ORIGINAL ARTICLE

Effect of Age and Obesity on Human Male Anterior Abdominal Wall Muscles: An Ultrasonographic Anthropometric Analysis

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ABSTRACT

Objectives: To study the differences in the thickness of anterior abdominal wall muscle, in age matched individuals having different body mass indices; and to determine if there is any correlation between the thickness of muscle with that of the body mass index (BMI).

Design: Cohort prospective.

Methods: 4160 observations were made on 260 healthy men of 20-50 years of age. Regression analysis and Pearson's correlation coefficient were computed and are statistically highly significant (p<0.01-0.001).

Results: Muscles show poor correlationship with that of the BMI and the results are statistically highly significant (p<0.01-0.001). Regressing BMI on abdominal muscles in different Age Groups, it was found that the relationship was linear and positive in 20-40 years, while it was linear and negative in 40-50 years.

Conclusion: Increase in abdominal muscles thickness till the fourth decade of life with an increase in obesity; thereafter, in the fifth decade of life there is decline in muscle thickness. Both age and obesity influence the abdominal, subcutaneous fat and muscle thickness.

Key words: Obesity, abdominal wall muscles, BMI

INTRODUCTION

The anterolateral muscles of the abdomen consists of four large flat muscular sheets forming the abdominal wall (obliqui internus et externus, transversus and rectus abdominis), and two smaller elements (cremaster and pyramidalis) concerned with suspension of the testes and tensing of the midline tendinous raphe of the abdominal wall[1].

Heredity and the level of testosterone secretion determine the basic size of a person's muscle. In men the muscles are considerably thicker as compared to women. However, with exercise muscles can become hypertrophied by an additional 30-60%. The cross-sectional area of the muscle correlates very well to the strength of the muscle[2]. Muscles that function under no load, even if they are exercised for hours upon end, increase little in strength. At the other extreme, muscles that contract at or near their maximum force of contraction will develop strength very rapidly even if the contractions are performed only a few times each day and that muscles can be fine-tuned to perform specific tasks that require actuators with a wide range of properties[3].

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Obesity is established when more than 20% of body weight is due to fat in men and more than 25% in women. Obesity is on the increase with improved socio-economic conditions in Pakistan and other developing countries. It is decreasing in higher socio-economic classes of the Western world but exhibiting a rise in its middle class population[4].

In human beings, lean body mass rises to plateau in the third decade of life, in the men it declines at an accelerating rate with advancing age. In women, the decline is slow up to the age of 50-55 years but rapid thereafter[5]. Consequently if food intake is not reduced with advancing age, obesity will result. Even more important than the total the fat content of the body is the site of fat accumulation. There are two types of obesity.

When fat accumulates predominantly in the trunk and particularly in the abdomen, it is known as central or visceral obesity. It is associated with an increased risk of developing cardiovascular diseases, non-insulin dependent diabetes mellitus, and stroke both in men and women[6]. The density of the subcutaneous abdominal fat is different from other sites[7]. When fat accumulates proportionately in the hips and limbs, it is called overall obesity. In this the risk of cardiovascular and related diseases is also increased[8].

Body mass index: The weight in relation to height is expressed as body mass index (BMI).

BMI = weight in Kg / height in m^2.

This simple measurement also known as Quetelet's Index correlates quite highly with other sophisticated technical methods of assessment of body fat[9]. The normal value for this index for men and women is 20-25 kg/m[2,10]. On the other hand a study published in 2010 that followed 11,000 subjects for up to eight years concluded that BMI is not a good measure for the risk of heart attack, stroke or death. A better measure was found to be the waist-to-height ratio[11]. The most accurate techniques, like denstiometry, computed tomography, magnetic resonance imaging, electrical conductivity; total body water determination by isotope dilution method, whole body counting of potassium 40, and neutron activation analysis is very expensive and not suited for clinical or epidemiological studies.

Ultrasound imaging: It is valid to use rehabilitative ultrasound imaging to measure trunk muscle size and activation during most isometric sub-maximal contractions. Ultrasound measures appear sensitive to both positive and negative change[12,13].

