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Laboratory 2 – Measurement of Body Fat Percentage Using Hydrodensitometry, Bioelectric Impedance Analysis (BIA) and Skinfold Caliper

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Measurement of Body Fat Percentage Using Hydrodensitometry, Bioelectric Impedance Analysis (BIA) and Skinfold Caliper

Body fat percentage had been a quintessential part of the field of medical sciences and athletics in the 20th century alone: interest in one's body fat had been growing ever since. In a recent study by Aerenhouts, D., Clarys, P., Taeymans, J., *et al*. (2015) outlined that accurate determination of body fat composition was important for adolescents and younger athletes who were pursuing early specialization and its related performance demands. That is, in striving for a particular morphology meant that inaccurate measurements of body fat percentage may yield unnecessary strain on diet and training, thus lower energy availability and perhaps even a negative effect on health and performance. Furthermore, childhood and adult obesity epidemic in the West had also prompted health professions and researchers to utilize effective fat percentage measurements for the general population (Wells, J., Fewtrell, M., 2006). With respect to type II diabetics, some research had suggested that changes in body composition, that is changes in fat mass and fat free mass, had a role in altering lipid metabolism as well as insulin resistance (Duren, D. L., Sherwood, R. J., Czerwinski, S.A., *et al*., 2008). All the above prompted for the attempt to develop accurate body composition measurement methods. While there were many techniques used to assess body composition, this paper's main purpose was to compare and contrast advantages and disadvantages of hydrodensitometry, bioelectric impedance analysis (BIA), and skinfold measurements. Hydrodensitometry measured body density directly via Archimedes principle that stated weight is equal to volume of water displaced: using Siri's and Brozek's equation percent body fat can be determined. BIA utilized electrical signal passed through body via path of least resistance to ascertain percent body fat. Skinfold measurements utilized measurement of subcutaneous fat at various locations to estimate total body fat via equations based on different gender and age ranges (Dumont, 2016). Provided a number of advantages and disadvantages, the hypothesis was that hydrodensitometry would be most accurate among the three measurements given that it had been the gold standard for measuring body composition for many years until dual-energy X-ray absorptiometry (DEXA) and other multi-compartment body composition analyses were founded (Yeong Lee, S., Fallagher, D., 2008).

Methodology

A group of 14 participants in APA 2314 E course at School of Human Kinetics at uOttawa utilized hydrodensitometry, BIA, and skinfold measurements techniques. The participant of interest was male, 24 years, and of South Asian heritage. For hydrodensitometry, the apparatus, densitometry pool, had strain gauge that was calibrated with various weights to corresponding voltages. Participant had not consumed any food 3 hours prior to testing, refrained from applying body lotion, and voided bladder. Participant had completely submerged himself in water and freed hair and bathing suit of all air bubbles before exhaling air from lungs as much as possible. Completely submerged in water, participant did not move to minimize wave formation in water and prevent interference when recording. While the first trial was invalid due to excess air in lungs, three subsequent trials were recorded with computer software: percent body was determined using Siri's and Brozek's equations. For BIA, participant was well hydrated by drinking water, abstained from eating other foods and coffee, and did not apply moisturizing creams. Stepping on the Tanita Body Composition Analyzer/Scale TBF-310A apparatus, body type was inputted as standard, male, aged 24 years, with height 164 cm and weight 52.9 kg. The Harpenden caliper was used for measuring skinfold measurements of specific anatomical landmarks such as posterior medial triceps, 1-2cm below inferior angle of scapula, and so on.

Due to time constraints, participant engaged only one appraiser, not two. Please refer to lab manual for complete protocol and appendix for skinfold prediction equations used to calculate percent body fat.

