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Analysis of Effects of Exercises on Middle-aged and Elderly Arthritics by Thermal Imagery and Automatic Auxiliary Diagnosis

[1,a]Chin-Lun Lai* [2,b]Tsung-Ching Lin and [1,c]Tung-Lin Yang
[1]Institute of Information and Communication Engineering, Oriental Institute of Technology, Taipei, Taiwan
[2]Department of Physical Medicine and Rehabilitation, Far Eastern Memorial Hospital, Taipei, Taiwan

Email: [a]fo001@mail.oit.edu.tw, [b]tclin0331@gmail.com, [c]maniya.ntcb@msa.hinet.net,

Abstract: In this paper, an automatic infrared thermal image analysis method is proposed to analyze the rehabilitation effects, after simple exercise intervention, on middle-aged and elderly osteoarthritic patients, while an automatic CV diagnosis criteria for distinguishing the patients from the healthy persons is also established, to assist medical personnel's diagnoses and suggestions. To approach this goal, the questionnaires from the Western Ontario and McMaster Universities are also used as basis for evaluating physiological changes before and after rehabilitative exercises and the data analyzed may also be used as the reference for subsequent exercise adjustment by the subject. Experimental results shows that the proposed method performs well in automatic judgement of degenerative arthritis hence can be a good reference for clinical diagnosis.

Keywords: Infrared thermal imaging, osteoarthritic, automatic diagnosis , WOMAC

1 INTRODUCTION

Some chronic diseases occur with age increasing and Osteoarthritis (OA) is just one of the most common ones. Degenerative gonitis is also referred to as knee osteoarthritis which is the most common joint disease across the world. It has gradually spread from the elderly to the young in recent years. The main symptom is articular cartilage damaged. Therefore some people hold that the degenerative arthritis is joint weak and degeneration and the degenerative joints are vulnerable to pain, hydrarthrosis and swelling resulting in the range of motion decreased. The arthritis may occur to various parts of the whole body, in particular to the weight bearing joint or joints with a large range of motion, such as cervical vertebra, lumbar vertebra, hip joints, knee joints and hand joints. Such symptoms will significantly affect daily motions of the patient, such as waking tread, surmounting obstacles, walking up and down the stairs, change from sitting to standing, etc. In the past, such physiological conditions relied on X-ray examination. The result is accurate while the issue of radiation dose exists. Infrared imaging is also called temperature-difference photographing and is a detection technique for observing shell temperature distribution using the infrared radiation photographing principle. The local heat balance will be affected when a human being contracts a disease or the physiological condition is abnormal and clinically the tissue temperature will increase or decrease accordingly. Thus the measurement of body temperature variation is one of the important indicators for clinical disease diagnosis. And then many studies focus on the application and limitation of exploring biomedicine via thermal imagery [1]. For example: evaluation of hand osteoarthritis and rheumarthritis, effect of lesion of nerves around the sole of the diabetics' foot soles on blood circulation [2-3]. The detection methods above are based on symptoms such as inflammatory responses, swell, fever, pain etc. These pathological processes will affect blood vessels and surrounding tissues. But, the heat radiation is the energy diffused naturally from the body temperature and can be remotely sensed to form thermal imagery data and analyzed. Hence the thermal image can be used to diagnose diseases occurring to body surface or proximity of body surface without invasive behavior or radiation dose problem, which is a highly safe physiological exploring approach. Thus great importance has gradually been attached to the approach in the medical circle. It is required that attention shall be paid to the operating errors when the thermal image assessment diagnosis is used for conditions. The errors will not be decreased unless the operating conditions for infrared thermograph are complied [4]. It is attributed that the experimental environment, equipment and physiological condition of the subject at the moment will affect the result. In addition, the assessment scale for OA patients is used in the study the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [5]. However, the assessment scale can only objectively reflect the conditions of the patient after exercise and a thermal imager is required for pathological detection in combination with the assessment scale. The heat generated can be used for detecting the skin surface temperature indicating pain intensity by the thermal imager since the area below the

