

Relationship between infrared skin radiation and muscular strength tests in patients affected by Emery-Dreifuss muscular dystrophy

A. Cabizosu^{a,*}, N. Carboni^b, A. Martínez-Almagro Andreo^a, G. Casu^b, Claudio Ramón Sánchez^c, J.M. Vegara-Meseguer^a

^a Universidad Católica de Murcia (UCAM), Spain

^b Azienda Sanitaria Locale Nuoro, Hospital San Francesco, Italy

^c Cátedra de investigación Hospital de Molina, Spain

ARTICLE INFO

Keywords:

Thermography
Emery-Dreifuss
Strength tests

ABSTRACT

Considering that infrared thermography is presented as a diagnostic technique for non-invasive, non-ionizing, fast and easy to use imaging and Emery-Dreifuss muscular dystrophy is a clinical condition that seems to be related to changes in the emission of infrared radiation at the skin level due to its neurodegenerative character, we have conducted an investigation by infrared thermography and the use of functional strength tests in the lower limbs in a family of 4 affected members of Emery-Dreifuss muscular dystrophy to try to establish a relationship between the evolution of the disease and the emission of infrared radiation in this pathology at the lower limb level and provide a more general view of this disease for a better evaluation and monitoring of the disease.

Introduction

Emery-Dreifuss muscular dystrophy (EDMD MIM 310300) is catalogued as a rare disease of degenerative character that affects the neuromusculoskeletal system [1–3]. It being a rare disease, data regarding its incidence are not fully clarifying, in fact, its prevalence is estimated to be of 1 in 100.000–300.000 patients, although it is relevant to highlight that this measure is in continuous evolution [4,5]. The main cause of this clinical condition is related to the gene mutations that affect certain nuclear proteins, although since its first bibliographic appearance in 1966, the investigations carried out in regards to this disease have caused the etiology to develop, and as a result we know nowadays that there are different types of this disease with both a recessive and dominant character [1–6].

Recent studies of a diagnostic nature, carried out on the level of inferior members on a population affected by this disease, have proven on a small sample of patients that the emission of infrared radiation at a cutaneous level, varies according to the evolutionary stage of the disease, thus, the authors asserted that the infrared thermography could be a good tool for the assessment of the evolutionary stage of the disease in this type of patient from the different cutaneous manifestations [6,7].

Infrared radiation is a property of all bodies with a temperature above zero Kelvin and it is defined as a type of electromagnetic

radiation with a wavelength over visible light, which makes it undetectable without a thermograph, and thanks to physics nobel prize Wilhelm Wien we know that the higher the temperature of a body the higher its emission of infrared radiation [8–10].

In general terms, the average power emitted in the form of heat by the human body, under normal pressure and temperature conditions 36 °C/37 °C, is of approximately 100 Watts, and it is possible to register this emission of infrared radiation through thermographic equipment [11,12].

Infrared thermography is, in fact, a very commonly used diagnostic technique in clinical practice and investigation, as well as in studies carried out in the areas of dermatology, neurology and traumatology [6,13,14].

Proposal

Considering that infrared thermography is presented as a simple, economical, rapid, non-invasive and non-ionizing imaging technique [6] and EDMD is a clinical condition that seems to be related to changes in the emission of infrared radiation at the skin level due to its neurodegenerative nature, we have conducted an investigation by infrared thermography and functional tests of strength in lower limbs, in a family of 4 affected members of Emery-Dreifuss muscular dystrophy to

* Corresponding author at: Av. de los Jerónimos, 135, 30107 Guadalupe, Murcia, Spain.

E-mail address: Acabizosu@gmail.com (A. Cabizosu).

<https://doi.org/10.1016/j.mehy.2020.109592>

Received 11 October 2019; Received in revised form 9 December 2019; Accepted 21 January 2020

0306-9877/ © 2020 Elsevier Ltd. All rights reserved.

try to establish a relationship between the evolution of the disease and the emission of infrared radiation in this pathology at the level of lower limbs, and provide a more general view of this disease for a better evaluation and monitoring of it. This study has been approved by the ethical committee dated October of 2018 acceptance number: 10/2018/CE.