Results

Table 1

Measured Body Fat (%) and Calculated Mean Values using Hydrodensitometry, Bioelectric Impedance Analysis, Skinfold Measurements Outlining Corresponding Sources of Error, Clinical Advantages and Disadvantages

Method		Trial Body Fat (%)	Mean Body Fat (%)	Sources of Error	Clinical Advantages	Clinical Disadvantages
Hydrodensitometry	Brozek[a]	19.50 20.84 18.80	19.71	-Calculations to estimate body density assumed residual air in GI tract as 0.1L instead of actual measurement of residual volume -Equations assume density of fat and lean tissue to be constant, thus does not account for differences in density in different lean tissue	-Relatively low standard error (2.7%) -Alternative to BIA for participants with heart pacemaker	-Not highly accessible or portable -Potentially difficult protocol for particular subgroups (i.e. older adults, obese individuals difficult to submerge completely, or children) -Requires relatively more time -Relatively expensive apparatus
	Siri[b]	19.76 21.21 19.00	19.99			
Bioelectric Impedance Analysis (BIA)		12.0[c]	12.0	-Dehydration, dry feet, moisturizing	-Simple and easy to administer	-Requires relatively less time

			lotion, callouses can impede electrical current thus overestimate body fat % -Female body fat % overestimated since lower body typically more mass than males	-Relatively inexpensive apparatus	
Skinfold Measurement	12.82[d] 12.65[d]	12.74[d]	-Use of equations generalized to population subgroups to estimate body fat % -Assumed that compressibility of fat similar between individuals - Assumed skin thickness negligible -Visceral fat not directly measured	-Simple and easy to administer -Portable and accessible -Relatively inexpensive	-Population generalized equations utilized -Potentially low accuracy for subgroups such as severely obese individuals

[a] Densitometry computer software calculated value using Brozek's Equation (% body fat = 457/body density – 414) (Dumont, 2016). See appendix for sample calculation.
[b] Computer software calculated value using Siri's Equation (% body fat = 495/body density – 450) (Dumont, 2016). See appendix for sample calculation.
[c] Only one trial conducted for BIA
[d] Refer to appendix for sample calculation for trial 1 that used Skinfold Prediction Equation Witner *et al*. (1987) for Males then Siri's equation. Trial 2 and mean value determined using Excel datasheet provided, also found in Appendix.

Table 2

Calculated Body Density (gm/cm³) using Various Equations and Body Fat (%) via Siri's Equation for Males Using Two Skinfold and Anthropometric Measurements and Mean Value

Author (Year Published)	Trial Body Density *(gm/cm³)*	Mean Body Density *(gm/cm³)*	Trial Body Fat (%)	Mean Body Fat (%)
Durnin and Womersley (1974)	1.0580	1.0580	17.88	17.85
	1.0581		17.81	
Forsyth and Sinning (1973)	1.0466	1.0471	22.98	22.74
	1.0475		22.55	
Sloan (1967)	1.0689	1.0693	13.08	12.91
	1.0696		12.80	
Thorland et al (1984)	1.0646	1.0647	14.96	14.92
	1.0648		14.90	
Jackson and Pollock (1980)	1.0739[b] 1.0672[c] 1.0739[d]	1.0741[b] 1.0674[c] 1.0743[d]	10.95[b] 13.83[c] 10.94[d]	10.84[b] 13.74[c] 10.77[d]
	1.0742[b] 1.0674[c] 1.0746[d]		10.80[b] 13.74[c] 10.64[d]	
Katch and McArdle (1973)	1.0723	1.0726	11.60	11.49
	1.0728		11.40	
Witner et al (1987)	1.0695[a]	1.0697	12.82[a]	12.74
	1.0699		12.65	

[a] Refer to appendix for sample calculation for trial 1 that used Skinfold Prediction Equation Witner *et al*. (1987) for Males then Siri's equation. Trial 2 and mean value determined using Excel datasheet provided, also found in Appendix.
[b]Jackson and Pollock (1980) sum 7 skinfolds (refer to Appendix for full equation)
[c]Jackson and Pollock (1980) sum 3 skinfolds, A (refer to Appendix for full equation)
[d]Jackson and Pollock (1980) sum 3 skinfolds, B calculation (refer to Appendix for full equation)

