Thermo-sensitivity factors influencing the use of infrared thermography

Nasution Abdillah Imron
Syiah Kuala University, Banda Aceh, Indonesia;
Northern (Arctic) Federal University named after M. V. Lomonosov, Arkhangelsk, Russi
Pankov Mikhail Nikolaevich
Candidate of Medical Sciences, Associate Professor
Northern State Medical University, Arkhangelsk, Russia

Abstract. Nowadays, the use of infrared thermography which working principle is by determining the thermal pattern of the skin is increasingly being applied as a diagnostic tool. This technique may influenced by external factor particularly thermo-sensitivity. Review that describes thermo-sensitivity factors for conducting research through infrared thermography approaches is still limited. The aim of this article is to review a classification of the thermo-sensitivity factors that influence the application of infrared thermography in humans. The cooling and warming thermo-sensitivity area of human body is depend on the spot area. Certain body parts have higher sensitivity greater and smaller sensitivity values than the whole-body average. Signals from the skin may be conveyed by thermoreceptors. The mechanism of thermoreceptors activity is related to thermoregulation and action potential. The other factors are the basic characteristics of the subject and are primarily related to age, sex, emotion, circadian rhythm, and medical history. In addition, the final group of potentially temperature sensitivity factors is thermal comfort that described as satisfaction of the mind in an environment. Based on this, there are four factors in thermo-sensitivity that can affect the application of infrared in human: the spot area; physiological factor, biophysical aspects, and thermal comfort.

Keywords: Infrared Thermography, Thermo-sensitivity, spot area; physiological factor, biophysical aspects, thermal comfort.

Introduction

One of method which working principle is by determining the thermal pattern characteristics is Infrared Thermography. Since infrared thermography capability has been approved to detect many groups of diseases at once, the use of infrared thermography in humans is more intensive in its application as a diagnostic tool. As a non-invasive and lowcost technique, infrared thermography causes no discomfort to the patient. Infrared thermography is completely safe and easy to operate. Even for more frequent use, the security level is very safe. This technique is also possible to use for pregnant women and children [1].

Working with infrared thermography requires accounting for many factors that can influence either the evaluation or the interpretation of the thermal images. One of the weakness of infrared thermography is that it takes into account several factors that can influence either the analysis or interpretation of thermal image [2]. Furthermore, human temperature sensing is not homogenous across the body. Individually differences in how people experience their thermo sensitivity [3]. Attempting to control for such a large number of factors may seem impossible, but simply being acquainted with this factor is an important step in many contexts. Moreover, review that describes thermo-sensitivity factors for conducting research through infrared thermography approaches is still limited. Therefore, the primary objective of this article is to propose a classification of the thermo-sensitivity factors that influence the application of infrared thermography in humans.

Disscussion.

Temperature sensitivity or thermo-sensitivity refers to the ability to detect changes in the temperature of the skin. These changes may involve either increases (warming) or decreases (cooling)-vice versa, relative to the adapted temperature level of the skin. The temperature-sensation system to serve primarily as an early warning system. Temperature sensitivity is important in protecting one's self from intense temperature that may cause damage to the body. Sensitivity to temperature allows a person to adapt to the temperature of her or his environment in order to maintain homeostatic [2]. Based on this, the group of potentially confounding factors in thermo-sensitivity that related to infrared thermography method are: The spot area, Physiological factors, Biophysical factors, and thermal comfort.

1. The spot area

In humans, skin temperature (Tsk) sensing is mediated by free nerve endings of the Aδ- and C-type classes (i.e., thermoreceptors) [4]. Selectively conveying warm and cold afferent inputs via the anterolateral spinothalamic tract to neural centers located in the insular and somatosensory cortices. When the physical stimulus is interpreted by the brain as "hot", the brain sends signals back to the body part in contact to withdraw away from the stimulus. The same response may be observed when the stimulus is perceived as "cold“.