Testing the proposal

To carry out our thermographic study, as it has been proposed by other authors in previously conducted studies with infrared thermography, we have based on the TISEM (Thermographic Imaging in Sports and Medical Exercise) recommendations with the aim of including all those factors that may influence or skew the recording of thermographic images both with respect to the sample, as well as the environmental conditions of the room. In order to obtain a pattern of thermographic images as sensitive and accurate as possible, an action protocol was established based on the most up-to-date bibliography in this type of studies [6,15].

Patient sample

To carry out our study we have a total sample of 4 male brothers, from the Neurology Service of the San Francesco Di Nuoro Hospital (Italy), aged between 22 and 38 years in different stages of the disease, being the patient younger the less affected and the more adult patient the most affected due to the degenerative nature of the disease. Before performing the tests, the patients underwent a clinical interview by the specialist in neuromuscular diseases for 20 min (acclimatization to the environment). The interview focused on all those data that could be sensitive when making thermographic records (Table 1). To rule out alterations in the basal temperature of the patients, the body temperature was measured with a digital thermometer, with the aim of excluding all those patients who had a basal temperature higher than 37 °C. Finally, none of the participants was excluded.

Table 1
Data collection in the clinical interview.

Patient	01	02	03	04
Basal Temperature (°C)	36.3	36.5	36.4	36.1
Time	15:30	16:00	16:30	17:00
Sex	MAN	MAN	MAN	MAN
Age (years)	22	28	35	38
Surgery	NONE	NONE	Internal Defibrillator	Internal Defibrillator
Eva (PAIN)	NONE	NONE	NONE	NONE
Weight (kg)	51.8	97.7	61.7	66.7
Height (cm)	170	168	172	173
Body mass index (BMI)	17.92	34.37	20.86	22.29
Alcohol	NONE	NONE	NONE	NONE
Coffee	NONE	NONE	NONE	NONE
Drugs	NONE	NONE	NONE	NONE
Smoke	NONE	NONE	NONE	NONE
Food	4 h before the medication	4 h before the medication	5 h before the medication	5 h before the medication
Cosmetics	NONE	NONE	NONE	NONE
Shower	5 h before the medication	5 h before the medication	6 h before the medication	6 h before the medication
Sun Rays	NONE	NONE	NONE	NONE
Sport	NONE	NONE	NONE	NONE
Physical Therapy	NONE	NONE	NONE	NONE

Room condition

The clinical interview was conducted in a room of 14 m², with a temperature between 23 °C and 24 °C, and with a humidity of the room of 40% (± 0.8) and an atmospheric pressure of approximately 1 atm. In addition, the room was illuminated by sunlight entering the room through a window located far from the measurement point and without electronic devices nearby, [14,17]. The only furnishings present in the room were a table and 2 wooden chairs, a stretcher for the evaluation of patients and a 1 cm thick cotton pad located on the floor to prevent patient feet from being in direct contact with the soil and thus generate temperature changes as there is a difference between the temperature of the soil and the temperature of the base of the feet.

Thermograph

Thermal image was saved by a FLIR™ camera E60 model, and analyzed in FLIR™ ResearcherIR™. This model has already been used in previous studies with patients of these characteristics. This thermograph has a thermal image quality of: 20 × 240 pixels, thermal sensitivity: < 0.05 °C and temperature records between −20 °C and +650 °C. The thermograph was placed on a tripod 50 cm from the patient registration point with an inclination of 15°/18°. The emissivity of the thermograph was set at 0.98 as suggested by the manufacturer, and this was corroborated in other scientific publications [19,20]. The analysis of the thermographic image was carried out with the “Flir researchIR” program. The measurement protocol used was developed from previous studies conducted with patient samples and similar regions of interest. Four images of the lower limbs of each study participant were recorded, both at the level of the thigh and at the level of the leg in anterior and posterior vision.

In the anterior view of the thigh at the proximal level, the ROI (region of interest) analyzed were the same as those proposed in previous research. The region of interest analyzed begins 15 cm below the anterior superior iliac spine and extends up to 2 cm above the edge of the patella (quadriceps region), while in the posterior view it begins immediately below the gluteal fold and extends to the upper edge of the poplitea region (hamstring region) (Figs. 1 and 2) [6,18].

In the anterior view of the leg, the ROI begins 2 cm below the lower edge of the patella up to 2 cm above the tibial malleolus (tibial region), while in the posterior view it is identified from the lower edge of the popliteal region up to 8 cm higher than the lower edge of the heel (gastrocnemius region) (Figs. 1 and 2) [6,18]. The images were taken by 2 different researchers in a blinded manner and from each ROI 3 images were taken.