According to results depicted in Table 1, mean body fat percentage varied greatly when contrasting hydrodensitometry measurement 19.71% (using Brozek's equation) and 19.99% (using Siri's equation) against BIA measurement and skinfold measurement, 12.0% and 12.74%, respectively. A maximum of 2% variation was observed comparing the three trials of hydrodensitometry for values derived from Siri's equation and also those derived from Brozek's equation. Skinfold measurement trials yielded approximately 0.2% difference. Witner *et al.* (1987) equation (refer to appendix) was used to calculate body density, which was then substituted into Siri's equation to derive percent body fat for skinfold measurement method.

According to results depicted in Table 2, Forsyth and Sinning (1973) calculation for estimating body density, then using Siri's equation to determine body fat percentage yielded the highest body fat percentage of 22.74% mean value. The lowest body fat percentage was calculated via Jackson and Pollack (1980) of 10.77% mean value. Thus, a 11.97% variation was observed in using the different equations to estimate body density and subsequently percent body fat. Maximum variation in body density of 0.03 gm/cm^3 was observed between Forsyth and Sinning (1973) and Jackson and Pollack (1980) mean values, 1.0471 gm/cm^3 and 1.0743 gm/cm^3, respectively.

Discussion

The purpose of the experiment was to compare and contrast advantages and disadvantages of three methods that measure body composition: hydrodensitometry, bioelectric impedance analysis (BIA), and skinfold measurements. The hypothesis was that hydrodensitometry would be most accurate among the three measurements. However given the disadvantages of hydrodensitometry as well as the sharp contrast in values when compared to the other two methods (refer to Table 1), it seemed that BIA and skinfold measurements provided a more accurate percent body fat; thus, the hypothesis was not supported in this experiment.

Elaborating on such advantages and disadvantages of each method can help explain differences in calculated body fat percentages. According to results depicted in Table 1, mean body fat percentage varied greatly when contrasting hydrodensitometry measurement 19.71% (using Brozek's equation) and 19.99% (using Siri's equation) against BIA measurement and skinfold measurement, 12.0% and 12.74%, respectively (refer to Table 1). BIA utilized an electrical current passed from the feet and through the body. One reason why fat percentage was lower via bioimpedance was because electric current took path of least resistance which covered the legs and pelvis and yet did not pass above the abdomen. In contrast, hydrodensitometry accounted for entire mass of body and thus yielded higher body fat percentage (refer to Table 1). Essentially, knowing that water conducts the electrical signal in BIA, it passes through fat-free mass more easily and quick than fat mass since fat mass only holds approximately 10-20% water while fat-free mass holds 70-75%. Dehydration due to intake of coffee or similar diuretics (a physiological condition), dry feet or callouses can all impede the electrical current, thereby yielding a higher percent body fat since impedance of electricity was interpreted as fat mass by the Tanita Body Composition Analyzer/Scale TBF-310A apparatus. In this case, as a source of error the participant perhaps was overhydrated due to excess water intake and thus a higher blood volume ultimately may have yielded lower body fat percentage.

Hydrodensitometry yielded higher body fat percentage values than the other two methods. When equations were used to estimate body density, constant values were assumed for density of fat tissue (0.90 gm/cm^3 for both Siri and Brozek's equation) and density of lean tissue (1.10 gm/cm^3 for Siri's equation and 1.095 gm/cm^3 for Brozek's equation). This assumption was false as not all lean tissue, that is organs, bone, muscles and so on, had the same constant density (Aerenhouts, D., Clarys, P., Taeymans, J., *et al*., 2015), thereby contributing to possible overestimation of body density; thus also overestimated percent body fat, by definition of Siri's and Brozek's equations (Dumont, 2016). This fact was further reflected in a difference of 0.28% between calculated fat percentage using Siri's equation contrasted to using Brozek's equation (refer to Table 1). Furthermore, 0.1L residual volume in GI tract and lungs had potential to overestimate density also as individuals may have had differences in thoracic cavity elasticity and thereby variation in residual lung volumes. Hydrodensitometry directly measured body density by dividing body weight by body volume. Archimede's principle stated that an object submerged in water was acted upon a buoyancy force such that the object's weight equaled volume of water displaced. Once body density was calculated via densitometry software, Siri's and Brozek's equation allowed for calculation of body fat percentage (Dumont, 2016).

