www.sensorsportal.com

Sensors & Transducers

http://www.sensorsportal.com

LipoWise: A New Generation of Skinfold Calipers

[1, 2] Manuel Rodrigues QUINTAS, [1] Tiago F. ANDRADE,
[1, 2] Maria Teresa RESTIVO, [1, 2] Maria de Fátima CHOUZAL,
[1, 3] Teresa AMARAL

[1] LAETA - Associated Laboratory for Energy, Transports and Aeronautics
[2] Faculty of Engineering, University of Porto
[3] Faculty of Nutrition and Food Sciences, University of Porto
Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
Tel.: 351225081400, fax: 351225081440
E-mail: mrq@fe.up.pt, tfa@fe.up.pt, trestivo@fe.up.pt, fchouzal@fe.up.pt, amaral.tf@gmail.com

Received: 14 November 2014 /Accepted: 15 January 2015 /Published: 28 February 2015

Abstract: The skinfold caliper is a non-invasive anthropometric technique regularly used to assess the nutritional status of clinical and non-clinical individual samples for evaluation of body composition percentage. A skinfold caliper allows obtaining important anthropometrical data using a simple and portable tool, with a non-invasive and cost-effective procedure. Using regression equations, the skinfolds thickness measurement allows estimating the individual body fat. However, this approach has some limitations and no evolution has been registered on the skinfold calipers recognized in the literature and used for health, sports and nutritional evaluations. Moreover, studies on the skinfolds compressibility pattern have not been explored because the available skinfolds calipers do not have not this feature which needs to be complemented by data storage tools, namely for large scale studies. Efforts for developing new algorithms, for example, if based in dynamic tissue response are also limited by the traditional skinfold calipers. The integrated LipoTool system intends to contribute to those goals due to its novel characteristics. The LipoTool features are briefly described. The paper highlights the innovative capacities of LipoTool, and explores preliminary studies of the tissue compressibility pattern in order to open new methodology for assessing other parameters rather than the skinfold evaluation based in the use of a high diversity of regression equations to estimate body fat percentage. Different prototypes have been used by people in the health and nutrition areas and, the feedback has been very positive as a powerful tool for assessing and tracking, training and study. Now, the next step is to carry on research in order to develop new models and different application domains. In this work a very exploratory attempt is presented. The LipoTool will be soon in the market and it has been registered as LipoWise. *Copyright © 2015 IFSA Publishing, S. L.*

Keywords: Skinfold caliper, Data recording, skinfold compressibility, Skinfold measurement protocol.

1. Introduction

Changes in the nutritional status of an individual are one of the most common health problems and with high impact in society at individual, social and economic levels [1]. Malnutrition, obesity or even the co-existence of both are a major world health problem documented by the World Health Organization (WHO) [2].

According to the WHO, over 50 % of the European adult population is overweight or obese. In fact, excess body fat may lead to the increase of coronary heart disease, high blood pressure, type 2 diabetes, obstructive lung disease, arthritis, and some types of cancer [3]. Malnutrition is also related to other diseases generating costs to the European Health System comparable to those associated with overweight and obesity [4].

Malnutrition is a global issue that affects billions of people. The term malnutrition refers to both undernutrition and overnutrition. Traditionally, undernutrition is prevalent in developing countries and obesity is an epidemic in developed countries. Recently, obesity has been increasing in developing countries, leading to a double burden of disease, especially in urban settings [5, 6].

Therefore, the quantification and screening of Body Fat (BF) composition is very important in the health area. For monitoring BF, several techniques are used being based the most usual on the estimation of Body Mass Index (BMI). BMI estimation is based on height and weight evaluation, although leading to very inaccurate results according to the literature [7, 8]. The measurement of skinfolds using a caliper and the Bioelectrical Impedance Analysis (BIA) measurement based in body resistance and reactance are techniques widely used. The Dual-energy X-ray Absorptiometry (DXA) for image evaluation is considered a valid body fat measuring device [9].