Test 30-S chair stand

For the realization of this test we have placed a 4-legged chair resting on a wall. Patients began the test based on a sitting position. At the lower limb level the feet were separated and supported on the floor, while, at the upper limb level, the arms were crossed by the wrists and the hands supported between the chest and the front of the shoulder. From this position, the patients had to get up completely and return to sit down for 30 s as often as possible [16,17].

Data of the test

The thermographic images, corresponding to the four patients, ordered from the lowest to the oldest age, of the anterior and posterior thigh, as well as the images of the anterior and posterior leg are shown below (Figs. 1 and 2).

The 30 s Chair Stand Test is a functional test commonly used and proven in the scientific and clinical spheres for the evaluation of lower limb strength [16,17].

Some previously published studies on healthy patients of advanced

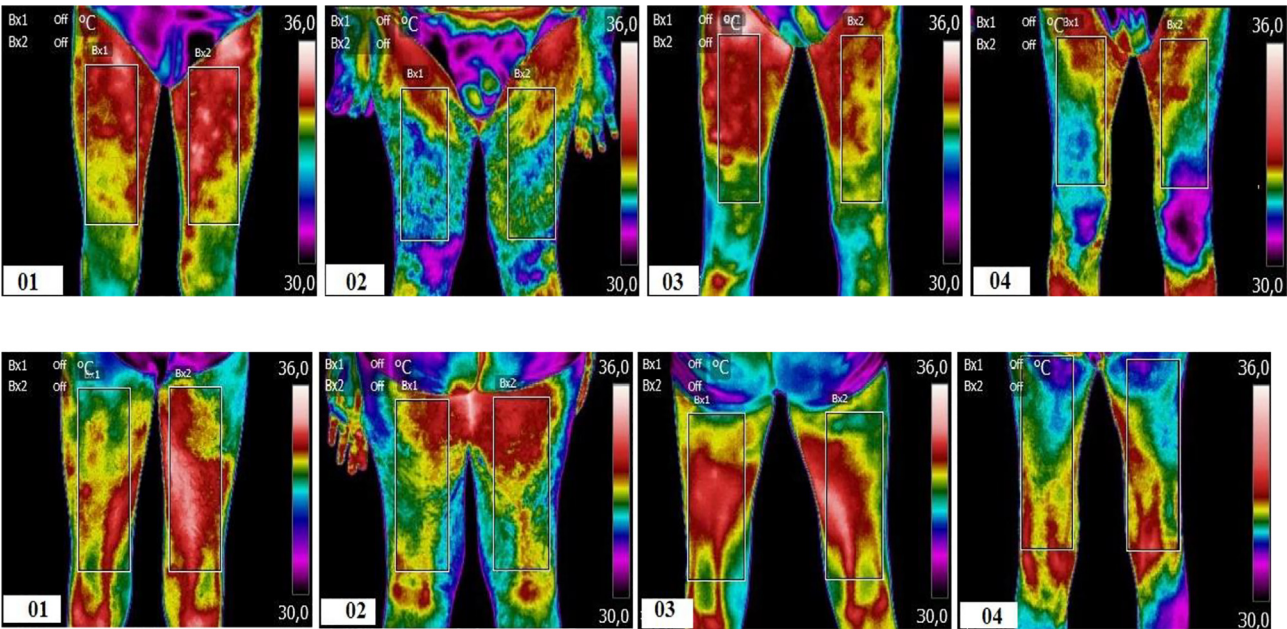


Fig. 1. Thermal image for the anterior and posterior thigh of four patients. Images ordered from least to greatest age, corresponding to the definition of the regions of interest (ROI) for the anterior and posterior thigh.

age have proven that the higher the number of repetitions, the higher the strength presented by patients on the lower limb level [17].

Notwithstanding the fact that patients were elderly, Jones and collaborators designed a value table with 5 year ranges from the age of 60 to the age of 94, evidencing that as the sample increased in age, strength decreased and, as a result, the number of repetitions executed decreased as well [17].

If we analyze the results obtained on our patients and compare them to the results obtained by Jones et al., we can observe how the range of our patients, between 8 and 13 repetitions, corresponds to the age range between 85 and 89 years of age in the study by Jones et al., being the sample of our study in the age range between 22 and 38 years of age [17].