Skin fold caliper testing were based on body density equations (refer to Table 2) that are generalized to gendered body types that may not have accurately judged individual body type differences among the 14 participants (Wells, J., Fewtrell, M., 2006). Upon inputting anthropometric measurements in Excel equation spreadsheet, the values for calculated body density and body fat percentage varied by approximately 0.03 g/cm^3 and 10.77%, respectively, for the male subgroup (refer to Table 2). As such the values were neither consistent nor did taking more skinfold and anthropometric measurements yield more accurate or reliable results. Reason being was that each equation's author used different constants as well as different body landmarks to calculate body density (refer to Appendix). Then calculated body fat percentage using Siri's equation yielded inconsistent values. Furthermore, the skinfold method replied heavily on the appraiser's performance: if they took inaccurate readings, increasing the number of skinfold measurements would simply also increase the percentage error.

In accordance with WHO guidelines for identifying abdominally obese adults, participant's mean value of waist circumference of 71.1cm was well below 90cm, the cut off for South Asian males. Furthermore, participant had BMI of 19.7 was categorized as normal weight with a corresponding health risk of "least". It was important to note that BMI health risk guidelines (refer to Appendix) did not differentiate based on ethnicity, body type, and other pertinent factors, but rather had one guideline for all individuals worldwide. It therefore may not had accurately judged an individual's health risk as even the term health risk is a rather vague one that does not specify how precisely one's health is at risk. One could say this was a robust measure of the participant's health risk.

Having seen that measurement of body fat percentage via BIA and skinfold testing were similar in value 12.0% and 12.74%, respectively compared to hydrodensitometry method suggested that either BIA or skinfold testing was most accurate and reliable assessment method for participant. Further, since BIA electrical current did not pass through the abdomen and upper body but only travelled through legs and pelvis, it is possible that body fat percentage was underestimated. However, skinfold measurement considered both upper and lower body fat percentage values and thus yielded a slightly higher body fat percentage than BIA. Despite the sources of error outlined in Table 1 for skinfold measurement, comparatively it was the most accurate measurement for the participant. Notably, a source of error was that the participant had difficulty expelling as much air from lungs as possible and submerging underwater for hydrodensitometry, as evidenced by the first invalid trial. As such, participant's performance in following protocol may have had an effect on body fat measurement using this particular method. Future suggestions to improve the protocol would be to have participants abide strictly to instructions such as adequate hydration by water intake, avoid food intake and so on. Moreover, conducting more trials for each method can help improve accuracy and reliability of percent body fat measurement.

Conclusion

To conclude, the experiment found that while there are both advantages and disadvantages to the three methods of determining body fat percentage, skinfold measurement was the most reliable method for the participant. It was possible that BIA underestimated body fat percentage since electrical current did not account for above abdomen. Hydrodensitometry offered a rather difficult protocol to follow and estimated a much higher body fat percentage than the other two methods. With a BMI of 19.7, the participant was categorized as having least health risk. He also had a waist circumference lower than 90cm, thus was not identified as obese according to WHO guidelines. In future experiments, researchers may wish to control for variables such as hydration levels, time of day, precise food intake levels, and multiple recordings of each method on different days, among others.

