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Subcutaneous Fat Patterns in Type-2 Diabetic Men and Healthy Controls

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A B S T R A C T

The optical device LIPOMETER enables the non-invasive, quick, and save determination of the thickness of subcutaneous adipose tissue layers at any given site of the human body. The specification of 15 evenly distributed body sites allows the precise measurement of subcutaneous body fat distribution, so-called subcutaneous adipose tissue topography (SAT-Top). In the present paper we focus on SAT-Top of male type-2 diabetes patients (N=21), describing very precisely their special SAT development and their SAT-Top deviation from a healthy control group (N=111), applying factor analysis and ROC curves. Factor analysis revealed three independent subcutaneous body fat compartments, which can be summarised as »upper body«, »lower trunk« and »legs«. The upper body SAT-Top is much more pronounced in diabetic men compared to their healthy controls ($p<0.001$). Furthermore, high diagnostic power by ROC curve analysis was achieved by different measurement sites of the upper body and summary measures of upper body obesity (sum_2, which is the sum of neck and biceps, provides: area index = 0.86, sensitivity = 81 %, specificity = 90.1 %, at an optimal cutoff value of 18.8 mm), ascribing a higher diabetes probability to subjects with a more upper body SAT-Top pattern. Calculating new ROC curves for diabetic patients with HBA_{1C} values >8 (N=17) and their healthy controls (N=111) we received improved discrimination power for several SAT-Top body sites, especially for sum_2, showing an area index of 0.91, a sensitivity of 94.1 %, and a specificity of 90.1 % at the optimal cutoff value of 18.8 mm. Concluding, the exact and complete description of the especial type 2 diabetic SAT pattern, which differs strongly from the SAT-Top of healthy controls, suggests the LIPOMETER technique combined with advanced statistical methods such as factor analysis and ROC curve analysis as a possible detecting tool for this disease.

Key words: *fat distribution, body composition, lipometer, subcutaneous adipose tissue topography (SAT-Top), metabolic disorders*

Introduction

Obesity, which has now developed into a world-wide epidemic with an increasing tendency, is a well known risk factor for type-2 diabetes mellitus in women and men. Some authors[1–7] reported on a relationship between this disease and an excess of central abdominal obesity, which can be assessed easily by waist circumference, waist/hip circumference ratio (WHR) or even more accurate by computed tomography (CT). Correlations have been found between body fat distribution and type-2 diabetes[3,8–10], especially, a concentration of fatness on the upper part of the body is discussed to be due to type 2 diabetes in men[8,11–13]. Though these results underline the importance of investigating the distribution of body fat, we have to face the problem that subcutaneous fat distribution is always measured in an inaccurate (Caliper) and/or very simplified way (CT cuts at 2 or 3 levels). Therefore, an exact and complete description of the subcutaneous body fat pattern in type 2 diabetic patients might contribute to the search for predictors of this disease among anthropometric measures.

The computerized optical device LIPOMETER (EU patent number 0516251) allows a non-invasive, quick,

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precise and safe determination of the thickness of subcutaneous adipose tissue (SAT) layers at arbitrarily chosen sites of the human body. The technical characteristics of the measurement system and a first validation of the results using CT as reference method have already been published earlier[14,15]. Fifteen anatomically well-defined body sites were specified to standardise LIPOMETER measurements[16,17], providing a subcutaneous adipose tissue topography (SAT-Top) of the human body. SAT-Top includes the complete subcutaneous fat distribution information of a subject, which is like an individual »fingerprint«.

Previously, we reported on the precise SAT-Top differences between women suffering from type-2 diabetes and healthy controls[18–21], suggesting the LIPOMETER technique as a possible predictor for this disease. Recently, we measured SAT-Top of male type-2 diabetes patients, compared their body fat distribution to healthy controls and described the results by common statistics[22].

In the present paper we investigate the number and location of independent subcutaneous body fat compartments for these male diabetic patients, which likely deviate from previous results of healthy adults[16,18]. Furthermore, the discriminative power of the 15 different SAT layer thicknesses between healthy and diabetic subjects is calculated and optimal cutoff values are determined. Finally, after describing precisely a typical subcutaneous fat pattern for male diabetics, we try to answer the question, if patients with higher HbA_{1C} values (> 8) provide also a more pronounced »diabetic fat pattern« compared to the group of all 21 diabetics (providing partly also lower HbA_{1C} values).