The link between age and strength in the study by Jones and

Table 2

Data corresponding to the average temperature (°C) measured in the region of interest selected in Fig. 1 in the anterior and posterior part of the thigh, as well as in the anterior and posterior part of the leg.

THERMOGRAPHY				
THIGH		LEG		
ANTERIOR	POSTERIOR	ANTERIOR	POSTERIOR	
01 RI:34,2 LE:34,3	RI:33,8 LE:34,3	RI:33,9 LE:33,4	RI:33,3 LE:33,7	
02 RI:32,1 LE:32,1	RI:32,3 LE:32,3	RI:32,6 LE:32,5	RI:31,9 LE:32,0	
03 RI:33,3 LE:33,1	RI:33,7 LE:33,7	RI:33,8 LE:33,5	RI:32,9 LE:32,9	
04 RI: 31,9 LE:32,1	RI:33,0 LE:33,2	RI:32,4 LE:32,6	RI:32,3 LE:32,3	

RI: Right; LE: Left.

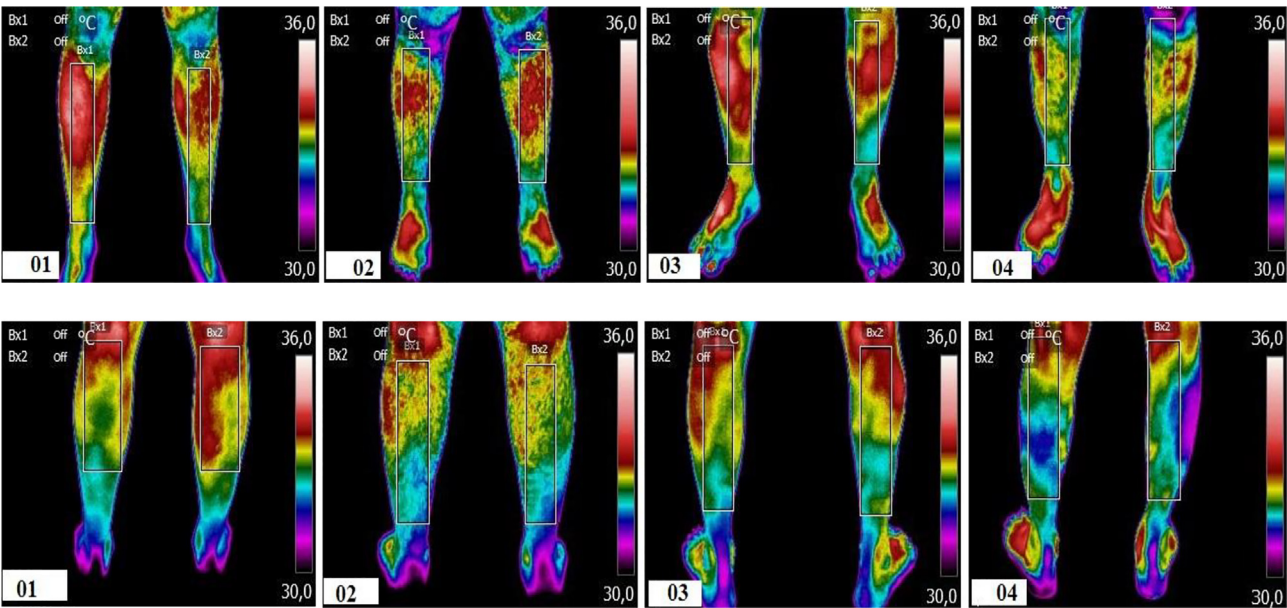


Fig. 2. Thermal image for the anterior and posterior leg of four patients. Images ordered from least to greatest age, corresponding to the definition of the regions of interest (ROI) for the anterior and posterior leg.

Table 3

Table corresponding to the Chair Stand Test of the four patients studied.

CHAIR STAND TEST	
01	13
02	9
03	11
04	8

collaborators is continual and progressive, whereas, as we can see on Table 2 in our study, there is no such continuity and progression between age and strength in our patients. There is a possible conflict between the result obtained in patient number 2 with respect to patient number 3, with patient number 2 carrying out less repetitions than patient number 3 of a more advanced age.

We believe that this fact, which a priori seems to contradict the most recent scientific information, can be justified through the analysis of one of the variables measured and analyzed in our patients: BMI.

