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Application of Sensory Thermography on Workers of a Wireless Industry in Mexico

Claudia Camargo, Enrique J. de la Vega, Jesús E. Olguín, Juan A. López, Sandra K. Enríquez

***Abstract*—**This study focuses on the application of sensory thermography, as a non-invasive method to evaluate the musculoskeletal injuries that industry workers performing Highly Repetitive Movements (HRM) may acquire. It was made at a wireless company having the target of analyze temperatures in worker's wrists, elbows and shoulders in workstations during their activities, this thru sensorial thermography with the goal of detecting maximum temperatures (Tmax) that could indicate possible injuries. The tests were applied during 3 hours for only 2 workers that work in workstations where there's been the highest index of injuries and accidents. We were made comparisons for each part of the body that were study for both because of the similitude between the activities of the workstations; they were requiring both an immediate evaluation. The Tmax was recorder during the test of the worker 2, in the left wrist, reaching a temperature of 35.088ºC and with a maximum increase of 1.856°C

***Keywords*—**Highly Repetitive Movements (HRM), Maximum temperatures (Tmax), Worker.

I. Introduction

MUSCULOSKELETAL disorders (MSDs), including those localized to the Upper Extremity Musculoskeletal Disorders (UEMSDs) such as CTS and forearm tendinitis, are common, widespread and disabling. They comprised 29% 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%. In service sector workers, slightly lower prevalence's prevailed. 51% of workers in the European Union used a computer at work in 2005, with an annual growth rate ranging from 3% to 4% [3].

C. Camargo is professor of the Department of Industrial Engineering, Faculty of Engineering, Architecture and Design, Autonomous University of Baja California, Ensenada, Baja California, 22760, Mexico (phone: 646-174-4333; fax: 646-174-4333; e-mail: ccamargo@uabc.edu.mx).

E. de la Vega is professor of the Department of Industrial Engineering, Hermosillo's Institute of Technology, México (e-mail: e_delavega_mx@yahoo.com).

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).

J.A. López is professor of the Department of Industrial Engineering, Faculty of Chemical Sciences and Engineering, Autonomous University of Baja California, Tijuana, Baja California, Mexico. (e-mail: jalopez@uabc.edu.mx).

Sandra K. Enriquez is master student of the Department of Industrial Engineering, Faculty of Engineering, Architecture and Design, Autonomous University of Baja California, Ensenada, Baja California, Mexico. (e-mail: sandra.enriquez@uabc.edu.mx).

It has long been known that repetitive motions of the 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 Cumulative Trauma Disorder [4]. The most common forms of Cumulative Trauma Disorder (CTDs) are: Tendonitis, tenosynovitis, epicondylitis, bursitis, and CTS. The latter is disabling condition of the hand(s) that can be caused, precipitated, or aggravated by repetitive motions combined with forceful and/or awkward postures [5], [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]-[11].

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 [12]. Infrared thermography (IR) is widely used to display temperature patterns on the surfaces of the skin by taking pictures [13], 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 [14]

The contribution of this paper is to analyze temperatures in worker's wrists, elbows and shoulders in workstations during their activities, this thru sensorial thermography with the goal of detecting Tmax that could indicate possible injuries.

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 research study.

Changes in body surface heat have interested physicians since the days of Hippocrates. Therefore it look over 4000 years-from heat estimation by touch when "fingers did the scanning," to sixteenth century thermometry, and then another three centuries before thermometers became a staple of medical practice-to arrive at thermography, today's thermometry of the skin surface. The body's thermal homeostasis and central control of surface temperature is maintained by a hypothalamic regulating center operating through feedback mechanisms [15]. Both sides of the body are affected uniformly and simultaneously; thus, thermal symmetry is the hallmark of normality, whereas skin surface asymmetry strongly suggests abnormality. The skin is one of the body's chief thermo regulators via its large vascular network and associated complex of nerve fibbers which together control blood flow within millimetres of the body surface. Superficial perfusion is largely influenced by the sympathetic nervous system. When stimulated by nerve root or peripheral nerve irritation, the sympathetic nervous system causes active vasoconstriction and decreased skin temperature, whereas it greater compromise or complete interruption causes vasodilatation and increased skin temperature. Up to date, the two most commonly used heat detection systems in clinical practice include infrared telethermography and liquid crystal contact thermography [12].

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

Reference [12] mention that the thermography scan can calculate temperature changes in small parts of the body surface. They illustrated the contribution of the IR in diagnosing and corroborating acute, recurrent and chronic clinical symptoms. 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 [16]. 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% [17].