Subjects and Methods

Diabetic subjects

Height, weight, HbA_1C and SAT-Top of a group of 21 men with clinically overt type-2 diabetes (m_d) were measured at the Department of Internal Medicine, Medical University Graz, in order to provide their subcutaneous body fat distribution. Their descriptive statistics are presented in Table 1.

Healthy subjects

A group of 287 »healthy« men was recruited as a part of a »health and fitness check« in order to measure their height, weight and SAT-Top. They were divided into five age groups by decades (m_1: 20–30 yr,..., m_5: 60–70 yr). Of these men, 111 belonging to the same age group as diabetic men were selected as a healthy control group (m_h). Fasting glucose levels below 110 mg/dl were defined as non-diabetic. Only men who were not suffering from a chronic disease were selected for the »healthy« group. Their personal characteristics are also presented in Table 1. Patients and healthy controls did not differ in physical activity, eating and smoking habits, alcohol consumption and ethnicity.

SAT-Top measurement

The sensor head of the optical device LIPOMETER consists of a set of light emitting diodes as light sources and a photodetector. During measurement this sensor head is held perpendicular to the selected body site. The diodes illuminate this SAT-layer, forming geometrically varying light patterns in succession. The photodiode measures the corresponding light intensities back scattered. These resulting light pattern values of a measured body site were calculated to absolute SAT layer thicknesses (in mm) using CT as reference method[14]. Concerning the measurement agreement between CT and Lipometer we received a correlation coefficient of $r = 0.99$, a regression line $y = 0.97 x + 0.37$, and a systematic deviation of the Lipometer measurements from the CT results of 0.0 ± 1.3 mm (Bias ± SD)[14].

To standardise the Lipometer measurements 15 specified body sites were chosen. An exact description of these body sites together with their coefficient of variation was previously presented[16,17,21]. The measurement points are evenly distributed over the whole body and top-down sorted from neck to calf. Measurements are performed on the right body side, while subjects are standing. The measurement results can be summarized as SAT-Top, describing precisely the subcutaneous fat distribution pattern of a subject[16,17]. The complete SAT-Top measurement cycle of one subject lasts about two minutes.

Statistics

Statistical calculations were performed by SPSS for WINDOWS. SAT-Top values are partly highly intercorrelated. Therefore, the application of factor analysis (principal components method) is very useful to reduce this multidimensional SAT-Top information[23]. The measure of sampling adequacy (MSA) by Kaiser-Meyer-Olkin[24], which is regarded to be the best testing criterion, was applied to test the qualification of the dataset for factor analysis. MSA ranges from 0 to 1 and should be higher than 0.8[25]. $MSA < 0.5$ is regarded as »unacceptable«; $MSA \geq 0.8$ is »meritorious«[26]. The MSA value for a data set is calculated by the statistical program SPSS and obtained as a result of factor analysis.

To calculate the factor value scores of an individual, we have to standardise SAT-Top values, using the means and standard deviations of all 132 subjects. The 15 standardised values are multiplied by the factor score coefficient matrix (FSCM), which is a result of factor analysis. The obtained factor values can be used as coordinates in a factor value plot.

To calculate the discrimination power of the different body sites between diabetic men and their healthy controls, ROC curve analyses were performed. For each parameter of the dataset, consisting of actually negative (healthy) and actually positive (diabetic) cases, an ROC curve was calculated. Two different *a priori* hypotheses can be specified for each investigated parameter: that smaller or larger values are stronger associated with the disease. The area under the ROC curve is calculated by

TABLE 1
DESCRIPTIVE STATISTICS [MEAN VALUE ± SD (MIN – MAX)] OF SAT-Top's OF 21 DIABETIC MEN AND 111 HEALTHY CONTROLS OF THE SAME AGE GROUP [1]