The fact that a higher BMI is linked to a lower performance in the physical tests, both those on strength and speed, especially when it comes to lower limbs, is a fact widely corroborated in the bibliography [18–21].

Since the muscular system is the main driving force of movement, and being our patients affected by a neuro-degenerative disease that presents a substitution of avascular trophic tissue for vascularized muscular tissue, there is no question that the relation between BMI and strength would be compromised in this type of patient.

The results obtained through this test can also be linked to understood regarding the results obtained with the thermographic test. For the analysis of our thermographic data, we believe that it is necessary and fundamental to consider the BMI variable and, especially the neurodegenerative component of the disease.

Previous studies carried out through infrared thermography have proved that the average temperature of the ROI analyzed in different body surfaces, abdomen and thighs among others, decreased as the percentage of body fat increased [22,23], while on another note, a recent study carried out through infrared thermography and CT on patients affected by Emery-Dreifuss has evidenced the usefulness of thermographic imaging in the evaluation of its neurodegenerative nature [6].

As we can observe in Table 3, both facts find support on our study. If, on the one hand, we can observe how temperature decreases as age increases and disease evolves, the patient with the highest BMI represents again an exception, being his infrared radiation emission on a cutaneous level in lower limbs inferior to patients 3 and 4 of a more advanced age.

Such difference is not as significant if we compare it to patient 4 of a more advanced age, which may derive from the fact that this last patient experiences a more advanced stage due to the neurodegenerative nature of the disease. If we analyze the average temperatures obtained in the different thermographic registers in Table 2, we can observe how in patients with similar BMI values, as age progresses, the emission of infrared radiation decreases.

This fact corroborates the theories by Cabizosu et al. who, in their studies, propose infrared thermography as a tool for monitoring and quantifying Emery-Dreifuss muscular dystrophy. It would be of interest to carry out a study in the near future which compares magnetic resonance imaging and infrared thermography with functional tests, measuring the long term evolution of the disease to better evidence and quantify the relation between muscular dystrophy, BMI and strength in lower limbs in this type of patients.

Limitation and future research

Since this is a very innovative line of research in a rare disease, we are aware that some features of our research can be improved, expanded and analyzed through new research projects. One of the aspects that may be improved is, without question, the sample size, in spite of the difficulty involved in obtaining a broad number of patients due to the rare, low incidence nature of the disease.

This study has provided new information with regards to this disease in relation to muscular strength and change of temperature. It would be interesting to carry out more research, even of longitudinal nature, to establish the real evolution of the disease concerning strength and temperature.

With that aim, it would be very interesting to carry out a study for a period of one year of follow up analyzing the strength tests and comparing them to the infrared thermographic images. With this type of study, we believe the foundation is being laid for new lines of research that can help us to better understand the evolutionary nature of this disease.

