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The anthropometric generalization of the Body Mass Index

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Abstract

The classic Body Mass Index, (BMI), developed in the 19th century by the Belgian mathematician Adolphe Quetelet [1] is an important indicator of the risk of death, of obesity, of negative health consequences, body fat percentage and of the shape of the body. While he BMI is assumed to indicate obesity in sedentary people and in people who do not practice sports, it is undisputed and a consensus among researchers [2][3][4][5][9][25] that Body Mass Index (BMI) is not a good indicator for obesity in people who developed their body through heavy physical work or sport but also in other segments of population such as those who appear to have a normal weight but in fact have a high body fat percentage and obese methabolism. The BMI also does not include all the variables essential for a health predictor. The BMI is not always a good predictor of metabolic disease, people who appear of healthy weight according to BMI have in some cases an obese metabolic syndrome. The BMI was developed as a law of natural sciences and "social physics" [1], as it was called then, before the middle of the 19th century, and it had been used from the 70s for medical purposes, to detect obesity and the risk of mortality [6][7]. The BMI has a huge importance for modern society, affected by an obesity epidemic [8]. BMI has applications in medicine, sport medicine, sport, fitness, bodybuilding, insurance, nutrition, pharmacology. The main limitation of the BMI is that it does not account for body composition including non fat body mass such as muscles, joints, body frame and makes no difference between fat and non fat components of the body weight. The body composition and the proportion of fat and muscles make a difference in health outcomes [12][13][14][25][26][27][35][36][37] [38][39][40][41] [42][43][44]…[100]. Body composition makes a difference also in the level of sport performance for athletes of every level. In nearly two centuries since the Body Mass Index was developed, no formula had been successfully developed to account for body composition and make the difference between muscle and fat in a consistent way. This can be considered a longstanding open problem of major importance for society. The objective of this analysis is to develop new formulae taking into account the health implication of body composition measured through indirect, simple indicators and making the difference between muscles and fat, healthy and non healthy metabolism. The formulae developed in this article are the only formula to successfully generalize BMI and make this difference. I develop a direct generalization of BMI, in the mathematical and physiological sense to account for fat and fat free mass and muscles, small and large body frames. It is the first such generalization because the classic BMI can be determined as a particular case of my formulae in the strict mathematical and practical physiologic sense. No other formula generalized the BMI to make the difference between fat and a large frame and muscles has ever been published in nearly two centuries since the BMI formula had been developed. The formulae I developed explain and generalize the conclusions of a large number of highly cited empirical experiments cited in the reference section. [35][36][37][38][38][39] [40][42][43][44]..[100] Most of the experimental proof I bring in support of my formulae and bodyweight quantification theory comes from many highly cited experimental research publications in medicine, sports medicine, sport science and physiology. My formulae explain also performance in decades of competitive sports and athletics

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Introduction and problem formulation

The Body Mass Index was developed based on the statistical research of 19th century Belgian mathematician Adolphe Quetelet [1] where it is formulated as a relation between weight and height in chapter II.2. ("Relations between the Weight and Height") of his book "A treatise on man", published in 1842:

"However, if we compare two individuals who are fully developed and well-formed with each other, to ascertain the relations existing between the weight and stature, we shall find that the weight of developed persons, of different heights, is nearly as the square of the stature. Whence it naturally follows, that a transverse section, giving both the breadth and thickness, is just proportioned to the height of the individual. We furthermore conclude that, proportion still being attended to width predominates in individuals of small stature."

Ancel Keys [6] at all formulated this natural law or fact of "social physics"[1] as an indicator of body weight and obesity [6]

$$\mathrm{BMI} = \frac{\mathrm{weight}}{\mathrm{height}\ \times\ \mathrm{height}} = \frac{weight}{height^2}$$

It has been found that the BMI is a predictor of obesity but not always a good one [2][3][4][5][9][25][73][74][75][76][77]. While it is the widely accepted scientific consensus that BMI has limitations and in some cases fails to offer a correct diagnosis of obesity [2][3][4][5][9][25][73][74][75][76][77][78], the aim of my new bodyweight quantification theory and subsequent formulae is to offer better indicators of the type of human body, indicators of health and metabolism, and develop formulae and equations which explain well known experiments cited in the reference section. These formulae do not have the limitations and errors of BMI. Many researchers consider the BMI has serious shortcomings [75]. The increase in BMI in fact may underestimate the obesity epidemic since the people have now less muscles and fat free mass than at the time when BMI was developed as a social statistic [76]. For this reason, my formulae, which use indicators of body shape and composition and indicators of fat free mass, differentiate fat and fat free mass, are essential and fill a void in this field of sport science and medicine. There is not all the data available yet, but my formulae explain and predict the outcomes of a large number of experiments published in highly cited scientific research papers which may be found in the reference section [35][38][39][40][41] [42][43][44]…[100]. I found at least 100 highly cited scientific papers presenting experiments where fitness and strength of grip and other muscles explain health outcomes better than BMI according to the results of these experiments. Nor other formulae [5][112] or theory published before explain these results or even attempts to explain these experiments in medicine and sport science, because [5][112] do not use any indicator of composition and function. Everybody who has contact with sports knows, large chest [19][20] and small waist is an indicator of athletic and muscular development not the waist alone and not the BMI. My formulae explain the outcome of those experiments. In addition, my formulae indicate what data must be collected and which future experiments must be

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performed. Another limitation of the BMI and [5] fitting a particular data set, which as described in [5] is far from representative for the population of the USA or for the world. [77]. Due to the shape indicators used and strength metrics, my formulae solve this problem to a larger extent than BMI, ponderal index or [5] or [112]. Because it is a different approach, I developed not only a new formulae but a new theory of body quantification. [35][38][39][40][47][49][50][78] show that strength is essential in maintaining functional capabilities through life. BMI does not have any indication in that regard nor does the ponderal index, Broca formula or formulae such as [5][112] and for this reason they do not form a complete or correct theory since they do not explain a very large number of highly cited experimental papers, cited in the reference section. Outside and beyond weight, height and waist there are dynamic and functional indicators, which predict and explain mortality, morbidity, illness, obesity and metabolic syndrome. [35][38][39][40][41] [42][43][44]…[100]

Obesity is a disease [71] and the cause of other diseases and negative health outcomes, a predictor of the risk of various diseases including cardiovascular diseases [113][114][115], coronary heart disease, angina, congestive hearth failure, deep vein thrombosis, orthopedic injuries [116], cancer [117], infectious disease including COVID 19 [122], endocrine problems and diabetes melitus [118], testosterone deficiency [119], erection problems, [119] fertility problems [121], birth roblems, dementia [120], osteoarthritis, fatty liver disease, dermatological, neurological, urological, liver and many other health problems. Obesity is an epidemic with major personal and social costs.[70] Obesity increases the risk of morbidity and mortality [70]. Due to decline in health and public image, obesity decreases the quality of life of those affected [70]. People suffering from obesity are stigmatized.[72] While some causes of morbidity and mortality cannot be prevented at reasonable financial and social costs, obesity can be prevented making economy of resources, saving money and resources in the same time. [73][74] have shown there is a paradox, there are people who appear overweight or obese according to the BMI definition and have normal metabolism while there are people who are of normal weight considering the BMI definition, but have an obese metabolism. This is a paradox BMI and other classic formulae, ponderal index, Broca index or recent [5][112] and other theories of optimal or normal weight cannot explain and as in every science, since they do not explain many relevant facts, these previous theories and formulae do not form a correct theory and certainly not a complete one. Even more, due to their nature [5][112] cannot be improved since they were based on biased data sets, therefore they do not fulfill many of the criteria of scientific theories. BMI can be improved, and an extension and generalization is shown through the formulae proposed in this paper. My bodyweight quantification theory and formulae is aimed to solve this paradox, of people who appear to have normal weight but have an obesity-like metabolism and they solve it, because they can predict overweight risk at weights (and size) where classical formula would not. The first step towards obesity is becoming overweight. The role of my formulae is to signal that point, through functional and shape indicators earlier than BMI can and also to signal when a well developed person is obese or not. Obesity is likely to be the most deadly epidemic of our time considering the widely accepted number of preventable deaths attributed to obesity.[WHO] Since the development of the BMI in the 19th century, society has changed, the type of occupations has changed, now people perform less physical labor and as a consequence, are on average less muscular than in the 19th century when Broca index and the BMI have been developed. So, the statistical basis on which these indicators, such as BMI were created changed. [5][112] were developed based on formulae fitted from data collected during an obesity epidemic and therefore are biased towards accepting obesity as a normal fact, as I show later, are not objective and based on logical principles or empirical experiments or functional capabilities. The experimental basis of my formulae is more than 100 highly cited experiments which were not explained or accounted by previous formulae such as BMI, Broca index, or [5] and [112]. However since the antiquity (as seen in statues) and also in our time there are people who are well developed physically, athletic, muscular and have larger weight than what is predicted as normal by BMI or ideal by Broca Index without being obese, because hey have larger muscles and body frames than the average. For this category the classic BMI and Broca Index do not offer a correct diagnostic, in many cases BMI and Broca Index would classify strong athletes and strong workers as obese or overweight because BMI and Broca index do not make the difference between muscle mass, large frames and body fat mass. On the other hand somebody who has weak muscles and narrow frame could have a high body fat percentage at weights were BMI would show normal weight. But of course these people can develop metabolic disease because a high percentage of body fat. Another problem not solved by the classic BMI and Broca index for people who are not athletes, is the distribution of fat in the body, the size and function of muscles and body frame. Fat deposits in certain areas of the body [120] and weak muscles and grip strength [35][36][38][39][40][41]…[100] are considered by researchers [107][35][36] more dangerous to health outcomes independent of weight and height used by BMI or waist used by [5]. BMI and Broca index do not make this difference while the formulae proposed in this analysis make this difference.

The generalization of the BMI using anthropometric metrics

It is possible to generalize the BMI, body mass index in the anthropometric sense to account for the body shape and volume and for the muscle mass because logically and experimentally [19][20][101][103], the larger the chest and the smaller the waist, the more likely the person to be muscular and the increased weight is more likely due to a large muscle mass. I have not seen. Nor there is any report any obese person, having a high fat percentage with larger chest than waist and this is unlikely and perhaps physiologically impossible and it is a true fact among animals too, the most lean and muscular and athletic animals such as cheetah, tiger, some dogs, have a smaller waist than chest. It is an immutable law of nature. There are explanations based on physiology, genetics, medicine and endocrinology and sport science why obese people have always much larger waist than chest but I do not aim on proving why it is so, I point out this fact as an observation that never fails to be true, like a law of nature which is true also among animals. The BMI and Broca Index are relations between height and weight, the formulae proposed by me are relations between height, weight, chest size, waist size, grip strength and age. Every of these formulae becomes similar to BMI for average people and for this reason my formulae

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generalize the BMI. I show this on many test cases. However I shows that the proposed formulae detect both false negative and false positives of BMI, people who are not classified as obese but are overweight due to a high fat percentage and low muscular rmass and people who are classified by BMI as obese but are not obese. The formulae I developed, simulate and test in this analysis have the advantage that they are universal and require minimum experience with body measurements, and are not very sensitive to input as methods proposed in [5][112] and do not require a very good body measurement technique as [5][112] or complex devices as other laboratory methods, but only very simple means, while offering more accurate classification and prediction than any formulae proposed until now. My new formulae, AGBMI (anthropometric generalization of body mass index) can be used by anybody for purposes of health and sport but if it is about a health problem, a person may ask a sport coach, a physiotherapist or physician for help in particular when it is about health problems and health diagnostics to help him or her use these formulae and interpret the result. Many people can benefit from AGBMI in improving their health, fitness and sport performance. AGBMI could be useful to athletes in improving performance in Olympic sports as well as in professional boxing, professional wrestling, MMA, bodybuilding, fitness, and crossFit. AGBMI may be used also by sport scientists in designing scientific studies, sport programs, may be used by coaches for guiding athletes towards optimal sport performance and improvement, by physiotherapists when helping people and athletes recover from injuries, and could help medical doctors when consulting and diagnosing people looking to improve their health and avoid different maladies, and could help chemists and pharmacists in improving the quality of their medical prescriptions and finding optimal doses of various medicine based on a new quantification of the body weight. Athletes and ordinary people can use these formulae to improve their physical shape by themselves. These formulae are new, are not based on any previous publication but are improving and generalizations over BMI which is still the standard of the field. [5] acknowledges that it does not replace BMI. formulae generalized BMI through the chest to waist proportion in AGBMI and using the handgrip strength in AGBMI.

When scientist research various substances with pharmacological applications, they develop various substances, then test them in laboratory, experimentally and in trials. In the same way I develop a number of formulae based on my AGBMI and AGGBMI theory and principles them test the formulae with test cases, simulate it and present it so that people who design experimental studies can verify these formulae in a large number of cases, on statistical basis. Based on reason, intuition and numerical verification, evidence shows, these formulae are correct and represent an advancement in the field.

I described the construction of the theory step by step, including the trial and error process, and the experimental papers whose result is predictable through my AGBMI and AGBMI formulae. The first step is to use the $\frac{\text{waist}}{\text{chest}}$ proportion as an indicator of how athletic is the body shape and factor it in the classical BMI of Adolphe Quelet and Ancel Keys making a generalization of the classic BMI formula and developing a new formula as ($AGBMI$ = anthropometric generalization of BMI)

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$$AGBMI(w,H,waist,chest) = \frac{waist}{chest} \text{ x } \frac{W}{H^{2.0}}$$

$\frac{\text{waist}}{\text{chest}}$ as an indicator of health outcomes independent of BMI is shown in [19][20] and in many experiments where muscular mass correlates with favorable health outcomes, because $\frac{\text{waist}}{\text{chest}}$ is the best shape indicator of an athletic shape and chest is an indicator of upper body strength and power. Experimental research papers show the importance of $\frac{\text{waist}}{\text{chest}}$ proportion alone in predicting health outcomes. [19][20] independent of BMI and weight. AGBMI has the same interpretation as the BMI, even if it is computed in a different way. This is a great advantage over any other method such as [5][112].
And as an ideal weight equation,

$$\frac{waist}{chest} \text{ x } \frac{W}{H^{1.9}} - 25 = 0$$

This could be also used as an ideal body weight, for everybody, which is of course lower than the high limit of normal body weight. Here I make a fusion of BMI and Broca index which are both particular cases. (predicting Broca formula and various modern optimal weight formula for the special case of average size people, the following equation.). This formula can also replace BMI for the special case of people who have low strength and muscular mass.

