	-0.74*	-0.71*	-0.72*	-0.51	-0.30
1/T	0.45	0.51	0.43	0.57	0.46	0.35
Females (n=17)						
W	0.93***	0.80***	0.70**	0.87***	0.67**	0.60*
H	0.31	0.27	0.20	0.35	0.33	0.27
WC	0.67**	0.61*	0.62**	0.49*	0.23	0.16
T	0.42	0.50*	0.57*	0.31	0.16	-0.02
1/H	-0.31	-0.26	-0.19	-0.35	-0.35	-0.28
1/WC	-0.69**	-0.63**	-0.63**	-0.52*	-0.30	-0.23
1/T	-0.42	-0.50*	-0.56*	-0.31	-0.17	0.00

AT: total body adipose tissue, TAT: trunk adipose tissue, SAT: trunk subcutaneous adipose tissue, IAT: trunk internal adipose tissue, W: weight, H: height, WC: waist circumference, T: anterior-posterior chest depth, *p<0.05,**p<0.01,***p<0.001.

total body weight before dissection and total tissue weight after dissection. The individual loss in each cadaver was allocated back to the different tissues in proportion to their respective masses. After this correction, the sum of the weights of all dissected tissues was equal to the cadaver's whole body weight prior to dissection, minus the result of evaporation during the time consuming and cumbrous dissection.

Definitions

Six body segments were defined: the four limbs, trunk and head. Weights of all tissues were recorded as total body adipose tissue mass (AT), total trunk adipose tissue mass (TAT) [=trunk subcutaneous adipose tissue mass (SAT) + trunk internal adipose tissue mass (IAT, the sum of intra-abdominal AT (i.e. visceral and retroperitoneal AT) and intra-thoracic AT)], muscle tissue mass, bone tissue mass, skin tissue mass and visceral tissue mass.

We also calculated two measures of internal adipose tissue proportion: the ratio of IAT to AT and the ratio of IAT to SAT.

Statistical analysis

All data were analyzed using Statistical Package for Social Sciences (version 17.0.1 for Windows, SPSS Inc, Chicago, USA). Data are reported as mean ± standard deviation. Normality of data distributions was verified using Kolmogorov-Smirnov Goodness of Fit test ($p>0.05$). Gender differences in BC were calculated using unpaired t-tests. Agreement between the different indices and BC constituents were assessed using Pearson correlation coefficients.

RESULTS

Total body weight (BW) for the whole sample before dissection was 59.1±12.1 kg. Evaporative loss of fluid (ELF) during dissection was 2.0±0.6 kg and the accuracy of the whole body dissection method (ELF/BW) was 3.3±1.3%.

Compared to females, males were significantly taller ($p<0.01$), showed higher biacromial breadth ($p<0.05$), higher A-P chest depth ($p<0.001$), higher WHR ($p<0.001$) and lower hip circumference ($p<0.05$). The male sample showed also lower AT mass ($p<0.05$), higher muscle tissue mass ($p<0.05$), higher bone tissue mass ($p<0.001$), higher visceral tissue mass ($p<0.05$) and higher proportions of IAT ($p<0.05$) (Table 1). No significant gender differences were found for age, weight, BMI and WC.

Several frequently used, unexplored and newly designed indices were significantly related to various AT masses and to measures of TAT proportions in both sexes (Tables 5 and 6). None of these indices were significantly ($p>0.05$) correlated to height (r-values between -0.25 and 0.51) (data not shown).

In each group and each category there is one index towering above. Regarding the male group, the BMI, the $H/\sqrt[3]{BV}$ index and the W/(H×WC×T) index are the better indices of their respective category. The BMI showed good correlations with all AT masses (r-values between 0.76 and 0.83, $p<0.01$). The $H/\sqrt[3]{BV}$ index showed similar but inverse correlations with all AT masses (r-values between -0.75 and -0.84, $p<0.01$) and with the IAT/AT ratio (r=-0.65, $p<0.05$). The W/(H×WC×T) index produced the best result with good to excellent correlations with all AT masses (r-values between 0.80 and 0.92, $p<0.01$) and with the IAT/AT ratio (r=0.78, $p<0.01$).