Another study which was aimed to characterize the differences in skin temperatures of between three groups of office workers is 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 UEMSDs without cold hands, and those with distal UEMSDs with cold hands [18]

Another study aimed to examine the suitability of using mean dorsal hand skin temperature, before and after a short typing task as an indicator of UEMSD severity. It demonstrated a reliable physicologic method of determining UEMSD severity in office workers through the measurement of dorsal hand temperature using IR under a controlled ambient environment from 18 to 22˚C recommended [19]

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 [20]. In addition, a study was published about a professional swimmer, and reflected the skin temperature analysis, in which temperatures were analysed with regard to the swimming styles developed in the experiment [21].

A study was published to determine the thermographic changes in temperature associated with the elderly and young people. The results contribute to improve the understanding about temperature changes in elderly people [22]. Note that it is mentioned that for a cumulative trauma disorder can be detected, this must have developed well in advance. It's so that a clinical criteria has limited use in developing a model of prevention, in early detection, and the minimization of days lost due to disability [23].

The contents of this paper are organized as follows: initially presents a general introduction to CTD, IR. Then it shows the materials and methods. Then, results are presented, and finally the conclusion and future research on the topic.

II. Methodological Formulation

A. Materials

The material and equipment used in this research study were the following: Digital Sköll thermograph with 7 sensors with a temperature range of 0˚C to 40˚C, precision ±0.3˚C, and a resolution of 0.1˚C [14] micropore tape; adhesive tape; stop watch; personal computer. For programming the thermographers, the Akela program was used. Lastly, Minitab®16 and Microsoft® Office Excel 2008 statistical packages were utilized.

B. Methods

The experiment was applied to 2 workers of a wireless industry in Mexico, one of the pre-requisites for the experiment was that the workers did not perform any physical activity during the 20 minutes prior to the start of this experiment [18], [24], this interval was derived based on previous research, in which it was stated that the required time to stabilize the body temperature after undertaking physical activity was approximately 20 minutes [25]. On the other hand, it was also asked to the workers to avoid the consumption of alcohol or tobacco [24], [19], due to the fact that smoking induces a reduction in body temperature [26], in contrast, alcohol rises the body temperature [20], [26].

The following step consisted of verifying the company temperature between 20ºC and 25ºC [25], controlled by their system of air-condition. After that, the workers sat in a chair and the sensors of the thermograph were placed in both: wrists (in nerve region), elbows and shoulders. Then, the workers started their operations for 3 hours.

TABLE I
Anthropometric Characteristics of the Workers

WORKER	BMI	Age	Weight (kg)	Height (m)
1	24.09	21	68	1.68
2	28.20	34	74	1.62

Finally, the after completing the cycle of 3 hours, the thermographs were detached, the data was downloaded in Microsoft® Office Excel 2008 for post processing, and finally the analysis and validation of data was done with Minitab®16.

The workers that participated in this research were two men work; they were in normal physical condition. The main anthropometric characteristics of the workers are summarized in Table I. It is important to point out, that none of the workers presented lumbar problems, arterial pressure (high or low) problems; moreover, none reported to have any type of alcohol/tobacco addiction. They are dominant hand.

III. Results

According to the temperatures obtained from workers during testing, be made graphics to know the trend of maximum temperature of each worker. Such graphics were developed in Microsoft ® Office Excel 2007 to see the trend for each test performed and were developed graphics in Minitab ® 16 to know the trend by each party evaluated body (RW: right wrist, LW: left wrist, RE: right elbow, LE: left elbow, RS: right shoulder and LS: left shoulder). Graphs were drawn up for the comparison of the worker 1 and worker 2, this is due to the similarity of the activities carried out between their areas. These comparisons were also made for each part of the body assessed; you can see the response surface comparison of the workers in the Figs. 1 to 6.