Personal parameters	Diabetic men (N=21)	Healthy men (N=111)	Significance of differences [2]
Age (y)	57.5 ± 6.7 (49.1–67.7)	59.0 ± 5.4 (50–69.7)	n.s. [3]
Height (cm)	173.1 ± 4.7 (165–183)	173.7 ± 6.3 (161–197)	n.s.
Weight (kg)	86.4 ± 8.6 (65.8–106)	81.7 ± 10.2 (60–110)	n.s.
1-Neck [4]	14.9 ± 3.6 (7.0–21.9)	9.9 ± 3.9 (2.4–29.1)	p<0.001
2-Triceps	6.1 ± 2.2 (2.5–10.9)	5.0 ± 2.0 (1.6–11.6)	p=0.020
3-Biceps	5.9 ± 2.0 (3.3–10.9)	4.0 ± 1.8 (1.4–14.2)	p<0.001
4-Upper back	8.1 ± 2.1 (4.5–11.2)	5.7 ± 1.8 (2.4–10.0)	p<0.001
5-Front chest	9.8 ± 2.7 (4.1–15.1)	7.5 ± 3.4 (1.5–18.3)	p=0.005
6-Lateral chest	10.6 ± 3.8 (3.7–18.0)	8.7 ± 3.1 (2.0–17.7)	p=0.010
7-Upper abdomen	11.9 ± 3.9 (6.3–20.5)	10.8 ± 3.8 (2.6–19.5)	n.s.
8-Lower abdomen	10.1 ± 2.1 (6.1–13.2)	9.5 ± 3.0 (2.1–19.5)	n.s.
9-Lower back	11.6 ± 2.5 (6.1–19.3)	9.1 ± 3.0 (1.8–17.2)	p=0.001
10-Hip	11.3 ± 3.9 (6.0–21.8)	10.1 ± 3.7 (1.6–23.7)	n.s.
11-Front thigh	5.6 ± 1.7 (3.3–9.7)	4.5 ± 1.7 (1.1–10.2)	p=0.005
12-Lateral thigh	4.5 ± 1.4 (3.1–9.7)	3.5 ± 1.8 (1.4–10.9)	p<0.001 [5]
13-Rear thigh	3.9 ± 1.2 (2.4–7.1)	3.0 ± 1.3 (1.4–7.3)	p<0.001 [5]
14-Inner thigh	8.4 ± 2.2 (4.7–13.5)	6.9 ± 2.5 (2.1–13.8)	p=0.013
15-Calf	3.3 ± 0.8 (2.3–5.4)	2.7 ± 1.2 (1.0–9.5)	p<0.001 [5]
Factor 1 [6]	1.0 ± 1.2 (–1.5–2.8)	–0.2 ± 0.8 (–1.7–3.9)	p<0.001
Factor 2 [7]	–0.0 ± 0.9 (–1.6–1.8)	0.0 ± 1.0 (–2.5–2.6)	n.s.
Factor 3 [8]	0.4 ± 0.9 (–1.1–2.1)	–0.1 ± 1.0 (–1.8–2.9)	p=0.040

[1] Previously, this set of data was partly published[22]
[2] By t-test for independent samples
[3] Not significant (p>0.05)
[4] SAT thickness of 15 body sites in mm
[5] By Mann-Whitney U-test
[6] Corresponds to upper body SAT development
[7] Corresponds to lower trunk SAT development
[8] Corresponds to leg SAT development

the statistical program, rendering a measure for the discriminating power of a parameter: an area index of 0.5 indicates a poor diagnostic test (low discriminating power), while a value of 1.0 indicates an ideal test (high discriminating power). An area index < 0.5 shows the necessity of changing the *a priori* hypothesis, and recalculating the ROC curve for this new assumption. E.g., an area index of 0.85 for the body site *neck* indicates that our subjects can be classified very well as healthy or diabetic by the measurement values of this body site.

Sensitivity and specificity are calculated for each parameter at different cutoff points (e.g. at the cutoff point of... 12 mm, 14 mm, 16 mm... for the body site *neck*). Using the specificity as x-coordinate and the sensitivity as y-coordinate, these cutoff points describe the corresponding ROC curve of a parameter. The highest sensitivity and specificity are obtained at the optimal cutoff value, which is estimated by the Youden index[27]. This optimal cutoff value provides the best discriminating results between healthy and diabetic subjects (e.g., 13.6 mm for the body site *neck*), whereby larger values are stronger associated with the disease.

Results

The SAT-Top measurement values of the 21 diabetic patients and their 111 healthy controls were partly highly intercorrelated (from r=0.20 to r=0.69), especially the body sites of the upper trunk and the arms provided high correlations (from *1-neck* to *6-lateral chest*: r=0.49 to 0.69). Therefore, the statistical method of factor analysis might be useful to analyse this dataset, to reduce the amount of data, and to extract the essential information.