References

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Appendix

Raw Data

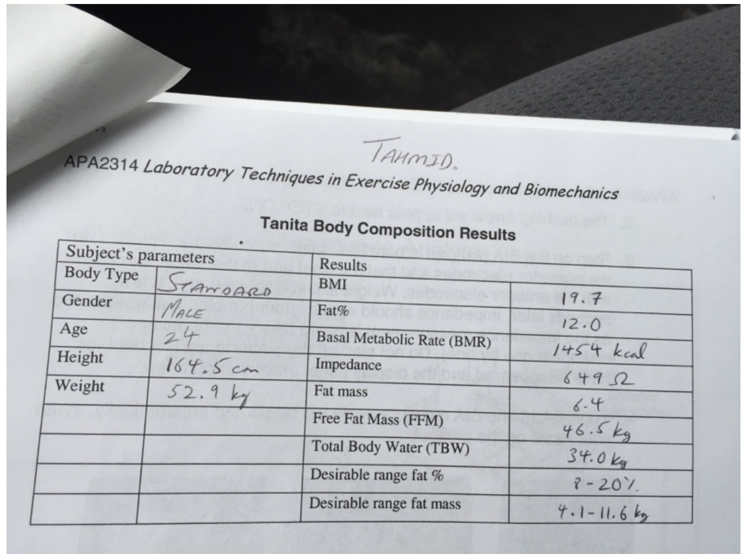
Choose closest values! Avs. those

Summary of Skinfolds and Other Anthropometric Measurements

Skinfolds	Appraiser 1: Height 164cm, Weight 52.9 kg				Appraiser 2: Height_____, Weight _____			
	Measure 1	Measure 2	Measure 3 (if #1≠#2)	Mean	Measure 1	Measure 2	Measure 3 (if #1≠#2)	Mean
Triceps	6.4	6.2		6.3				
Subscapular	10.8	10.4		10.6				
Biceps	4.0	4.0		4.0				
Suprailiac A	19.8	20.0		19.9				
Suprailiac B	18.0	18.4		18.2				
Suprailiac C	5.6	5.4		5.5				
Chest	10.8	10.8		10.7				
Abdomen A	21.2	21.0		21.1				
Abdomen B	21.6	21.4		21.5				
Thigh	16.0	15.8		15.9				
Calf	8.8	9.0		8.9				
Mid-axilla	9.0	9.0		9.0				
Anthropometric Measurements (girths and diameter)								
Upper arm relaxed	30.5	30.4		30.5				
Upper arm flexed and tensed	33.8	33.8		33.8				
Forearm	25.0	25.0		25.0				
Wrist	14.5	14.6		14.6				
Gluteal (hip)	86.0	86.0		86.0				
Thigh	50.0	50.2		50.1				
Waist	72.0	72.2		72.1				
Distance between humerus's epicondyles	6.5	6.5		6.5				

TANITA
BODY COMPOSITION
ANALYZER
TBF-300A

BODY TYPE	STANDARD
GENDER	MALE
AGE	24
HEIGHT	164 cm
WEIGHT	52.9kg
BMI	19.7
FAT%	12.0%
BMR	6085 kJ 1454kcal
IMPEDANCE	649 Ω
FAT MASS	6.4kg
FFM	46.5kg
TBW	34.0kg
DESIRABLE RANGE	
FAT%	8-20%
FAT MASS	4.1-11.6kg