We could of course use formulae such as

$$AGBMI(w,H,waist,chest) = C1 \text{ x } \frac{waist}{chest} \text{ x } \frac{W}{H^{C2 \text{ x } 2.0}}$$

And the optimal weight equatin

$$C1 \text{ x } \frac{waist}{chest} \text{ x } \frac{W}{H^{C2 \text{ x } 1.9}} - 25 = 0$$

I found through numeric and experimental verification, such constant C1 and C2 are not needed and the formula works through its inner logic without fitting any constants. New constants can be fitted at a latter time through new experiments based on these formulae.
I used the values in this table to describe the size of the chest and waist. Of course, this table could be described as a convention but it is practical, popular with people from every walk of life and easy to use.

Men’s size:

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size	Chest size(cm)	Chest size (inch)	Waist size(cm)	Waist size (inch)
Small (S)	89-94	35-37	74-79	29-31
Medium (M)	95-102	38-40	80-86	32-34
Large (L)	103-109	41-43	87-91	35-36
Xlarge (XL)	110-117	44-46	92-97	37-38
XXL	118-124	47-49	98-102	39-40
XXXL	125-135	50-53	103-109	41-43

Woman size:

Size	Chest Size (cm)	Chest size (inch)	Waist Size(cm)	Waist Size (inch)
XS	81-84	32-33	61-66	24-26
S	86-89	34-35	68-71	27-28
M	91-94	36-37	71-74	28-29
L	96-99	38-39	79-81	31-32
XL	101-106	40-42	84-86	33-34
XXL	106+	43+	86+	35+

Aiming now to improve the previous formulae it could be seen that Waist and chest usually do not have the same size, and as a consequence, if I factor the indicator $\frac{waist}{chest}$ in the expression of the BMI

$$\text{AGBMI} = \frac{waist}{chest} \times \text{BMI}$$

$would\ change\ the\ BMI\ by\ itself\ even\ for\ the\ average\ person.$ A normalization must be performed so that I add a factor to the BMI which is equal to 1 for the average person. In order to find a proportion factor which would indicate the athletic form and shape as a variation from 1.0, it must be determined a constant C so that the fraction $\frac{waist}{chest - C(size)}$ would be close to 1.0. Because 18.0 is the average difference between high L chest and waist of the same size then we can reduce the length of the chest by 18. It can be used a size adjusted to the size of the person, but I use as example for simulation 18 as a higher standard than BMI predicts for most people and also to show through simulation how my formula works for athletes which usually a lower body fat percentage, have a large chest and relatively thin waist.

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$Factoring\ BMI\ with\ a\ body\ shape\ indicator \frac{waist}{chest - 18.0}$ would alter BMI changing its outcomes, only when it is logically to do so, better approximating the athletic shape of the person, adjusting the result to the athletic shape and fat percentage and level of the person. This change could be performed, because the difference between waist and chest is about 18 cm for the athletic person with L chest, so it is possible to keep the same limits for the classification of normal weight and obesity as they are in the classic BMI. This is a major advantage of AGBMI (anthropometric generalization of BMI)
over any other formula. The new formula for males would be

$$\text{AGBMI(w,H,waist,chest)} = \frac{waist}{chest - 18.0} \text{ x } \frac{\text{W}}{\text{H}^{2.0}}$$

or

$$\text{AGBMI(w,H,waist,chest)} = \frac{waist}{chest - C1} \text{ x } \frac{\text{W}}{\text{H}^{2.0\text{x}C2}}$$

This is already a great improvement over standard BMI but it is possible to develop the model and construct improved formulae, there are even better estimators. Because waist, chest and height are often connected structurally, the above formula

$$\text{AGBMI(w,H,waist,chest)} = \frac{waist}{chest - C(\text{H})} \text{ x } \frac{\text{W}}{\text{H}^{2.0}}$$

may be written also as

$$\text{AGBMI(w,H,waist,chest)} = \frac{waist}{chest - 10.0\text{xH}} \text{ x } \frac{\text{W}}{\text{H}^{2.0}}$$

(anthropometric generalization of BMI)

Choosing a linear function C(H)=K x H and using a parameter K=10 which could be matched from the previous examples and formulae to observations.
This allows also to integrate BMI and Broca index and define a new optimal body weight through and equation of optimal weight

$$\frac{waist}{chest - 10.0\text{xH}} \text{ x } \frac{\text{W}}{\text{H}^{1.9}} \text{ - } 25 = 0$$

For woman, the equation of optimal weight would be

$$\frac{waist}{chest - 10.0xH} \text{ x } \frac{W}{H^{1.8}} - 25 = 0$$

Would describe the weight of a lean woman but not as thin as a model. This formula can describe also athletic, fit and strong woman. Using the Broca index or BMI for average woman would result in accepting a high body fat percentage. As shown empirically BMI and Broca Index fit woman who are bodybuilding or crossFit champions or Olympic champions in strength sports and those have much larger muscles than normal woman. For a particular case where H = 1.6 m, the equation becomes

$$\frac{waist}{chest - 16} \text{ x } \frac{W}{H^{1.8}} = 0$$

Which seems to fit data based on the examples I tested. The idea behind the formula is that females have smaller muscular mass, narrower shoulders and smaller frame compared to males as scientific research [124] and observation show so their weight increases less with height than in case of males and for that reason I used power 1.8 for height instead of 1.9 for the height of male when computing the optimal weight. Models are thinner than that. This difference in muscularity and body frame between males and females is clear also at athletes of the same level. This is very clear in cases of athletes and bodybuilders, female bodybuilders are not very heavy compared to normal females of the same height but top male bodybuilders and strength athletes are very heavy compared to normal males of the same weight. This difference between males and females in physical development and in the way weight should increase with height exists also in other sports, not only in bodybuilding but this is most obvious in bodybuilding. For this reason I used power 1.8 for height for female and 1.9 for male. I verified through simulations. Using power 1.8 for height would not create an ideal body weight as narrow as a model but it would model a lean shape. The objective of the ideal body weight as I defined it here is optimal health not describing the shape used by females for modeling.

There are also other ways to develop such formulae, for example by deducing the value of the difference between waist and chest corresponding to the size of the chest as could be seen in the previous table

$$\text{AGBMI(w,H,waist,chest)} = \frac{waist}{chest - C(chest)} \text{ x } \frac{W}{H^{2.0}}$$

And the equation of optimal weight

$$\frac{waist}{chest - C(chest)} \text{ x } \frac{W}{H^{1.9}} - 25 = 0$$

And for woman

 doi:10.20944/preprints202007.0662.v1

$$\frac{waist}{chest - C(chest)} \text{ x } \frac{\mathrm{W}}{\mathrm{H}^{1.8}} - 25 = 0$$

Where C(chest) is the difference between the length of the chest and of the waist of the same size, for example if the chest is XL, then C(chest) is the difference between the XL chest and the XL waist. It is possible to calculate the constant C(chest) in the following way, if chest is S, then using the difference between the middle of the intervals C(chest) = 15, if chest is medium, then C(chest) is 16, if chest is large, then C(chest) is 17, if chest is XL, then C(chest) is 19, if chest is XXL, then C(chest) is 21, if chest is XXXL, then C(chest) is 24

The equation of optimal weight for male

$$\frac{waist}{chest - C(waist)} \text{ x } \frac{\mathrm{W}}{\mathrm{H}^{1.9}} - 25 = 0$$

or for females

$$\frac{waist}{chest - C(waist)} \text{ x } \frac{\mathrm{W}}{\mathrm{H}^{1.8}} - 25 = 0$$

Where C(waist) is the difference between the length of the chest and of the waist of the same size as the waist, for example if the chest is XL, then C(chest) is the difference between the XL chest and the XL waist.

Another strategy would be to let c = c(chest, waist)

$$\mathrm{AGBMI(w,H,waist,chest)} = \frac{waist}{chest - C(chest, waist)} \text{ x } \frac{\mathrm{W}}{\mathrm{H}^{2.0}}$$

And optimal weight equation

$$\frac{waist}{chest - C(chest,\ waist)} \text{ x } \frac{\mathrm{W}}{\mathrm{H}^{1.9}} - 25 = 0$$

or by finding a constant C through statistical analysis or machine learning with the property that best fits a formula of the form

$$\mathrm{AGBMI(w,H,waist,chest)} = \frac{waist}{chest - C} \text{ x } \frac{\mathrm{W}}{\mathrm{H}^{2.0}}$$

and optimal male weight equation

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$$\frac{waist}{chest - C} \text{ x } \frac{\mathrm{W}}{\mathrm{H}^{1.9}} - 25 = 0$$

And for females

$$\frac{waist}{chest - C} \text{ x } \frac{\mathrm{W}}{\mathrm{H}^{1.8}} - 25 = 0$$

I tested the formula with the particular constant C=18

$$\mathrm{AGBMI(w,H,waist,chest)} = \frac{waist}{chest - 18} \text{ x } \frac{\mathrm{W}}{\mathrm{H}^{2.0}}$$

For a large chest = 109cm and a medium waist = 80cm, an athletic shape, for a tall athlete 2.00 m, we find this formula predicts a maximum normal weight 113kg. We may see there are such athletes among top heavyweight boxers. If we increase the waist to 85 cm, which is still very lean and athletic, then the formula predicts a maximum normal weight up to 107 kg.

It is possible to develop a more general formula

$$\mathrm{AGBMI(w,H,waist,chest)} = \left(\frac{waist}{chest - 10Height}\right)^{gama} \text{ x } \frac{\mathrm{W}}{\mathrm{H}^{2.0}}$$

Such parameter gama is not essential, the formula works without it or when gama takes the value 1. However, it is possible to use power gama to develop different classes of performance, but according to my experiments it fits observations and data without gama power different than one.

A question is if power 2 of Height in the BMI is a coincidence or fitted data in the 19th century by coincidence. Another problem is scaling , this new formula allows larger weight for taller people if they have an athletic shape. This solves the problem of scaling because the classic BMI allowed relatively larger weight to shorter people. In reality, short people who compete in strict category sports are thinner compared to their height in comparison to taller people. This is true not only in case of competitors in strength sports and in fighting sports but it is true to a smaller extent to every person which is reasonably lean and that is why this formula corrects the well known scalling problem of the Body Mass Index.

We can use a power of H function of H itself in order to solve the problem of the natural increase of weight with height.

$$\mathrm{AGBMI\_2(w,H,waist,chest)} = \left(\frac{waist}{chest}\right)^{Height} \text{ x } \frac{\mathrm{W}}{\mathrm{Height}^{\mathrm{Height}}}$$

or more generally

$$\text{AGBMI\_2(w,H,waist,chest)} = c\,x\left(\frac{waist}{chest}\right)^{Height} \;x\; \frac{\text{W}}{\text{Height}^{\text{Height}}}$$

Prior to that I tested also formulae of the form

$$\text{BMI(W,H)} = \frac{\text{W}}{\text{Height}^{\text{Height}}}$$

which seem to be promising because they solve the problem of scaling with height. In any case for short people BMI and Broca index do not fit lean normal individuals properly. They fit only very muscular individuals like record holders in small categories in weightlifting. Broca Index and BMI are completely inadequate in describing the weight of medium and taller strength athletes but are adequate in describing the relation of weight to height in short strength athletes, and of course are completely wrong in describing the relation of height to weight normal short people who are not athletes. If Broca Index and BMI describe the optimal weight for short Olympic weightlifting champions, these formulae clearly overestimate the normal weight of short people who are not Olympic weightlifting champions and have smaller muscular mass and body frames. But this new formula solves this problem. All there formulae mentioned as new AGBMI solve well this shortcoming of BMI and Broca index. It must be simulated and tested but the idea is to scale the weight with the height when the person has an athletic shape. Of course an engineering approach would be to develop several formulae on logical and intuitive basis and chose the best formula, which works for all or certain categories. However, nearly every formula I include in this analysis works much better than the classical BMI and Broca Index for athletic people and works better also for average people and diagnoses obesity in a more accurate way than any other formula developed until now. Statistical testing of some formulae require mass testing and a health risks and illness, morbidity, loss of function and mortality risk analysis based on mortality statistics but this could be performed subsequently by people who have more data from sport science and student experiments or medical experiments and more data from social statistics and insurance. The formulae shown in this analysis are more general and universal for every body type compared to the classic BMI but even so, some formulae are better than other formulae for certain purposes. I used a large number of simulations to construct these formulae while adding factors on logical basis, and many of these simulations cannot be shown here due to space and readability. The analysis is very large already. I think others can simulate and test by designing experiments to fit these methods and formulae. Intuition plays a role in mathematics and in every branch of science, including the most theoretic, such as mathematics and physics and even more so in sport science and sport medicine. In part this formulae are developed based on intuition but I tested them against data I found on internet and against limit and average cases, for sport champions and average people. Such formula is the next one, which I developed step by step from previous formulae and then simulated.

$$\text{AGBMI\_2(w,H,waist,chest)} = \left(\frac{chest}{waist}\right)^{Height} \;x\; \frac{\text{W}}{\text{Height}^{\text{Height}\,x\left(\frac{chest\,-\,5Height}{waist}\right)}}$$

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$$\text{AGBMI\_2} = \left(\frac{chest}{waist}\right)^{Height} \text{ x } \frac{\text{W}}{\text{Height}^{\text{Height}\text{x}\left(\frac{chest - KxHeight}{waist}\right)}}$$

The corresponding optimal weight formulae for females are

$$\text{AGBMI\_2(w,H,waist,chest)} = \frac{waist}{chest - C} \text{ x } \frac{\text{W}}{\text{H}^{1.8}}$$

$$\text{AGBMI\_2(w,H,waist,chest)} = \frac{waist}{chest - 15} \text{ x } \frac{\text{W}}{\text{H}^{1.8}}$$

$$\text{AGBMI\_2(w,H,waist,chest)} = \left(\frac{waist}{chest - 10Height}\right)^{gama} \text{ x } \frac{\text{W}}{\text{H}^{1.8}}$$

$$\text{AGBMI\_2(w,H,waist,chest)} = \left(\frac{chest}{waist}\right)^{Height} \text{ x } \frac{\text{W}}{\text{Height}^{\text{Height}}}$$

$$\text{AGBMI\_2} = \left(\frac{chest}{waist}\right)^{Height} \text{ x } \frac{\text{W}}{\text{Height}^{\text{Height}\text{x}\left(\frac{chest - 5Height}{waist}\right)}}$$

Considering again the formula from where I started the analysis,

$$\text{AGBMI} = \frac{waist}{chest - 18.0} \times \frac{weight}{height^2}$$

If we develop a test case to see how the weight increases with height, for taller people, where the height was 2m, the chest is very large at 117cm, the waist is large at 90.0, then the maximum predicted normal weight would be 109cm.