The BMI calculation is a highly empirical method that only gives a rough idea of body fat. The DXA method has great accuracy, but is invasive and requires very expensive bulky type equipment, adequate facilities, and expert technicians, resulting in high cost/test rate [10].

The BIA is the technique that competes directly with the skinfold caliper. The BF is calculated based in correlating impedance and reactance values obtained by passing an alternating electrical current through the body [11]. It is a recent and widely used method requiring a convenient preparation not often respected. Individual preparation before the test typically includes several requirements:

- Avoid exercising within 12 hours of the test;
- No alcoholic drinks within 48 hours of the test;
- Do not drink coffee within 48 hours of the test;
- Avoid diuretics within 24 hours of the test;
- Urinate completely prior to testing;
- Abstain from eating and drinking within 4 hours of the test.

Failure to meet these requirements leads to very poor, inaccurate results.

Skinfold caliper methodology has advantages over other techniques because it is a simple method (portable, easy to use and not requiring special individual preparation), non-invasive and low cost; it provides reliable results compared with the DXA [12].

The measurement protocol prescribes a uniform distributed pressure of 10 gf/mm^2 [13] to be applied to the skinfold by the end tips. After positioning the end tips, three seconds should be counted (as recommended), and then, the skinfold thickness value may be recorded. With the value of skinfold thickness and with the individual anthropometric data, the percentage of BF is estimated by selecting an equation from a huge set of equations (more than 60) related with individual data.

In fact, the assessment method based on the skinfold measurement has a well-defined protocol but the commercial equipment, considered in the literature and available in the market, lacks technical evolution.

The challenge of this work starts precisely from the lack of progress and precision that this type of device has experienced since its development in the 1960s and aims at overcoming these limitations. A new measurement system called LipoTool was designed and tested for BF measurement. The integrated LipoTool system intends to achieve all requirements for this method: the pressure between end tips should be uniform and constant (10 gf/mm^2) as established by the protocol, to guaranty and to improve the precision and measurement resolution, to offer a larger measurement range, to minimize or even to discard subjective operator errors (thickness reading and measurement time counting), to facilitate the recording and monitoring of patient results (data recorded in database), to guide the technician through the complete procedure, and to provide a database for large scale studies. Additionally, the system also intends to allow further studies in the health and nutrition fields and even for other applications in distinct areas (now, it is possible to record the dynamic tissue response during the skinfold compression interval).

The work aims at highlighting new studies and some results already available due to the device unique features. The authors believe that new algorithms, namely, based on dynamic tissue response will be possible to be developed with LipoTool. However, these studies will need samples referred to another method reported in the literature.

In the present work, Section 2 describes the integrated system LipoTool, comprising a digital skinfold caliper, named Adipsmeter, and its communication system with the LipoSoft application, highlighting the used technology. Section 3 provides details of the LipoTool performance, namely, the constant pressure between end tips according with the followed measurement protocol and its novel capabilities for evaluating tissue compressibility. This allows accurate studies on the effect of the time interval duration for skinfold measurement and its significance in the final evaluation of %BF. Section 4 presents preliminary studies based on the evaluation of tissues compressibility. Finally, in the conclusions, it is stressed how it can be a powerful tool in the assessing and tracking, training, study and research domains, such as nutrition and health, forensic sciences, veterinary science and sports.

2. The LipoTool Integrated System

The technological solution of LipoTool, depicted in Fig. 1, comprises a new digital skinfold caliper Adipsmeter (1), an antenna AirPCOn (2) for wireless communication with a computer and a software application LipoSoft (3).