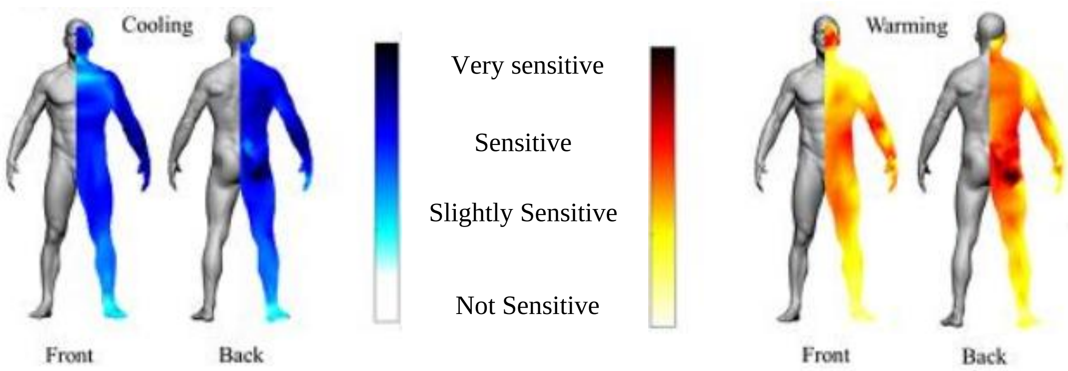

Figure 1. The Mapping of Cool and Warm Sensitivities across the Human Body [5]

Figure 1 shows the mapping of cool and warm sensitivities across the human body from both front and back views. In general, the back is more sensitive than the front (darker colors for back than front for both heating and cooling. The cooling and warming coefficients show that the foot, lower leg and upper chest are much less sensitive, while the cheek, neck back, and seat area, are very sensitive to both cooling and warming [5]. There is clearly a large regional variation in thermal sensitivity for different body part.

Table 1 shows that body parts like buttock, face, dorsum of hand, and belly have higher sensitivity coefficients greater than 1 while the foot, lower leg, and chest had smaller sensitivity values than the whole-body average. The coefficients for the neck is quite close to the whole-body average, but the back part of the neck is much more sensitive than its front part. [6]

Table 1. Sensitivity Coefficient of 15 different body parts

No	AREA	COOLING	WARMING
1	Face	1.14	1.34
2	Neck back	1.00	1.24
3	Neck front	0.89	0.55
4	Chest	0.94	0.92
5	Belly	1.15	1.38
6	Back	1.17	1.16
7	Upper arm	1.20	1.17
8	Forearm	1.08	1.02
9	Hand palm	1.03	0.96
10	Hand dorsum	1.48	1.22

11	Buttock	1.25	1.92
12	Thigh	1.10	1.16
13	Lower leg	0.87	0.82
14	Sole 5	0.44	0.40
15	Foot dorsum 5	0.64	0.50
16	Sole 7	0.59	0.38
17	Foot dorsum 7	0.63	0.60
18	Overall average	1	1

2. Physiological factor

Density of sensory innervation: thermal perceptions is rely on separate neural pathways involving thin myelinated or unmyelinated axons of the peripheral nervous system. Cold receptor endings lie within 0.15mm of the dermis, whereas warm receptor endings are buried more deeply, at 0.6mm. In addition to being closer to the surface, cold receptors are also three to ten times more numerous than warm receptors across the majority of body regions. Behavioral responses including thermal are depend on signals from peripheral thermosensors to initiate intracellular signaling pathways [7].

Sensory receptors become activated by stimuli in the environment by receiving signals. Signals from the skin may be conveyed by thermoreceptors [8]. These receptors display a constant discharge to their specific temperatures, and when an experience of the opposite temperature occurs, there is a sudden ceasing of receptor discharge. Cold receptors mainly sense temperatures between 25-30°C. Temperatures below this cause release of bursting discharges. In touching dangerously hot objects (greater than 45°C), there can be a brief sensation of cold due to the paradoxical firing of cold receptors. Warm receptors respond to the approximate temperature range of 30-46°C. Higher temperatures may result in the decreased firing of these receptors [9].

As a stimulus constantly excites the receptor consequently influencing the rate of action potentials. An action potential occurs when a neuron sends information down an axon, away from the cell body. The action potential is an explosion of electrical activity that is created by a depolarizing current. This means that some event (a stimulus) causes the resting potential to move toward 0 mV. When the depolarization reaches about -55 mV a neuron will fire an action potential which is known as threshold. If the neuron does not reach this critical threshold level, then no action potential will fire. [10].

Moreover, receptors can adapt to a constant, unchanging stimulus, if there is a change, whether loss of the stimulus or change in intensity, the receptor is able to respond. Researchers found that the human skin has a normal range of adaptation temperature – from 29-37°C [11]. Different body parts have different temperature sensitivity levels; causing their respective thresholds to vary as well. Temperature threshold is the point at which one can tolerate the hotness or coldness of a stimulus [12].