I tested numerous test cases however, an example of how this formula works very well is for example to show how a tall and athletic and muscular athlete is correctly classified in a clearly better way than through the standard BMI (Body Mass Index). The result is for the case when the power of H is 2. If we chose the power of H = 1.9, then we aim for a higher standard, a more lean standard. The results are for H = 2. For a tall athlete height = 200 cm, with a large chest = 109 cm, medium waist = 80, then the formula predicts a normal weight up to 113kg. This example is an athlete of the size of world professional boxing champion Anthony Joshua. Standard BMI would show him as overweight, but this method classifies him correctly. As could be seen, I did not use any arbitrary constant or parameter fitted to certain data sets as all the other modern methods do, I did not use any special constants, with the exception of 18.0, which I added for a logical reason explained, not to fit any data set blindly. I also developed a formula where not even that constant is needed as we see later in the analysis. The constant 18 is the difference between the small limit of the chest size L (large) and small limit of waist size L (large) and is close for all the other sizes. I chose the

difference in the case of L size because it was the middle of sizes. For this reason the method and formulae are developed logically not to fit certain particular data or as [5] limited to certain countries and races as [5]. It is for this reason a much general formula than those used in the body shape methods [5][112] who fit only certain data set and acknowledge the bias in those data sets, which in any case would include any significant number of top athletes and for this reason they are not fit for sport but are developed to fit as a new normal a population affected by an obesity epidemic. There may be an obesity epidemic but this is not a new normal as any formula fitting such population does. [5] does not use any anthropometric indicator of the upper body such as the chest.
Except the formulae I propose, no other method ever used in the same formula the chest, waist and BMI, a BMI(height, weight, chest, waist) function and my formulae are the first to be a generalization of the BMI to be a correct quantification of all body types from short to tall and from muscular to thin and from obese to lean. No other method using anthropometric measurements has ever been developed as a generalization of the BMI and AGBMI is a new formula and concept.

Another possibility is to determine the chest corresponding to the waist using the following method: if the waist is larger than 103, then the "corresponding Chest" is 130, else if the waist is larger than 98, the "corresponding chest" is 121, else if the waist is larger than 92, the corresponding chest is 113.5, else if the waist is larger than 87, the "corresponding chest " is 106, else if the waist is larger than 80, the corresponding chest is 98. In this way we define a proportion

$$\frac{corresponding\ chest}{chest}$$

and a results a new equation for ideal weight

$$\frac{\text{corresponding chest}}{\text{chest}} \times \frac{W}{H^{1.9}} - 25 = 0$$

or for maximum normal weight limit

$$\mathtt{AGBMI}(w,H,waist,chest) = \frac{\text{corresponding chest}}{\text{chest}} \times \frac{W}{H^{2.0}}$$

I tried various combinations and the formula works for athletes of the size of a very large bodybuilder such as a Mr. Olympia or near that size, and it works also for normal people or for people at various levels of training, strength and fitness, including Olympic athletes and gym athletes, so it is truly an universal formula accounting very well for muscle mass and body frame and shape. The classic BMI does not predict correctly (morbid obesity) for the size of Mr. Olympia for certain and not even for beginning athletes in many cases. On the other hand this formula would classify an obese as obese without problems and a muscular athlete as muscular without error.

For females the optimal weight formula would be

$$\mathtt{ABMIG\ ow}(w,H,waist,chest) = \frac{\text{corresponding chest}}{\text{chest}} \times \frac{W}{H^{1.8}}$$

According to this formula, if the waist is larger than 103 cm, then the relative chest used in the formula is 130, else if the waist is larger than 98, the relative chest is 121, else if the waist is larger than 92, the relative chest is 113.5, else if the relative chest is larger than 87, then the relative waist is 106, else if waist is larger than 80, the relative chest is 98, else if waist is larger than 74, the relative chest is 92..

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I developed these formulae first on intuitive ideas and then on logical basis and then on mathematical basis by taking into account the numerical experiments and empirical observations in regard to previous formulae and on physiological logic, not machine learning or statistical fitting some samples. These formulae have a logical explanation step by step as I derived them from previous formulae and numerical experiments and comparing to real cases of well known athletes where I could find the data on internet. As I mentioned before a large number of experiments published in highly cited research papers are explained through this formulae, through this theory of optimal weight limits.

Another example For waist = 91.0, chest = 109, height = 1.8, the maximum normal weight of such athlete would be 95.0. This means a large improvement over the classic BMI. The value is reasonable]y correct and reflects feasible human proportions. I tried also sizes of normal people and they are calculated well. Also minimum and maximum acceptable weights are well computed. I do not have space to shows all the test cases and I invite others to try them and send me their observations. And use these formulae to develop experiments in medicine and sport science. No other published formula has this precision in both high and low acceptable weight. For sizes similar to Mr. Olympia bodybuilding, exceptionally muscular people, for example height = 1.8m, chest = 140cm, waist = 91cm, then the maximum normal weight is 122kg, very much the way it is in reality, without any special constants, just because the formula is exactly as good as a law of human nature.

$$\text{ABMIG3}(w,H,waist,chest) = \frac{waist}{chest - 17.0} \text{ x } \frac{W}{H^{2.0+\log(\frac{chest-17.0}{waist})}}$$

But of course 17 is a particular case extracted from the difference in the tables for average size people with normal weight. If I consider a formula such as

$$\text{ABMIG3} = \frac{waist}{chest - C} \text{ x } \frac{W}{H^{2.0+\log(\frac{chest-C}{waist})}}$$

It is possible to use C = 10.0xH to have a formula of type

$$\text{ABMIG3} = \frac{waist}{chest - 10.0\text{x}H} \text{ x } \frac{W}{H^{2.0+\log(\frac{chest-10xH}{waist})}}$$

While C = C(Height), it is also C = C(chest)

$$\text{ABMIG3} = \frac{waist}{chest - C(chest)} \text{ x } \frac{W}{H^{2.0+\log(\frac{chest-C(chest)}{waist})}}$$

Numeric example: For a medium chest=102 and waist=86, at height 1.8, we find the maximum allowed weight is 80 kg, like in the classic BMI, which is a particular case.

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The fine tuning of the constant C could be made based on this principle, to recover the classic BMI as a particular case. I usually did not do this fine tuning and even if I would do that, it is very little fine tuning compared to the statistical fitting used by most of the modern methods, my method is based rather on deductive logic and physiology and mathematical deduction, not fitting through statistical procedures. Fine tuning using statistics and machine learning could be performed, but the formula fits every body and all combinations of chest and waist, which could be 6x6 cases. I developed these formulae in part trough deduction, in part through experience, in part through intuition and through trial and error but the number of attempts was rather small, even if engineering is sometimes based on trial and error. Even engineering geniuses like Thomas Edison sometimes tried many combinations. Trial and error and comparison with real cases has a role in the development of these formulae as they are but I did not perform a large number of attempts, I considered few attempts to fit various functions. I consider the search approaches using many blind attempts as not satisfactory in the logic and scientific sense and because I worked alone, I did not have time to try many things and test everything. This formula fits for average people with little or no sport training as one could see from the above example but works also for people as muscular as Mr. Olympia. For example for somebody with very large chest = 140 and large waist = 91, height 1.8, the maximum possible weight would be 132kg. However, these are unique large chest sizes, compared to the waist. For world class large bodybuilders, for example a chest size 135 and waist 95 which is still quite lean for such a large chest, then the maximum normal weight would be 115 kg, so credible.

Using a function C=C(H) and choosing a linear function C(H)= 10H to match the previous formulae and that ABMIG3 is a generalization of BMI, the following formula could be obtained

$$\text{ABMIG3} = \frac{waist}{chest - 10.0\text{xH}} \text{ x } \frac{\text{W}}{\text{H}^{2.0+\log(\frac{chest - 10xH}{waist})}}$$

Or optimal body weight equation

$$\frac{waist}{chest - 10.0\text{xH}} \text{ x } \frac{\text{W}}{\text{H}^{1.9+\log(\frac{chest - 10xH}{waist})}} \text{ - } 25 = 0$$

For females the corresponding normal weight (new BMI) formulae would be

$$\text{ABMIG3} = \frac{waist}{chest - 15.0} \text{ x } \frac{\text{W}}{\text{H}^{1.9 + \log(\frac{chest - 15.0}{waist})}}$$

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$$\text{ABMIG3} = \frac{waist}{chest - C} \text{ x } \frac{\text{W}}{\text{H}^{1.9+\log(\frac{chest - C}{waist})}}$$

It is possible to use C = 10.0xH

$$\text{ABMIG3} = \frac{waist}{chest - 10.0\text{xH}} \text{ x } \frac{\text{W}}{\text{H}^{1.9+\log(\frac{chest - 10xH}{waist})}}$$

For example, we can develop logically from previous formulae, in few attempts, matching the observations and data from athletics, cases of strong athletes

$$\text{ABMIG4=} \frac{weight{*}waist{*}\log(waist)}{Height^{2.4}{*}\log\left(Height\right){*}chest{*}\log(chest)}$$

The formula is logical since it may be written also

$$\text{ABMI4} \quad = \frac{weight}{Height^{2.4}} \text{ x } \frac{waist}{chest} \text{ x } \frac{\log(waist)}{\log(chest)} \text{ x } \frac{1}{\log(Height)}$$

For example for a large athlete, height = 2.0 m, chest = 135, waist = 109, the maximum normal weight would be 118, and could describe a disc thrower or another large athlete. In any case, it is much closer to correct than classical BMI. If we decrease chest and waist so that chest is large but the waist not so large, the formula allows even greater weight, at 2.00m, allows up to 120kg, showing the weight is sensitive to the shape. In any case the previously developed body shape methods created by others [5][112] were developed on data from normal people, so it is unlikely they would describe that well the shape of large athletes which did not exist or were very rare in the population used for their statistics.
Testing my formulae, for a shorter athlete with the dimensions described previously, at 1.8 m, the maximum weight is 79 kg and this makes sense because the waist is relatively large and therefore it does not have the advantage of a very lean shape. However, if we decrease the chest and waist up to normal values, average values, chest 102 and waist 80, the maximum allowed height for this 1.8 m athlete is 80 kg. So the formula is universal for smaller and larger athletes and has common sense and the classic BMI and Broca index are a particular case as we could see for average people. If we increase the chest now at 112 cm, keeping the waist constant we find the maximum allowed weight is 90kg in this formula, so it works very well in adjusting the weight based on the athletic shape, regardless of height and shape and it fits the shape of athletes with the expected weight. This has not been achieved by any previous body shape method and no other method ever developed has been a generalization of BMI and Broca index. This method has also the advantage that it is a formula similar to the classic BMI and is intuitive, anybody can understand the role of every factor. It scales also better than the classic BMI with height when the shape is athletic.
None of the previous formulae ever quantified the strength factor in the optimal weight and this is a very important factor, independent of body mass as highly cited experimental research proves.
Using the strength factor, the formula may be written as [35][36][37][38][39][40][41] …[100] show. My formulae fit the results and of these experiments and could predict such outcome. BMI certainly des not and nor the other optimal weight and normal weight formulae which do

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not factor the strength function. Grip strength often correlates with overall strength and with the health status, is a predictor of future health, mortality and morbidity.

$$\mathrm{AGGBMI} = \frac{weight}{Height^{1+\frac{grip}{54}}} \text{ x } \frac{waist}{chest} \text{ x } \frac{\log(waist)}{\log(chest)} \text{ x } \frac{1}{\log(Height)}$$

In a similar way, if we look to normalize, we obtain the formula

$$\mathrm{AGBMI} = \frac{weight}{Height^{2.4}} \text{ x } \frac{waist}{chest - C} \text{ x } \frac{\log(waist)}{\log(chest - C)} \text{ x } \frac{1}{\log(Height)}$$

Or

$$\mathrm{AGBMI} = \frac{weight}{Height^{2.4}} \text{x} \frac{waist}{chest - 10xH} \text{ x } \frac{\log(waist)}{\log(chest - 10xH)} \text{ x } \frac{1}{\log(Height)}$$

A corresponding formula for woman would be

$$\mathrm{AGBMI} = \frac{weight}{Height^{2.2}} \text{x} \frac{waist}{chest - 10xH} \text{ x } \frac{\log(waist)}{\log(chest - 10xH)} \text{ x } \frac{1}{\log(Height)}$$

But it may need fine tuning with a constant C so that

$$\mathrm{AGBMI} = C * \frac{weight}{Height^{2.2}} \text{x} \frac{waist}{chest - 10xH} \text{ x } \frac{\log(waist)}{\log(chest - 10xH)} \text{ x } \frac{1}{\log(Height)}$$

fits practical examples of normal woman and athletic woman.

$$\mathrm{AGBMI} = \frac{weight * \log(waist) * \log(waist)}{Height^{2.5} * \log\left(Height\right) * \log(chest) * \log(chest)}$$

The formula is logical since it may be written also

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$$\text{AGBMI} = \frac{weight}{Height^{2.5}} \text{ x } \frac{\log(waist)}{\log(chest)} \text{ x } \frac{\log(waist)}{\log(chest)} \text{ x } \frac{1}{\log(Height)}$$

For and average person height = 1.8, chest = 100cm, waist = 81 cm, then it predicts the optimal weight is 70kg, which is good for a lean person, it is optimal for people who are not developed and muscular and it is good also for some athletes such as boxers and MMA who are very lean in that class.

It may be seen however, there is a difference between the waist and the chest of the same person, on average, so we have to adjust the formula based on this so that the natural difference of the two does not alter the GBMIA (Generalized BMI using Anthropometric proportions).

$$\text{AGBMI} = \frac{weight}{Height^{2.5}} \text{x} \frac{\log(waist)}{\log(chest-18)} \text{x} \frac{\log(waist)}{\log(chest-18)} \text{x} \frac{1}{\log(Height)}$$

And

$$\text{AGBMI} = \frac{weight}{Height^{2.5}} \text{x} \frac{\log(waist)}{\log(chest-10xH)} \text{x} \frac{\log(waist)}{\log(chest-10xH)} \text{x} \frac{1}{\log(H)}$$

Where H is height.