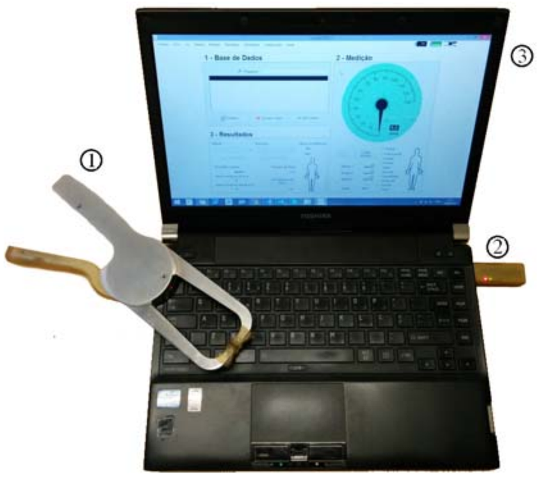

Fig. 1. LipoTool system.

2.1. The Adipsmeter Digital Skinfold Caliper

The Adipsmeter mechanical design was studied, conceived and implemented in order to guarantee a constant pressure value of 10 gf/mm^2 between end tips, to increase the caliper measurement range and to reduce the measurement subjectivity due to five novel features: a constant force actuator mechanism, a cam to compensate changes in force, a controlled end tips articulation for keeping their clamping surfaces parallel to each other over all its opening range, a large jaws center distance permitting greater openings without increasing the device size and, finally, a symmetric design to make it independent of the operator dominant hand.

The entire mechanism can be seen in Fig. 2. The two jaws (4) opening is accomplished by the operator through the manipulation of a fixed handle (1) and a lever (2). The simultaneous opening is achieved because the two jaws rotate around fixed axes and are interconnected by means of mechanical elements. Jaws closing action is operated by a transmission chain connected at the other end to a constant force actuator based on an elastic element. This actuator has the double effect of being the force element of the system while simultaneously eliminating all possible backlash in the transmission chain. The inclusion of a cam (3) whose profile compensates variations in the length of the applied force arm, guarantees the application of a constant force by the clamping surface of the end tips (5) to the skinfold under measurement. The end tips are hinged at the rotation axes in the extremities of the jaws, keeping their clamping surfaces parallel to each other at any opening level. This is achieved by a movement transmission mechanism that provides a constant and uniform pressure on the complete contact area between the end tip clamping surfaces and the skinfold.

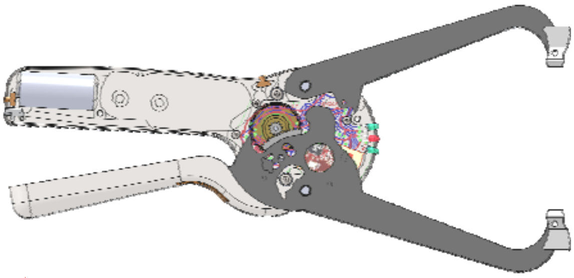

Fig. 2. Schematics of the transmission chain.

LipoTool is much more convenient and precise than any traditional skinfold caliper both in daily use and in large scale actions.

The integration of the mechanical design with electronics and informatics design enables to obtain a final resolution of 0.025 mm, to reduce the time measurement subjectivity, to reduce individual reading errors, to follow the tissue compressibility, to facilitate the use of the method by incorporation of all known equations, and also to integrate a database that enables the monitoring of individuals.

2.2. The Communication and the LipoSoft Application

The transmission rate for the wireless communication between the Adipsmeter and LipoSoft (60 samples/s) allows to register the dynamic tissue response for any skinfold under compression. It is also possible to monitor small changes in temperature during the compression process.

So, studies based on dynamic tissue response will be performed using traditional dynamic systems modelling techniques, such as time and frequency response, artificial neural networks, and genetic algorithms. We think that more flexible models could be achieved offering additional methods for BF evaluation, overcoming the use of more than 60 regression equations, at the present. In line with this idea, a study using neural networks has been reported by Barbosa, et al. [14].

The current electronic solution uses Microchip Technology Inc. [15] components for both processing and wireless communication. For the communication, data processing 8 bit microcontrollers were used. For the wireless communication, antennas were used with the communication protocol MiWi, based on the IEEE 802.15.4 standard for Wireless Personal Area Networks (WPANs) [16].