We obtained an MSA value of 0.91 which is regarded as »marvellous«[26], showing that the dataset is highly adequate for the application of factor analysis. The statistical program extracted three factors (eigenvalues > 1), which corresponds to the existence of three independent subcutaneous body fat compartments in our subjects. Each of the 15 SAT-Top values provides a »loading« to each of the three factors, showing the strength of the relationship (Table 2). Factor 1 consists of five body sites of the upper trunk and the arms (*1-neck*, *2-triceps*, *3-biceps*, *4-upper back* and *5-front chest*). The body site *6-lateral chest*, which is situated between upper and lower trunk, (consequently) provides high loadings for factor 1 and factor 2, and could be added to both of these factors. Because of the higher loading it was added to factor 2, together with four body sites of the abdominal region (*7-upper abdomen*, *8-lower abdomen*, *9-lower back* and *10-hip*). Factor 3 consists of five body sites of the legs (*11-front thigh*, *12-lateral thigh*, *13-rear thigh*, *14-inner thigh* and *15-calf*). The resulting three independent subcutaneous body fat compartments – which can be summarised as »upper body«, »lower trunk« and »legs« – are depicted in Figure 1, showing the special and precise subcutaneous body fat development of diabetic men and their healthy controls.

The factor 1, factor 2 and factor 3 scores of each individual can be calculated using the FSCM, mean values and standard deviations presented in Table 3. The resulting factor scores can be applied as x-, y- and z-coordinates in a three-dimensional factor value plot (Figure 2): Upper body SAT-Top increases for healthy men from age group 1 (m_1) to age group 3 (m_3), afterwards it decreases slightly (m_4, m_5); it is much more pronounced in diabetic men (m_d) compared to their healthy controls (m_h) ($p<0.001$, Table 1). Lower trunk SAT-Top provided no significant differences between healthy and diseased subjects. Leg SAT development decreases for healthy subjects through all subsequent age groups (from m_1 to m_5). Diabetic patients showed slightly significant ($p=0.04$, Table 1) higher leg SAT-Top values than their healthy controls.

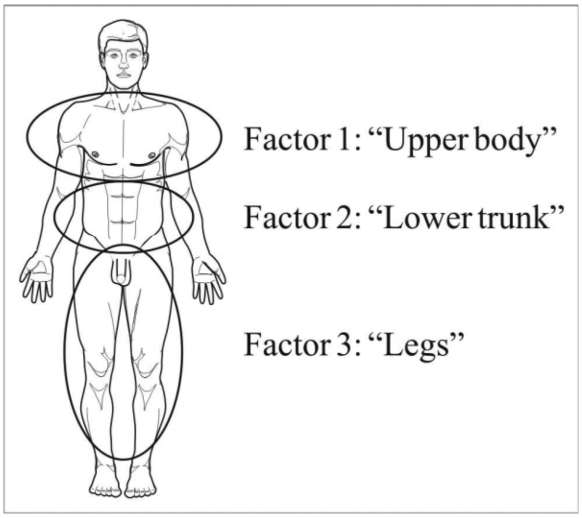

Fig. 1. In male type-2 diabetic patients and their healthy controls the fifteen top-down sorted SAT-Top body sites are summarised to three independent subcutaneous body fat compartments by factor analysis: upper body (factor 1), lower trunk (factor 2) and legs (factor 3).

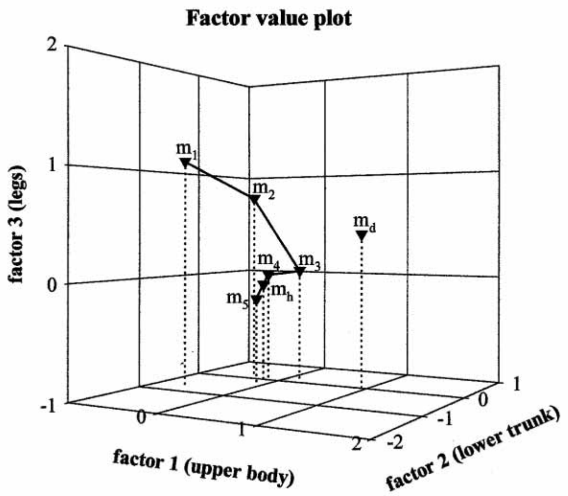

Fig. 2. A factor value plot showing the precise SAT-Top development of type-2 diabetic men (m_d), their healthy control group (m_h), and different age groups of healthy men (m_1: 20–30yr, ..., m_5: 60–70yr) for comparison with m_d in relation to the three factors.

