Estimation of subcutaneous fat in men – Part 1: Accuracy of 3 to 9 point measurements

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Abstract

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Purpose

1. To measure whole body subcutaneous fat in men
2. To develop formula for the calculation of whole body subcutaneous fat using three to nine measuring points.

Methods:
In 25 men, aged 23 to 75 (46±14) years, total body subcutaneous fat ("TBSF") was measured using a skin fold calliper. In each person, 116 square sectors with a mean area of 10 square cm were marked on the skin. Subcutaneous fat of each square sector was repeatedly measured using a calliper. No measurements of head, feet, hands and genital area were done. Additionally skin fold measurements were taken at typical points for whole body fat measurement using the calliper method ("CM-points"). TBSF was calculated by adding up the subcutaneous fat of all 116 square sectors. Then an attempt was made to calculate TBSF from either CM-points or a best fit of other skin locations. Both, CM-method and best fit methods, were calculated by means of a forward and backward regression analyses.

Results
Mean body weight of the subjects was 88 ± 15 kg. Whole body subcutaneous fat was 9,11 ± 4,03 kg (10.4% of whole body mass). The estimation of TBSF using CM-points markedly overestimated real TBSF values together with a large range of standard deviation of the differences. The regression analyses of various skin fold measurements proved the use of three points: scapula, tigh and calf. The resulting regression is: $TBSF_{(calc)} = 0.036 + 0.431*scapula + 0.546*tigh + 0.374*calf$.
From the regression analyses three other points were detected: medium back, vastus lat., biceps. The respective regression was: $TBSF_{(calc)} = 0.205 + 0.389*back + 0.692*vastus\ lat. + 0.553*biceps$. Mean difference from real TBSF values was zero in both formula, the latter regression showed even smaller standard deviations of the difference.

Conclusions:
In 25 men subcutaneous fat was estimated using 3-point methods with a tolerable variation from real values. The common points and calculations of calliper skin fold measurement should not be used to estimate subcutaneous fat.

Key words:
subcutaneous fat, total body fat

Introduction

The most direct method to estimate total body fat (TBF) is dual energy X-ray absorptiometry (DXA-scan), where two different x-ray fat absorption images are subtracted from each other [1]. TBF can also be estimated more indirectly using, e.g., air displacement plethysmography (ADP), bioelectric impedance (BIA) and calipometry [3, 4, 5]. All these indirect approaches are based on assumptions, e.g. a two compartment model (ADP), comparison with quite different methods (calipometry) or the body resistance due to electric currents in relation to body weight (BIA). All these methods allow for TBF measuring, without further information about the localisation of the fat. In all cases of high intra abdominal fat, calipometry would even markedly underestimate total body fat since these measurements are based on the amount of subcutaneous fat.
Since it is obvious that the outcome of patients with high intra abdominal fat is worse compared to those with the same amount of extra abdominal fat, a differentiation between intra abdominal and extra abdominal fat would be of high interest.
The so called "essential" fat (about 2-5% in men and 10-13% in women[1]) is quite similar within the gender groups and may be seen as a constant of extra abdominal fat. It may further be assumed that muscle lipids are another part of extra abdominal fat which is a dependent variable

of muscle mass. So the major amount of extra abdominal lipid is subcutaneous fat, which may be directly measured using a skin fold calliper or ultrasound [3]. Total body fat minus essential fat (constant) minus muscle lipids (constant) minus subcutaneous fat (changing due to caloric balance) therefore would indicate intra abdominal fat (IAF). IAF then could be used as an additional quantitative factor of cardio vascular risk. In all available data bases and literature search systems no information about subcutaneous fat measurement has come to our knowledge. So this is apparently the first study to measure subcutaneous fat in a direct approach.

Methods

Study population and clinical measurements

25 men, aged 23 to 75 (46±14) participated in the study after written informed consent (for details see part 2). Since no invasive or threatening procedures were done, no statement of the ethics committee was necessary.

Whole body subcutaneous fat measurement: Whole body surface was mapped by marking 116 (58 left / right) square fields on the skin, each field about 100 mm^2 with the exception of head, hands and feet and pubic area. Measurements were taken in the middle of each field. Subcutaneous fat volume was estimated by multiplication of the square field and fat thickness of each measuring point. The fields were similar on both sides of the body.

As equipment for subcutaneous fat measurement a conventional skinfold calliper (Holtain Calliper, Wales, UK) and an ultrasound measuring device (Bodymetrix BX 2000, IntelaMetrix Inc, Levermore, CA, USA) were used. Since skinfold measuring records double cutaneous and subcutaneous thickness, these results were divided by 2.

Additional measurements: body weight, body composition (proportions of fat, muscle; Tanita SC-240, Tanita Europe B.V. Amsterdam, Netherlands) and body composition (BIA, Akern, SMT Medical, Wuerzburg, Germany); body height, circumference of waist, hip, chest, upper and lower arm and leg in defined regions. Anamnestic data were date of birth and daily activities. The measurements were performed in the morning, the subjects were instructed to keep fasting until all measuring was finished. For all procedures a mean of 4 hours was needed.

Statistical analyses

All data are presented as means ± SD. To compare values, regression/correlation analyses was calculated. To compare the accuracy of various methods, Bland-Altmann Plots [2] were used.