patella is most sensitive to pain for the arthritic [6]. Besides, it will be very difficult to distinguish from other arthritis or symptoms and the temperature detected by the thermal imager may approximate the temperature of a normal subject if no change is observed or only slight stenosis of articular cavity is noted on the X-ray film for the initial degenerative arthritis. In such a case, it is difficult to judge the subject as an arthritic or a healthy person. Hence, the paper presents a set of rehabilitation exercise method to induce the difference between an arthritic and a healthy person after exercise and calculate the center point [7] of patch below the patella with the image captured automatically by the thermal imager. Compare the difference (if any) between the skin surface temperate of the experimental group and control group after the temperature of the area is obtained, and the rehabilitation effect after exercise for two weeks. Then overlap the two different images (visible image and thermal image), adjust the contrast after overlapping [8], to allow the location of local abnormal temperature to be more easily observed on the overlapped image. With such detections, the medical personnel are able to judge the patients' conditions even more accurate and quicker.

The paper will introduce methods in the following section, the third section will present and discuss and experimental results, the fourth section will present conclusions and suggestions.

2 Experimental Methods

According to the bibliography, it is known that the infrared thermal image can be used to detect degenerative arthritis. But the detection effect of the person with slight symptom is not necessarily significant compared with that of a healthy person. Therefore, the study is conducted in cooperation with a doctor from the rehabilitation division. Annular oil pressure resistance training movement as induced to detect the difference between the degenerative arthritics and healthy persons, and collected data as the basis for establishing an automated auxiliary discrimination program, in order to make the process more clear, the flow chart for the system operation is showed as the Fig. 1 below and then the function of each block is described as follows:

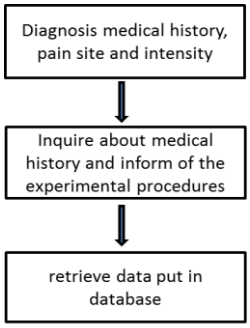

Fig. 1. Collected data System Diagram.

Step 1: Doctor diagnosed the medical history, pain site and severity of the patient and delivered the statistical study data to the study personnel for photographing the pain site.

Step 2: The study personnel are required to inform the subject of precautions in advance. The subject shall stay in the isolation room for 15 minutes prior to the start of the first-week exercise. Apply a patch with diameter of about 2cm to the central point of the knee patella as the locating point and photograph the temperature before the first-time exercise. The subject shall do warm-up exercises first and then take rehabilitation exercise under the direction of the coach in the fitness center (annular oil pressure resistance training, eight apparatus in total, one minute for each apparatus, and three circles in total). Take note of the exercise effect of each subject at all times. The subjects will be lead to the isolation room for experiment following exercise. They shall also stay in the isolation room for 15 minutes before the experiment, understand the experiment procedures to be performed and fill in the WOMAC questionnaires. All procedures will be performed at a room temperature of about 23±1℃. In addition, be sure to make infrared image measurement after the body temperature reaches the balance state to avoid temperature errors caused by heat accumulation. Maintain low humidity for the body and prevent the measurement being influenced by the convection and heat radiation.

Step 3: Repeat the steps in A and B above , retrieve the Image Data of the experimental group and the control group and input them to the data base. Then write computer identifying programs based on the images in the database. The flow chart for the automatic computer identifying system operation is showed as the Fig .2 below the automatic identifying program is as follows:

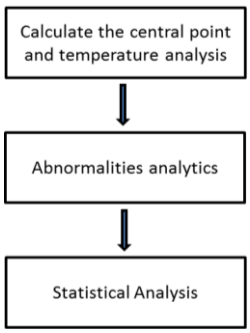

Fig. 2. Automatic computer identifying System Diagram.