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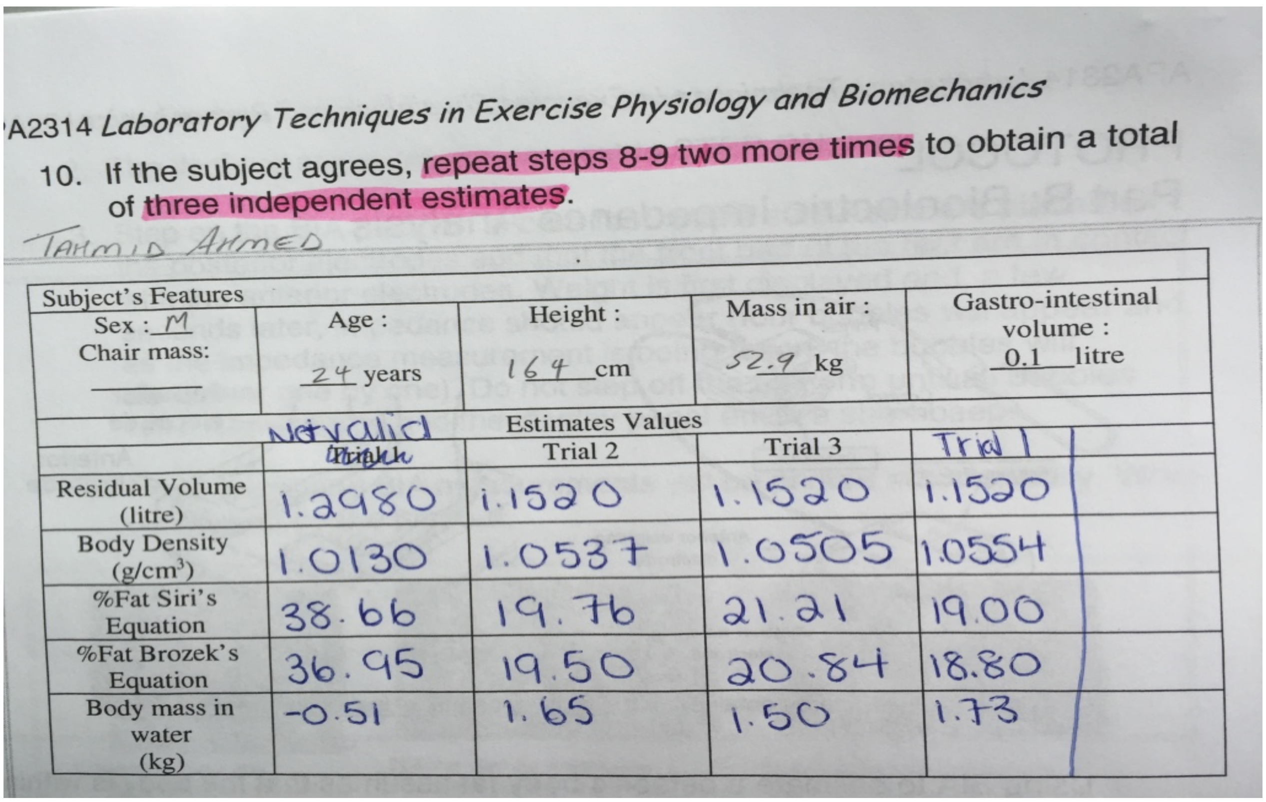
Tanita Body Composition Results

Subject's parameters		Results	
Body Type	STANDARD	BMI	19.7
Gender	MALE	Fat%	12.0
Age	24	Basal Metabolic Rate (BMR)	1454 kcal
Height	164.5 cm	Impedance	649 Ω
Weight	52.9 kg	Fat mass	6.4
		Free Fat Mass (FFM)	46.5 kg
		Total Body Water (TBW)	34.0 kg
		Desirable range fat %	8-20%
		Desirable range fat mass	4.1-11.6 kg



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10. If the subject agrees, repeat steps 8-9 two more times to obtain a total of three independent estimates.

