ADIPSMETER
A New Skinfold Calliper System

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Abstract: Nowadays, the assessment of body composition is of great meaning but traditional skinfold callipers recognized in the nutritional area have not been technologically updated to provide a more effective performance with greater accuracy, allowing automatic data processing and recording in a database, offering a more user friendly handling not requiring technicians with a high degree of expertise. In order to overcome many of these deficiencies a new instrument named Adipsmeter was designed and developed. A new mechanical skinfold calliper structure has been digitally instrumented for reading skinfold thickness and equipped with wireless communication capabilities with a personal computer where a software application, integrating a database, is installed and prepared for driving a technician along a specific protocol incorporating many regression equations used in current body fat measurement at an affordable price. Its measurement range is from 0 to 110 mm, consistent with a range of use from children to obese individuals. Between the two opposing clamping surfaces mounted on its rigid arms the pressure has a constant value of 10 gf/mm^2 in the whole measurement range. It has small dimension and weight and while being robust provides comfortable handling. The sensing system resolution is less than 0.1 mm, the wireless communication (MiWi) is suitable for healthcare environments, with 25 h of autonomy. The software application, with an intuitive and user friendly interface, is based in Visual Basic 2008.

1 INTRODUCTION

Nowadays, the assessment of body composition by estimating the percentage of body fat (%BF) has a great impact due to the constant demand from the World Health Organization (European Parliament, 2008) in order to combat obesity, now considered the twenty-first century disease.

The measurement of skinfold thickness using a skinfold calliper is a simple, non-invasive and cost-effective method for assessing body composition (Jackson et al., 2009), recognized in the nutritional area as an expeditious, portable and affordable tool.

However, the traditional skinfold calliper available in the market does not take advantage of today´s technology in order to provide more effective assessment with greater accuracy, allowing automatic data processing and recording in a database, offering a more user friendly handling not requiring technicians with high degree of expertise. In order to overcome many of these problems a new instrument named Adipsmeter was designed and developed, consisting in a skinfold calliper electronic instrumented structure and a software application.

Initially, some amendments were done to the mechanical support of a Harpenden skinfold calliper in order to integrate digital sensing and a wireless communication system with a software application developed in LabVIEW (Restivo et al., 2009, Restivo et al., 2010).

This sequential test procedure application helps technicians with low level of expertise, not requiring reading or mental time counting always subjective (Norton and Olds, 1996), increasing test efficiency and quickness. Moreover, it immediately processes data using many regression equations allowing its recording.

The performance of this equipment has been compared with that of a traditional Harpenden and also validated against the reference Dual-energy X-ray Absorptiometry system (DXA). A significant

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agreement in the assessment of body composition was found in a sample of 40 adults (Amaral et al., 2010).

In spite of the important features of this skinfold calliper solution, problems related with mechanical, handling and ergonomic caracheristics still existed. Also the wireless communication protocol was not the most suitable for health care environments. Due to the inherent characteristics of the Harpenden structure the skinfold calliper force between clamps did not remain constant for the whole measurement range (42% variation) and the clamps stiffness did not allow them to remain parallel, specially for higher skinfold thickness.

For solving all the mechanical weaknesses inherent to the Harpenden skinfold calliper a new structure has been carefully designed.

2 INTEGRATED SYSTEM

The main goal of the Adipsmeter prototype development has been to create an advanced digitally instrumented skinfold calliper for reading skinfold thickness, capable of wireless communication with a personal computer software application, integrating a database.

This integrated system for assessing body composition, the Adipsmeter, consists of a software application, LipoSoft-2010, and a mechanical device, a skinfold calliper specially designed to interact with such an application and to provide better technical characteristics than those available in the market.

2.1 Mechanical Device

The mechanical device comprises basically a closed cylindrical body and a structure of two jaws terminated by mechanically oriented clamps, manipulated by a handle and a lever, Figure 1.

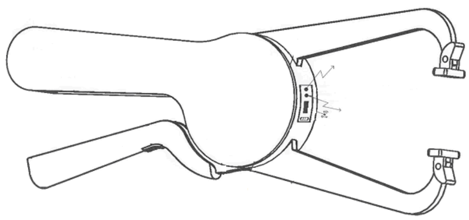

Figure 1: The mechanical device.

The cylindrical body includes all the mechanical elements of constant force transmission to the jaws, the sensing element, the interaction buttons, the battery and all the electronics.