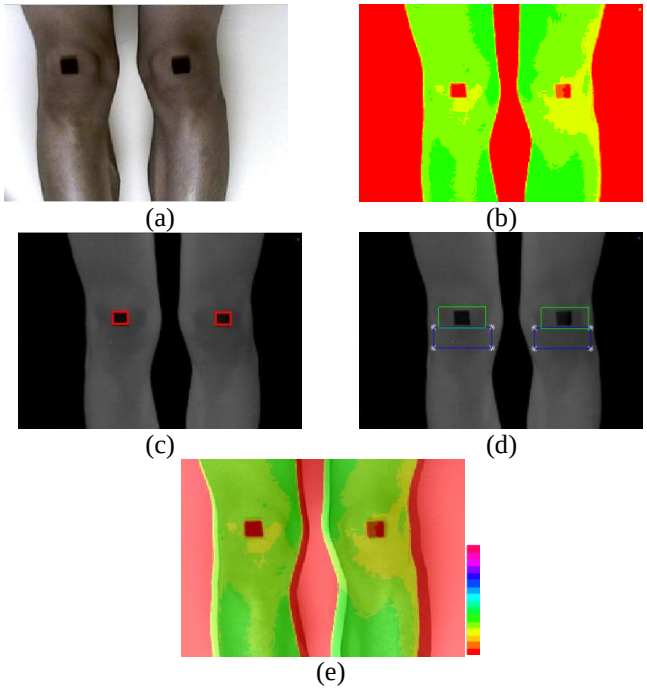

Fig. 3. (a) Original visual image, (b) thermal image, (c) the black patch marked as 2 cm, applied to the center of the patella, the red box for confirming the patch's registration with the central point, and the stance during photographing, (d) the blue box for calculating the temperature below the patella, (e) the overlapped image is convenient for identifying the variation of skin surface.

Step 4: Reference [16], set the black patch as the desired object, calculate the central point of the patch, in addition, stick the patch with diameter about 2cm to the central point of the knee patella as the positioning point to confirm that the positions of the thermal image and visible image are consistent the mark displays as a red block on the thermal imager shown in Fig. 3(b). Therefore, it is easy to identify the registration of the two images. Finally, adjust the thermal imager to the optimal angle and height for photographing the knee joints. Fig. 3(c) is for confirming whether the patch is selected, whether the standing position for photographing is excessively close to or away from the camera. The range of the black patch will be beyond the red box and affect the judgment if the standing position for photographing is excessively close to the camera. Calculate the temperature of the feet down from the central point of the patch. The blue box below the central point (below the patella) can be simply defined as:

$$S(x, y) = I(c + d, r + i) < k . \quad (1)$$

The green box in Fig. 3(d) is the patch range set, variables c and r are the central points of the patch, d is the distance between the upper and the lower end of the central point, i is the distance between the left end and the right end of the central point, k is the value of background pixel. Record the coordinate value of the previous point if the pixel of the following point is less than the pixel value of k point. Repeat the above steps for four times to obtain the average temperature, maximum temperature and minimum temperature of the pixel sum in the blue box.

Step 5: The coordinates of the central points from the two images shown in Fig. 3(a) and Fig. 3(c) subtract and the resulting new central point is exactly the distance between the two cameras shown in Fig. 3(e). Perform image overlapping for conveniently viewing the abnormal sites on the skin. Finally, retrieve the temperatures of the experimental group and the control group before and after exercise and find out the difference.

Step 6: Input the collected data of subjects to the database and apply Gaussian distribution statistical data to the experimental group and control group. Normalize the derived average value and standard deviation to determine the probability of each observed value in the data distribution as the basis for inferring whether the data from a certain population. In the database, one-point density function is applied per 0.01℃ for the data of ten groups of patients and ten groups of healthy persons collected based on the average value and standard deviation. The curve derived is distributed as shown in Fig. 4 (the red points on the left and right curves are the actual temperatures of ten subjects). The two curves significantly show the temperature difference between the arthritics and healthy persons. In addition, collect the data of four subjects with condition unknown and input it to the database (purple round points) as probability for testing the system prognosis, which can assist the medical personnel in diagnosis.

3 Experimental Results

In order to achieve the expected results of the study, listed t he following precautions: infrared thermal imager, subjects information, shooting distance, and environmental factors.