For the female group the better indices were the BMI, the $H/\sqrt[3]{BV}$ index and the W/(H×WC) index.

The BMI showed moderate to good correlations with all AT masses (r-values between 0.61 and 0.80, $p<0.01$)

Table 5. Comparison between indices and body composition of 11 male cadavers by dissection with Pearson correlation coefficients

	AT	TAT	SAT	IAT	IAT/AT	IAT/SAT
Frequently used indices						
BMI	0.83**	0.80**	0.77**	0.76**	0.59	0.36
WC	0.74*	0.75**	0.72*	0.71*	0.48	0.27
WHR	0.37	0.43	0.41	0.41	0.27	0.07
Unexplored indices						
H/B	-0.63*	-0.67*	-0.64*	-0.65*	-0.61*	-0.29
H/T	0.50	0.52	0.41	0.62*	0.56	0.54
H^2/WC	-0.47	-0.54	-0.58	-0.43	-0.17	0.13
H^2/BSA	-0.57	-0.53	-0.55	-0.43	-0.19	0.05
$H/\sqrt[3]{BV}$	-0.84***	-0.81**	-0.75**	-0.80**	-0.65*	-0.42
B/T	0.72*	0.76**	0.65*	0.82**	0.73*	0.57
Newly designed indices						
W/(HxWC)	0.78**	0.71*	0.66*	0.72*	0.63*	0.48
W/(H^2xWC)	0.77**	0.71*	0.67*	0.70*	0.60	0.40
W/(H^3xWC)	0.72*	0.68*	0.65*	0.66*	0.54	0.30
$H/(\sqrt[3]{W}\times WC)$	-0.82**	-0.81**	-0.76**	-0.79**	-0.60	-0.36
W/(H×WC×T)	0.92***	0.89***	0.80**	0.92***	0.78**	0.58
W/(H^2×WC×T)	0.92***	0.90***	0.83**	0.91***	0.76**	0.51
W/(H^3xWC×T)	0.87***	0.88***	0.82**	0.87***	0.70*	0.41
$H/(\sqrt[3]{W}\times WC\times T)$	-0.59	-0.55	-0.55	-0.50	-0.37	-0.19

AT: total body adipose tissue, TAT: trunk adipose tissue, SAT: trunk subcutaneous adipose tissue, IAT: trunk internal adipose tissue, BMI: body mass index, WC: waist circumference, WHR: waist-to-hip ratio, H: height, B: biacromial breadth, T: anterior-posterior chest depth, BSA: body surface area, BV: body volume, W: weight, *$p<0.05$,**$p<0.01$,***$p<0.001$.

Table 6. Comparison between indices and body composition of 17 female cadavers by dissection with Pearson correlation coefficients

	AT	TAT	SAT	IAT	IAT/AT	IAT/SAT
Frequently used indices						
BMI	0.80***	0.69**	0.61**	0.72**	0.54*	0.50*
WC	0.67**	0.61*	0.62**	0.49*	0.23	0.16
WHR	0.09	0.13	0.25	-0.11	-0.32	-0.34
Unexplored indices						
H/B	-0.28	-0.15	-0.11	-0.21	-0.29	-0.39
H/T	-0.20	-0.29	-0.37	-0.09	0.02	0.14
H/WC	-0.37	-0.34	-0.38	-0.21	-0.05	-0.03
H^2/BSA	-0.59*	-0.59*	-0.56	-0.60*	-0.50	-0.31
$H/\sqrt[3]{BV}$	-0.74**	-0.64**	-0.58*	-0.65**	-0.52*	-0.48
B/T	0.03	-0.12	-0.21	0.07	0.22	0.37
Newly designed indices						
W/(HxWC)	0.84***	0.70**	0.55*	0.87***	0.80***	0.78***
W/(H^2xWC)	0.72**	0.60*	0.47	0.75**	0.68**	0.69**
W/(H^3xWC)	0.56*	0.46	0.36	0.56*	0.51*	0.53*
$H/(\sqrt[3]{W}\times WC)$	-0.72***	-0.64**	-0.62**	-0.58*	-0.40	-0.35
W/(HxWCxT)	0.56*	0.40	0.24	0.65**	0.66**	0.72**
W/(H^2xWCxT)	0.47	0.32	0.18	0.54*	0.56*	0.64**
W/(H^3xWCxT)	0.35	0.23	0.11	0.41	0.43	0.51*
$H/(\sqrt[3]{W}\times WC\times T)$	-0.71***	-0.66**	-0.66**	-0.56*	-0.39	-0.30