Relation of abdominal wall musculature with various movements and with fat: The viscera in the human body are contained in well-protected bony cavities like skull and thorax, unlike the abdomen where soft tissues provide the necessary support. In the erect posture the weight of the abdominal organs is largely borne by the pelvic bones[14], as is demonstrated by electromyographic studies. Mostly the movements of the trunk, whether in sitting or standing position, there is very little involvement of the abdominal musculature, unless considerable resistance is applied[15]. Rectus Abdominus and external oblique muscles are involved less in abdominal hollowing exercises than in pelvic-tilting excercises[16]. Little data are available on the changes in anterior abdominal wall anatomy associated with obesity[17].

In normal healthy individuals the abdominal wall is not responsible for providing support to the abdominal contents whereas in obese individuals, the pendulous anterior abdominal wall does get stretched. Isometric and shortening but not lengthening mode training resulted in increased muscle insulin-like growth factor I mRNA levels. The results indicate that relatively pure movement mode exercises result in similar levels of compensatory hypertrophy that do not necessarily track with the total amount of force generated during each contraction[18]. Tyrrel[8] et al found that the density of subcutaneous fat in anterior abdominal wall is 18% more than that of posterior abdominal wall fat. Muscle activity, to some extent, is related to intramuscular fat content[33]. The effects of the increased stresses on the muscle are well established. Isometric and shortening but not lengthening mode training resulted in increased muscle insulin-like growth factor I mRNA levels. The cross-sectional area of the muscle correlates very well to the strength of the muscle[17].

Hence, it is tempting to postulate that, increased intra-abdominal contents due to increased abdominal fat, especially higher density subcutaneous fat, could affect the abdominal musculature.

Age: With advancing adult age there is decrease of both types of muscle fibers, but relatively slow twitch fibers are reduced more[19,20]. The skin is echogenic. The subcutaneous fat is usually hypoechoic. The muscles reveal medium-level echoes with a lamellar pattern of the muscle fibers[21].

MATERIALS & METHODS

The study was conducted in an Ultrasound Clinic on two hundred and sixty middle class healthy men. All the subjects were volunteers; usually accompanying the patients coming for ultrasound scan to the clinic. A Performa for every subject was filled. The subjects were weighed on the weighing machine, with minimal clothing. Their height was measured in centimeters. The weight and height of the subjects were recorded in multiples of 0.5 kilograms and 0.5 centimeters, respectively.

The subjects were grouped according to the age and obesity. The obesity was measured with the help of the Body mass index. According to these two criteria, i.e., Age and BMI, the subjects were divided into six different Groups (Table-1), three age groups-A, B & C and three BMI groups I, II & III. Subjects were examined to rule out any abnormality, especially of the anterior abdominal wall. A general scan of the abdomen and pelvis was conducted for any space occupying lesion or pathological condition.

The ultrasonography was carried out with a linear array probe of 3.5 MHz. The probe was very carefully applied to the subjects every time, as lightly as possible and generous amount of gel was applied under the probe, so as to avoid tissue compression. The ultrasonographic recordings were made while the subjects were lying comfortably in supine position. The urinary bladder was empty at the time of the measurements. The abdomen was examined and seven different points were marked on the right side of the abdomen, with skin pencil (Figure-1), as under:

i. LINE - A: Three points were defined on a vertical line - A, passing through the geometric center of the Right rectus abdominis muscle. The distance between the upper border of the symphysis pubis and the costal margin was divided into four parts. Point - 1, 2 and 3, were taken at the junction of these quarters.

ii. LINE – B: Three points were taken on line-B. It was drawn perpendicular to the mid-clavicular point (passing through the tip of the ninth costal cartilage). It, too, was divided into four equal parts between costal margin and inguinal ligament. Three points named 1, 2 and 3 were taken at the junction of these quarters.

iii. LINE – C: Mid axillary line was defined as line - C. A single point on this line was defined, at the center between the costal margin and the iliac crest, (Figure 1). The thickness of muscles was recorded on all these seven points, for every subject. The linear array probe (3.5 MHz) was kept perpendicular to the abdominal skin.