ROC curves, the corresponding area indices, and the optimal cutoff values were calculated for age, height, weight, SAT-layer thicknesses at all 15 body sites, and the three factors. Results are presented in Table 4, showing the area indices for these variables for the two assumptions that either small or large values provide stronger evidence for type-2 diabetes. High area indices (> 0.8) were obtained only for the second assumption, that larger values are indicative for the disease: 0.85 for the body site *neck* (sensitivity = 76.2 %, specificity = 87.4 %, at the optimal cutoff value 13.6 mm), 0.81 for the *biceps* (sensitivity = 90.5 %, specificity = 58.6 %, at the optimal cutoff value 4.1 mm), and 0.81 for the *upper back* (sensitivity = 71.4 %, specificity = 81.1 %, at the optimal cutoff value 7.3 mm). Consequently, factor 1 (which is related to upper body SAT-Top) shows high discriminating power (area index = 0.78, sensitivity = 66.7 %, specificity = 85.6 %, at the optimal cutoff value 0.58). Poor results are obtained, for example, for the body sites at the abdominal region (*upper abdomen* (0.58), *lower abdomen* (0.58) and *hip* (0.59)), and consequently for factor 2 (0.51), which is related to lower trunk SAT-Top.

With the idea of further increasing the resulting area indices, several composite variables based on the numerous separate body sites were constructed. Body sites providing high discriminating power were combined to different summary measures. Among these variables, the best area indices were obtained by:

$$sum_1 = \text{neck} + \text{biceps} + \text{upper back},$$

$$sum_2 = \textit{neck} + \textit{biceps}, \text{ and}$$

$$sum_3 = \text{neck} + \text{upper back}.$$

Notably, all these constructed summary measures consist of upper body sites, whereby large values are related more strongly to the disease. If upper body obesity is

TABLE 2

THE ROTATED FACTOR MATRIX PRESENTS THE LOADINGS OF THE FIFTEEN BODY SITES FOR THE THREE FACTORS FOR EXAMPLE, THE BODY SITE NECK IS STRONGER RELATED TO FACTOR 1 (0.753) THAN TO FACTOR 2 (0.351) OR FACTOR 3 (0.193)

Body site	Factor 1	Factor 2	Factor 3
1-Neck	0.753	0.351	0.193
2-Triceps	0.580	0.296	0.383
3-Biceps	0.779	0.227	0.322
4-Upper back	0.787	0.169	0.275
5-Front chest	0.622	0.448	0.184
6-Lateral chest	0.533	0.631	0.144
7-Upper abdomen	0.293	0.761	0.082
8-Lower abdomen	0.176	0.750	0.174
9-Lower back	0.331	0.421	0.375
10-Hip	0.211	0.767	0.200
11-Front thigh	0.188	0.408	0.697
12-Lateral thigh	0.303	0.169	0.686
13-Rear thigh	0.155	0.097	0.840
14-Inner thigh	0.148	0.506	0.638
15-Calf	0.400	0.023	0.680

more pronounced these values increase. Sum_1 provided an increased area index of 0.87 (sensitivity = 81 %, specificity = 83.8 %, at an optimal cutoff value of 24.7 mm), sum_2 showed a result of 0.86 (sensitivity = 81 %, specificity = 90.1 %, at an optimal cutoff value of 18.8 mm), and sum_3 provided also 0.86 (sensitivity = 76.2 %, specificity = 87.4 %, at an optimal cutoff value of 20.5). The ROC curves of the best discriminator, sum_2 (best combination of sensitivity and specificity), and for the poorest discriminator, factor 2, are depicted in Figure 3. Calculating further ROC curves for diabetic patients with HBA_{1C} values >8 (N=17) and their healthy controls (N=111) we received improved discrimination power for several SAT-Top body sites, especially for the *neck* (area index=0.89), the *biceps* (0.83), *upper back* (0.83), *lower back* (0.81), and consequently for factor 1 (0.83), sum_1 (0.90), sum_2 (0.91) and sum_3 (0.90). The best result was obtained for sum_2, showing an area index of 0.91, a sensitivity of 94.1 %, and a specificity of 90.1 % at the optimal cutoff value of 18.8 mm (Figure 4).