AT: total body adipose tissue, TAT: trunk adipose tissue,SAT: trunk subcutaneous adipose tissue, IAT: trunk internal adipose tissue, BMI: body mass index, WC: waist circumference, WHR: waist-to-hip ratio, H: height, B: biacromial breadth, T: anterior-posterior chest depth, BSA: body surface area, BV: body volume, W: weight, $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$.

and moderate correlations with the IAT/AT ratio (r=0.54, $p<0.05$) and the IAT/SAT ratio (r=0.50, $p<0.05$). The $H/\sqrt[3]{BV}$ index showed moderate to good but also inverse correlations with all AT masses (r-values between -0.58 and -0.74, $p<0.05$) and with the IAT/AT ratio (r=-0.52, $p<0.05$). The W/(H×WC) index showed moderate to excellent correlations with all AT masses (r-values between 0.55 and 0.87, $p<0.05$) and good correlations with the IAT/AT ratio (r=0.80, $p<0.001$) and the IAT/SAT ratio (r=0.78, $p<0.001$).

DISCUSSION

The relation between unexplored and newly developed indices with BC constituents may provide new insights in BC assessment. The validation of these indices occurred in a post mortem population (n=28) and is, to our knowledge, the first report relating these ratios to directly obtained measurements of BC constituents. The design of the study is unique in the sense that it requires no assumptions regarding the measurement and the calculation of the BC constituents. The exact determination of the BC constituents is difficult in living humans, and mainly based on 'reference' BC methods such as CT or MRI.[23,30,31]

It is well established that overweight and obesity are associated with an increased burden of cardiovascular disease, other chronic diseases, disability and certainly discomfort. However, it equally confirmed that cardiovascular fitness provides a strong effect against all-cause and cardiovascular disease mortality in healthy men and men with a metabolic syndrome.[32] The health benefits of leanness are limited to fit men and being fit may reduce the hazards of obesity.[33]

Besides the determination of absolute AT quantities, its distribution within the body is an important health consideration.[34] It is well known that intra-abdominal AT concentration carries greater cardiovascular health risk compared to subcutaneous AT accumulation.[35] Intra-abdominal AT and subcutaneous AT can predict different health-risks, based on their own morphological and functional features, even for a given level of abdominal adiposity. Intra-abdominal AT has been repeatedly linked to an increased risk of dyslipidemia, dysglycemia and vascular disease. By contrast, subcutaneous AT has been associated with better metabolic outcomes.[23] In the present study sex specific differences in AT distribution were observed. Males showed lower AT, TAT and SAT masses, but similar proportions of IAT compared to females of similar age. This observation validates previous findings as determined by MRI.[23,36]

When analyzing frequently used indices, such as the BMI, WC and WHR, we can see that the BMI was positively related to regional AT distribution in females only, suggesting that BMI-values do not allow distinction between internal and subcutaneous adipose tissue accumulation in males. In addition, in a critical appraisal of the BMI, evidence was presented that the high proportion of unexplained variance between BMI and direct BC constituents limit its use both as a segmental and as a whole BC index.[37] Data suggested that the BMI could be alternatively a better index for bone mass e.g. bone mass index.

WC and WHR were not significantly correlated to measures of TAT distribution in both sexes. In both groups and amongst the unexplored indices, the $H/\sqrt[3]{BV}$ index in particular indicated moderate to good but inverse relationships with the AT masses and with the IAT/AT ratio suggesting that no distinction between internal and subcutaneous adipose tissue accumulation can be made.