Statistical analysis: The statistical analysis was conducted for the whole data (n=260), for all the three age Groups (Group A, n=87, Group B, n=88 and Group C, n=84), and for all the three BMI Groups (Groups, I n=100, II n=97 and III n=63). Mean, median, mode and standard deviation for all the observed values were computed. The data proved to be quite consistent; hence it was decided to use the mean for all further computations, as required. The computer software, "Statistical Package for Social Sciences" was used for all computations and data handling. Pearson's Correlation was computed for actual observations of the whole data. Correlations were considered statistically significant with confidence level 0.05 and highly significant with level 0.01.

Regression analysis: Regression analysis was searched using simple Linear, Log linear and multiple linear models. Simple linear model resulted in good regression coefficients, which were statistically significant too, but with multiple linear models, the regression coefficients improved and the statistical significance remained high. Multiple regression equations were computed. Age and BMI were regressed on abdominal muscles. Results were statistically tested by F-Statistics.

Statistics for regression coefficients outs are ANOVA. Criteria were PIN (.05) and POUT (.10) and method was enter Ma1, Ma2, Ma3, Mb1, Mb2, Mb3, Mc and TMabc.

Curvefit Linear Regression lines were plotted to know the effect of the age and BMI on the muscles of the anterior abdominal wall for the three age Groups and the three BMI Groups. These lines were grouped for age and BMI and are presented together for comparison. It was observed that when multiple regression equations were computed the sum of all the seven sites (TMabc) entered on step No. 1 in all the age and BMI Groups (Table-2). Hence, for the ease of description and understanding, it was decided to plot the curvefit regression lines for these observations.

The dependency of BMI on the thickness of the abdominal wall muscles was determined by multiple regression analysis for the three age Groups; regressing BMI on abdominal wall muscles. The influence of age on the abdominal wall muscles was determined by regressing age on the abdominal wall muscles in the BMI Groups. The coefficient of determination (MR), constant (C) and slope (β) were computed (Table 3).

After noting the statistically significant results of influence of age and obesity on human anterior abdominal wall, the age and BMI Groups were also analyzed empirically.

RESULTS

Correlation analysis for complete data

Pearson's Correlation Coefficients for the actual values at seven defined sites of abdomen for complete data are shown in Table-2. Age and BMI illustrated little correlation with that of abdominal muscles. Though the relationship was poor, but notable observation was that all the defined seven sites of abdominal wall muscles thickness are negatively correlated to that of Age, (Table-2). Whereas sum of muscles and fat thicknesses are significantly correlated with BMI on almost all points of observations, (Table 2).

Correlation analysis for split data age groups

Muscles

Muscles show poor correlationship with that of the BMI and the results are statistically significant (Table-2). Only in Group I (3rd decade of life), the points at line B, give the relationship in the range of 0.6579 to 0.7751. In the Group II and Group III (4th and 5th decades of life), the relationship of BMI and muscles further deteriorates, confirming the above mentioned statement that fat becomes the major determinant of BMI, and muscles play a poor role in altering the BMI. Similar results were obtained for calculated values (Table-2).

Fat and Muscles

When the thickness of fat and the muscles immediately under it was summed up, the results give good correlationship with that of the BMI in all the three Groups. The best-correlated results are offered by the point A2, the mid-point of the rectus muscle in all the three Groups (Table-2).

Correlation analysis for split data BMI groups

Muscles

The relationship of Age and BMI with all the values of muscles was poor. The only notable point being that the relationship of Age with that of Muscles in all the BMI-matched Groups, was negative (Table-2).

Fat and Muscles

The absolute value of the coefficient for the fat + muscles improves slightly in all the BMI Groups for all the points of measurements, as that of the fat and muscles separately (Table-2).

Regression analysis

Muscles

The coefficients of determination for muscles in both Age and BMI Groups were low (Table-3). Regressing BMI on abdominal muscles in different Age Groups, it was found that the relationship was linear and positive in group I and II, while it was linear and negative in group III (Figure-3). This implies that increase in Age up to fourth decade (Group II) with increase in obesity, there was increase in the abdominal muscle thickness, but there was slight decrease in thickness in fifth decade.