A. Subject Information

The study is approved by Institutional Review Board for coo perating with the doctor from rehabilitation division of Far E astern Memorial Hospital.

B. Operating Way

The sequences: wait for 15 minutes, stand by the foot mat, researchers subjects paste patch to automate capture images show the temperature of the subjects, and analysis belongs to which part of the ethnic groups with a probability value.

In WOMAC questionnaires for evaluating pain intensity (knee pain, stiff degree, motion difficulty) from patients with objective conditions, the pain intensity of second time is weaker than that before and after the exercise of first time and the second time and the temperature before and after exercise decreases significantly. Therefore it is determined that the rehabilitation exercise can generate rehabilitation effects as shown in Table 1. The result of experimental numerical analysis shows that partial subjects are not easily judged as arthritics due to the fact that their temperature

differences before exercise are not significant. Therefore, the temperatures after induced rehabilitation exercise are used to plot the normal distribution curve in the form. The temperature of the left foot is higher than that of the right foot among all subjects, which may relate to footedness. Therefore, the temperatures of left feet are uniformly adopted for the distribution curve for more convenient difference distinguishing as show in Table 2. Observe the Normal distribution curve established with the experimental group and control group in Fig. 4 if the prediction demonstrates that the method after simple exercise is able to identify the range value for the difference temperature between the patients and healthy persons. It is assumed that a subject with condition unknown is measured to be 33.17℃ as shown in Table 3. It is predicted that the probability of the subject in the database range for degenerative arthritics accounts for 25.30% while the probability of healthy persons accounts for 0.10%. But the probability of patients is much higher than that of healthy persons. Hence the subject is judged as an arthritic finally. And the temperature is within the range of patient database and partial area is within the range of healthy persons. Hence the part is also judged as error rate.

Table 1. Differences after Exercise

Arthritic	First Detection	Second Detection
WOMAC(pain intensity)	12.66	10.92
Temperature before exercise (left/right)	32.44/33.85	30.78/32.92
Temperature after exercise (left/right)	31.93/33.84	30.48/32.80

Table 2. Characteristics of the study participants

	Degenerative Arthritis	Without Degenerative Arthritis
Quantity	10	10
Age	66.8±14.2	20.8±3.2
Average temperature before exercise (left foot)	32.44	28.41
Average temperature before exercise (right foot)	31.93	28.30
Average temperature after exercise (left foot)	33.85	29.35
Average temperature after exercise (right foot)	33.84	29.28
Grade	Grade Ⅰ-Ⅱ	Grade 0

Table 3. Analysis of System auxiliary Discriminant

Temperature	Probability of Patient	Probability of Healthy Person	Cross Error Rate
29.35	5.20e-06%	47.46%	5.20e-06%
30.19	1.64e-04%	24.21%	1.64e-04%
33.17	25.30%	0.16%	0.16%
33.85	50.12%	0.03%	0.03%

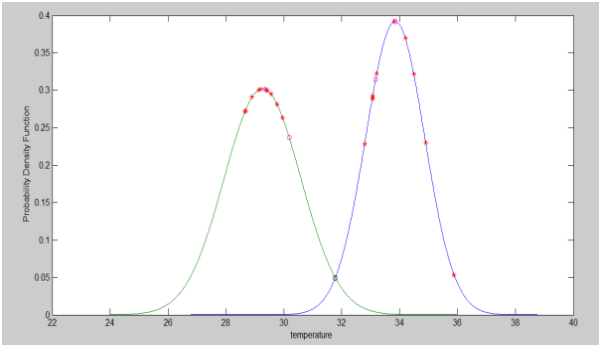

Fig. 4. Normal distribution of subjects

4 Conclusions And Suggestions

The experiment result verifies the following arguments. The thermal imager can be used to detect the difference between the degenerative arthritics and healthy persons after rehabilitation exercise and it is obviously observed that the rehabilitation exercise is significantly helpful for the patients. In addition, the questionnaire assessment also shows that the pain index of the patients involved in rehabilitation is decreasing.

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