The newly designed indices with W/(H×WC×T) (males) and W/(H×WC) (females) correlated significantly with AT, TAT, SAT and IAT. W/(H×WC×T) correlated significantly with the IAT/AT ratio, while W/(H×WC) correlated significantly with both IAT/AT ratio and IAT/SAT ratio. This means that only the W/(H×WC) index allows distinction between internal and subcutaneous adipose tissue accumulation. It should also be observed that the W/(H×WC×T) index correlates better with IAT than with SAT in both sexes, suggesting that this index is a more appropriate indicator of internal adiposity as opposed to subcutaneous AT.

No recent studies are available reporting the relationship of the unexplored and newly designed indices with AT and TAT distribution.

The 'reference' method for the determination of BC in the present study was cadaver dissection. Although this method has limitations including tissue dehydration, an age matched *in-vivo* and post mortem constitutional and anthropometric comparison has shown an overall similarity of anthropo-morphologic characteristics between subjects.[38] Since no data are available on the duration of the clinical-pathologic status of the subjects, it remains unclear to which extent body composition might have been affected in the chronically ill subjects (6 out of 28). On the other hand, it has to be pointed out that adiposity indices are regularly used in the evaluation and follow-up of the nutritional status both in healthy elderly and in patients. The precision of our method to determine BC averaged 3.3%, which indicates that dehydration and/or losses of material during the dissection procedures were negligible. It is therefore unlikely that the method of choice biased the results presented here. Moreover the mean difference between actual weight and CT derived or MRI estimated weight reaches 5.6% to 6.0%, the latter being considered as a gold standard method in BC.[21,28,34] An inevitable restriction to a whole-body dissection is the relatively limited number of individuals whose BC can be determined. This is due to the work-related insensitivity of the dissection procedures and the limited availability of subjects.

CONCLUSION

The present study shows significant correlations between several indices and segmental and whole body constituents. Each group and each category have one index towering above. For the males the BMI, the $H/^3\sqrt{BV}$ index and the W/(H×WC×T) index are the better indices of their respective category. For the females the better indices were the BMI, the $H/^3\sqrt{BV}$ index and the W/(H×WC) index.

The regression analysis of the various findings of this study suggests that the newly designed indices (e.g. weight to height-waist circumference-depth index [W/(H×WC×T)] in males and weight to height-waist circumference index [W/(H×WC)] in females) are better correlates of whole body adipose tissue masses and trunk e.g. internal adipose tissue distribution than the frequently used indices.

These indices may be considered as a new screening tool in predicting whole body, trunk composition in particular, but validation against an *in-vivo* population deserves further or at least additional investigation.

AUTHOR DISCLOSURES

None of the authors had any financial interest for this paper.

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Original Article

Comparison of frequently used, unexplored and newly designed indices for the assessment of segmental and whole body constituents

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常用的、未探討的或新設計的指標對於評估部分或全身體組成的比較

許多體組成指標做為公共衛生的篩檢項目，已經被研究(活體)且應用很多年，但是到目前為止卻沒有一個大家認同的通用指標。這反映出究竟以什麼體組成指標當作代表仍是混亂的，或至少是缺乏一致性。此研究目的為探討常用的、未探究的及新設計的指標，對於脂肪質量及軀幹脂肪組織分佈在解剖上 5 項組成份模式的直接相關性。以直接解剖至組織-系統層級，評量 28 具高加索白人大體(年齡 78.4±6.9 歲)的全身與軀幹組成。在男性組，身體質量指數、身高/身體體積開立方及體重/身高-腰圍-體厚度指數，顯示與全部脂肪組織質量(r 值在 0.75-0.92 間)及內部脂肪組織/脂肪組織(r：0.59-0.78)具有良好或是極佳的相關性。在女性，身體質量指數、身高/身體體積開立方及體重/身高-腰圍指數，顯示與全部脂肪組織質量(r：0.58-0.87)、內臟脂肪組織/脂肪組織(r：0.52-0.80)及內臟脂肪組織/皮下脂肪組織(r：0.48-0.78)有中度到很好的相關性。研究結果呈現，新設計的指標(例如男性的體重/身高-腰圍-厚度指數及女生的體重/身高-腰圍指數)對於全身脂肪組織質量及軀幹脂肪組織分佈，比起常使用的指標有更好的相關性。

關鍵字：脂肪組織、體組成、健康狀況指標、指數、(組織)解剖