When Age was regressed on abdominal muscle in BMI Groups, the relationship remained linear but negative in all Groups (Table-3). This reinforces the results of correlation analysis where abdominal muscles gave negative relationship with that of Age. The rate of change increased with increase in BMI Groups (Fig 2). That is, the influence of Age was becoming more marked on abdominal muscles as the obesity was increasing.

It is thus apparent that both Age and obesity exert an influence on abdominal wall fat and muscles. This justifies separate consideration of Age and BMI Groups. The influence of BMI on abdominal muscles and fat is more and the effect of Age is less. The influence of Age both on muscles and fat becomes more marked with increase in obesity.

Table 1: Grouping of the subjects

BMI Groups **Age Groups**	**Group- A** **= < 25 Kg /m^2**	**Group - B** **> 25 - 35Kg/m^2**	**Group - C** **> 35 Kg / m^2**	**Total No of subjects in Age Groups**
(Group-I) 21-30 years	n=31	N= 34	n=22	n=87
(Group-II) 31-40 years	n=35	N=31	n=23	n=88
(Group-III) 41-50 years	n=34	N=32	n=18	n=84
Total	n=100	N=97	n=63	260

Table 2: Correlation Coefficient of Complete Data, Age and BMI Groups.

Measurements	**Complete data**		**Split Data**					
	Age	**BMI**	**Age Groups (Cor. Coeff. for BMI)**			**BMI Groups (Cor. Coeff. for Age)**		
			A	B	C	I	II	III
Line-A Point-1	-0.2076**	0.1320*	0.1749	0.1347	0.2484*	-0.1781	-0.2927**	-0.1175
Point-2	-0.2201**	0.3871	0.5466**	0.2553*	0.4415**	-0.1630	-0.2259**	-0.2890*
Point-3	-0.2699**	0.0152**	0.4602**	0.5116**	0.2631	-0.0547	-0.4026**	-0.4401**
Line-B Point-1	-0.4491**	0.3472**	0.6579**	0.1514	0.3882*	-0.3320**	-0.4831**	-0.5906**
Point-2	-0.3913**	0.3912**	0.7751**	0.1494	0.4273**	-0.1118	-0.5217**	-0.6765**
Point-3	-0.3561**	0.4410**	0.7063**	0.2523*	0.4446**	-0.1548	-0.3780**	-0.6489**
Line-C Point-C	-0.3133**	-0.1844**	0.4604**	0.4253	0.2568*	-0.1103	-0.5388**	-0.3900**
Total Lines A,B,C	xxxxxxxx		0.7148	-0.0505	0.3260	-0.7855	-0.5664**	-0.5487**
*p=0.05 **p=0.01 (2-Tailed)								

Table 3: Regression Analysis for the anterolateral abdominal Muscles, in Age and BMI Groups.

Measurements	**Age Groups**			**BMI Groups**		
	A	**B**	**C**	**I**	**II**	**III**
Multiple Regrs. Coef.(MR)➔	.614*	.692*	-.654*	-.661	-.643	-.744
Constant or Y-Intercept(C)➔	18.32	25.47	31.48	40.32	46.39	52.98
Independent Variables (□)🡻						
LINE - A, Point-1	1.17	.557	-.299	-1.54	-.028	-.198
Point – 2	.002	1.595	-.602	-1.54	-1.01	-.748
Point - 3	.570	1.50	-1.02	-.983	-1.15	-2.31
LINE - B, Point-1	.488	.656	NI	-3.70	NI	NI
Point - 2	.442	NI	-.023	NI	-.933	-2.75
Point - 3	.442	.724	-.332	-1.32	-.692	-1.82
LINE - C, Point C	1.02	.362	-1.57	-1.28	-1.00	-.819
Total at Lines A, B, & C	.693	.216	-.524	-1.32	-.966	-.912
* P < = 0.001 NI = Not Included in the equation.						

Fig 1: Seven defined points on Lines A,B & C on anterior abdominal wall.