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Subject's Features Sex : M Chair mass: ____	Age : 24 years	Height : 164 cm	Mass in air : 52.9 kg	Gastro-intestinal volume : 0.1 litre
	Estimates Values			
	Not valid Trial 1	Trial 2	Trial 3	Trial 1
Residual Volume (litre)	1.2980	1.1520	1.1520	1.1520
Body Density (g/cm^3)	1.0130	1.0537	1.0505	1.0554
%Fat Siri's Equation	38.66	19.76	21.21	19.00
%Fat Brozek's Equation	36.95	19.50	20.84	18.80
Body mass in water (kg)	-0.51	1.65	1.50	1.73

Skinfold Prediction Equations

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Appendix I: Skinfold Prediction Equations

Skinfold Prediction Equations

SKF Sites	Gender	Age*	Equations
Σ7SKF (1980)* (C + AA + Th + Tr + Sub + Sup C + MA)	Women (black or hispanic)	18-55	$Db\ (g/cc) = 1.0970 - 0.00046971(\Sigma 7SKF) + 0.00000056(\Sigma 7SKF)^2 - 0.00012828(AGE)$
Σ7SKF (1978)* (C + AA + Th + Tr + Sub + Sup C + MA)	Men (black or athlete)	18-61	$Db\ (g/cc) = 1.112 - 0.00043499(\Sigma 7SKF) + 0.00000055(\Sigma 7SKF)^2 - 0.00028826(AGE)$
Σ4SKF (1980)* (Tr + Sup C+ AA + Th)	Women Athlete	18-29	$Db\ (g/cc) = 1.096095 - 0.0006952(\Sigma 4SKF) + 0.0000011(\Sigma 4SKF)^2 - 0.0000714(AGE)$
Σ3SKF (1980)* (Tr + Sup C + Th)	Women caucasian	18-55	$Db\ (g/cc) = 1.0994921 - 0.0009929(\Sigma 3SKF) + 0.0000023(\Sigma 3SKF)^2 - 0.0001392(AGE)$
Σ3SKF (1978)* (C + AA + Th)	Men caucasian	18-61	$Db\ (g/cc) = 1.10938 - 0.0008267(\Sigma 3SKF) + 0.0000016(\Sigma 3SKF)^2 - 0.0002574(AGE)$
Σ2SKF (1988) (Tr + Ca)**	Boys	6-17	$\%BF = 0.735(\Sigma SKF) + 1.0$
Σ2SKF (1988) (Tr + Ca)**	Girls	6-17	$\%BF = 0.61(\Sigma SKF) + 5.1$

ΣSKF = sum of skinfolds (mm) ; AA=abdomen A, C=chest, Ca=calf, MA=midaxilla, Sub=subscapular, Sup C=suprailiac C, Th=thigh, Tr=tricep ; Age in years.

Additional information: J Exerc Phys online 2001, 4.

*Jackson and Pollock 1978 et 1980
**Slaughter 1988

Health Risk Guidelines Derived from Waist Circumference and Body Mass Index (BMI)

Appendix II: Health Guidelines Derived from Waist Circumference and Body Mass Index

When all the measurements have been taken, you can use the following indicators for the assessment of body composition.

- **Waist Circumference (cm):** Simple recording of the measurement taken.
- **BMI - Body Mass Index**: the ratio of body weight divided by height squared (kg/m^2)

Health Risk for Waist Circumference and for identifying abdominally obese adults (cm) (WHO Expert Consultation, 2008)

Country or ethnic group	Men	Women
North American (85% caucasian)	< 90	< 80
Europe, Sub-Saharan African, Eastern Mediterranean and Middle East (Arab)	< 94	< 80
South Asian, Chinese (based on Chinese, Malay and Asian Indian population), South and Central American	< 90	< 80
Japanese	< 90	< 80

Health Risk for Body Mass Index

BMI (kg/m^2)	BMI Category	BMI Risk
< 18.5	Underweight	Increased
18.5 – 24.9	Normal weight	Least
25 – 29.9	Overweight	Increased
30 – 34.9	Obese class I	High
35 – 39.9	Obese class II	Very High
≥ 40	Obese class III	Extremely High