This formula works without any arbitrary constant even if it possible to use a constant in front as in

$$\text{AGBMI} = C \times \frac{weight}{Height^{2.5}} \times \frac{\log(waist)}{\log(chest-18)} \times \frac{\log(waist)}{\log(chest-18)} \times \frac{1}{\log(Height)}$$

For smaller sizes of chest and weight the difference as seen from the previous table is 15 and the formula becomes for smaller sizes

$$\text{AGBMI} = C\frac{weight}{Height^{2.5}} \times \frac{\log(waist)}{\log(chest-15)} \times \frac{\log(waist)}{\log(chest-15)} \times \frac{1}{\log(Height)}$$

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If we look for a modern person who does not work in a physically demanding job we can replace the power 2 which had been obtained based on people who were mostly performing physical work in the 19th century with power 1.9 and the optimal weight equation becomes

$$C \times \frac{weight}{Height^{2.4}} \times \frac{\log(waist)}{\log(chest-18)} \times \frac{\log(waist)}{\log(chest-18)} \times \frac{1}{\log(Height)} - 25 = 0$$

For a smaller size of the chest and waist we take the difference 15 as seen in the above table and the equation becomes

$$\frac{weight}{Height^{2.4}} \times \frac{\log(waist)}{\log(chest-15)} \times \frac{\log(waist)}{\log(chest-15)} \times \frac{1}{\log(Height)} - 25 = 0$$

In order to remove every constant, making the formula more universal. we could introduce a function C = C(waist, chest) in a similar way with the method used above in this paper. The resulting formula is

$$\text{AGBMI} = \frac{weight}{\log(Height)*Height^{2.5}} \times \frac{\log(waist)}{\log(chest - C(chest, waist))} \times \frac{\log(waist)}{\log(chest - C(chest, waist))} \times \frac{1}{\log(Height)}$$

So

$$\text{AGBMI} = \frac{weight}{\log(Height)*Height^{2.5}} \times \left(\frac{\log(waist)}{\log(chest - C(chest, waist))}\right)^2 \times \frac{1}{\log(Height)}$$

For large people with athletic shape it is clearly superior to BMI but it offers good results for everybody type.
It is needed to scale with height where the person has an athletic shape and therefore we use the ratio $\frac{waist}{chest}$ as indicator of the shape. The formula becomes:

$$\text{AGBMI} = \frac{weight}{Height^{2+\frac{chest-18}{waist}}} \times \frac{\log(waist)}{\log(chest-18)} \times \frac{\log(waist)}{\log(chest-18)} \times \frac{1}{\log(Height)}$$

The formula is useful for advanced strength athletes but it works well also for other athletes and it is a more precise way to quantify the ideal weight limits than the standard classical BMI. For a test case, height = 1.8m, chest=135kg, waist=90.0, the maximum allowed weight is 114kg. the sizes are similar to a top level professional bodybuilder, so the maximum weight is predicted correctly. For an athlete with smaller chest, for example 120cm, but still a large and mezomorphic type, the maximum weight allowed is 95kg, so a large reduction. But in this case also the chest is relatively large compared to the waist. Lets find now the maximum weight for a large chest 110cm and a large waist 90. For this size, a large and mesomorphic shape, the maximum normal weight, according to this formula is 86kg. Something of common sense. For example now lets see the prediction for a medium large chest and waist for height = 1.8m. The maximum allowed weight for this person with medium-large chest and waist is 83 kg. Lets see now a person with the same chest but smaller waist, a more athletic type. This person with medium-large chest and small waist could have up to 89kgs. Again, a result of common sense because the shape is very athletic and mesomorphic. We chose now an average person, chest 98 cm and waist 83 cm. Then the maximum predicted weight would be 82kg. Correct, and very close to the value predicted by Broca Index or the BMI formula, but a bit higher. It is remarkable the formula works so well, without using special parameters. However, the reason why at this point the formula shows a bit more than expected is because the constant 18, the only constant used, was determined based on larger sizes, large plus. If we chose a test case where the person does not have a highly athletic shape, for example height = 1.8, the chest is not to large, chest = 95.0, waist = 86.0, then the maximum weight allowed by this formula is 76 kg, this shows the formula can allow higher weight for people with athletic shapes but accepts as normal far smaller weights for shapes which are not athletic.

Now the difference between chest and waist is 15 not 18. The formula becomes

$$\text{AGBMI} = \frac{weight}{Height^{2+\frac{chest-15}{waist}}} \times \frac{\log(waist)}{\log(chest-15)} \times \frac{\log(waist)}{\log(chest-15)} \times \frac{1}{\log(Height)}$$

Using 15, we find the maximum accepted weight is even a bit higher. If we chose a test case where the person does not have a highly athletic shape, for example height = 1.8, the chest is not to large, chest = 95.0, waist = 86.0, then the maximum weight allowed by this formula is 79 kg, so very near the Broca Index and the classic BMI of Quelet and Ancel Keys, which are seen as a limit case, particular cases of my formula. These two formulae can be recovered as a particular case for an average person with small-medium frame.

However there is a optimal weight formula which works better for every size and that is by using the 1.9 power instead of 2.0. The explanation is that Adolf Quelet used the power 2 for people who were performing hard physical work as most people were doing in the first decades of 19th century and who were also younger than the population of today, were more muscular and younger. So for our time we can use the power 1.9 because now much fewer perform physical work and even those not in the same demanding way as those who performed physical work in the 19th century. So the equation of optimal weight OW becomes

$$\frac{weight}{Height^{1.9+\frac{chest-18}{waist}}} \text{x} \frac{\log(waist)}{\log\left(chest-18\right)} \text{x} \frac{\log(waist)}{\log(chest-18)} \text{x} \frac{1}{\log(Height)} - 25 = 0$$

And predicts the maximum weight for an average person of 1.8, chest 98 cm and waist 83 is 77kg which make sense. . If we chose a test case where the person does not have a highly athletic shape, for example height = 1.8, the chest is not to large, chest = 95.0, waist = 86.0, then the maximum weight allowed by this formula is 73 kg, which is closer to some optimal weight methods such as that of Hamwi. However, unlike those formulae, my equation has the advantage of generality, it works for average people but it works also for the largest and most muscular people.

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$$\frac{weight}{Height^{1.9+\frac{chest-15}{waist}}} \text{x} \frac{\log(waist)}{\log(chest-15)} \text{x} \frac{\log(waist)}{\log(chest-15)} \text{x} \frac{1}{\log(Height)} - 25 = 0$$

Using 15 as a constant the maximum allowed weight is exactly 80 kg and it is found as a particular case for average modern person the formula of the classical BMI and the formula of Broca. Along with other formulae shown in this paper these are the first generalizations of BMI. If we chose a test case where the person does not have a highly athletic shape, for example height = 1.8, the chest is not to large, chest = 95.0, waist = 86.0, then the maximum weight allowed by this formula is 74 kg, It is certainly a better formula than the BMA and Broca Index also for average people but in particular for large and athletic people. Also in this case if we increase the waist, then the person would be shown as overweigh quite fast.

In order to remove every constant, making the formula more universal. we could introduce a function C = C(waist, chest) in a similar way with the method used above in this paper. The resulting equation is

$$\frac{weight}{Height^{1.9+\frac{chest-15}{waist}}} \times \frac{\log(waist)}{\log(chest-C(chest,waist))} \times \frac{\log(waist)}{\log(chest-C(chest,waist))} \times \frac{1}{\log(Height)} - 25 = 0$$

So

$$\frac{weight}{Height^{1.9+\frac{chest-15}{waist}}} \times \left(\frac{\log(waist)}{\log\left(chest-C\left(chest,waist\right)\right)}\right)^2 \times \frac{1}{\log(Height)} - 25 = 0$$

Or as a generalization of BMI

$$\frac{weight}{Height^{2.0+\frac{chest-15}{waist}}} \times \left(\frac{\log(waist)}{\log\left(chest-C\left(chest,waist\right)\right)}\right)^2 \times \frac{1}{\log(Height)} - 25 = 0$$

And by using a C(H) = 10xH

$$\text{AGBMI} = \frac{weight}{Height^{2.0+\frac{chest-10xH}{waist}}} \times \left(\frac{\log(waist)}{\log\left(chest-10xH\right)}\right)^2 \times \frac{1}{\log(H)}$$

And the optimal weight equation

$$\frac{weight}{Height^{1.9+\frac{chest-10xH}{waist}}} \times \left(\frac{\log(waist)}{\log\left(chest-10xH\right)}\right)^2 \times \frac{1}{\log(H)} - 25 = 0$$

Where H is height

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Replacing power 2 with the height

$$\text{AGBMI} = \frac{weight}{Height^{2.0+\frac{chest-10xH}{waist}}} \times \left(\frac{\log(waist)}{\log\left(chest-10xH\right)}\right)^{H} \times \frac{1}{\log(H)}$$

And the optimal weight equation

$$\frac{weight}{Height^{1.9+\frac{chest-10xH}{waist}}} \times \left(\frac{\log(waist)}{\log\left(chest-10xH\right)}\right)^{H} \times \frac{1}{\log(H)} - 25 = 0$$

could be considered

It is possible to use a function instead of the constant C, but is not necessarily and it works very well without

$$C\,x\,\frac{weight}{Height^{1.9+\frac{chest-15}{waist}}} \times \frac{\log(waist)}{\log(chest-C(chest,waist))} \times \frac{\log(waist)}{\log(chest-C(chest,waist))} \times \frac{1}{\log(Height)} - 25 = 0$$

The classic BMI and Broca index offers the same weight limits for males and female of the same height which in my view is not right for everyday people and certainly not for athletes. Because the difference in muscular mass and bone density between males and females, as well as due to esthetic considerations, I think we should not use the same formulae for male and female.

Female analogous of these formulae (BMI generalization) would be

$$\text{AGBMI} = \frac{weight}{Height^{1.9+\frac{chest-10xH}{waist}}} \times \left(\frac{\log(waist)}{\log\left(chest-10xH\right)}\right)^{2} \times \frac{1}{\log(H)}$$

And the optimal weight equation

$$\frac{weight}{Height^{1.8+\frac{chest-10xH}{waist}}} \times \left(\frac{\log(waist)}{\log\left(chest-10xH\right)}\right)^{H} \times \frac{1}{\log(H)} - 25 = 0$$

We explore now the use of a constant before the expression in order to determine its impact as a simulation experiment, the previous formulae already function well and we do not need a constant in front of the formula. A constant in front may be used for scaling but a better solution is to scale through a variable power of height based on the shape of the individual as I did in the previous formula. Even so I tried also the following formulae

$$\text{AGBMI} = 1.25 \times \frac{weight \times waist \times \log(waist)}{Height^{2} \times chest \times \log(chest)}$$

Or

$$\text{AGBMI} = 1.25 \times \frac{weight}{Height^2} \times \frac{waist}{chest} \times \frac{\log(waist)}{\log(chest)}$$

For a tall athlete with a muscular shape, very large chest and not so large waist the formula allows up to 122kg. However if the chest would not be that large, if it were 110, then the formula suggest the athlete is very obese with BMI = 33.35. The maximum allowed weight would be 91kg, which shows very high flexibility. I believe the solution of making the power of Height as variable of the shape using the proportion $\frac{waist}{chest}$ as in the previous formula, is more elegant, more general and more accurate, perhaps, because it scales from small to large with the shape, something no other formula outside those in this analysis have ever successfully achieved previously. For a large chest and corresponding large waist, chest = 109 and waist = 91, at height = 1.9, the maximum weight determined by this formula is 89, similar to the classic BMi and very close to Broca index, where we see, this formula is also truly a generalization of BMI and Broca Index and works well for everybody, from the people with the body of a Mr. Olympia to average people, something no other formula previously achieved outside those in this analysis. For a tall person = 1.9 with a medium-large frame, the formula predicts a maximum weight of 88kg. However if we reduce the frame in a symmetric way even more, then the maximum weight decreases slowly. This shows this formula scales better than BMI and Broca index for both large frames and small frames and for the entire continuum from extremely large chest frame to small and finds BMI and Broca index as particular cases for average persons.

The formula does not use in its current form any special constant and parameters and is developed logically. For a large and proportional person with a large chest = 109 cm, but not a very large chest and a large waist of 91 cm, a height of 1.8m, the maximum normal weight predicted is 80kg, it is similar to the Broca index and classic BMI. These indexes were developed in the 19th century and were based on observation and statistics of the people who lived at that time, most of them performing physical work, hard physical work and were more robust and stronger than the average person today. So this case matches the classical metrics, but unlike classical BMI and Broca index, it is capable of successfully predicting the maximal weight and optimal weight ranges also for strong athletic types and also for average people from today. For example we could give the example of an athletic type, where the chest is large = 109cm, the waist is medium = 83cm and the height is 1.8m. The maximum weight predicted by this formula is 90kg. If we increase also the chest from large = 109 cm to very large 130cm, and keep the waist medium –large at 86 cm, then the maximum normal weight would be according to this formula 110 kg, quite similar to the weight of a professional or advanced bodybuilder. So the shape matches the weight. The formula works for everybody from average to professional bodybuilder. Now, lets see what happens if we increase the waist. If we increase the waist to 95cm, which is not really out of shape for such a large chest, then the maximum normal weight would be 98kg. If we increase the waist even more to 105, which would be proportional XXXL with the chest, then the maximum accepted weight would be 87 kg. The more athletic the shape is, the higher the accepted normal weight. However, if we keep the waist high and decrease the chest, like in the case of obesity, the formula determines obesity where previously was determining normal weight. For example for height = 1.8m, weight = 93kg, chest = 109 cm and waist = 105 cm, the AGBMI calculated through this formula is 34, obesity. If we increase the chest up to 139 cm, then the AGBMI appears 24.1, in the normal range, therefore the use of shape gives intelligent indication of obesity or athletic shape.

It is possible to use the factor $\frac{waist}{chest}$ as obesity predictor itself. Using the definition of sizes as in the previous table, if a person has the same size for chest and waist (for example L and L) then it is of normal weight, if a person has waist one size larger than the chest (for example waist XL and chest L), then it is overweight, if a person has waist two size larger than the chest (for example waist XXL and chest L), then it is obese and if the difference is larger it is very obese. In the size of the chest is larger than that of the waist (for example large chest and medium waist), the person is mesomorph, if the person has chest two number larger than waist, then the person is very mesomorph. The disadvantage is that this new formula does not use the weight or the height or strength or power as indicators, which may have a relevant role. But its advantage is simplicity.

In the case of next formulae I tested various values and parameters but there is not enough time and space to write down an extensive analysis of each of the following formulae. I show only where the formula works and when the classic BMI and the Broca index fail and where my new formula works in a similar way for average people and where the BMI and Broca index are found as special cases. This is also the way I developed these formulae, based on a logical step by step approach.