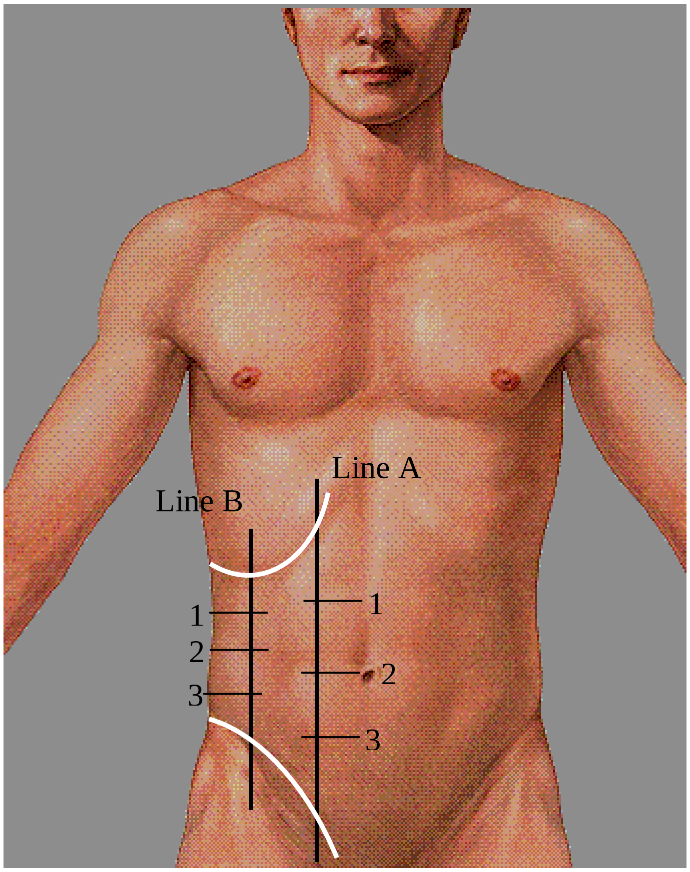


Fig 2: Curvefit linear regression lines of three age groups, dependent variable-BMI, independent variable total of observed abdominal muscles.

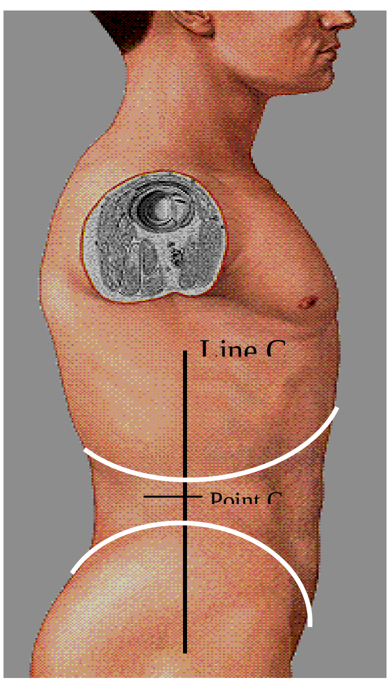
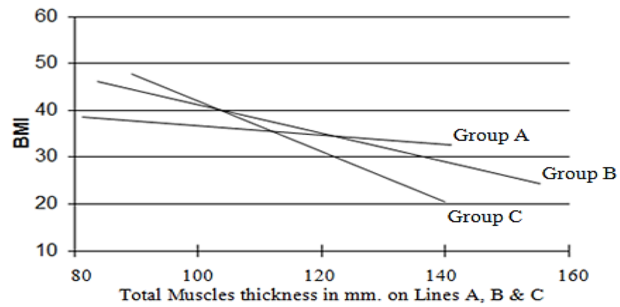
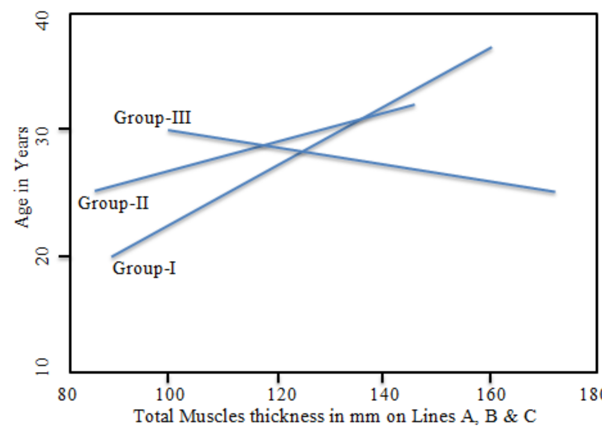


Fig 3: Curvefit linear regression lines of three BMI groups, dependent variable -age, independent variable - total of observed abdominal muscles.