Ethical publication statement

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

Equal contribution

These authors contributed equally to this work.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- [1] Madej-Pilarczyk A, Kochański A. Emery-Dreifuss muscular dystrophy: the most recognizable laminopathy. *Folia Neuropathol* 2016;54(1):1–8. <https://doi.org/10.5114/fn.2016.58910>.
- [2] Emery AE, Dreifuss FE. Unusual type of benign x-linked muscular dystrophy. *J Neurol Neurosurg Psychiatry* 1966;29(4):338–42.
- [3] Bonne Gisèle, Quijano-Roy Susana. Emery-Dreifuss muscular dystrophy, laminopathies, and other nuclear envelopathies. *Handb Clin Neurol* 2013;113:1367–76. <https://doi.org/10.1016/B978-0-444-59565-2.00007-1>.
- [4] Sato M, Shirasawa H, Makino K, Miura H, Sato W, Shimizu D, et al. Perinatal management of pregnancy complicated by autosomal dominant Emery-Dreifuss muscular dystrophy. *Am J Perinatol Rep* 2016;6(1):e145–7.
- [5] Cabizosu A, Carboni N, Figus A, Vegara-Meseguer JM, Casu G, Hernández Jiménez P, Martínez-Almagro Andreo A. Is infrared thermography (IRT) a possible tool for the evaluation and follow up of Emery-Dreifuss muscular dystrophy? A preliminary study. *Med Hypotheses* 2019;127:91–6 https://www.orpha.net/consor/cgi-bin/OC_Exp.php?Lng=ES&Expert=2616.
- [6] Cabizosu A, Carboni N, Martínez Almagro-Andreo A, Vegara-Meseguer JM, Marziliano N, Gea Carrasco G, Casu G. Theoretical basis for a new approach of studying Emery-Dreifuss muscular dystrophy by means of thermography. *Med Hypotheses* 2018;118:103–6. <https://doi.org/10.1016/j.mehy.2018.06.027>. [Epub 2018 Jun 28].
- [7] Maldague X. *Theory and practice of infrared technology for nondestructive testing*. New York, NY, USA: Wiley; 2001.
- [8] Houdas Y, Ring EFJ. *Human body temperature*. New York, NY: Plenum; 1982.
- [9] Jones BF. A reappraisal of the use of infrared thermal image analysis in medicine. *IEEE Trans Med Imaging* 1998;17:1019–27. <https://doi.org/10.1109/42.746635>.
- [10] Ring EFJ. The historical development of temperature measurement in medicine. *Infrared Phys Technol* 2007;49:297–301.
- [11] Hardy JD. The radiation of heat from the human body. III. The human skin as a black-body radiator. *J Clin Investig* 1934;13(4):615–20. (American Society for Clinical Investigation).
- [12] Laino L, Di Carlo A. Telethermography: an objective method for evaluating patch test reactions. *Eur J Dermatol* 2010;20:175–80.
- [13] Owen R, Ramlakhan S, Saatchi R, Burke D. Development of a high-resolution infrared thermographic imaging method as a diagnostic tool for acute undifferentiated limp in young children. *Med Biol Eng Comput* 2018;56.

- [14] Moreira DG, Costello JT, Brito CJ, Adamczyk JG, Ammer K, Bach AJE, et al. Thermographic imaging in sports and exercise medicine: a Delphi study and consensus statement on the measurement of human skin temperature. *J Therm Biol* 2017;1(69):155–62.
- [15] Hayes KW, Johnson ME. Measures of adult general performance tests: the Berg Balance Scale, Dynamic Gait Index (DGI), Gait Velocity, Physical Performance Test (PPT), Timed Chair Stand Test, Timed Up and Go, and Tinetti Performance-Oriented Mobility Assessment (POMA). *Arthritis Rheum* 2003;49 Suppl:S28–42.
- [16] Jessie Jones C, Rikli Roberta E, Beam William C. A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. *Res Q Exerc Sport* 1999;70(2):113–9. <https://doi.org/10.1080/02701367.1999.10608028>.
- [17] Daniel Arriscado, Joaquín Muros José, Mikel Zabala, María Dalmau Josep. Relación entre condición física y composición corporal en escolares de primaria del norte de España (Logroño). *Nutr Hosp* 2014;30(2):385–94 http://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S0212-16112014000900022&lng=es. <https://doi.org/10.3305/nh.2014.30.2.7217>.
- [18] Artero EG, España-Romero V, Ortega FB, Jiménez-Pavón D, Ruiz JR, Vicente-Rodríguez G, et al. Health-related fitness in adolescents: underweight, and not only overweight, as an influencing factor. The AVENA study. *Scand J Med Sci Sports* 2010;20:418–27. <https://doi.org/10.1111/j.1600-0838.2009.00959.x>.
- [19] Tomkinson GR, Olds TS. Secular changes in pediatric aerobic fitness test performance: the global picture. *Med Sport Sci* 2007;50:46–66.
- [20] Taş S, Yılmaz S, Onur MR, Soyulu AR, Altuntaş O, Korkusuz F. Patellar tendon mechanical properties change with gender, body mass index and quadriceps femoris muscle strength. *Acta Orthop Traumatol Turc* 2017;51(1):54–9. <https://doi.org/10.1016/j.aott.2016.12.003>. Epub 2016 Dec 20. PubMed PMID: 28010997; PubMed Central PMCID: PMC6197583.
- [21] Chudecka M, Lubkowska A, Kempnińska-Podhorodecka A. Body surface temperature distribution in relation to body composition in obese women. *J Therm Biol* 2014;43:1–6.
- [22] Savastano DM, Gorbach AM, Eden HS, Brady SM, Reynolds JC, Yanovski JA. Adiposity and human regional body temperature. *Am J Clin Nutr* 2009;90(5):1124–31. <https://doi.org/10.3945/ajcn.2009.275>.