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Application of Sensory Thermography as Measuring method to Study Median Nerve Temperatures

Javier Ordorica Villalvazo, Claudia Camargo Wilson, Jesús Everardo Olguín Tiznado

***Abstract*—**This paper presents an experimental case using sensory thermography to describe temperatures behavior on median nerve once an activity of repetitive motion was done. Thermography is a noninvasive technique without biological hazard and not harm at all times and has been applied in many experiments to seek for temperature patterns that help to understand diseases like cancer and cumulative trauma disorders (CTD's). An infrared sensory thermography technology was developed to execute this study. Three women in good shape were selected for the repetitive motion tests for 4 days, two right-handed women and 1 left handed woman, two sensory thermographers were put on both median nerve wrists to get measures. The evaluation time was of 3 hours 30 minutes in a controlled temperature, 20 minutes of stabilization time at the beginning and end of the operation. Temperatures distributions are statistically evaluated and showed similar temperature patterns behavior.

***Keywords*—**Median nerve, temperature, sensory thermography, wrists, CTD's.

I. Introduction

MUSCULOSKELETAL disorders, including those localized to the upper extremity such as carpal tunnel syndrome (CTS) and forearm tendinitis, are widespread and disabling. They compromised 29 percent of the approximately 1.2 million total workplace illnesses and injuries resulting in lost days from work in 2007 in the United States [1]. In a general European working population [2] found neck/shoulder pain prevalence of approximately 30-50% and arm pain prevalence of 11-28%. It has long been known that repetitive motions of he different anatomical structures of the hand and upper extremities can cause injury and disability of one or both limbs. The National Institute of Occupational Safety and Health. Estimates that over 20% of the labor force involved in jobs of repetitive nature is at risk of developing CTDs [3].

J. Ordorica is professor of the Engineering and Technology Center, Autonomous University of Baja California, Tijuana, Baja California, Mexico. (e-mail: villalvazo@ uabc.edu.mx)

C. Camargo is professor of the Department of Industrial Engineering, Faculty of Engineering, Architecture and Design, Autonomous University of Baja California, Ensenada, Baja California, Mexico. (e-mail: ccamargo@uabc.edu.mx)

J. E. Olguín is professor of the Department of Industrial Engineering, Faculty of Engineering, Architecture and Design, Autonomous University of Baja California, Ensenada, Baja California, Mexico. (e-mail: jeol79@uabc.edu.mx)

The most common forms of CTDs are: Tendonitis, tenosynovitis, epicondylitis, bursitis, and CTS. The later is disabling condition of the hand (s) that can be caused, precipitated, or aggravated by repetitive motions combined with forceful and/or awkward postures [4]-[6]. CTS are a specific form of neuropathy in which nerve injury results from compression of neighboring anatomical structures. It occurs up to 10 times with more frequency in women than men, and it is often seen concomitant to hysterectomy, diabetes mellitus, ophorectomy, and pregnancy [7]-[12].

Musculoskeletal disorders include sprains, strains, tears, soreness, carpal tunnel syndrome, hernias, and connective tissue injuries of the structures previously mentioned. According with the national institute for Occupational Safety and Health (NIOSH), several epidemiological studies have demonstrated evidence of a causal relationship between physical exertion at work and work-related musculoskeletal disorders (WMSD). Several factors have been associated with WMSD such as repetitive motion, excessive force, and awkward and/or sustained postures, prolonged sitting of standing [13].

Occupational computer use has been associated with upper extremity musculoskeletal disorders (UEMSD's), but the etiology and pathology of some of these disorders are poorly understood. Various theories attribute the symptoms of biomechanical and/or psychosocial stressors. The results of several clinical studies suggest that elevated antagonist muscle tension may be a biomechanical stress factor. Affected computer users often exhibit limited wrist range of motion, particularly wrist flexion, which has been attribute to increased extensor muscle tension, rather that to pain symptoms [14].

Thermography is a noninvasive technique without biologic hazard. It detects, measures, and converts invisible, surface body heat into a visible display, which is then photographed or videotaped as a permanent record. It graphically depicts temperature gradients over a given body surface are at a given time and has been used to study biologic thermoregulatory abnormalities directly or indirectly influencing skin temperature [15].

Infrared thermography (IR) is widely used to display temperature patterns on the surfaces of the skin by taking pictures [16], unlike thermography sensory which bases its operation as its name says in sensors. This technology has its historical basis in the development of underwater digital temperature recorders used to measure the temperature under

the water in natural environments, and with potential applications in areas such as oceanography, marine ecology, and industry, among others [17]. Thermography is an easy noninvasive tool for recording surface temperature. In healthy people, thermal symetry is observed. Differences in skin temperature opf more than 0.5 °C between sides of the body or extremeties are suggestive of an underlying pathology [18].