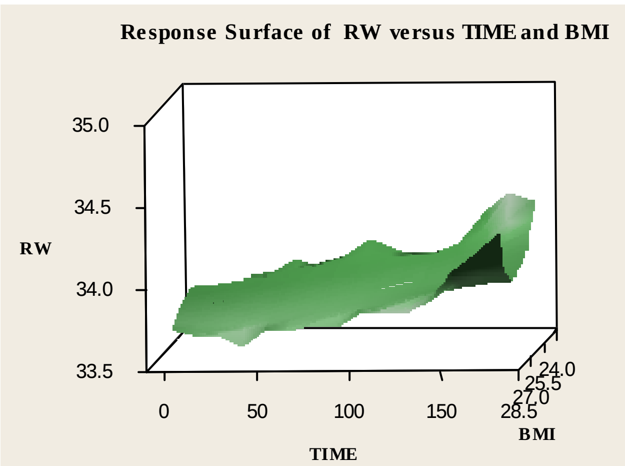

Fig. 1 Response Surface of Right Wrist versus time and BMI

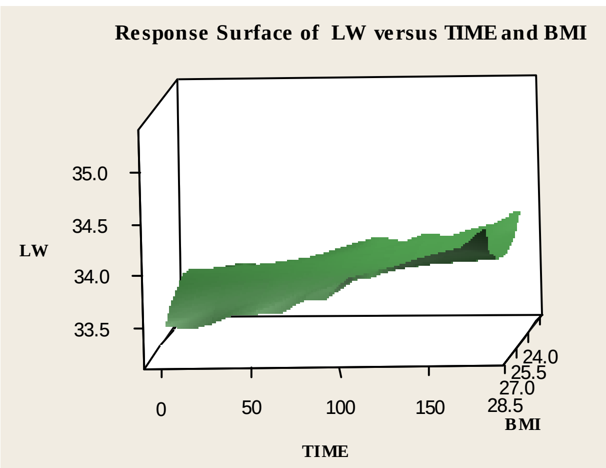

Fig. 2 Response Surface of Left Wrist versus time and BMI

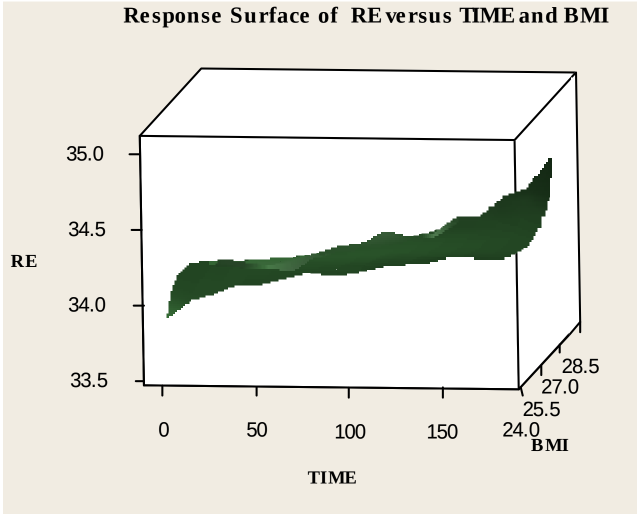

Fig. 3 Response Surface of Right Elbow versus time and BMI

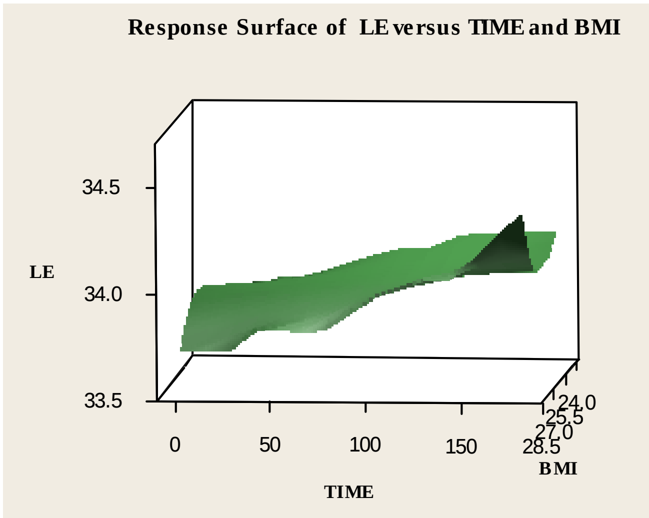

Fig. 4 Response Surface of Left Elbow versus time and BMI

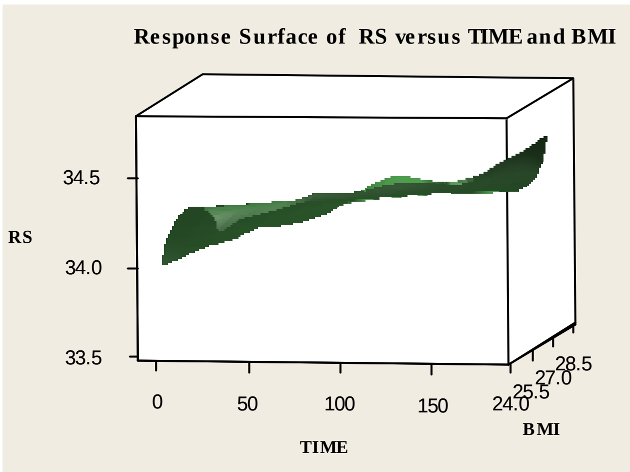

Fig. 5 Response Surface of Right Shoulder versus time and BMI

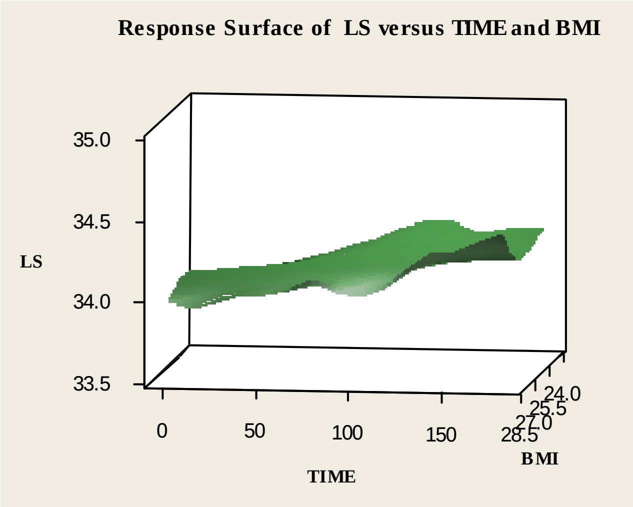

Fig. 6 Response Surface of Left Shoulder versus time and BMI

Based on the results of the comparison of the worker 1 and 2, it is recommended to analyze the wrist right and left respectively, since as you can see in the trend graphs always recorded Tmax in Fig. 1 and 2.

The ranges considered for the determination of each of the areas of work and for each part of the body assessed that should have an immediate assessment, assessment in the medium term, and not necessary, as indicated in Table II:

TABLE II
RANGES CONSIDERED FOR THE TYPE OF ASSESSMENT REQUIRED

Colour		Ranges in ˚C	Evaluation
(red)	Red	35.249 - 34.751	Immediate
(yellow)	Yellow	34.7509 - 34.502	Medium-term
(green)	Green	Less than 34.502	Not necessary

In Table III you can see that the maximum temperature was recorded on the right wrist with 34.788°C requiring an immediate assessment. Following this, the other areas evaluated (with the exception of the left elbow) require an evaluation over the medium term.

TABLE III
MAXIMUM TEMPERATURES OF THE WORKER1

Área Evaluated	Tmax
RW	34.788
LW	34.585
RE	34.599
LE	34.498
RS	34.702
LS	34.617

Table IV shows that the left wrist, right elbow, left shoulder and right shoulder; in descending order they require an immediate assessment. Following this, the rest of the evaluated areas require an evaluation over the medium term.

TABLE IV
MAXIMUM TEMPERATURES OF THE WORKER 2

Área Evaluated	Tmax
RW	34.550
LW	35.088
RE	35.028
LE	34.694
RS	34.780
LS	34.857

IV. CONCLUSION