The handle has passive return through a transmission chain ensuring a nearly constant pressure between clamps of about 10 gf/mm^2 for the whole measurement range which at present goes up to 110 mm allowing its use in obese individuals. But the mechanical solution developed allows this measurement range to be further increased without losing the mechanical performance. The devices in the market offer a limited measurement range, below 80 mm.

A mechanical rotating mechanism keeps the parallelism between the clamps faces for any jaw opening angle.

The electronic system integrates a battery charging system, the conditioning signal and a dedicated microcontroller. It also enables wireless communication with the LipoSoft-2010 application. The microcontroller is responsible for managing the entire device. Interaction with the application is performed with buttons in the device body. The electronics energy consumption has been optimized and the device offers 25 hours autonomy.

Compared to the skinfold callipers available in the market this device is a medium size, lightweight and handling balanced. Its design symmetry allows easy use by left handed technicians.

2.2 Digital Sensing and Communication

For measuring skinfold thickness a rotary incremental encoder is used. The jaws rotating angle is multiplied by five.

The encoder provides two quadrature channels, each with 500 pulses/revolution. Since the maximum jaw opening (110 mm) is equivalent to a 250° rotating angle, the skinfold measurement resolution is 0.07 mm.

The wireless communication system uses a MiWi protocol, suitable for health care environments.

The measurement resolution and the data transfer rate are suitable for future studies of dynamic tissue behaviour.

2.3 Software Application LipoSoft2010

The software application LipoSoft-2010, developed in Visual Basic 2008, offers a user friendly graphical interface suitable to be used by technicians without high training level, Figure 2.

A database integrated with the application allows the searching of individual files and data updating, as well as the registration of any new individual.
A body image is also presented and helps to clarify the body location of the chosen skinfold under

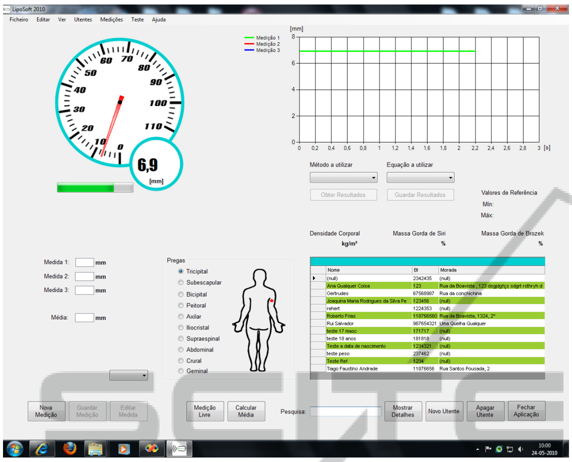

Figure 2: The LipoSoft-2010 application.

measurement, for any of them. When the measurement procedure is finished, by using any of the available methods, this image is also used for giving a pictorial idea of the percentage of the individual body fat composition evaluation by using the colour associated to the established %BF levels. A final assessment report can be generated and printed.

The software application allows an easy inclusion of new features, such as regression equations or any other developed algorithm. It can be used as a training tool by guiding the user through the established procedure and allowing the step-by-step progress along the measurement protocol.

3 MAIN CHARACTERISTICS

The new mechanical design, the improved sensing system and the communication solution give to Adipsmeter better technical features, which combined with its easier use, make it a very competitive device.

The measuring range of 0 to 110 mm allows obesity evaluation with constant pressure between clamps.

The sensing system presents an overall measurement resolution of 0.07 mm. The MiWi system for wireless communication is suitable for healthcare environments. The device autonomy is of 25 h.

This skinfold calliper presents a medium size dimension and offers robustness, easy handling and lightweight. Its configuration is adequate for both right- and left-handed users. The production cost is low, definitely below that of the Harpenden skinfold calliper.

Table 1 summarizes the main characteristics of this integrated system, Adipsmeter, in comparison to those of the traditional Harpenden skinfold calliper.

Table 1: Some characteristics of Harpenden and Adipsmeter skinfold callipers.

	Harpenden	Adipsmeter
Measurement range	0 - 80 mm	0 - 110 mm
Resolution	0.2 mm	0.07 mm
Pressure	10 gf/mm^2 >25 % variation	10 gf/mm^2 <5% variation
Type of reading	Analogue	Digital
Material	Metal	Metal
Weight	475 gf	340 gf
Cost	700 £	< 500 €

Although the 10 gf/mm^2 pressure value between clamp surfaces has been consistently found in the literature as a standard for the measurement protocol and so referred as a characteristic for all skinfold callipers available in the market, this pressure value is far from being kept constant throughout the whole measuring range for the Harpenden calliper.