TABLE 3

FACTOR SCORE COEFFICIENT MATRIX (FSCM) OBTAINED BY FACTOR ANALYSIS. TO CALCULATE THE FACTOR 1, FACTOR 2 AND FACTOR 3 SCORES OF AN INDIVIDUAL, THE SAT MEASUREMENTS OF THIS INDIVIDUAL MUST BE STANDARDISED THEREFORE, MEANS AND SDs OF THE 132 HEALTHY AND DIABETIC SUBJECTS ARE PRESENTED

Body site	FSC 1	FSC 2	FSC 3	Means ± SDs
1-Neck	0.333	–0.049	–0.131	10.7 ± 4.2
2-Triceps	0.189	–0.052	0.026	5.1 ± 2.1
3-Biceps	0.355	–0.145	–0.051	4.3 ± 1.9
4-Upper back	0.389	–0.175	–0.071	6.1 ± 2.1
5-Front chest	0.221	0.049	–0.115	7.9 ± 3.4
6-Lateral chest	0.117	0.187	–0.136	9.0 ± 3.2
7-Upper abdomen	–0.063	0.344	–0.125	11.0 ± 3.8
8-Lower abdomen	–0.159	0.362	–0.042	9.6 ± 2.9
9-Lower back	–0.010	0.098	0.070	9.5 ± 3.0
10-Hip	–0.148	0.358	–0.039	10.3 ± 3.7
11-Front thigh	–0.182	0.093	0.288	4.7 ± 1.7
12-Lateral thigh	–0.031	–0.080	0.282	3.7 ± 1.8
13-Rear thigh	–0.145	–0.096	0.414	3.2 ± 1.3
14-Inner thigh	–0.222	0.170	0.253	7.2 ± 2.5
15-Calf	0.092	–0.220	0.277	2.8 ± 1.1

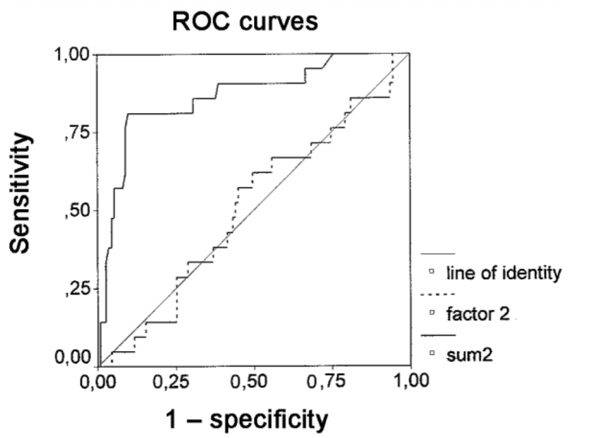

Fig. 3. ROC curves for discrimination between male type-2 diabetes mellitus patients and healthy men by SAT-Top measurements. The best discriminator (sum_2) and the poorest result (factor 2) are depicted.

Discussion

The optical device LIPOMETER offers the possibility of precisely determining the complete subcutaneous fat pattern of a subject. This is an important novel feature for investigating the SAT distribution in healthy subjects and patients suffering from different metabolic disorders, which often go along with obesity, zonal obesity and/or a typical body fat distribution[28–30].

Comparing the LIPOMETER SAT thicknesses to Caliper skinfolds at comparable body sites, we always find higher values for Caliper measurements[17,31], whereby great differences are found especially at plain body sites (e.g. sub-scapular), and small differences at rounded body sites (e.g. triceps). Generally, the differences between the two methods might be caused by measuring a double layer of skin and a compressed double layer of SAT using the Caliper technique, which leads to inaccurate measurements[32].

In the present paper we focus on SAT-Top of male type-2 diabetes patients, describing their special SAT development and their SAT-Top deviation from a healthy control group. Most studies concerning this topic investigate the importance of visceral adipose tissue (VAT) for this disease, others applied inaccurate measurement methods (Caliper) and/or present only fragmentary results. Using this measurement device LIPOMETER combined with advanced statistical methods for data evaluation, we are able to present a satisfying and complete solution for the problem mentioned above.

In healthy subjects, factor analysis provided two independent subcutaneous fat compartments: trunk and extremities. With growing age, subcutaneous fat is shifted away from the extremities towards the trunk, which is a well-known masculinizing process[16,33]. In female type-2 diabetic patients we previously reported on three top-down sorted SAT compartments: upper trunk, lower trunk and legs[18], which underlined the different SAT development in healthy and diseased subjects. Now we could find the same classification of SAT compartments in male type-2 diabetic patients, showing the similar SAT-Top development for both sexes in case of this disease, and confirming the present results.