In fact, the mechanism of thermoreceptors are responsible for helping maintain homeostasis in the body and for allowing the body to best react to internal and external stimulus. One of important type of homeostasis known as thermoregulation. Thermoregulation, by definition, is a mechanism by which human maintain body temperature by tightly controlled self-regulation, no matter the temperature of their surroundings. Without thermoregulation, the human body would not be able to adequately function and inevitably [13].

Thermoregulation has three mechanisms: afferent sensing, central control, and efferent responses. Afferent sensing works through these receptors to determine if the body is experiencing either too hot or too cold of a stimulus. TRPV3 may be more responsible for detecting warm temperatures. In contrast, for colder temperatures, it is believed that TRPM8 ion channels are one of many receptors responsible. These receptors are capable of detecting temperatures from below 16°C to 26°C. The belief is that other undiscovered receptors also have a role in cold detection.[14] Next, the hypothalamus is the central controller of thermoregulation. If the hypothalamus senses external temperatures growing too hot or too cold, it will automatically send signals to the skin. Lastly, efferent responses are carried out primarily by the body's behavioral reactions to fluctuations in body temperature. Efferent responses also consist of automatic responses by the body to protect itself from extreme changes in temperature, such as sweating, vasodilation, vasoconstriction, and shivering [15][16].

When external environments are exceedingly warm, the heat is produced inside his or her body is typically transported to the blood. The blood then carries the heat through numerous capillaries that are located directly under the skin. Because the blood is near the surface, it can cool the person down. This cooled blood can then be transported back through the body to prevent the body temperature from becoming too high. Sweat is also a means by which the body cools itself down; it is created by glands to carry out evaporation at the topmost skin layer, the epidermis, to release heat. This describes vaporization, one of the four mechanisms used to maintain core body temperature. Radiation is when the heat that is released from the body's surface is moved into the surrounding air; convection occurs when cooler air surrounds the body's surface, and conduction comes into play when a person is either triggered by cold water or uses an ice pack in relation to infrared thermography application-their internally generated heat is transferred to the cold water or the ice pack. This is another reason why it is very important to stay hydrated in the heat or during physical activity-not only to maintain adequate intravascular fluid volume, but also to aid in conduction processes that cool the body down. When cold fluids are ingested, the heat is released into the fluid and excreted out of the body as sweat or urine [17].

3. Biophysical Aspects

The other group of potentially confounding factors in thermo-sensitivity that related to infrared thermography method are biophysical factors. Biophysical aspects are the basic characteristics of the subject and are primarily related to age, sex, emotion, circadian rhythm, and medical history.

Age influences the structures, physiologic, functions of the nervous system, leading to age-related changes in thermal perception [18]. In humans adapted for a long time to various conditions-cold, heat, and physical exercise-directed changes in temperature sensitivity, women having a higher percentage of body fat than men, female sex hormones etc. woman's body temperature is higher during ovulation and pregnancy, and lower at the start of the menstrual cycle.[19]

Body temperature undergoes significant fluctuation over the course of a diurnal variation. It is usually at its lowest early in the morning and slowly climbs up after a person wakes up, reaching its peak late in the afternoon. This variation corresponds to the level of metabolic activity, which is lowest during sleep and slowly climbs up as the day progresses. Many pharmaceutical drugs, including several classes of antibiotics (cephalosporins, penicillins etc), methyldopa, phenytoin, among others, are known to cause an increase in body temperature. [20]

4. Thermal comfort

The final group of potentially temperature sensitivity factors is related to infrared thermography method is thermal comfort. Comfort can be described as satisfaction of the mind in an environment. In this satisfied environment, physical and mental productivity of human become higher. In general, thermal comfort occurs when body temperature is held within narrow ranges, skin moisture is low, and the physiological effort of regulation is minimized [21].

Body temperature increases in response to stressful situations. Stress hormones such as cortisol and adrenaline mediate this increase in body temperature. This increase in temperature is an adaptive response of the body to deal with perceived threats. Adrenaline, which mediates the body's "fight or flight" response, stimulates increased heat production in the liver, in addition to driving other adaptive changes. The liver being one of the body's largest and most metabolically active organs, has a notable impact on body temperature [20].

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