Other research using sensory thermography was developed in order to study body temperature changes in two man. Same exercise and materials were took in account for the study. Results shown simillary wrist temperature patterns over the whole tests. Main objetives pointed out that subject shown lower back problems and it was possible to carry out curve fitting of third order to represent the behaviour of temperatures during the experiment. Also it was possible to identify when the highiest temperatures were reached. By the other hand, the maximum temperatures reached were on the right wrist of 35.078 ℃ over a period of 1 hour 41 minutes 52 seconds and on the left wrist 34.663 ℃ over a period of 2 hours 42 minutes 51 seconds. The two individuals showed pain in their right shoulder and wrist in the time range which identified the highest temperatures. New evidence data were found in this current experiment with new subjects and by changing the gender, in this case, three women in good shape [19].

This paper aimed to contribute to analize, evaluate and describe the vartion of temperature generated on right-wrist surface and left-wrist surface on each subject took in account for the study by doing a repetitive motion task for about 3 hours 30 minutes non stoping chance. Also, prove if the data adjust to a normal distribution and/what type pof distribution adjustmets base on the data collected from the experiment.

This investigation allowed the making of questions as: What is the behavior of the temperatures of individuals to perform highly repetitive motion over a period of time of 3 hours and 30 minutes? What are the maximum temperatures (Max T) achieved and its symptoms? Do the temperatures show a similarity on the patterns? Data fit a third order polynomial? What type of distribution data stick?

A review of the state of the art research or sensory thermography applications so far not has been found, but the IR which serves as reference for this study.

Applications of infrared thermography are many. A study was published applying a thermal nondestructive testing to estimate nonuniformity of temperature fields in materials [20]. A study was published to characterize the effect of exercise (balance for 15 min) and responses in the skin temperatures in people with and without carpal tunnel syndrome [21].

It was also published a study characterizing the effect of exercise (on an ergonomics bike) and responses in the skin temperatures due to controlled levels of exercise and temperature conditions [16]. A study was published on the detection of breast cancer by thermography, which has become a powerful tool in conjunction with mammography for diagnostic purposes. Breast cancer is one of the most common diseases among women around the world in these times and is caused by epithelial cells [22].

In recent times, its applications have extended to fields such as engineering and in particular to medicine. It is passive in nature and because of that, will not emit any radiation that could harm the patient or put him in some kind of risk. The ideal temperature for making thermal images is between 20 and 25˚C, and as to the percentage of moisture, this must be between 40% and 60% [23].

Another study which was aimed to characterize the differences in skin temperatures of between three groups of office workers assessed by dynamic thermography (writing of 9 min). Post-typing differences in skin temperature in response to a 9 min typing challenge were detectable through infrared thermography in three groups of office workers: asymptomatic controls, those with distal upper extremity musculoskeletal disorders UEMSDs without cold hands, and those with distal UEMSDs with cold hands [24].

A study was published to estimate the temperature conditions that could cause mental stress, this by immersing both hands in a container of water at a temperature of 3˚C [25]. In addition, a study was published about a professional swimmer, and reflected the skin temperature analysis, in which temperatures were analyzed with regard to the swimming styles developed in the experiment [26].

II. Methodological Formulation

A. Materials

Materials and equipment used for the development and validation of this research are: a Pentium PC, a 1.2GHz processor, and 598MHz in RAM, two Skoll sensory thermographers with a range of 0 - 40 ˚C, accuracy ± 0.3˚C, resolution of 0.1˚C [16], an ergonomic chair, a stopwatch, a house heater, a sewing machine, cotton fabrics, micro porous tapes and adhesive tapes. For programming the sensory thermographers, the Akeley program was used. The statistical analysis software is Minitab ® 15 and Microsoft ® Office Excel 2007.

B. Methods

Women were asked that before the test to refrain from doing any exercise for a period of 20 minutes [24],[25] since previous studies have determined that the estimated period for the temperature of the human body to stabilize (thermalization) is after performing a particular exercise of 20 minutes due to a reduction in the range of body metabolism [27]. On the other hand were also asked to avoid drinking alcohol or smoking previously [25], since smoking causes a decrease in body temperature [28] and drinking alcohol increases it [29].