The digital measurement sensor of the caliper is an encoder of angular type and also includes a temperature sensor (miniaturized thermocouple bid). The angular encoder is connected directly to the microcontroller through two specific ports. The antenna and the temperature converter communicate with the microcontroller by Serial Peripheral Interface bus (SPI) and the set of buttons (included in the Adipsmeter) communicate through digital ports. In the AirPCOn antenna, two microcontrollers are used, communicating with Universal Synchronous/Asynchronous Receiver/Transmitter (USART) between them. One is used to communicate with the computer via Universal Serial Bus (USB) and the other with the antenna by SPI, as shown in Fig. 3.

The LipoSoft application was developed in Visual Basic.NET and communicates with the antenna through the USB port. The interface is divided into three blocks: Database, Measurement and Results, as shown in Fig. 4.

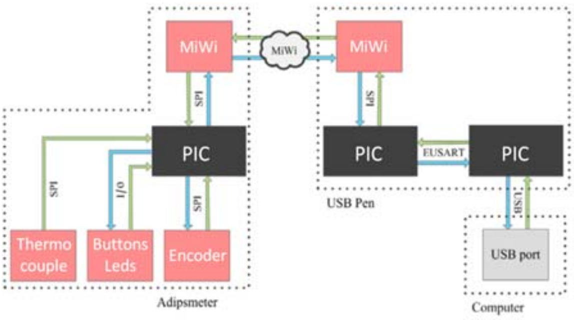

Fig. 3. Communications diagram.

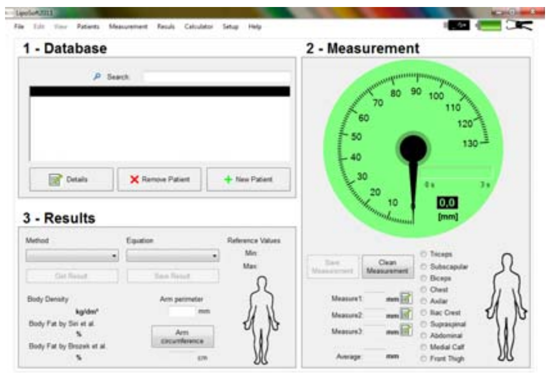

Fig. 4. LipoSoft interface.

It is possible to introduce different settings through the LipoSoft user interface, as well as to turn off the Adipsmeter.

3. Testing the LipoTool Performance

This section provides details of the LipoTool performance, namely, the constant pressure between end tips according with the followed measurement protocol. It also describes novel capabilities for evaluating tissue compressibility with relevant outcomes in the investigation of the influence of the skinfold measurement protocol time in the final skinfold thickness evaluation and to identify the type of tissue response under a constant applied force during skinfold thickness measurement.

The first goal was achieved by comparing the pressure between caliper end tips within the measurement range for the Adipsmeter and the Harpenden caliper [17], the latter being the market reference. The second objective is to study the relevance of the protocol time interval value for measuring skinfolds.

3.1. Constant Pressure Between End Tips

According to the protocol, the pressure between end tips should be 10 gf/mm^2 for the whole measurement range.

In order to compare the pressure values between end tips, their area and the force between them were digitally monitored and measured. A mechanical structure able to ensure repeatability and the same conditions in force measurements for both devices (Adipsmeter and Harpenden) was developed integrating a load cell of 5 LBS measurement range. An aluminum structure was built for housing the load cell (ensuring the force discharge without friction) and room for gauge blocks in order to measure force for different skinfold calipers accurate opening, from 15 mm to 120 mm.

The Adipsmeter end tips are articulated; so their surfaces are always parallel for any opening. For that reason, the measurement process is simple to carry out. In other cases in which there is no parallelism between end tips (and so between skinfold contact surfaces), which is the case of the Harpenden caliper, it is essential to use special care by introducing additional calculations for compensating the lack of parallelism. Once the force is equally distributed by careful design of the mechanical test system, this leads to uniformity in the pressure distribution on the surface of the end tips, and therefore, in the skinfold surface.