Using the same principle implementing the control factor as a fraction $\frac{chest}{waist}$ we develop a AGBMI, anthropometric generalization of BMI formula

AGBMI = f(weight, height, chest, waist)

$$\text{AGBMI}=\frac{(\log waist)^2}{(\log(chest-18))^2}\times\frac{weight}{Height^2}$$

and

$$\text{AGBMI}=\frac{(\log waist)^2}{(\log(chest-10xHeight))^2}\times\frac{weight}{Height^2}$$

We test first how the formula compares to the standard BMI and Broca index for the average person, height=1.8 m, chest large but normal = 109 cm, waist large but normal = 91 cm, then the maximum normal weight predicted is 80kg. The prediction for a normal but well developed person, like somebody who works heavy or is a beginning strength athlete is comparable to that of Broca index and the maximum upper limit of normal values for the standard BMI. The BMI and the Broca index have been developed in the 19th century based on the observations of the relatively strong people of the time which were performing physical work, and those types of people performing heavy physical work match the upper large size in the test case. Now I show where this formula can do better than classical BMI. For example if the chest would be 135cm, so a very large chest and we keep the waist unchanged at 91 cm. If the chest is very large=135, the waist, large=91 but not very large then the maximum normal weight predicted by the formula is 90kg. Of course it is much better than standard BMI but it does not work for the largest and strongest athletes. We can try a formula which has a larger accepted weight increase with the chest/waist proportion. In this way we try the power 3 so we obtain:

AGBMI = f(weight, height, chest, waist)

$$\text{AGBMI}=\frac{(\log waist)^3}{(\log(chest-18))^3}\times\frac{weight}{Height^2}$$

and

AGBMI = f(weight, height, chest, waist)

$$\text{AGBMI}=\frac{(\log waist)^3}{(\log(chest-10xHeight))^3}\times\frac{weight}{Height^2}$$

Numerical test and example: this formula predicts normal weight up to 95kg for somebody with very large chest and athletic waist. Now we test again the formula for ordinary people, chest = 109, waist = 91. We find for normal people or a bit stronger than normal the maximum accepted weight is still 80kg, so the formula works better for heavier people but as well for normal people and it is a generalization of BMI having similar results for normal people and much better results for athletic people. We can try now to use power 4 and the formula becomes

AGBMI = f(weight, height, chest, waist)

$$\text{AGBMI}=\frac{(\log waist)^4}{(\log(chest-18))^4}\times\frac{weight}{Height^2}$$

and

$$\text{AGBMI}=\frac{(\log waist)^4}{(\log(chest-10xHeight))^4}\times\frac{weight}{Height^2}$$

This formula allows up to 100 kg for a very athletic shape. This formula fits for almost all athletes except the very top bodybuilders where power 5 fits. Power 5 works actually for everybody, including for not so advanced and even for average people so it is a truly universal formula and a generalization of the classic BMI.

$$\text{AGBMI(chest,waist,weight,height)}=\frac{(\log waist)^5}{(\log(chest-18))^5}\times\frac{weight}{Height^2}$$

Also in this case it is needed to have
c = c(waist,chest)

$$\text{AGBMI}=\frac{(\log waist)^5}{(\log(chest-\text{c(waist, chest)}))^5}\times\frac{weight}{Height^2}$$

Finding an optimal C is a good fine tuning idea but for c=18 works well already. Examples of how to determine the C are above and there is no space for more.

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Using C = 10xHeight

$$\text{AGBMI}=\frac{(\log waist)^5}{(\log(chest - 10\text{xHeight}))^5} \times \frac{weight}{Height^2}$$

It is possible to define a new optimal weight equation as

$$\frac{(\log waist)^5}{(\log(chest - 10\text{xHeight}))^5} \times \frac{weight}{Height^{1.9}} - 25 = 0$$

And a lean male body weight as

$$\text{LBW(AGBMI)}=\frac{(\log waist)^5}{(\log(chest - 10\text{xHeight}))^5} \times \frac{weight}{Height^{1.8}}$$

For LBW, more experiments are needed and it may be that lean body weight, fat free would be more like

$$\text{LBW(AGBMI)}=\frac{(\log waist)^5}{(\log(chest - 10\text{xHeight}))^5} \times \frac{weight}{Height^{1.7}}$$

Of course fat free with no fat would be neither compatible with life, nor desirable. But this lean body weight value is important in quantification of medical doses. Without taking in account the chest and waist it would be impossible to calculate a lean body weight because it is needed am indicator of body development.
And the similar BMI generalization formulae for females would be

$$\text{AGBMI} =\frac{(\log waist)^2}{(\log(chest - 15))^2} \times \frac{weight}{Height^{1.9}}$$

and

$$\text{AGBMI} =\frac{(\log waist)^2}{(\log(chest - 10xHeight))^2} \times \frac{weight}{Height^{1.9}}$$

$$\text{AGBMI} =\frac{(\log waist)^3}{(\log(chest - 18))^3} \times \frac{weight}{Height^{1.9}}$$

and

$$\text{AGBMI} =\frac{(\log waist)^3}{(\log(chest - 10xHeight))^3} \times \frac{weight}{Height^{1.9}}$$

$$\text{AGBMI} =\frac{(\log waist)^4}{(\log(chest - 15))^4} \times \frac{weight}{Height^{1.9}}$$

and

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$$\text{AGBMI} = \frac{(\log waist)^4}{(\log(chest - 10xHeight))^4} \times \frac{weight}{Height^{1.9}}$$

$$\text{AGBMI} = \frac{(\log waist)^5}{(\log(chest - 15))^5} \times \frac{weight}{Height^{1.9}}$$

and

$$\text{AGBMI} = \frac{(\log waist)^5}{(\log(chest - 10xHeight))^5} \times \frac{weight}{Height^{1.9}}$$

The optimal weight equations for female would be similar but using height at power 1.8

$$\frac{(\log waist)^5}{(\log(chest - 10xHeight))^5} \times \frac{weight}{Height^{1.9}} - 25 = 0$$

Handgrip strength predicts mortality as well as morbidity and loss of function and illness from large array of causes regardless of body weight, body composition.[35][36][37][38][39][40][41][42][43][44]…[100] The grips strength also correlates with the strength in general. Because handgrip strength explains mortality and morbidity regardless of age and weight and shape, it is clear the body mass index and other formulae [5][112] do not explain this side of excessive weight. Optimal weight is also relative to strength and power, which are the best indicators of muscular mass. Optimal weight cannot be function only of mass and height. It must be observed that chest circumference is not only an indicator of the size of pectorals muscle but also of the body frame the breadth of the shoulders. People with large body frame will have also larger chest circumference. But no optimal weight or normal weight or even lean body mass formulae until now included the strength factor. I include the strength factor and show through simulation how it explains the experimental findings of many highly cited research papers [35][36][37][38][39][40][41][42][43][44]…[100]. No other formula of normal or optimal body weight developed until now explained or would predict the findings in these important and highly cited experimental papers which essentially show strength and power contribute to health expectations and reduced likelihood of morbidity and death independent of body weight and height and are not correlated in these experiments with anthropometric measures. However, I expect a relatively large chest compared to waist is often the best indicators of upper body muscular development compared to any other anthropometric measure.

Using the hand grip strength and the normalization $\frac{grip}{54}$ an Anthropometric Grip Strength generalization of BMI, (AGGBMI) could be defined as

$$\text{AGGBMI} = \text{AGGBMI(waist,chest,height,weight,grip)}$$

 doi:10.20944/preprints202007.0662.v1

$$\text{AGGBMI(waist,chest,height,weight,grip)} = \frac{(\log waist)^{\frac{grip}{54}}}{(\log(chest - 10\text{xHeight}))^{\frac{grip}{54}}} \times \frac{weight}{Height^2}$$

I assume 54 is the grip strength of a strong male with no training in sport. This places a higher standard (lower body fat percentage) than the BMI offers now and it is in my view aligned with the original BMI meaning because BMI had been developed in the early 19th century based on statistics which were based on a society where many people performed very hard physical work, when there was far less mechanization and no work protection regulation and were stronger physically than most people are now. The average age was also younger. Therefore people were at that time working physically and were stronger than today usually. For this reason I used 54 which is the grip strength of a strong male who is not a competitive sportsperson.
The classic BMI and Broca index offers the same weight limits for males and female of the same height, which in my view does not fit average people and certainly not athletes. Because the difference in muscular mass and bone frame and density between males and females, as well as due to esthetic considerations, the same formulae for male and female must be different.

I investigated several ways to generalize the BMI using as a dimension the body shape and strength, first is by adjusting the power of H from 2 to a variable power function of strength or body shape, a second idea is to generalize the classical BMI by factorization with a measure of shape or strength, a third idea is to consider the fat free mass and adjust the weight to a new weight where a measure of muscular mass and strength is substracted from the weight, a fourth way is by substracting from the BMI directly a measure of shape, strength and there are of course combinations of these methods.
This evaluation function approach is perhaps the best way to quantify and classify the body types.

AGBMI=AGBMI(weight,height,chest,waist)

$$\text{AGBMI}= \frac{weight - weight \times \frac{chest - weist - 18}{waist}}{height^2}$$

$$\text{AGBMI}= \frac{weight \times (1 - \frac{chest - weist - 18}{waist})}{height^2}$$

Test case/numerical example: For an very muscular shape chest= 135cm, waist=90cm, height = 1.8m, the maximum normal weight would be 111 kg, which makes sense. For a well build active person, chest=109cm, waist=90cm, height=1.8m, the maximum normal weight, calculated with this formula is 79 kg which is close to the values of the Broca index and classical BMI. This shows Broca Index and BMI are particular case of this more general formula. On the other hand, this formula fits also for athletic, muscular and very muscular people while the classic BMI and Broca index do not.
A more general expression would use $10xHeight$

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$$\text{AGBMI} = \frac{weight \times (1 - \frac{chest - weist - 10xHeight}{waist})}{height^2}$$

As above, it is possible to define an optimal weight equation based on this new concept of AGBMI

$$\frac{weight \times (1 - \frac{chest - weist - 10xHeight}{waist})}{height^{1.9}} - 25 = 0$$

The classic BMI and Broca index offers the same weight limits for males and female of the same height, which is not right for everyday people and certainly not for athletes. Because the difference in muscular mass and bone density between males and females [124], as well as due to esthetic considerations, the same formulae does not fit for male and female. Good evidence from sport, in particular strength sports show males are heavier than woman at the same height, in particular due to muscles.

The similar BMI generalization formula for females would be

$$\text{AGBMI} = \frac{weight - weight \times \frac{chest - weist - 16}{waist}}{height^{1.9}}$$

And the optimal weight equations for female

$$\frac{weight \times (1 - \frac{chest - weist - 16}{waist})}{height^{1.8}} - 25 = 0$$

And in general for C = $10xHeight$

$$\text{AGBMI} = \frac{weight \times (1 - \frac{chest - weist - 10xHeight}{waist})}{height^{1.9}}$$

and then it is possible to define a female optimal weight equation as

$$\frac{weight \times (1 - \frac{chest - weist - 10xHeight}{waist})}{height^{1.8}} - 25 = 0$$

Let AGBMI = AGBMI (weight, height, chest, waist)
We can use a constant C, dependent on waist and chest, C=C(waist, chest)

$$\mathrm{AGBMI} = \frac{weight}{height^{2.0+\frac{chest - waist - \mathrm{C(waist,\ chest)}}{waist}}}$$

The formula is very natural, we do not use any particular constants. The formulae are a result of natural laws.
Numerical test case: For a large athlete, height=1.9, chest=145cm, waist=90cm, the maximum normal weight predicted by this formula is 115kg. The prediction does not use any special constant. If we chose strong but normal people, not athletes, taking as a case height = 1.8 m, chest = 109 cm, waist=90cm, then the maximum normal weight is 80kg, the same predicted by Broca index and the upper limit of the classic BMI which are particular cases of this formulae in the mathematic and physiologic sense. But Broca Index and BMI cannot express correctly the BMI of people with athletic and muscular body, nor the BMI of those who have less than average muscle mass because even at normal weight as described by BMI or Broca, those with less muscular mass would still have a great body fat percentage. This solves the pradox obesity metabolism in people who appear to have normal weight. This is the explanation of a large number of experimental papers in the reference section.

We could use, in order to determine the optimal weight also an equation of the form

$$\frac{weight}{height^{1.9+\frac{chest - waist - \mathrm{C(waist,\ chest)}}{waist}}} - 25 = 0$$

It is likely the waist-chest difference in size is in many cases a function of height, so it is possible to state the formula as

$$\mathrm{AGBMI} = \frac{weight}{height^{2.0+\frac{chest - waist - 10\mathrm{xheight}}{waist}}}$$

and if we are interested in lean body weight which is not indicated as ideal body weight but for calculating the fat free body eight

$$\mathrm{FFBW} = \frac{weight}{height^{1.8+\frac{chest - waist - 10\mathrm{xheight}}{waist}}}$$

The classic BMI and Broca index offers the same weight limits for males and female of the same height, which in my view is not right for everyday people and certainly not for athletes. Because the difference in muscular mass and bone density between males and females, as well as due to esthetic considerations, I think we should not use the same formulae for male and female.

Similar formulae for woman could be considered

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$$\text{AGBMI}=\frac{weight}{height^{1.9+\frac{chest - waist - 10\text{xheight}}{waist}}}$$

Let the following new AGBMI formula

$$\text{AGBMI} = \frac{waist}{chest - 17} \times \frac{weight}{height^{2+\frac{chest-17}{waist}}} - \frac{chest - 17}{waist}$$

As a test case I chose a well developed person, with athletic shape, very large chest = 135 cm, large waist=90, height=1.8m. The maximum normal weight according to this formula is 125 kg. If it is changed the chest to 109 cm, then the formulae classifies the person as morbidly obese. For chest = 109, the maximum normal weight predicted is 82 kg which is similar but a bit higher than the classic BMI and Broca Index which is 80 kg. However chest 109 cm is larger than average, if we decrease very little, for instance to 108 cm, which is still large, we find the maximum normal weight is 80 kg, and therefore the BMI and Broca index are found as particular cases of my formula.

Broca and BMI are particular cases of AGBMI

$$\text{AGBMI} = \frac{waist}{chest - 17} \times \frac{weight}{height^{1+\frac{chest-17}{waist}}} - \frac{chest - 17}{waist} + 1$$

So that $1 + \frac{chest - 17}{waist}$ is exactly 2 when $\frac{chest - 17}{waist}$ is one. This formula likely performs well for strong athletes and also for normal people and even for people with less than normal muscular mass. The formula covers is good for every case from the medical or sport point of view.
Of course, it is possible to use constants but it is not necessarily because it already works very well.

$$\text{AGBMI} = c1 \times \frac{waist}{chest - 17} \times \frac{weight}{height^{1+\frac{chest - C(chest, waist)}{waist}}} -$$
$$c2 \times (\frac{chest - 17}{waist} - 1)$$

An optimal weight equation would be

$$c1 \times \frac{waist}{chest - 17} \times \frac{weight}{height^{0.9+\frac{chest - C(chest, waist)}{waist}}} - c2$$
$$\times (\frac{chest - 17}{waist} - 1) - 25 = 0$$

Let c(chest,waist) = 10Height then the normal weight new BMI

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$$\text{AGBMI} = \frac{waist}{chest - 10H} \times \frac{weight}{height^{1+\frac{chest-10H}{waist}}} - \frac{chest - 10H}{waist} + 1$$

A simpler form is

$$\text{AGBMI} = \frac{weight}{height^{1+\frac{chest-17}{waist}}} - \frac{chest - 17}{waist}$$

and it works for normal sizes, if the height of the person is 1.9 m, has a large chest = 109.0 cm, waist = 91.0 cm, then the maximum normal weight is 91, which solves the problem of weight increase with height in BMI and is a generalization for Broca Index. Using a larger person, chest = 135, very large, waist = 91, the formula predicts maximum normal weigh 111 kg which is expected for a large person with athletic shape.