After the room temperature of the lab was warmed in order to keep it an ideal range of 20 to 25˚C. [30], with the help of a heater to room temperature. After the stabilization period, the individuals were asked to sit in an ergonomic chair and then placed thermographers are sensory in both wrists. Already placed thermographers the subjects were asked to rest their arms on a perfectly flat table at the height of the ribs [30] for a period of 20 minutes.

Then, a highly repetitive operation was emulated as is usually performed in the textile industry for 3 hours and 30 minutes because this period represents the longest working hours of workers which makes these highly repetitive movements. The operation involved the movements of reaching, taking, and dropping, among others.

During the test, anomalies or pain were described by the individuals who informed of such pain and in which area was specifically present, to be written down in the log data. Finally, having completed the cycle and after 20 minutes rest, it was proceeded with the withdrawal of the thermographers from the wrists of each individual, and then to the data extraction from the thermographers, and then, do the analysis of results.

Individuals who participated in this research were three women in good shape. The main anthropometric characteristics of individuals are summarized in Table 1. It is important to say that none of the individuals had lower back problems of blood pressure problems and in parallel none reported problems from addictions to alcohol and / or stuff. By the other hand it was clarified the fact that one of the individuals had a right hand wrist fracture 15 years ago. Besides none of them had previous experience in developing operations involving repetitive movements in previous works of other long-terms motor activity workstation.

III. Results

The experiment was to carry out Section 2. The results of this experiment are in Table 2. For the analysis of experimental results in this Section 3 presents only the example of the complete analysis for the individual 3, test day 2, because this presented the highest temperature (specifically the left wrist).

TABLE I
ANTHROPOMETRIC CHARACTERISTICS OF INDIVIDUALS

Individual	Age	Gender	Weight (Kg)	Height (m)	Dominant hand	Fractures
1	20	F	54	1.60	Right	No
2	20	F	53	1.64	Left	Yes
3	27	F	59	1.54	Right	No

TABLE II
TEMPERATURE PATTERNS

Individual/Test day	Max Temperature in right wrist	Max Temperature in left wrist	Anderson Darling in right wrist	Anderson Darling in left wrist	R Adjusted in right wrist	R Adjusted in left wrist
1/1	32.762	32.864	1424.224	414.725	0.697	0.597
1/2	33.601	33.924	259.030	351.562	0.929	0.956
1/3	32.411	31.862	633.881	1492.771	0.797	0.689
1/4	33.024	33.073	416.929	450.669	0.979	0.978
2/1	33.221	33.622	3019.99	263.479	0.535	0.395
2/2	32.723	33.448	977.214	839.849	0.930	0.878
2/3	33.151	33.702	243.409	361.942	0.935	0.962
2/4	33.753	34.085	354.778	113.137	0.878	0.657
3/1	33.426	32.226	113.940	43.810	0.850	0.765
3/2	34.303	34.505	90.643	54.873	0.861	0.886
3/3	33.249	34.258	411.608	192.966	0.813	0.830
3/4	33.523	33.784	518.749	447.997	0.885	0.879

It is important to describe that none of the individuals had lower back problems or blood pressure. Fig. 1 and Fig 2 show that in both cases it was possible to carry out curve fitting of third order to represent the behavior of the temperatures during the experiment. Getting the coefficient R Square of 89.6% for the left wrist and 86.6% for the right wrist. In both cases it was possible to observe that the behavior of the temperatures were so similar, beginning the

ascent during the first hour of the exercise, followed a decline of the temperature until the end of the test. The highest temperatures in test day 2 were 34.303 ˚C for the right wrist and 34.505 ˚C for the left wrist, in a period of 2 hours 18 minutes and 53 seconds and 2 hours 52 minutes and 46 seconds respectively temperature and times were rougly similar. During the test day 1 no pain was detected on the subject. On test day 2 upper back problems started to appear on the experiment. Pain began with low levels but increasing it by the end of the test. Neck pain was detected on test day 3. Finally, an increasing of upper back pain was detected on test day 4. No wrist pain was observed during the 4 tests. As part of the evidence supporting that the data presented do not follow a normal distribution. Fig. 3 and Fig. 4 show the histograms and Fig. 5 and 6 show the normality test.