Fig. 5 presents the results from lab tests for comparing the Adipsmeter and the Harpenden calipers in terms of pressure between the end tip surfaces at different openings. Fig. 5 shows the evolution of the pressure between end tips for different jaw opening along the measurement range of each caliper - Harpenden: 0-80 mm; Adipsmeter: 0-120 mm.

It also shows a non-constant pressure between end tips, i.e., Harpenden caliper does not accomplish the protocol requirement exhibiting a decreasing pressure with the opening increase. On the other hand, the Adipsmeter offers an increase of 50 % in the measurement range and a constant pressure between end tips.

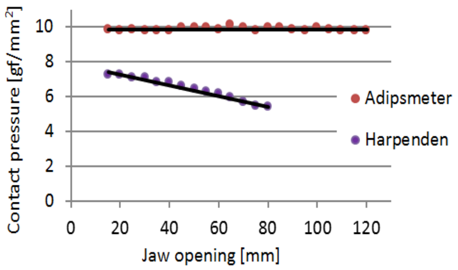

Fig. 5. Pressure test between end tips for different jaw opening.

3.2. Tissues Compressibility Pattern

LipoTool provides a unique ability by allowing to monitor and to register the skinfold behavior along the skinfold measurement.

LipoTool offers a transmission rate of 60 samples/s and thus it is possible to record the tissue compressibility pattern during a standard time interval but it allows it to be adjusted for performing additional studies.

Fig. 6 shows an example of the recorded information during a tricipital skinfold measurement procedure for a heterogeneous set of 10 individuals. The data were processed in order to exhibit a normalized evolution of individual skinfolds during measuring time allowing a better comparison between individual skinfolds behavior.

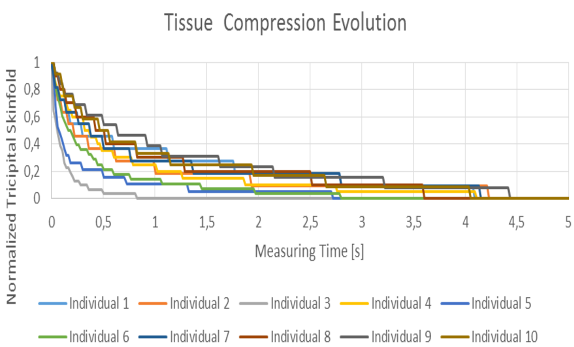

Fig. 6. Normalized tissue compression evolution of tricipital skinfolds.

The dynamic evolution of tissue compressibility shows very different characteristics among individuals.

3.3. Time Interval for Skinfold Measurement

The time evolution of the tissue response measurement permits to evaluate the time required for the skinfold measurement by observing the tissue response.

Studies of the protocol time interval have never been done based in an accurate procedure. The LipoTool system is able to read skinfold thickness and perform time evaluation in an intrinsic and precise digitally automatic way and to record them for later processing and evaluation. Nevertheless, Lohman [18] and Norton and Olds [19] have recommended the use of 2 s and 3 s after applying the calipers' end tips to the skinfold, as result of their empirical studies based in huge samples; but, it was impossible to read time and thickness with precision as it can be made by LipoTool.

In our study for evaluating tissue compressibility, the measurement procedure has followed the International Standards for Anthropometric Assessment recommendations [20]. A sample of 36 adults (50 % women) aged between 21 and 49 years old was evaluated and all the participants were informed of the study purposes as well as the different procedures.

The tricipital skinfold was measured with the LipoTool system and the evolution of tissue compressibility during the initial 5 s was registered. The body density was estimated using the equations of Durnin and Womersley [21] and the % BF was estimated using the equation of Siri [22]. All these estimations were done in intervals of 0.5 s and the difference between these values in consecutive moments was calculated. The results are presented in Table 1.

Table 1. Body fat percentages for tricipital skinfold.