Age:	24				
	Skinfold (mm)		**Girths (cm)**		**diamet (cm)**
#1: Triceps	6.4	#10 Upper arm relaxed	30.5	#17 epicondyle	6.
#2: Subscapular	10.8	#11 Wrist	14.5		
#3 Biceps	4	#12 Upper arm flexed and tensed	33.8		
#4 Suprailiac B	18	#13 Gluteal (hip)	86		
#5 Chest	10.8	#14 Waist	72		
#6 Abdomen B	21.6	#15 Forearm	25		
#7 Front thigh	16	#16 Thigh	50		
#8 Medial calf	8.8				
#9 Mid-axilla	9				
#18 Suprailiac A	19.8				
#19 Suprailiac C	5.6				
#20 Abdomen A	21.2				

Equation to estimate the % of body fat

Authors	**% body fat**	**Density**	**Equations**
Durnin and Womersley (1974)			
Men	17.88	1.0580	BD = 1,1765 - 0,0744(log(#1+#2+#3+#4))
Women	24.84	1.0425	BD = 1,1567 - 0,0717(log(#1+#2+#3+#4))
Forsyth and Sinning (1973)			
Men	22.98	1.0466	BD = 1,10647 - 0,00162(#2)-0,00144(#6)-0,0007
Sloan (1967)			
Men	13.08	1.0689	BD = 1,1043-0,001327(#7)-0,001310(#2)
Women	18.67	1.0562	BD = 1,0764-0,00081(#4)-0,00088(#1)
Thorland et al (1984)			
Men	14.96	1.0646	BD = 1,1091-0,00052(#1+#2+#4+#6+#7+#8+#9
Women	17.42	1.0590	BD = 1,0987-0,00122(#1+#2+#4)+0.00000263(#
Jackson and Pollock (1980)			
Men (sum 7 skinfolds)	10.95	1.0739	BD = 1,112 - 0,00043499*(#1 +#2 +#19 +#5 +#2
Men (sum 3 skinfolds) A	13.83	1.0672	BD = 1,10938 - 0,0008267*(#5 +#20 +#7) + 0,0(
Men (sum 3 skinfolds) B	10.94	1.0739	BD = 1,1125025 - 0,0013125*(#1 +#2 +#5) + 0,(
Women (sum 7 skinfolds)	16.98	1.0600	BD = 1,097 - 0,00046971*(#1 +#2 +#19 +#5 +#2
Women (sum 3 skinfolds) A	12.55	1.0702	BD = 1,0994921 - 0,0009929 * (#1+#19 +#7) + (
Katch and McArdle (1973)			
Homme	11.60	1.0723	BD=1,09665-0,00103(#1)-0,00056(#2)-0,00054(
Femme	17.28	1.0593	BD=1,09246-0,00049(#2)-0,00075(#4)+0,00710
Witner et al (1987)			
Homme	12.82	1.0695	BD = 1,0988-0,0004(#1+#2+#3+#19+#6+#7+#8
Femme	18.35	1.0569	BD = 1,20953-0,08294xlog(#1+#2+#19+#6+#7+

Sample Calculations

<u>Trial 1 - Witner et al. (1987) equation for body density used for Male – Skinfold and Anthropometric Measurement:</u>
Body density = 1.0988 – 0.0004 (6.4+10.8+4.0+5.6+21.6+16+8.8)
= 1.06952 gm/cm^3

Substitute body density into Siri's equation:
% fat = 495/BD - 450
% fat = 495/1.06952 g/cm^3 – 450
% fat = 12.82%

<u>Percent body fat using Siri's equation for Trial 1 in Hydrodensitometry:</u>
% fat = 495/body density – 450
% fat = 495/1.0537 g/cm^3 – 450
% fat = 19.76%

<u>Percent body fat using Brozek's equation for Trial 1 in Hydrodensitometry:</u>
% fat = 457/body density – 414
% fat = 457/1.0537 g/cm^3 – 414
% fat = 19.50%

<u>Mean values calculated for Brozek's equation trials in Hydrodensitometry:</u>
Mean = (19.50% + 20.84% + 18.80%) / 3
Mean = 19.71%