DISCUSSION

The correlation of muscles with BMI (Tables-3) shows significant results (p<0.01), with poor coefficient of determination, possibly, indicating that the muscles play a little role in altering the BMI. In adults the increase in weight is directly related to the accumulation of fat rather than any change in muscles. In case the weight of a person is increased due to the fat free mass resulting in an increase in BMI, the individual may falsely be labeled as obese. In one study BMI-defined obesity showed high specificity (95% and 99% in men and women presenting BMI-defined obesity also presented Body Fat percent defined obesity) but BMI showed poor sensitivity (BMI only identified 36% of the men and 49% of the women with body fat percent defined obesity)[22]. Muscle fiber lipid content was greater in obese individuals with DM than in lean individuals[23].There is evidence that lean body mass rises to a plateau in third decade of life in males[2].The present study demonstrates that the correlation coefficient of BMI and fat is significantly higher ($p<0.01$), while in case of BMI and muscles it is much less (Table 2). Similar results are reported by[22, 24].

The correlation coefficient of abdominal muscles with that of age shows poor relationship ($p<0.01$), although it is negative in all the observed sites (Table 2, Fig 3). A.Sartorio[25] et al in their study states, 'In the obese individuals of the present study (their study), maximal voluntary lower limb power output was relatively constant up to a certain age (the peak value being displayed by subjects of both genders in the third decade) and then steadily decreased thereafter at the rate of about 1.5–1.6% per year. Evans and Campbell[20], reported profound changes in body composition associated with advancing age, expressed as Sarcopenia, which is defined as age related loss of skeletal muscle mass. In the present study when regression analysis was conducted between BMI and the total muscles, the lines for the third and fourth decades of life showed a positive relationship with that of BMI. The increase in weight is generally due to an increase in fat content of the body especially after third decade of life[2]. The regression line for the fifth decade gave negative relationship. The different positions of the lines justify separate consideration of each group. The higher position of regression line for Age Group B to that of Age Group A is suggestive of slight increase in corresponding total thickness of abdominal muscles with increase in age from third to fourth decade of life. While in the fifth decade of life the relationship between muscle thickness and BMI is found to be negative, as is indicated in Age Group C. In this group the muscle thickness is decreased.

With the increase in BMI, there is slight increase in the thickness of muscles (Table 2), except at site 'Mc' i.e., lateral abdominal muscles in mid-axillary line. This represents the effect of BMI on seven defined sites of the muscles in the anterior abdominal wall on empirical grounds. Thus the position for the regression lines for three age groups differed and rate of change in slope increased with increase in obesity.

The prevalence of obesity increases dramatically with increase in age[26,27] along with a decline in muscle mass[28], a view is also supported by estimation of urinary creatinin excretion methodology[29].

In human beings, the abdominal muscles are not much used especially as the age advances after adulthood. Rectus Abdominus and external oblique muscles are involved less in abdominal hollowing exercises than in pelvic-tilting excercises[16]. The abdominal muscles are not required for quiet breathing[15], for supine and standing posture[30] and even for certain exercises[16].

CONCLUSION

The present study concludes increase in abdominal muscles thickness till the fourth decade of life with an increase in obesity; thereafter, in the fifth decade of life there is decline in muscle thickness, contrary to the findings of Ricart[31] et al., who observed no change after fourth decade of life. The slight difference in results could be explained on the basis of geographical, racial and periodical grounds. Similar geographic differences had been pointed out by other authors[32].