		Time [s]										
		0	0,5	1	1,5	2	2,5	3	3,5	4	4,5	5
%BF (Siri)	Men	27,1	26,1	25,9	25,9	25,8	25,8	25,7	25,7	25,7	25,7	25,6
% dif*			1,0	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0
%BF (Siri)	Women	26,6	25,4	25,2	25,2	25,1	25,1	25,0	25,0	25,0	25,0	24,9
% dif*			1,3	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0

Observing data from Table 1, it is evident that changes over 2.5 s are not meaningful when determining the % BF and this suggests the need for revision of the time interval for skinfold measurement.

4. Evaluation of Tissues Compressibility: Preliminary Studies

The variation in skinfolds compressibility may be due to several factors, including differences in skin thickness and tension caused by the subcutaneous tissue and the distribution of connective tissue and blood vessels. This variability can be mediated by genetic factors or result from changes in nutritional status and degree of hydration. In fact, the proportion of intra and extra-cellular water affects the thickness of the skin folds. However, studies conducted on the relationship between hydration state and the tissues compressibility pattern has not been conducted.

Thus the compressibility of the skinfolds has not yet been characterized. The advancement of knowledge in this area could contribute to the optimization of the measuring process of subcutaneous fat and the estimation of body composition.

One of the reasons that can justify the fact that the skinfold compressibility pattern has not been explored is the inability of the available equipment for performing this type of measurement. The new system LipoTool has these capabilities and has been already used in preliminary studies in Forensic [23, 24] and in Nutrition areas [25, 26].

4.1. The Formulated Hypothesis

Observing Fig. 6, the authors are formulating the hypothesis that for each individual it is possible to distinguishing two behaviors in the skinfold thickness compressive evolution. One to be related with the connective tissue and the other with the adipose tissue, each one corresponding to different decay rates, being the first decay rate higher than the second one. These decay rate values, are to be related with the percentage of connective and adipose tissue, respectively.

4.2. The Sample

For preliminary exploration a cross-sectional study was conducted on a sample of 29 adults. Those individuals provided free and informed consent to this investigation.

Exclusion criteria were defined such as the existence of pacemaker, amputation, lipodystrophy, pachyderm and dialysis therapies, as these situations prevent the complementary evaluation using BIA or decrease its validity. The assessment of body composition and hydration status was performed by tetrapolar BIA (model Tanita Body Corporation Multi Frequency Analyser MC - 180 MA). Anthropometric measurements were also collected. The measurement of skinfolds was performed by using the LipoTool system, for the standard protocol time of 3 s.

4.3. Results

Fig. 7 shows an example of the recorded information during a tricipital skinfold measurement procedure for a sample of 29 individuals. The data were processed to get the normalized evolution of individual skinfolds during measuring time.

A very simple consideration on the tissue compression pattern for the individuals, suggests that the skinfold behavior under compression as being is like a 1st order system response to a step excitation (the constant force applied by the caliper end tips).

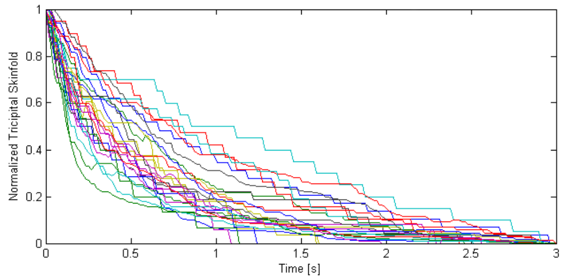

Fig. 7. Normalized tissue compression evolution of tricipital skinfolds.

This leads to fit each individual data, by a function like:

$$f(t) = f_0 + a \cdot e^{-t/\tau}, \qquad (1)$$

where $f(t)$ is the skinfold thickness time evolution, f_0 is the final skinfold thickness traditionally used for evaluating the BF, and τ is the time constant, as depicted in Fig. 8 based in one individual tricipital skinfold measured values.