This research allowed to conclude that Tmax in the worker 1 and 2 were reached in the RW and LW respectively, requiring both wrists an immediate assessment. In addition, the temperatures for the worker 1 and 2 were 34.788 and 35.088°C respectively. On the other hand, in the area C was recorded the maximum temperature increase of the study this 1.856°C being presented in the left wrist. In addition, it is important to emphasize that all registered temperatures of area C are above the optimum temperature to work: 34.5°C. It is important to mention that in all of the experiments detected discomfort in the right wrist in the time range where the Tmax were identified.

The sensory thermography offers the early detection of cumulative trauma disorders and with it, it would be possible to prevent further injuries, and perhaps prevent CTD's from occurring. Disorders like the Carpal tunnel disorder or tendinitis could be avoided by using an early monitoring system like the sensory thermography, which in fact provides a cost benefit acceptable relation

Therefore, it is recommended to give priority to the improvement of these areas for on the rest of the areas evaluated. In addition, we recommend to starting evaluation in both wrists, specifically the left first since, as previously mentioned, he presented the maximum temperature and the maximum increase of temperature in the study.

Also, to avoid the workers to reach such maximum temperature ranges the following is recommended: that for both lines of the area to have a break of at least 10 minutes (or to carry out the rotation of these workers) before the 135 minute and, for worker 1 and 2 have a break of at least 10 minutes (or to carry out the rotation of these workers) and before the 150 minute.

Finally, we recommend that you the company set deadlines to carry out each evaluation type, as it authorized by the management which was presented and delivered all the information of this project. As a proposal, it is suggested to make an immediate assessment within 2 weeks and in the medium term to within 2 months after presented this analysis.

Future work is to evaluate a greater number of workers under the same methodological conditions. C. Camargo, E. J de la Vega, J. Olguín and J. López are currently exploring this research study in addition to proposing predictive models for the detection and reduction of CTDs in the workplace.

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