The slight decrease in abdominal muscle thickness with advancing age is observed by simultaneous increase in intramuscular fat content, as was also observed by others[19, 23, 33].

The results of present study also suggest that with an increase in obesity the muscle thickness also increases which probably is due to an increase in fat content of muscles, more so in the fourth than in the fifth decade of life. Both age and obesity influence the abdominal, subcutaneous fat and muscle thickness. There is an increased deposition of subcutaneous fat influenced by age, which are more marked in normal weight individuals than in overweight or obese.

REFERENCES

1. William PL, Bainnister LH, Berry NN, Collins P, Dyson M, Dussek JE, and Furgoson MWJ. Muscle: Muscle of Abdomen. In: Gray's Anatomy. 38th ed. Chirchill Livingstone: Edinburgh. 1995p 819-829.
2. Ganong WF. Review of Medical Physiology. 23rd ed. The McGraw-Hill Companies, Inc.: US. 2010: 291.
3. Lieber RL, Ward SR. Skeletal muscle design to meet functional demands. Philos Trans R Soc Lond B Biol Sci, 2011 366(1570):1466-76.
4. J. M. M. Evan, R. W. Newton, D. A. Ruta, T. M. MacDonald, A. D. Morris. Socio-economic status, obesity and prevalence of Type 1 and Type 2 diabetes mellitus. Diabetic Medicine Volume 17, Issue 6, pages 478–480, June 2000
5. Gilbert B. Forbes, Julio C. Reina. Adult lean body mass declines with age: Some longitudinal observations. Metabolism. 1970; 19, (9), 653–663
6. Yusuf S, Hawken S, Ounpuu S, Dans T, Avezum A, Lanas F, McQueen M, Budaj A, Pais P, Varigos J, Lisheng L. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study". Lancet 2004: 364 (9438): 937–52.
7. Tyrrel RT, Montemayor KA and Bernardino ME. CT Density of mesenteric, retroperitoneal, and sbcutaneous fat in cirrhotic patients: comparison with control subjects. Am J Roentegenol., 1990: 155 (1): 73-75.
8. Supriya Krishnan, Lynn Rosenberg, Luc Djoussé, L. Adrienne Cupples and Julie R. Palmer Overall and Central Obesity and Risk of Type 2 Diabetes in U.S. Black Women Obesity. 2007: 15, 1860–1866.