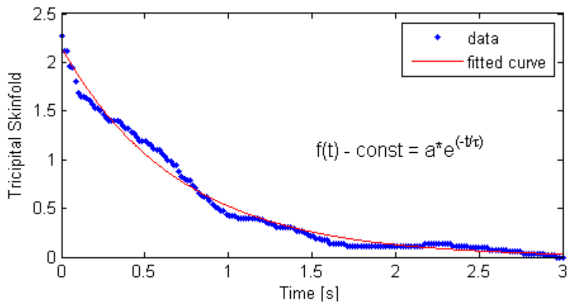

Fig. 8. Example of an excitation step response of a first order system.

One of the formulated hypotheses is that the response time for each individual could be related with the connective tissue parameter, as the body water.

Fig. 9 plots the relation between the time constant for each individual and the respective body water data obtained from BIA. This relation, even for a very small sample, depicts a tendency that suggests that a smaller time constant means higher body water, once this material will exhibit a higher compression rate when compared to that of adipose tissue.

6. Conclusions

LipoTool presents innovations that allow its use for accurate and fast assessment of body composition by measuring skinfolds. These new novel features open possibilities for new studies as evidenced and suggested in the previous work [27] and reinforced in the present new data analysis. These studies are original and can provide the basis for the identification of novel parameters based in skinfold caliper, a simple and non-invasive method. Based on the skinfold tissue compressibility new models can be implemented and lead to the evaluation of new parameters, in addition to the % BF.

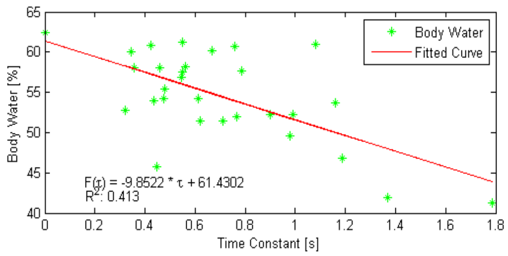

Fig. 9. Body water [%] versus time constant [s].

However, future studies have to be based in homogeneous and convenient samples sizes with a reduced number of influencing variables in order to enable the derivation of a mathematical model that provides optimal data fitting.

LipoTool is now under market development, registered as LipoWise, and can easily incorporate such new models in the future.

Acknowledgements

The authors wish to thank the support of the Portuguese national Foundation for Science and Technology (FCT).

References

[1]. European Parliament Resolution of 25 September 2008 on the White Paper on nutrition, overweight and obesity – related health issues (2007/2285(INI)) P6_TA(2008)0461.

[2]. World Health Organization, Global health risks: mortality and burden of disease attributable to selected major risks, (NLM classification: WA 105), 2009.

[3]. Y. C. Wang, K. McPherson, T. Mars, S. L. Gortmaker, and M. Brown, Health and economic burden of the projected obesity trends in the USA and the UK, *The Lancet*, Vol. 378, Issue 9793, 2011, pp. 815 - 825.

[4]. C. A. Russell, The impact of malnutrition on healthcare costs and economic considerations for the use of oral nutritional supplements, *Clinical Nutrition Supplements*, Vol. 2, Issue 1, 2007, pp. 25–32.

[5]. A. M. Prentice, The emerging epidemic of obesity in developing countries, *International Journal of Epidemiol*, 35, 1, 2006, pp. 93-9.

[6]. World Health Organization, Global strategy on diet, physical activity and health, *57th World Health Assembly (WHA)*, 2004.

[7]. K. J. Rothman, BMI-related errors in the measurement of obesity, *International Journal of Obesity*, 2008, Suppl. 3, pp. 56-59.

[8]. S. B. Heymsfield, T. G. Lohman, Z. Wong, and S. B. Going, Human Body Composition, 2nd edition, *Human Kinetics*, Champaign, 2005.

[9]. K. J. Ellis, Human body composition: in vivo methods, *Physiol Rev.*, 80, 2, 2000, pp. 649–680.

[10]. S. B. Heymsfield, Development of imaging methods to assess adiposity and metabolism, *International Journal of Obesity*, 32, 7, 2008, pp. 76-82.