A formula which is a more exact generalization of BMI and Broca index would be obtained after normalization (anthropometric generalization of BMI)

$$\text{AGBMI} = \frac{weight}{height^{1+\frac{chest-17}{waist}}} - \frac{chest - 17}{waist} + 1$$

The classic BMI and Broca index offers the same weight limits for males and female of the same height, which is according to consensus research not fit for everyday people and certainly not for athletes. Because the difference in muscular mass and bone density between males and females, as well as due to esthetic considerations, it is not possible to use the same formulae for male and female.

The formulae for woman would be (anthropometric generalization of BMI)

$$\text{AGBMI} = \frac{waist}{chest - 10Height} \times \frac{weight}{height^{1.9+\frac{chest-10Height}{waist}}} - \frac{chest - 10Height}{waist}$$

And optimal weight equation

$$\frac{waist}{chest - 10H} \times \frac{weight}{height^{1.8+\frac{chest-10H}{waist}}} - \frac{chest - 10H}{waist} - 25 = 0$$

Or as a strict generalization of BMI and Broca index

$$\text{AGBMI} = \frac{waist}{chest - 10H} \times \frac{weight}{height^{0.8+\frac{chest-10H}{waist}}} - \frac{chest - 10H}{waist} + 1$$

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$$\mathrm{AGBMI} = \frac{waist}{chest - 18} \times \frac{weight}{height^2} \times \frac{1}{\log(height + \frac{chest - 18}{waist})}$$

The formula works very well where BMI and Broca index fail, it is able to correctly classify strong muscular athletes and the other side of the spectrum, those with small muscular mass but with apparently normal weight. There is no example I have ever seen of obese person with larger chest than waist, on contrary obese individuals have large waist and small chest often due to medical causes which prevent them from developing muscles, while the energy is channeled to building fat deposits. We use a test case of a large athlete, height = 1.9 m, XXXL chest 140 cm, large waist = 90cm. The predicted maximum normal weight is 142 kg. It is true the dimensions are enormous, but some bodybuilders and wrestlers have such proportions without being obese. Also, no obese man has such a large chest and relatively small waist. If we decrease the chest to 130 cm and keep the waist to 90 cm, then the maximum allowed weight would decrease to 129 kg. Some bodybuilders and wrestlers have similar sizes, for example Alexander Karelin had that sort of size while relatively lean for his weight. If we decrease the height to 1.8 and the chest to 120, then the maximum predicted weight would be 98kg. It makes sense again. Now we test a more average case, we decrease the chest to 109 cm, which is large, in order to test the upper weight limit predicted by this formula for normal people. This formula gives 84 kg as the upper limit of normal weight for somebody with large chest. It makes sense, since 109 cm for somebody at 1.8 m is usually a result of significant sport workout and some weight training or very hard physical work. It is a bit higher than BMI or Broca index predicts, but it is normal for well build individuals. For this normal person with larger than average chest and normal waist, the maximum weight allowed by this formula is 79 kg. For normal people the results are similar to Broca Index and the classical BMI, which are particular cases of my formula.

A new ideal body weight equation could be derived from AGBMI

$$\frac{waist}{chest - 18} \times \frac{weight}{height^{1.9}} \times \frac{1}{\log(height + \frac{chest - 18}{waist})} - 25 = 0$$

While there is not enough space to discus in details, I developed and simulated also other formulae, generalizing the BMI.

$$\mathrm{AGBMI} = \frac{weight}{height^{\frac{chest - 18.0}{waist}} \times height^{\frac{chest - 18.0}{waist}}}$$

In the case when waist = chest-18.0, then we obtain the classical

$$\mathrm{BMI} = \frac{weight}{height^2}$$

If waist < chest – 18.0 then we have a situation where the person has not very much muscle mass and the weight scales less with the height than in the case of a person with waist > chest – 18 or in general waist > chest – c(waist, chest) where
c(waist, chest) is the difference between the chest and the corresponding waist.

We could develop a formula using several constants c1, c2, c3, c4, c5 and find them from data but the formula above works because its logic without using machine learning to determine constants from data using by trial and error.

$$\text{AGBMI} = c1 \times \frac{weight}{\left(c2 * height\right)^{\frac{c4*(chest - c5)}{waist}} \times (c3 * height)^{c6 * \frac{chest - c7}{waist}}}$$

For example, for a large athlete, height = 1.95 m, chest = 135.0cm waist = 95.0cm, the formula allows a maximum "normal" weight of up to 129 kg

This formulae describe the variation of optimal weight with age, taking in account the decrease in muscular mass and bone density with age

$$1.28 \times \frac{weight \times waist \times \log(waist)}{height^{1.8 + \log\left(height\right) - 0.0025 * age) \times (chest - 15) \times \log(chest - 15)}} - 25 = 0$$

and if C = 10Height

$$1.28 \times \frac{weight \times waist \times \log(waist)}{height^{1.8 + \log\left(height\right) - 0.0025 * age) \times (chest - 10h) \times \log(chest - 10h)}} - 25 = 0$$

Numeric example and test case. For a subject 30 years old, chest = 100 cm, waist = 85 cm, height = 1.8, the formula gives maximum normal weight = 76 kg, if we increase the age to 70, the maximum optimal weight is 71 kg. This is normal due to a person loosing muscle mass with age. In order to keep a lower fat percentage, lower weight is optimal.

Through trial and error I found this new generalization of the BMI which is the first use of age in a BMI formula

$$\text{AGBMI} = \frac{weight}{height \times height \times height^{\frac{chest - waist - 20}{waist}}} \times height^{0.0025 \times age}$$

Numeric example and test case. This formula works well for large athletes, for example as a test case, similar to a professional bodybuilder, or a top wrestler, chest=145cm, waist = 90cm, height=1.9m, age = 30 the maximum weight would be 121kg. Makes sense. Now we develop a test case for an average person, chest = 102, waist=86, age=30, height = 1.8, then the maximum weight is 82 kg, so close to the classic BMI. And Broca Index, from this we prove Broca Index and classical BMI can be recovered as particular cases of my formula. The size of chest and waist are upper medium, a bit larger than the average. However I did not use any constant and the formula can be easily tuned to have the same value as Broca index or BMI for the average person, if they do not already have. Now we change the age to determine how

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the optimal weight changes. We change the age from 30 to 60 and we obtain the maximum normal weight as 72kg which is normal because people lose muscular mass with age.

And

$$\text{AGBMI} = \frac{weight}{height \times height \times height^{\frac{chest - waist - 10h}{waist}}} \times height^{0.0025 \times age}$$

Where h is height

We assume grip strength is a measure of reduced death risks as some scientific studies show [35][38][39][40][41][42][44]. Grip strength is also easier to measure and it correlates with the strength of the entire body. Grips strength also often develops through physical work not only through sport and for this reason it is a good metric for active people witch developed their body through work.

$$\text{AGGBMI} = \frac{weight}{height*height^{\frac{chest-17}{waist}}} - \frac{grip-54}{54} \times \frac{grip-54}{54}$$

For example a test case with weight=88.0kg, height=1.8m, chest=105cm, waist=85cm, and a very strong grip=125 kg, the maximum normal weight described by this formula is 88 kg, considerably better than classic BMI for this case.

As a more strict generalization of the BMi when the person is average $\frac{grip-54}{54} \times \frac{grip-54}{54}$ approximates 1 and the formula would close to BMI

$$\text{AGGBMI} = \frac{weight}{height*height^{\frac{chest-17}{waist}}} - \frac{grip-54}{54} \times \frac{grip-54}{54} + 1$$

Let the formula BMI(weight,height,chest, waist,grip)

$$\text{AGGBMI} = \frac{weight}{height*height^{\frac{chest-17}{waist}}} - \frac{grip-54}{54} \times \frac{chest-17}{waist}$$

This formula works for large and muscular athletes but not for the largest, however it performs far better than the classic BMI and the Broca index, for any category, but in particular the larger people. A test case would be for a large athlete, chest = 117cm, waist = 86cm, height = 1.8m, grip strength = 120kg, the maximum weight considered normal by this formula is 93kg. For larger chest, 130 cm, then the maximum accepted weight is 103 kg. The formula indeed allows much larger weight for athletic shapes compared to the classic BMI, and gives correct values for many large athletes and advanced bodybuilders. Another example, a large athlete like a heavyweight wrestler or bodybuilder, chest=135.0, waist=95.0,

height=1.93, grip strength = 150, the formulae gives maximum normal weight as 118.0.
We can generalize this formula to replace the constant 17 to a constant of form 10xHeight so

AGGBMI =

$$\frac{weight}{height*height^{\frac{chest-10\times height}{waist}}} - \frac{grip-54}{54} \times \frac{chest-10\times height}{waist}$$

And as a more strict generalization of BMI, for $\frac{grip-54}{54} \times \frac{chest-10\times height}{waist}$ being close to 1 for standard BMI

AGGBMI =

$$\frac{weight}{height*height^{\frac{chest-10\times height}{waist}}} - \frac{grip-54}{54} \times \frac{chest-10\times height}{waist}+1$$

The formula AGGBMI (height, waist, chest) is a simplification of the previous formula

$$\text{AGBMI} = \frac{weight}{height^{\frac{chest}{waist}}*height^{\frac{chest-10\times height}{waist}}}$$

or using the grip strength factor

$$\text{AGGBMI} = \frac{weight}{height^{\frac{grip}{54}}*height^{\frac{chest-10\times height}{waist}}}$$

In order to find the ideal weight we can add 5% to the BMI and compare it to the limit of 25.

$$\frac{weight}{height\times height^{\frac{chest-10height}{waist}}} - \frac{grip-54}{54} - \frac{chest-17}{waist} + \frac{5}{100}\times\frac{weight}{height\times height^{\frac{chest-10height}{waist}}} + \frac{age-30}{10} - 25 = 0$$

And as a more precise generalization of BMI for $\frac{grip-54}{54} - \frac{chest-17}{waist}$ being close to 2 for standard BMI

$$\frac{weight}{height\times height^{\frac{chest-10height}{waist}}} - \frac{grip-54}{54} - \frac{chest-17}{waist} + 2 +$$

$$\frac{5}{100} \times \frac{weight}{height \times height^{\frac{chest - 10height}{waist}}} + \frac{age - 30}{10} - 25 = 0$$

We could also develop a more general formula by replacing the constant 17 which is not always the best for all sizes with 10height

$$\frac{weight}{height \times height^{\frac{chest - 10height}{waist}}} - \frac{grip - 54}{54} - \frac{chest - 10height}{waist} + \frac{5}{100} \times \frac{weight}{height \times height^{\frac{chest - 10height}{waist}}} + \frac{age - 30}{10} - 25 = 0$$

In order to find the ideal weight we can add 10% to the BMI and use the same scale as for the maximum normal weight, comparing to the limit of 25

$$\frac{weight}{height \times height^{\frac{chest - 10height}{waist}}} - \frac{grip - 54}{54} - \frac{chest - 17}{waist} + \frac{10}{100} \times \frac{weight}{height \times height^{\frac{chest - 10height}{waist}}} + \frac{age - 30}{10} - 25 = 0$$

and

$$\frac{weight}{height \times height^{\frac{chest - 10height}{waist}}} - \frac{grip - 54}{54} - \frac{chest - 10height}{waist} + \frac{10}{100} \times \frac{weight}{height \times height^{\frac{chest - 10height}{waist}}} + \frac{age - 30}{10} - 25 = 0$$

It is possible to define a BMI generalization formula to quantify also the effect of work on physical development. We use a parameter work_strength with values between one and 5 to quantify the strength required for the work, we use work_volume to quantify the volume of work, for example the volume of lifting done in a job, we use hours_per_day number of hours of work per day, we use endurance as an indicator of the number of moves required, we use walking as an indicator of the number of the walking distance covered, we use standing as an indicator of the amount of time the person stands.

$$\text{AWBMI} = \frac{weight}{height \times height^{\frac{chest-10height}{waist}}} - \frac{grip-54}{54} - 0.35 \times \frac{chest-10height}{waist} + \frac{age-30}{10} + 0.35 \times \log(\text{work\_strength+work\_volume+hours\_per\_day+endurance+walking+standing})$$

And an optimal weight equation as

$$\frac{weight}{height \times height^{\frac{chest-10height}{waist}}} - \frac{grip-54}{54} - 0.35 \times \frac{chest-10height}{waist} + \frac{10}{100} \times \frac{weight}{height \times height^{\frac{chest-10height}{waist}}} + \frac{age-30}{10} + 0.35\times$$

log(work_strength+work_volume+hours_per_day+endurance+walking+standing) – 25 = 0

Where work_strength, work_volume. hours_per_day, endurance, walking+standing have values between one and five.

Discussion

Simple anthropometric indexes existed also before but they were not connected to the BMI or Broca index. Such an index was the $\frac{waist}{heigh}$ ratio. The index is very sensitive to variations and measurements of waist and height. These proportion do not make difference between fat and muscles or between fat and large frame.

We could generalize this formula in the following way $\frac{waist}{height}$ < 0.5 * C(strength,chest-size) and in particular we could develop formulae of the form $\frac{waist}{height} < 0.5 * \frac{f(subject\,strength)}{g(average\,strength)}$. To determine the fraction $\frac{f(subject\,strength)}{g(average\,strength)}$ we could use various metrics of strength such as grip strength, which is relatively easy to measure and could be done at home with small investment or in a doctors office or physical therapist office or in a gym. Another way would be to determine the fraction $\frac{f(subject\,strength)}{g(average\,strength)}$ using strength exercises such as classical strength measures such as the classical lifts, bench press, squat, deadlift or the snatch and the clean and jerk. Descriptions of these exercises exists on the internet.