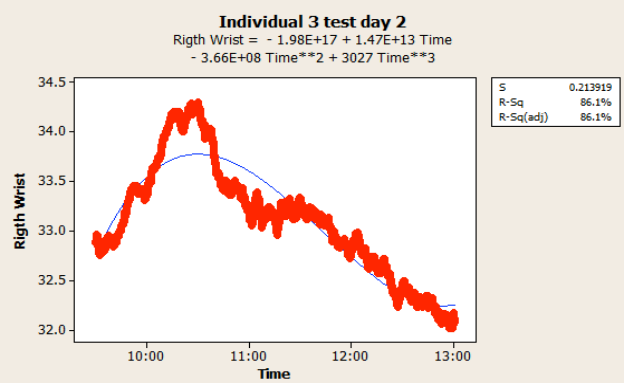

Fig.1Individual 3 test day 2 right wrist Polynomial Adjustment

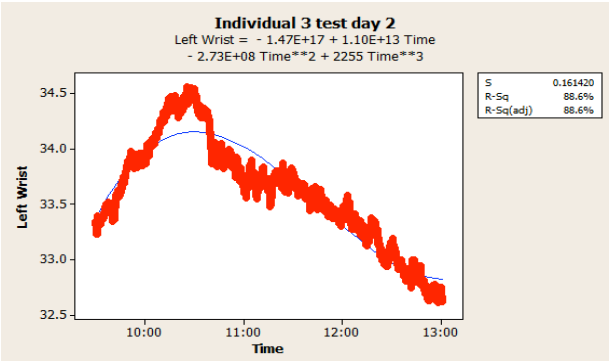

Fig. 2 Individual 3 test day 2 left wrist Polynomial Adjustment

In Table III, it was showed that in both wrists was possible to set some kind of probability distribution, which was 3-parameters Weibull distribution (3PW), the Weibull (W) and 3-parameters lognormal (3PL). Table IV shows that it was the 3 parameters Weibull (3PW) that best fits to the data, except on the individual 2 test day 1. Table IV shows the summary of the results presented in the tests in the four days of tests. This table is an approach from a viewpoint in the binary code to represent whether there is similarity in the patterns of temperature, and if one or more probability distributions were presented to discuss the left wrist or right wrist, as was the case, this is 1 affirmative or 0 is negative.