[11]. A. Fürstenberg and A. Davenport, Comparison of Multifrequency Bioelectrical Impedance Analysis and Dual-Energy X-ray Absorptiometry Assessments in Outpatient Hemodialysis Patients, *American Journal of Kidney Diseases*, 57, 1, 2010, pp. 123-129.

[12]. H. J. Krämer and H. V. Ulmer, Two-second standardization of the Harpenden Calliper, *European Journal of Applied Physiology and Occupational Physiology*, 46, 1981, pp. 103-104.

[13]. D. A. W. Edwards, W. H. Hammond, M. J. R. Healy, J. M. Tanner, and R. H. Whitehouse, Design and Accuracy of Callipers for Measuring Subcutaneous Tissue Thickness, *British Journal of Nutrition*, 9, 2, 1955, pp. 133–143.

[14]. M. R. Barbosa, T. Amaral, M. F. Chouzal, and M. T. Restivo, Neural Networks Based Approach to Estimate Body Fat (%BF), in *Proceedings of the 9th Portuguese Conference on Automatic Control (CONTROLO'10)*, 2010, pp. 7-10.

[15]. Microchip Technology Inc. [Online]. Available from: http://www.microchip.com/ 2014.10.24

[16]. Y. Yang, Microchip MiWi™ P2P Wireless Protocol, *Microchip Technology Inc.*, 2010.

[17]. Baty International. Harpenden Skinfold Caliper. [Online]. Available from: http://www.harpenden-skinfold.com/ 2014.10.24

[18]. T. G. Lohman, Advances in Body Composition Assessment: Current Issues in Exercise Science, Champaign, *Human Kinetics*, Vol. 5, Issue 2, 1992, pp. 3–4, Series Monograph No. 3.

[19]. K. Norton and T. Olds, Anthropometrica, *University of New South Wales Press*, Sidney, Australia,1996.

[20]. M. Marfell-Jones, T. Olds, A. Stewart, and L. Carter, International standards for anthropometric assessment, Potchefstroom, South Africa: *International Standards for Anthropometric Assessment*, 2006.

[21]. J. V. Durnin and J. Womersley, Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years, *British Journal of Nutrition*, 32, 1, 1974, pp. 77-97.

[22]. W. E. Siri, Body composition from fluid spaces and density. Analysis of methods, in Techniques for Measuring Body Composition, (Brozek J, Henschel A., Eds.), *National Academy of Sciences*, Washington, DC, 1961.

[23]. F. L. Ferreira, Estimation of cadaveric rigidity – modifications of the mechanical properties, FEUP-MSc thesis in Bioengineering, 2013.

[24]. P. Martins, R. N. Jorge, M. Parente, and A. Santos, Necromechanics: death induced changes on the mechanical properties of human tissues, submitted to Part H: *Journal of Engineering in Medicine*, 2014.

[25]. M. T. Restivo, T. F. Amaral, M. F. Chouzal, C. P. Leão, R. S. Guerra, E. Marques, J. Mendes, M. Quintas, and J. Mota, A digital Calliper for training and study purposes, *Asia Pacific Journal of Clinical Nutrition*, 2012, Vol. 21, 2, pp. 182-190.

[26]. T. F. Amaral, T. Restivo, M. R. Quintas, F. Chousal, C. M. Silva, and T. F. Andrade, LIPOTOOL – A New Integrated System for Assessment of Body

Composition, in *Proceedings of the XXXIV ESPEN Congress*, 2012, Vol. 7, Issue 1, pp. 177,

[27]. Manuel Rodrigues Quintas, Tiago F. Andrade, Maria Teresa Restivo, Maria de Fátima Chouzal, Teresa Amaral, LipoTool: Evaluation of Tissues Compressibility (*SENSORDEVICES'14*), *The 5th International Conference on Sensor Device Technologies and Applications*, November 16 - 20, 2014, Lisbon, Portugal, pp.103-108.