Total subcutaneous fat was calculated as the sum of fat volumes of all mapping squares. Mapping results of whole body subcutaneous fat were compared to existing formula of total body fat measurement (3 and 7 points according to Jackson & Pollock 1978 [4], 9-points according to Parrillo & Greenwood 1993 [6]) and one to three own best fit points.

Results

Comparison of existing calipometry to determine total body fat with whole body subcutaneous fat:

Fig. 1 shows a comparison between mean fat values using whole body subcutaneous fat and the 3 point method according to Jackson & Pollock. The 3 point method would overestimate subcutaneous fat by 3 kg. In all cases (3,7 and 9 point method) subcutaneous fat would be substantially overestimated (3-point method 3.64 ± 2.84 kg; 7-point method 6.8 ± 4.82 kg; 9-point method 13.08 ± 5.07 kg). It becomes further obvious that these differences increase with increasing fat mass.

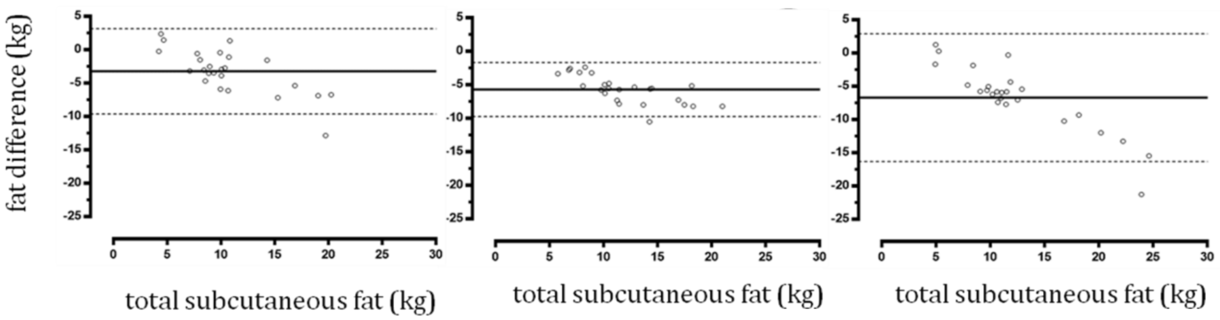


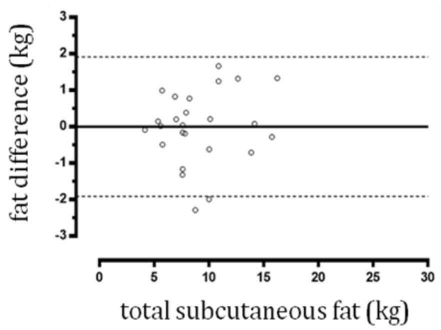
Figure 1. Total subcutaneous fat (x-axis) vs fat estimations derived from 3 or 7 point method (Jackson & Pollock 1978, left and middle) and 9 point method (Parillo 1993, right).

Estimation of best single or multiple points to determine whole body subcutaneous fat:
For the prediction of total body subcutaneous fat (TBSF) 2 models were used.
Model 1: Skin folds typically used for total body fat calipometry.
Model 2: Skin folds as determined from best fit points

In model 1 from 10 points 3 showed to work best. The resulting formula (TBSF1) is:
TBSF1 (kg) = 0.036 + 0.431 x scapula + 0.546 x thigh + 0.374 x calf (skin fold in mm).

In model 2 12 points all over one half side of the body were used. The respective formula (TBSF2) is:
TBSF2 (kg) = 0.205 + 0.389 x back + 0.692 x thigh + 0.553 x biceps

When compared, the variance of model 1 was smaller than ± 1.92 in 95% of all cases, compared to ± 1.17 for model 2 (Fig. 2). TBSF measurements were: Mapping 9.11 ± 4.03, model one 9.11 ± 3.26 and model two 9.12 ± 3.36.



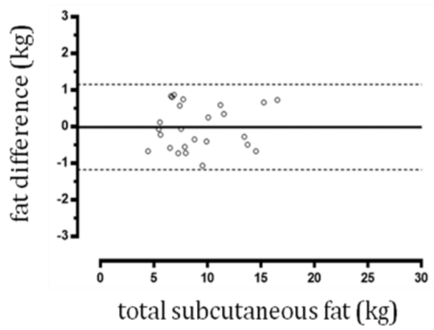


Figure 2. Total subcutaneous fat (x-axis) vs. fat estimations derived from model 1 (left) or model 2 (right; explanations see text)

Discussion and Conclusions

To our knowledge this is the first study to measure subcutaneous fat in men by whole body mapping. It could further be shown that the use of 3 single points allows the estimation of total body subcutaneous fat with sufficient precision, compared to gold-standard total body mapping. Skinfold thickness in the middle of scapula, thigh and calf may easily and repeatedly be used for fast measurement of total body subcutaneous fat. Since the variation of models 1 and 2 differed only moderately and since mean subcutaneous fat values and variations were similar to mapping results in models 1 and 2, model one may be recommended for general use due to the easiest handling.
Total body formula using skin fold measurements, corrected by whatever constant, are not suitable for subcutaneous fat estimations since the results vary in dependency of subcutaneous fat mass.

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