9. Xavier F and Sunyer P., Obesity: Nutritional diseases. In: Wyngarden SF; Smith DE and Bernet eds. Cecil's Text Book of Medicine. 19th ed., 1992. W. B. Saunders: Philadelphia. P 1162.
10. Isselbacher, Obesity. In: Harrison's Text Book of Internal Medicine. 1990. Churchill Livingstone: New York. p789.
11. Harald J. Schneider, Nele Friedrich, Jens Klotsche, Lars Pieper, Matthias Nauck, Ulrich John, Marcus Dörr, Stephan Felix, Hendrik Lehnert, David Pittrow, Sigmund Silber, Henry Völzke, Günter K. Stalla, Henri Wallaschofski and Hans-Ulrich Wittchen. The Predictive Value of Different Measures of Obesity for Incident Cardiovascular Events and Mortality. The Journal of Clinical Endocrinology & Metabolism. 2010: 95 (4): 1777–1785.
12. Koppenhaver SL, Hebert JJ, Parent EC, Fritz JM. Rehabilitative ultrasound imaging is a valid measure of trunk muscle size and activation during most isometric sub-maximal contractions: a systematic review. Aust J Physiother. 2009; 55(3):153-69.
13. Kumar P, Bradley M, Gray S, Swinkels A. Reliability and validity of ultrasonographic measurements of acromion-greater tuberosity distance in poststroke hemiplegia. Arch Phys Med Rehabil. 2011;92(5):731-6.
14. Last RJ. Pelvic cavity. In: Last's Anatomy: Regional and Applied. 7th ed. Edinburgh, Chirchill Livingstone. 1983; P 378.
15. Goldman JM, Lehr RP, Millar AB and Silver Jr. An electrtomyographic study of the abdominal muscles during postural and respiratory manoeuvers. J Neurol Neurosurg Psychiatry, 1987; 50(7): 866-869.
16. Cheri L. Drysdale. Surface Electromyographic Activity of the Abdominal Muscles during Pelvic-Tilt and Abdominal-Hollowing Exercises. J Athl Train. 2004 Jan-Mar; 39(1): 32–36.
17. Hurd WH, Bude RO, DeLancey JOL, Gauvin JM & Aisen AM. Abdominal wall characterization with magnetic resonance imaging and computed tomography. J Reprod Med., 1991; 36(7): 473-476.
18. Adams GR, Cheng DC, Haddad F, Baldwin KM. Skeletal muscle hypertrophy in response to isometric, lengthening, and shortening training bouts of equivalent duration. J Appl Physiol. 2004; 96 (5):1613-8.
19. Evans WJ and Campbell WW. Sarcopenia and age related changes in body composition and functional capacity. J Nutr., 1993; 123 (2 PT 2 Suppl):465-468.
20. Evans WJ and Campbell WW. Sarcopenia and age related changes in body composition and functional capacity. J Nutr, 1993; 123 (2 PT 2 Suppl):465-468.
21. Sudheer Gokhale. High resolution ultrasonography of the anterior abdominal wall content is increased in obesity and decreased by weight loss. Indian Journal of radiology and imaging. 2007; 17 (4): 290-298
22. Romero-Corral, A.; Somers, V. K.; Sierra-Johnson, J.; Thomas, R. J.; Collazo-Clavell, M. L.; Korinek, J.; Allison, T. G.; Batsis, J. A. et al. Accuracy of body mass index in diagnosing obesity in the adult general population. International Journal of Obesity. 2008; 32(6): 959–966.
23. Bret H. Goodpaster, Remy Theriault, Simon C. Watkins, David E. Kelley. Intramuscular lipid content is increased in obesity and decreased by weight loss. Metabolism. 2000; 49, (4) 467-472.
24. Randrianjohany A, Balkau B, Cubean J, Ducimetiere P, Warnet JM and Eschwege E. The relationship between behavioural pattern, overall and central adiposity in a population of healthy French men. Int J Obes. 1993; 17: 651-655.
25. A Sartorio, M Proietti, P G Marinone, F Agosti, F Adorni and C L Lafortuna. Influence of gender, age and BMI on lower limb muscular power output in a large population of obese men and women. International Journal of Obesity. 2004; 28, 91–98.
26. Mohsen AF El-Hazmi, PhD, FRCPath, FACB, Arjumand S Warsy. Relationship between Age and the Prevalence of Obesity and Overweight in Saudi Population Bahrain Medical Bulletin. 2002; 24(2).
27. Heseker H. An epidimiological study of food consumption habits in Germany: comparison with other western countries. Medicographia. 1994; 16(3):7-10.
28. Doherty TJ. The influence of aging and sex on skeletal muscle mass and strength. Curr Opin Clin Nutr Metab Care. 2001; 4 (6):503-8.
29. Welles S, Thornton C, Jozefowicz R and Statt M. Myofibrillar protein synthesis in young and old human subjects after three months of resistance training. Am J Physiol., 1993; 264 (5 Pt 1): E693-698.
30. Strohl KP, Mead J, Robert B, Banzett, Loring SH and Kosch. Regional differences in abdominal muscle activity during various maneuvers in humans. J Appl Physiol. 1981 41: 1471-1476.
31. Ricart W, Gonzalez F and Conde V. Evluation of the nuritional status through determination of anthropometric parameters: new charts for the working population of Catalonia Group for the evaluation of the body composition in the population of the Catalonia. Med Clin Barc. 1993; 100 (18): 681-691.
32. Mitchel LE, Nirmala A, Rice T, Reddy PC and Rao DC. Commingly analysis of adiposity in an Indian population. Int J Obes Relat Metab Disord. 1994; 19(1): 1-8.
33. Spilia S and Suominen H. Knee extension strength and walking speed in relation to quadriceps muscle composition and training in elderly women. Clin Physiology, 1994: 14:433-442.