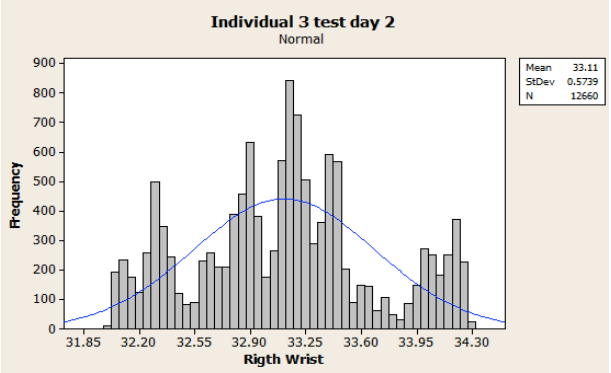

Fig. 3 Individual 3 test day 2 right wrist Histogram

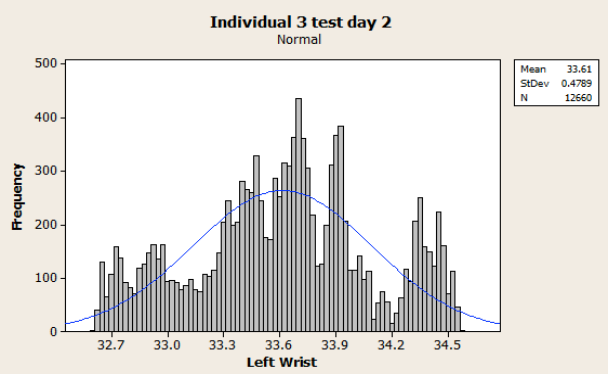

Fig. 4 Individual 3 test day 2 left wrist Histogram

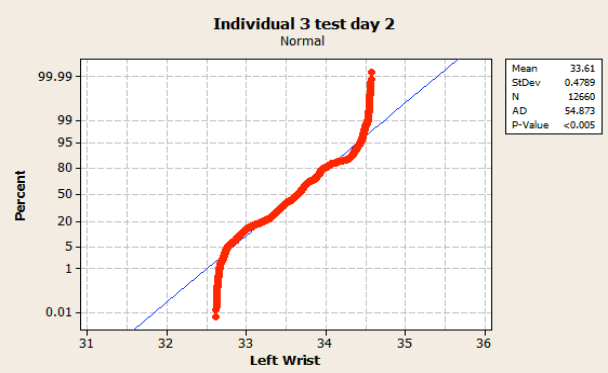

Fig. 5 Individual 3 test day 2 right wrist Normality test

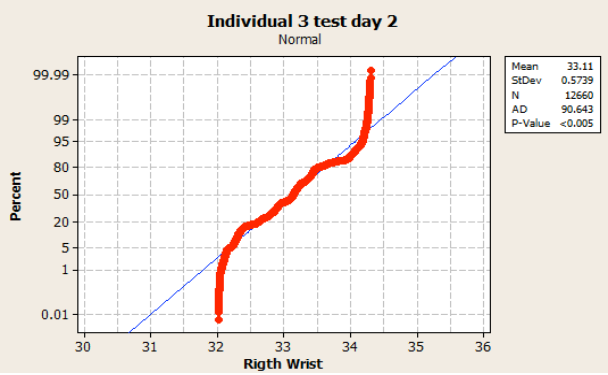

Fig. 6 Individual 3 test day 2 left wrist Normality test

TABLE III
PROBABILITY DISTRIBUTIONS OF THE INDIVIDUAL 3 TEST DAY 2

Distribution	Anderson-Darling (adj) right wrist	Correlation- Coefficient right wrist	Anderson-Darling (adj) left wrist	Correlation-Coefficient left wrist
Weibull	645.228	0.943	387.564	0.959
3-Parameter Weibull	116.315	0.985	74.684	0.985
3-Parameter Lognormal	89.260	0.986	58.507	0.989

TABLE IV
PROBABILITY DISTRIBUTIONS AND SETTINGS FOR ALL TESTS

Individual / Test Day	Polynomial fit right wrist	Polynomial fit left wrist	Pattern similarity	Weibull right wrist	3 Parameter Weibull right wrist	3 Parameter Lognormal right wrist	Weibull left wrist	3 Parameter Weibull left wrist	3 Parameter Lognormal left wrist
1/1	0	0	1	1	1	1	1	1	0
1/2	1	1	1	1	1	1	1	1	1
1/3	0	0	1	1	1	1	1	1	0
1/4	1	1	1	1	1	1	1	1	1
2/1	0	0	0	0	0	0	1	1	1
2/2	1	1	1	1	1	1	1	1	1
2/3	1	1	1	1	1	1	1	1	1
2/4	1	0	1	1	1	1	1	1	1
3/1	1	0	1	1	1	1	1	1	1
3/2	1	1	1	1	1	1	1	1	1
3/3	1	1	1	1	1	1	1	1	1
3/4	1	1	1	1	1	1	1	1	1

IV. CONCLUSION

This research allowed answering the questions in Section 1, being the maximum temperatures reached for the individual 1 in right wrist 33.601 ˚C over a period of 1 hour 38 minutes and 20 seconds. Individual 1 left wrist 33.924 ˚C over a period of 57 minutes and 44 seconds. Individual 1 test day 1 showed moderate lower back pain in most of the four tests, this seems to occur by the end of each test. An increasing of temperature was detected in the four tests during the first hour of the repetitive task. Also rigth shoulder pain in the time range where the maximum temperatures was identified. The maximum temperatures reached for individual 3 were tested for day 2, right wrist 34.303 ˚C over a period of 1 hour 0 minutes and 23 minutes and on the left wrist 34.505 ˚C over a period of 55 minutes and 38 seconds. The highest temperatures were reached at similar times in both wrist. Disconfort was detected on upper back by the end of the tests and also neck pain problems showed up at the same time. Individual 3 was the oldest of the individuals took in account for the experiment, so the continuous variable *age* could be a variable that need and effort to study and investigate because this may affect the increasing or decrasing of temperature when repetitive tasks are done.

By the other hand it was found that individual 2 test day 1 described the lowest average correlation coefficients on rigth wrist but good and high correlation coefficients on left wrist. Cualitative variable *dominant hand* could be a strong variable to study temperatures changes usign sensory thermography, since individual 1 dominant hand was left and none of the three distributions coefficient describe and previous sections were over of 72%. It is concluded that temperatures show similar pattern (Table 4), that the data fit a polynomial of third order in most cases, and that it gets the type of distributions that would fit more the data, such as the 3 parameters Weibull distribution. It is concluded that working with sensory thermography provides good and satisfactory results in the analysis and evaluation of the

temperatures of the wrist of the diagnosis or prediction of possible cummulative trauma disorders. It is concluded that data does not fit a normal distribution for left wrist and right wrist since a Anderson Darling normality test was done for all the individuals on each day of test. Future work is to evaluate a greater number of individuals under the same methodological conditions but putting more analysis effort in those variables that were identified as important in this study. Themographers with more than one sensor are being developed to conduct more researchs related with the study of the cummulative trauma disorder like the carpal tunnel syndrome.

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