The factor value plot (Figure 2) might be a good instrument for visual description of individual SAT-Top development. Additional (male) subjects can be depicted in this plot after measuring their SAT-Top values. A higher risk for type-2 diabetes might be ascribed to subjects situated closer to the diabetic group m_d, which means that they provide a more pronounced upper body obesity compared to healthy subjects.

Vague[11] described sex-related patterns of adipose tissue distribution in relation to type-2 diabetes, characterizing lower-extremity adiposity as »gynoid adiposity« and noting that it had less impact on the manifestation of type-2 diabetes than accumulation of truncal fat, which was characterized as »android adiposity«. Our results, which are more precise, might contribute to this still ongoing search for diabetes predictors among anthropometric measures. Moreover, changes in VAT, either as increases over time or as decreases in relationship to weight loss interventions, predict associated changes in glucose and insulin homeostasis[5]. However, some studies also suggest that the abdominal subcutaneous adipose tissue area was a better correlate of these variables and upper-body subcutaneous fat is the dominant contributor to circulating free fatty acids[34]. By adding measures describing the VAT development (like waist circumference), our results might be improved in future studies.

In addition to the visualising results of factor analysis, ROC curve statistics extracted the discriminating power between the healthy and diseased group out of the dataset, providing area indices, sensitivities, specificities and optimal cutoff values. Concluding, high diagnostic

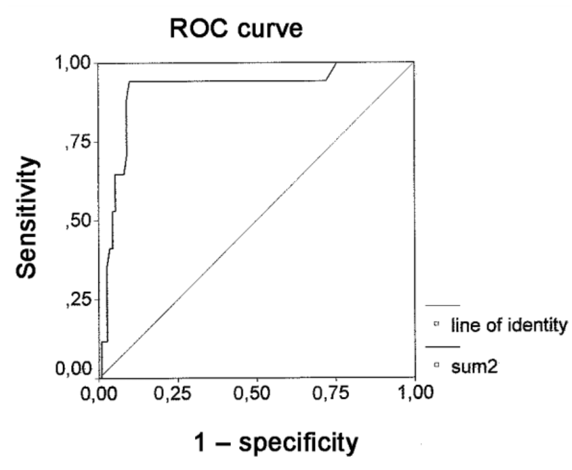

Fig. 4. ROC curve for discrimination between male type-2 diabetes mellitus patients with a HbA_{1C} value >8 and healthy men by SAT-Top measurements. The best discriminator (sum_2) is depicted.

TABLE 4
AREA INDICES TOGETHER WITH THEIR SIGNIFICANCE OBTAINED FROM ROC CURVE ANALYSIS FOR AGE, HEIGHT, WEIGHT, 15 SPECIFIED SAT-LAYERS, THREE FACTORS, AND THREE SUMMARY MEASURES OF 21 MALE TYPE-2 DIABETES PATIENTS AND 111 HEALTHY MEN. OPTIMAL CUTOFF VALUES ARE SHOWN FOR VARIABLES WITH HIGH AREA INDICES (>0.7)

Personal parameters	Area index H_0: small [1]	Area index H_0: large [1]	p-value cutoff [2]	Optimal
Age	0.582	–	n.s. [3]	–
Height	0.535	–	n.s.	–
Weight	–	0.645	p=0.036	–
1-Neck	–	0.847	p<0.001	13.6 mm
2-Triceps	–	0.641	p=0.041	–
3-Biceps	–	0.810	p<0.001	4.1 mm
4-Upper back	–	0.813	p<0.001	7.3 mm
5-Front chest	–	0.722	p=0.001	8.1 mm
6-Lateral chest	–	0.659	p=0.021	–
7-Upper abdomen -	–	0.580	n.s.	–
8-Lower abdomen -	–	0.576	n.s.	–
9-Lower back	–	0.757	p<0.001	10.6 mm
10-Hip	–	0.586	n.s.	–
11-Front thigh	–	0.695	p=0.005	–
12-Lateral thigh	–	0.758	p<0.001	3.1 mm
13-Rear thigh	–	0.743	p<0.001	2.9 mm
14-Inner thigh	–	0.687	p=0.007	-
15-Calf	–	0.740	p<0.001	2.3 mm
Factor 1 [4]	–	0.777	p<0.001	0.582
Factor 2 [5]	–	0.505	n.s.	–
Factor 3 [6]	–	0.653	p=0.027	–
Sum_1 [7]	–	0.869	p<0.001	24.7 mm
Sum_2 [8]	–	0.862	p<0.001	18.8 mm
Sum_3 [9]	–	0.863	p<0.001	20.5 mm