It is possible to integrate $\frac{waist}{heigh}$ in the BMI in a similar way, however $\frac{waist}{heigh}$ does not carry the same advantages as using the size of the chest since the size of the chest correlates better with upper body strength including pushing strength, pulling strength, and

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arms strength. By using the Rohrer condition $\frac{waist}{heigh} < 0.5$ and for example condition $\frac{waist}{heigh} = 0.4$, we may find $\frac{waist}{heigh} = \frac{4}{10}$ and $\frac{waist*10}{height*4} = 1$. We factor this to the BMI and obtain

$$\text{WHBMI} = \frac{waist*10}{height*4} \times \frac{weight}{Height^2}$$

This formula may be studied against statistical means but it is likely the formulae using chest and waist are more likely to be closer to correct.

The formula $AGBMI = \frac{waist}{chest - 10*Height} \text{ x } \frac{W}{H^{2.0}}$

could be improved by developing a variable function of the thickness of the skin over the pectoral, over the chest, measured with a caliper and in this way we quantify how much the size of the chest is from the muscle. The formula would become

AGBMI = c(thickness of the skin pectoral and waist) x $\frac{waist}{chest - 10*Height}$ x $\frac{W}{H^{2.0}}$

The normalization condition would be that

$c(\text{thickness of the skin pectoral and waist}) = 1$ for average people

In this way, it is possible to integrate all three methods in one formula, the BMI, the anthropometric waist over chest and the skinfold methods in just one formula.

Discussion of other approaches to the problem

A formula which [5] claimed to differentiate muscle and fat was developed by [5] however it is easy to show that is not the case and while the aims of the formula were to predict risk of mortality, it does no show anything about fitness, morbidity, illness or loss of function.

The ABSI (A body shape index) method is based on the assumption that the risk of mortality is associated not only with the weight but also on the location of the fat deposits. The formula uses the waist circumference as a factor of the risk of mortality. [5]. It aims to predict the mortality hazard independent of the BMI (Body mass index).

If WC is a notation for waist circumference, BMI means body mas index and Height is the height of the person then [5] defines an index through the formula:

$$\textbf{ABSI} = \frac{\text{WC}}{\text{BMI}^{\frac{2}{3}} \times \text{Height}^{\frac{2}{3}}}$$

[5] claims ABSI has a strong correlation with their data on morality hazard over age, sex, BMI and for both ethnicities, white and black, but not Mexican.

[5] does not mention if it is useful also for Asian Americans, Asians, east Asian, south Asian, middle eastern people, white Europeans, South Americans, Africans and it does not use data from these populations in the development and validation of the formula or the risk profile and testing. It will be given an argument suggesting it does

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not correlate also for these groups. Indeed, from the data it appears it is useful only for White Americans and possibly African Americans. A serious error is that it is claimed in [5], the ABSI formula correlates with hazard rates for blacks while in fact the sample contains African Americans, which have a different body built compared to Blacks from Africa or even from elsewhere. It is mentioned in [5] the data is from African Americans not from blacks from Africa. This outlines the limitations of the ABSI formula proposed by [5]. The description of the formula in [5] is not easy to read by people without mathematical background making it less useful to the people who would benefit most from a body shape formula, athletes and who would understand its obvious limitations of this formula for anybody with some experience in sport. However, despite being designed claiming to aim a differentiation of muscles and fat in the body weight, the sample contains no or few athletes because it is a biased sample from the general population of USA, where there are not many top athletes. Also because it is tested statistically, the very few athletic people in the sample would not influence the validation. Along with the bias of the sample this is a major problem. Not the only one.

[5] States the formula proposed is not a significant predictor of mortality in Mexicans. For this reason it is perhaps not a significant predictor of mortality in South Americans or North Americans with Native American ancestry and is not a significant predictor of mortality in Asians, south or east Asians or central Asians because these groups are genetically related to people having Native American origins and have some similarities in the way they are physically developed. The reason is that these groups have a greater genetic tendency to have larger abdominal circumference relative to their weight, without being an added risk of death. Differences in body composition and density between Europeans and Asians are determined here [125] [23]. With the rise in number of Asian Americans it is surprising [1] did not address this group. Perhaps they do not discuss its application to Asians and Asian Americans because and South Americans and Black Africans because the formula does not predict their mortality risk well.

[5][112] do not explain many of the important experiments where it is shown that outside BMI and fat distribution, the strongest role is that of dynamic and functional factors such as grip strength. [5] and [112] do not aim to explain at all and do not offer a good explanation for many of the important experiments [35][36][37][38][39][40] [41] [42][43][44]…[100]. where it is shown the importance of functionality, like grip strength, therefore [5][112] offer little or no explanation to the important experiments in the field.

On the other hand my AGBMI and AGGBMI formulae are universal, in particular where a factor is functional abilities such as grip strength is used, as it correlates to muscular mass in well in all populations. My formulae AGBMI and AGGBMI also explain and could predict the important experiments [35][36][37][38] [39][40][41] [42][43][44]…[100].

[5] Makes clear the ABSI formula is predictive in the case of white people from the USA. Indeed, the parameters where the mortality is lowest show a waist circumference far greater than what is considered normal by the standard of European whites. This is obvious also looking the data from UK where the obesity rates are highest in Europe, even there the data is different compared to the USA. It is certainly

[5] is not good for making the difference between muscle and mass for athletes as in many cases athletes, are a lot thinner than the waist predicted by this formula as optimal. The formulae is tested against supposed mortality rates not against overweight or fitness goals or life quality or health or morbidity or loss of funciton. In many countries and perhaps also in the USA in previous generations such predicted optimal waist circumference would be associated with being obese and it appears more than what would be overweight by European standards. This is because the population on which the ABSI was determined were white Americans and African Americans and in particular those of lower income where obesity is more frequent, therefore the basis on which the ABSI statistics relies contains a lot more fat and obese people than in other populations which distorts the formula in that direction, and from this the accepted waist circumferences are large. Making the statistic over a population heavily affected by obesity makes obesity a normal. The statistic over which the BMI was developed was based on normal people in the first part of the 19th century, who were in good physical shape due to having physical work, which was common then. For this reasons [5] has limited application outside the population and sub-populations from which the date from which it was developed comes. What the ABSI [5] predicts as lower mortality waist is so large that it would be large even for somebody strong enough to lift their own weight and it is huge for ordinary average people. Most optimal values of waist circumference would be considered obesity by white Europeans and also in previous generations of white and black USA population. These values of smallest risk waist circumference would be certainly considered obesity in Asia or Africa. In fact even if you are strong enough to lift a barbell with a weight equal to your own, quite strong even for an athlete, then even for this person, the optimal waist size predicted by ABSI is very large. . In fact even Olympic level athletes in small categories in areas with much greater muscularity than the average person, for example weightlifting, wrestling, boxing, judo have a far smaller weight and waist than ABSI considers low risk, meaning that if somebody has a large amount of muscles, ABSI allows a large percentage of body fat. BMI was validated [6] by comparing its predictions with the body fat percentages measure through other methods. ABSI of [5] was not validated in this way and if its predictions would be compared to the body fat percentage measured in various ways, with calipers or laboratory methods, then the body fat percentages would be in some or even many cases very high for parameters considered low risk by ABSI [5]. ABSI does not make a classification or diagnosis of obesity and it is likely studies on body fat percentage would show ABSI [5] considers some people affected by obesity as having low or normal risk. Even if that would be true, it does not mean obesity does not affect health in negative ways as well as self image and fitness abilities, loss of mobility, etc.

Overall, it is clear that people with a large amount of fat but not large waist circumference, appear according to [5] at low risk. But even if their risk of death is not high, negative health effect such as orthopedic injuries and endocrine disruption are higher than normal. While of course the waist is an area where fat is often deposited, fat is stored also in muscles or over muscles, in particular among people who practice sport or practiced sport in the past. Even non-abdominal fat is actively metabolically triggering inflammation and it is certain to affect the athletic performance and various health parameters. If one trains the midsection, the fat deposits around waist grow slower with the increase of weight, because the body deposits fat elsewhere but this does not mean it is optimal as health or sport performance.

It is clear that [5] is based on data taken during an obesity epidemic and it does not reflect a normal fat percentage in human body. Other problem is that while the input is affected by errors, the prediction range is very small, and therefore the formula of ABSI suffers from sensitivity of parameters.

Another problem is that ABSI does not seem [5] to be adjusted to alcohol consumption, because excessive alcohol consumption can lead to enlarged waist and may explain why waist size adds a lot to mortality risk. Because it is not adjusted to drinking habits, it fails to take in account health risks caused by alcohol and not by being obese or overweight or by abdominal fat itself. Alcohol consumption is a cause of death in some.

Another assumption in [5] is that large waist means lack of muscles. This is not true, for example heavyweight weightlifters or some American football players. But large waist and small chest may indicate obesity and lack of muscular develpment. For this reason I use chest and waist as anthropometric indicators.

The main problem is that [5] considers optimal "low risk" waists much higher than normal and even that of strength athletes of short built, something unlikely to be correct and wrong from the perspective of optimal weight for sport or for normal people. Also, its indications of muscularity are not correct always because the best way is to determine it functionally and the athletes with such a muscular mass can easily use their practical performance in lifting or other exercise or grip strength. For this reason I developed the AGGBMI and other methods.

Another argument is through my own data. One year ago I was training more, I was able to lift a barbell equal to my weight overhead. I was never very large and muscular, but I used power and strength methods of weightlifting used by weightlifters and wrestlers in Eastern Europe and it is possible to develop strength without very large muscular mass. I used also rings, dips at parallels, pull-ups, one hand pushups. Then I had a knee injury while running and doing aerobics, at first mild but then it increased until I had to stop training. And due to eating to much carbs, and not going to gym during COVID epidemic, I gained weight from 74 to 91kg. Even at this point I was able to do 6 pull-ups and 60 pushups. But I entered my data in the calculator of Nir Krakauer , height = 1.8, weight = 91, waist = 92, then the BMI is 28.1 but the risk from ABSI is shown as 0.7, which is smaller than the average risk according to the ABSI method and explanation. I looked also at the risk from BMI and even with this high BMI it appeared lower risk than their statistical base. I think the only explanation is that their base is very overweight and out of shape.

My formulae AGBMI predicts I am overweight now, and I know that and I see this and the calipers tells me that and the sport bodyweight exercises show that. I also entered the data from when I was 74 kg, waist was 86 cm (I had a strong abdominal and back section), for that the relative risk from ABSI is higher at 0.9, which is a result I find inconsistent, illogical and paradoxical. It must be mentioned that the injury appeared after I gained weight from 74 to 84kg, while doing things I did many times at 74 kg, so gaining weight, regardless of ABSI is a risk for injury and health in particular for people who train in sport. At 74 kg I was able to perform 15 pull-ups, at

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91 only 6, so weight changes the performance in sport and fitness, regardless of ABSI. There could be dangers for those who rely on ABSI both in sport and outside. I used also other examples and many of the results from the ABSI calculator of Nir Krakauer were against common sense and against performance metrics and contrary to healthy sport and life. My conclusion is that BMI is often a better indicator than ABSI of [5], while ABSI is not a correct metric of fitness, and of risks on health, morbidity, and mortality and certainly not for people outside their statistical base. People who perform experiments in medicine and sport should compare the predictions of [5] with the body fat percentages measured through several methods.

Conclusions

Methods, ideas, new models and the validation of the new scientific theory

My bodyweight quantification theory (AGBMI and AGGBMI) and formulae explain the experiments published in highly cited scientific papers where it shown that BMI does is considered not always a good measure of metabolic health in thin and fat people and BMI does not always quantifies obesity making errors in both false positives and false negatives. Even more, it fails to quantify the distribution of fat on the body, fails to differentiate fat and fat free mass, fails to quantify muscular mass and its implication to health, to risk of death and morbidity. All these are shown to be important predictors of mortality, morbidity, health and illness as well as loss of function. [35][36][37][38][39][40][41] [42][43][44]…[100]. No other formulae until now quantify and predict these findings.

The formulae developed by me could be compared to skinfold measurements and estimation of body fat percentage or experimentally through precise laboratory measurements and will likely show significant correlation, outperforming other formulae previously developed. This type of experimentsl evidence had been used by Ancel Keys at all in [6] to validate the BMI as an indicator in medicine. I did not perform these measurements because I did not have access to a laboratory and subjects but the experimental design is not difficult. I developed these formulae on theoretic basis using some data I found online and the developing formulae that would predict the outcomes of experiments cited. Like in physics, some people develop theories and formulae and others make the experiments. I provide formulae to explain the outcome of those experiments and which could be the basis for future experiments. Of course I could make experiments and measures on myself as I have enough experience for that but I am afraid more subjects would be needed. My experience and experiments contribute to the development of these formulae.

At first I observed my formulae are correct generalizations of the BMI and more consistent than the BMI and Broca index over various body types. The BMI is an approximation because it predicts an optimal weight which is to large for people who are not developed in the sense of body frame and muscles and on the other hand predicts a maximum normal weight which is to small for people with athletic muscular build and large body frame, broad shoulders for example.