The tests, reported in Table 2, show that the new mechanical device respects this pressure standard and maintains the 10 gf/mm^2 value throughout its extended measurement range with an error below 5%.

Table 2: Comparative study of the error in pressure.

		Harpenden	Adipsmeter
Pressure (gf/mm^2)	0-40 mm	6.7 – 7.9	9.8 – 10.2
	40-80 mm	5.0 – 6.6	9.8 – 10.2
	80-110 mm	--	10.2 – 10.3
	Total range	5.0 – 7.9	9.8 – 10.3
Error in pressure	0-40 mm	17.0%	3.6%
	40-80 mm	27.5%	3.6%
	80-110 mm	--	1.2%
	Total range	45.6%	4.8%

4 SYSTEM PERFORMANCE

The performance of this new system was evaluated in a first instance, using a sample of 14 adults, aged from 19 to 26 years. Both callipers, traditional Harpenden and Adipsmeter, were used for measuring biceps, triceps, subscapular and iliocristal skinfolds.

The body density was estimated using the equations of Durnin & Womersley (Durnin and Womersley, 1974) and the %BF was estimated using the equation of Siri (Siri, 1961). Table 3 presents the statistical data corresponding to the respective sample.

Table 3: Characterization of the sample (n =14)[a].

Age (years)	21.36 ± 4.80
Height (m)	1.64 ± 1.33
Weight (kg)	59.60 ± 8.01
Original Harpenden BF (%)	27.94 ± 5.49
Adipsmeter BF (%)	28.26 ± 5.52
Adipsmeter - Harpenden (%)	0.31 ± 0.58

[a] Mean values ± standard deviation.

A strong association between the values of the %BF, calculated by the equation of Siri, with skinfold measurement made with both the original Harpenden skinfold calliper (%BF Harpenden) and with the Adipsmeter (%BF Adipsmeter) was achieved (r = 0.996). The slope of the regression line is near the unit (0.999), corroborating the agreement between these two variables, Figure 3.

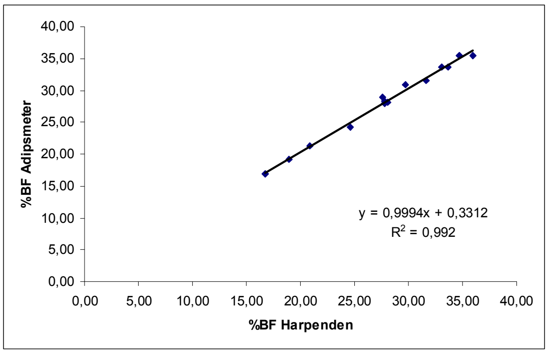

Figure 3: Percent body fat (%BF) measured by Harpenden and by Adipsmeter linear relationship. (—) linear fit line.

In this study, the value of SEE (standard error of the estimate) (0.58) is ideal according to the existing bibliography indicating that SEE must be less than 3% for a new method to be accepted as accurate (Lohman, 1996).

It is also reported in the literature that the total error, TE, can be calculated as:

$$TE = \sqrt{\sum (y_A - y_H)^2 / n} \qquad (1)$$

where y_H and y_A are the values measured by Harpenden and Adipsmeter, respectively) is the best parameter for evaluating differences between two measures (Lohman, 1992). In our study, TE is 0.31, indicating a very high level of agreement between the measurements obtained by the two skinfold callipers.

5 FINAL COMMENTS

The integrated system Adipsmeter, due to its mechanical design, presents better technical characteristics, namely an extended measurement range, a near constant pressure between clamp surfaces for the whole measurement range, better handling and lighter weight. Its electronics provides also a better resolution and a suitable wireless protocol for health environments.

The automatic task procedure during measurement significantly reduces evaluation subjectivity and considerably increases the checking task efficiency, offering graphical information of the %BF individual level.

Nevertheless, new developments are now being prepared for improving even further the novel skinfold calliper performance. Since the rate and resolution of the data transfer are suitable for studies of tissue dynamics, the main idea is to explore the dynamic response of subcutaneous tissues when subject to a compression effect in order to better characterize the body composition.

Furthermore it is within one of the main objectives to take advantage of current techniques such as artificial neural networks as well as the Adipsmeter capabilities for developing new algorithms for data processing (Barbosa et al., 2010).

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