1 There are two possible hypotheses (H_0): that small/large values provide stronger evidence for disease
[2] Optimal cutoff value estimated by Youden index[27]
[3] Not significant (p>0.05)
[4] Corresponds to upper body SAT development
[5] Corresponds to lower trunk SAT development
[6] Corresponds to leg SAT development
[7] Sum_1 = neck ± biceps ± upper back
[8] Sum_2 = neck ± biceps
[9] Sum_3 = neck ± upper back

power was achieved by different measurement sites of the upper body and summary measures of upper body obesity, ascribing a higher diabetes probability to subjects with a more android fat pattern. The ROC results for male diabetics even surpass the findings for women suffering from type-2 diabetes on which was reported previously[20].

Concluding, the exact and complete description of the especial type 2 diabetic SAT pattern, which differs strongly from the SAT-Top of healthy controls, suggests the Lipometer technique combined with advanced statistical methods such as factor analysis and ROC curve analysis as a possible detecting tool for this disease.

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RASPORED POTKOŽNE MASNOĆE KOD MUŠKARACA S DIJABETESOM TIPA 2 I KONTROLNE SKUPINE

S A Ž E T A K

Optički uređaj LIPOMETER omogućava ne-invazivno, brzo i sigurno određivanje debljine potkožnih adipoznih slojeva tkiva na bilo kojem mjestu ljudskog tijela. Utvrđivanje 15 podjednako raspoređenih mjesta na tijelu omogućava precizno mjerenje distribucije potkožne tjelesne masnoće, takozvanu topografiju potkožnog adipoznog tkiva (SAT-Top). U ovom se radu fokusiramo na SAT-Top (topografiju potkožnog adipoznog tkiva) muškaraca s dijabetesom tipa 2 (N = 21), opisujući vrlo precizno razvoj njihovog potkožnog adipoznog tkiva (SAT) i devijaciju njihove topografije potkožnog adipoznog tkiva (SAT-Top) u usporedbi sa kontrolnom skupinom (N = 111), primjenjujući faktorsku analizu i ROC krivulje. Faktorska analiza otkrila je tri nezavisne šupljine s potkožnom tjelesnom masnoćom, koje se mogu definirati kao »gornji dio tijela«, »donji dio trupa« i »noge«. Gornja tjelesna topografija potkožnog adipoznog tkiva (SAT-Top) znatno je izraženija kod muškaraca dijabetičara u usporedbi sa zdravom kontrolnom skupinom ($p < 0{,}001$). Osim toga, velika je mogućnost dijagnostike analizom ROC krivulja dobivena mjerenjem na različitim mjestima gornjeg dijela tijela i ukupnih mjera pretilosti gornjeg dijela tijela (sum2, koja je zbroj vrata i bicepsa, omogućava: područni indeks = 0,86, osjetljivost = 81%, specifičnost = 90,1%, na optimalnoj graničnoj (cutoff) vrijednosti od 18,8 mm), pripisujući veću vjerojatnost dijabetesa kod ispitanika s većim rasporedom SAT-Top (topografije potkožnog adipoznog tkiva) gornjeg dijela tijela. Računajući nove ROC krivulje za pacijente dijabetičare s HBA1C vrijednostima > 8 (N = 17) i za kontrolnu skupinu (N = 111) dobili smo poboljšanu mogućnost razlikovanja za nekoliko SAT-Top mjesta na tijelu, osobito za sum2, pokazujući područni indeks od 0,91, osjetljivost od 94,1% i specifičnost od 90,1% optimalne granične (cutoff) vrijednosti od 18,8 mm. Zaključno, točan i potpun opis posebnog uzorka potkožnog adipoznog tkiva (SAT) dijabetesa tipa 2, koji se bitno razlikuje od topografije potkožnog adipoznog tkiva (SAT-Top) zdrave skupine, ukazuje da LIPOMETER tehnika kombinirana s naprednim statističkim metodama poput faktorske analize i analize ROC krivulja može biti sredstvo za otkrivanje ove bolesti.