My Anthropometric Body Mass Index (ABMI) and Anthropometric Grip strength Body Mass Index (AGBMI) formulae form a new theory of optimal body quantification. The formulae found explain the relation between the height, strength, measurable indicators of strength, measurable anthropometric parameters and normal weight for individuals with those parameters who do not have excessive fat or even have optimal weigh in the sense of minimal fat for certain values of the indicators. This theory explains the relation between dynamical and static parameters of the human body. These formulae model optimality in regard to minimization of fat for certain dynamic parameters or minimization of health related risk or maximization of dynamic muscular parameters in regard to certain weight limits. The theory can be easily tested and there are even results from science, medicine [35][36][37][38][39][40][41] [42][43][44]…[100]. and sport records and competitions on which I verified the formulae. The formulae explains the results in various sport competitions where the dynamic features are similar to those in the tests quantified in the theory and through the formulae. Experiment can be performed in lab, and in some cases are already performed [35][36][37][38][39][40][41] [42][43][44]…[100] and recorded in sport competitions or through bodybuilding and fitness measurements. It is a <strength, volume, mass, composition> quantification of the human body. The new quantification model gives prediction where the optimal weight finds itself with the highest probability given certain static and dynamic parameters of the body. The formulae are based on observations but can be tested and are very good for each example not only as a statistic of many examples, my AGBMI and AGGBMI bodyweight quantification model works for every case, while BMI works, at most on average. I performed the comparison with average people as well as by listing the weight, strength, mass and anthropometric measurements of a number of ordinary people as well as well known athletes, considered close to the optimal in their class. The strength of these formulae and the AGBMI and AGGBMI theory described is given by the fact that they explain the optimal weight domain for each type of body from obese to thin and from strong to weak individuals and to a significant extent have a prediction power of fitness and health higher than any formula previously published. It explains also the paradox where people with apparently normal weight have a deficient metabolism. From the perspective of the strength of the theory, it is much higher than the classic BMI, the Broca formula or any other formula published. Examples are many in [35][36][37][38][39][40][41] [42][43][44]…[100]. More examples cannot be given due to the size of the analysis which is already much bigger than most publications. In [35][36][37][38][39][40][41] [42][43][44]…[100]. are dozens of examples that BMI, Broca index or any other formulae do not quantifies properly or even close to acceptable while my theory and subsequent formulae does that. Even more, the methods form a set of universal formulae unlike disparate examples published in the last 2 centuries which may be correct only for relatively average people of that time and are a particular case of the formulae outlined in this paper. The formulae outlined forme the basis of a new model or theory of body weight quantification. One goal of the theory was to be able to make the difference between muscle and mass, something no other formula or theory had done before. Only in the last years some attempted this but their formulae were adjusted on data from average people not from people who have developed body frames and muscles and do not

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achieve this aim as I show. None of these formulae is a BMI generalization and the results are not better than BMI and the authors themselves state their formulae cannot replace BMI or improve over it and in some cases the complexity of their formulae make the verification harder and are less useful. No universal formula has until now been developed. In order to prove and test my theory I collected the data of people where this difference is most clear, the competitive athletes, which develop their muscles to a significant extent. For these cases, the BMI, Broca index and other formulae published before failed in some cases in particular for upper sport weight categories in sports. They also fail to quantify the optimal weight of people who are very sedentary and have reduces muscular mass. I tested my formulae for world and Olympic champions for which I found data relevant to these formulae online. My formulae worked well, the other did not, in particular for strength sports. Other formulae failed in ways I explain a bit later. The strength of my theory outlined in this paper and the derived formulae is given by the great number and diversity of relations between body height, weight, density, anthropometric measures, density measures, strength and functional measures, and caliper measures. The original BMI, the Broca Index or any other formula do not make such relations possible and do not account for many observations and experiments [35][36][37][38][39][40][41] [42][43][44]…[100]. The AGBMI and AGGBMI theory relies on few assumptions compared to the BMI, which assumes people have similar body composition and certainly less assumptions than [5] and [112] where the use of statistic in the constructive phase makes these formulae useful and statistically biased for the characteristics of the very limited statistical populations and narrow purpose for which they were developed, looking to predict death risk but do not even aim to solve important problems such as optimal weight, fitness, morbidity or health. We will see that even the problem of mortality is solved under strong assumptions. Even that aim is not proven.

The AGBMI and AGGBMI model is observable because it relies on measurable parameters, every parameter entering my formulae is easily measurable and this measurement can be repeated as many times as one wants. For this reason my AGBMI and AGGBMI theory satisfy the essential criteria of a scientific theory describing the relation between these parameters of human body and physiological function. The AGBMI - AGGBMI theory can be refuted if evidence appears to contradict the validity of the formulae through individual cases or statistics. But because it is a statistical theory as the original body mass index, then only statistical evidence can prove my theory wrong. I strongly believe it works for every example not only as averages, being much more precise and accurate compared to the classic BMI and Broca Index. There are many examples proving BMI partially incorrect and dozens are in [35][36][37][38][39][40][41] [42][43][44]…[100]. and various data I tested, but still BMI is considered the most important formula and model until now. It is unlikely that anybody can claim my formulae AGBMI and AGGBMI have more false cases than BMI in particular since I show countless cases where my formulae are correct and BMI far from correct and since the BMI is a particular case of many of my formulae for average people, then it cannot be more accurate for average people and certainly is not comparable in accuracy with AGBMI and AGGBMI formulae for well developed, strong and athletic people. The ABMI (anthropometric BMI) formulae make predictions in regard to the relation between the above mention

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parameters in a systematic way and these predictions are always close to evidence and a lot more than any other formula known until now. This is another characteristic of a correct scientific theory. These predictions are in the area of sport science and health and could be verified through observations and statistics in both sport science and health sciences [35][36][37][38][39][40][41] [42][43][44]…[100]. The importance of the AGBMI and AGGBMI formulae developed is high because obesity is a disease itself causing a global epidemic and is the cause of other diseases. Obesity has personal costs in terms of money, health, public perception and social costs through healthcare and reduction of work capability. AGBMI and AGGBMI formulae have the potential to be very important for individual people and for society and offer an improvement and a generalization over the BMI formula and the statistical theory of Adolphe Quetelet [1], a theory called "social physics" by him, a theory nearly two centuries old. Improving the BMI would be a large step in the right direction in sport science and health sciences. These formulae predict if the person is obese or not and if it runs certain health risks and predict which is the optimal weight. These formulae have the potential to predict if the competitive form of an athlete is not optimal. It is a theory of optimal body weight and normal body weight limits, generalizing the social physics of Belgian mathematician Adolphe Quetelet [1] and the medical model of Ancel Keys [6]. The predictions of AGBMI and AGGBMI are 100% observable and could be computed with my formulae and compared with data which is the most important element of any such theory. The consistency and quality of the predictions are showing the universality of the AGBMI and AGGBMI model. Fundamental mechanical and dynamical and physiologic properties of the human body may be an explanation of the new formulae. The range of evidence is very high, from explaining the optimal weight and health consequences of weight of ordinary people to explaining the optimal weight of champions in many sports such as weightlifting, wrestling, boxing, judo, bodybuilding, athletics, etc and military fitness. I used the data I found about a large number of athletes of all sizes and sports. It is consistent with all data I found from sport or society and it is consistent with BMI and the very large number of scientific observation on which is based. AGGBMI and AGBMI are in many cases provable and are generalization of the BMI in some cases mathematical and physiological generalization of BMI in a precise way not only approximate generalizations. BMI can be found as a special case. I used both inductive and constructive methods to develop formulae from evidence and also from one formula, using logic to find the next. The first formulae or set are empirical explaining my observations but also experiments such as [35][36][37][38][39][40][41] [42][43][44] …[100] but the next are constructed from the first formulae and verified empirically and through simulation. Actually, many of the formulae generalize also the Broca index which is found as a particular case, making a unification of the most important formulae of the field, the BMI, the anthropometric formulae and the Broca optimal weight formula. These formulae are very useful to the health of individuals and of society. The formulae AGBMI and AGGBMI work very well but it is possible to improve them by finding through observation, statistics or machine learning parameters to fit new data sets or application to experiments in various fields of medicine and sport science. In many cases, the theory can be optimized, but even so the formulae work very well without any additional optimization. I believed at first I

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must find the parameters but I found the formula already fitted every example available. The formulae are not simple, are more complex than BMI but are the simplest possible to quantify all body types, to be universal. The AGBMI and AGGBMI are also the simplest way to solve the problems of generalizing the BMI to account for the mass, density, strength, height and shape of the body. It is possible to add more parameters, but the result would not be better and there would be a danger in showing the causality. In the current form, the bias-variance tradeoff is achieved in the optimal way. There is no other simpler way to solve the problem and this is clear for anybody who reads [35][36][37][38][39][40][41] [42][43][44]…[100]. I tried more complex formulae but additional complexity brings marginal improvements if any. These subsequent improvements were smaller than the improvement AGBMI and AGGBMI represents over the classic BMI. New formulae can be developed and tested by changing the AGBMI and AGGBMI formulae, in the same way chemical formulae are developed and tested in chemistry and a similar model of development is also this. It is possible to develop based on data even more specialized formulae for certain fields of sport, sport-science or for healthcare purpose, for predicting the risk our outcome of certain disease. An advantage of the AGBMI and AGGBMI theory is that it is also the easiest to test, does not require sophisticated labs or formulae and in any case no other method has ever been shown to work for such a large range of body types from ordinary people to muscular athletes, and from thin to obese. No other formulae had even been validated on examples of muscular athletes while I did this in [][][][][] for many examples. My model is the simplest and easiest to test, explain, apply and validate. Initially when I developed the formulae, I supposed they will not work for every case but my surprise is that I did not find cases of athletes of world class level for which it does not work very well. But I tested them also for average body types. I expect that such a statistical theory does not work and cannot work for each case but using dozens of cases it did not make any false positive to classify a muscular athlete as obese while BMI and Broca index would have failed every time for such cases. These formulae are incomparable to any formula in accuracy in regard to testing the data of world class athletes but they are also better in scaling with height and for beginning athletes as well as for ordinary people with every body types. I developed and published these simulations and verification in order to help people designing large scale statistical studies. When validating these formulae I looked at the data of medalists in Olympic games from various fields such as weightlifting, wrestling, boxing, athletics, judo, gymnastic and compared their performance with the results of my formulae. Then I always looked to see if these formulae still worked for ordinary people and compared them with the predictions of BMI and Broca index. I also looked at experiments published in highly cited papers, cited at the end where outcomes were not explained by existing formulae. The interpretation of these formulae is not only that of optimal weight or optimal muscle growth for certain weight or optimal performance, but they also represent a model of human physiology. Deep microscopic explanations may be one day found in the details of physiological processes of the human body. The AGBMI and AGGBMI formulae are empirical at the core and developed constructing another formula, term by term and factor by factor, adding them logically and verifying them empirically. The correctness and the fact AGBMI and AGGBMI formulae offer the best solution is supported by a vast

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number of examples given in this paper as well as the experiments cited and offer a comprehensive description of ways to calculate and understand the optimal weight functions and normal weight limits for a large variety of body types. First step was intuitive and then I verified the core formulae AGBMI and AGGBMI but no new data would change the idea or the core formulae substantially , despite some trial and error taking place through simulation and verification with real examples. I believe the formulae are fundamental description of human body proportions and development, are certainly statistically correct, but also for each example I found. The various formulae developed are like chemical formulae derived from a core, each has its own properties and advantages over other formulae researched from a structure. One of the most important features of these formulae is that they provide prediction of health, fitness, body type and composition, body fat percentage, body frame, health and life prospects, sport optimality. They can be used also for individuals which have not been part of the core data as well as for predicting illness not investigated statistically in connection to these formulae, because strength and vitality is a predictor of many diseases, morbidity and death as experiments cited show. I think these formulae would be a great predictor for fitness, for cardiovascular health, for metabolic health, for endocrine health. New experiments are welcomed. I did not use obscure statistics and questionable statistical procedures as others have tried before with their less intuitive formulae. I developed these intuitive formulae because in part I had experience in sport, in mathematics and in simulation, therefore I understood the impact of the terms and the need to develop a theory and a model with formulae which could predict highly coted experiments such as those cited [35][36][37][38][39][40][41] [42][43][44]…[100]. My interpretation is that these formulae, AGBMI si AGGBMI express fundamental laws of human nature, human biology and physiology, not just optimal weight formulae and obesity classification formulae, because they explain fundamental experiments cited above. The evidence is in every sport record book and in data of athletes at the highest level in their field but it is also about everybody you see on the street in regard to proportions where I chose the most relevant in regard to criteria of shape. These formulae could be seen as scientific modeling of quantifiable human body parameters such as height, weight, strength, age, shape, volume. The aim is to better understand the relation between these parameters, define new indicators, better quantify the body, visualize the functions and simulate the formulae based on variations of various components. The formulae AGBMI and AGGBMI are the new model of body quantification and classification and are complementary one to each other. These are mathematical constructs aimed at quantification of human body, its state, function and composition. These formulae are developed empirically but in some case the experiments and the data needed to perfectly support the models does not exist and the models AGBMI and AGGBMI aim to guide the future experimental studies in sport science and medicine. The advantages of AGBMI and AGGBMI are that they explain past observations, experiments and statistics, including those on which BMI was developed and could be estimators of the state of health, state of fitness and body composition, without expensive laboratory devices and at a small cost, and with high reliability. Measurements require the simplest devices and do not require a specialist. Interpretation is based on the BMI limits, a specialist may help, but everybody can

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understand the output. The scientific method require the development and testing for hypothesis by deriving predictions. The hypothesis are the relations between variables described by the formulae themselves, the experiments cited [35][36][37][38][39][40][41] [42][43][44]…[100]. the numerical examples and causality are the predictions and the comparison with the data from the outcomes of experiments such as [35][36][37][38][39][40][41] [42][43][44]…[100] is the proof that predictions of the models make sense and are the correct or closest to that. My numeric examples are simulations of those experiments. The formulae represent a framework through which results from sport to and health sciences can be derived. As a new bodyweight quantification theory it makes possible the correct classification of people which have high BMI but are not obese and of those who have normal BMI but have metabolic disease similar to those caused by obesity. This paradox is mentioned in cited articles. This is proven over many real and realistic examples. The evidence is strong without doubt showing that the formulae developed make the difference between the obese and well developed individuals to high accuracy. Every test is easy and feasible compared to most scientific theories. Prediction in regard to the health risk evaluation value of the formulae would likely be proved and are provable through statistical tests. Perhaps in specialized areas of health science, particular modification and parameters could bring optimization further improving the AGBMI and AGGBMI theory. Experiments in sports science and various branches of medicine could bring improvement to these formulae. These formulae could be considered laws of body quantification and composition, could be seen as possible new laws of nature. I expect more evidence will come from health sciences when such experiments will be performed. In essence the theory consist of a set of formulae each being sufficient for quantification and classification of every body type, but using different strategies, measurements and indicators. It could open new fields of research in various areas of medicine and sport science helping to develop studies, statistics and explaining those statistics. The results are consistent over measurements, the method has a great stability, the measurement errors cancel each other and consistency over repeated measurements having a advantage over every method published. The method has great stability and consistency over populations compared to any other method including BMI and Broca Index and [5][112] because strength is universal. The AGBMI and AGGBMI method and formulae are consistent over weight classes and body types, for people who are slim or fat and for people who are muscular and not muscular, for every type of build. The AGBMI and AGGBMI model are parsimonious, because the formulae described are the smallest possible to achieve the requirements of optimal weight quantification and normal weight limits quantification of every body type and the simplest in mathematical terms and assumptions. The AGBMI and AGGBMI theory, model and formulae have a high predictive power explaining the outcomes of many experiments in sport science and medicine published in highly cited scientific research papers [35][36][37][38][39][40][41] [42][43][44]…[100]. For every level AGBMI and AGGBMI can predict competitive chances in sport, better than any other formulae, because the indicators used, chest, waist and grip strength are very important in most sports and fitness, no other formula uses such relevant indicators for sport. It is true, more studies need to be done, in particular in terms of health implications, but in regard to physical shape, I already tested the formulae for data from a large number of athletes and it works and has predictive power in regard to performance and body type, explains why some are champions. Often, a theory starts with little evidence in science but there is already a lot of evidence from my AGBMI and AGGBMI. The verification examples are based on real data, even if I usually do not mention the names of the athletes from which the measures were taken. The formulae are testable with data which, in part already exists and could form a model for aims of future tests. The formulae are empirically testable by scientists and also by everybody.

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