

*Full Length Research Paper*

# A new measurement method for determination of low back pain

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The patient's low back pain can be determined using the visual analog scale (VAS) as subjective methods. This study aims to design a device used in evaluating low back pain objectively, by measuring skin resistance. To test the developed system, 8 low back pain (experimental group) and 8 healthy (control group) subjects were admitted in Dumlupinar University, Medical Faculty, Physical Therapy and Rehabilitation services. The skin resistance of all the subjects has been measured from their back using both the DC and the AC supplies. The skin resistance of the experimental group before the treatment and at the end of 15 days of the treatment was measured. The results of the treatment of the experimental group before and after treatment have been found to be statistically significant ( $p < 0.05$ ). The measured skin resistance values were found to be statistically significant, when compared to the control and the experimental groups ( $p < 0.05$ ). As a result of these findings, the developed system can be used to objectively determine low back pain by measuring skin resistance.

**Key words:** Skin resistance, low back pain, visual analog scale, objective measurement.

## INTRODUCTION

Low back pain creates dysfunction of the muscular-skeletal system and is known as a common problem. Low back pain can stem from the pulling or forcing of muscles, connective and soft tissues or alternatively, it occur as a result of the deformation of vertebrae and discs (Langevin and Sherman, 2007). The patient's low back pain level is diagnosed by physicians according to the patient's own statement. This approach has been known to be visual analog scale (VAS). The patient's pain can be measured using the VAS scale, as follows: A horizontal line numbered from 0 (no pain) to 10 (maximum pain) is shown to the patients. The patients are required to indicate the level of pain on this scale. Thus, the pain is determined subjectively (Gould et al., 2001). Although the VAS was reported to be reliable and to be a valuable method in the literature, the determination of the effect level of pain remains inadequate (Stener-Victorin et al., 2003). There are also various studies in recent years that diagnosed low back

pain, based on skin conductivity as a replacement method for VAS. Although in these methods, the skin conductivity is taken into account, the effect of skin resistance or impedance is not investigated (Shankar et al., 2009; Weng et al., 2004, 2005).

The inhibitory component of the skin against a given electrical current is called the electrical skin resistance (Cho and Chun, 1994). Skin resistance has been used since 1930s to determine sites of pathological conditions and is defined as the resistance offered to the passage of an electrical current (direct current) through the skin (Richter and Katz, 1943; Riley and Richter, 1975). Skin resistance is related to skin conductance, which changes in the presence of sweat; a fluid composed of water and ions. It is determined by passing a weak current through the measuring changes in electricity flow or by measuring the current generated by body itself. It has been correlated with emotion, attention and stress. Correlations among the skin resistance and attitude, empathy, and social interactions, especially when associated with small group interactions, have been shown (Clariana, 2005). Skin resistance and skin blood flow decrease, and that perspiration increases transiently at the deh-chi stage (described as a kind of soreness,

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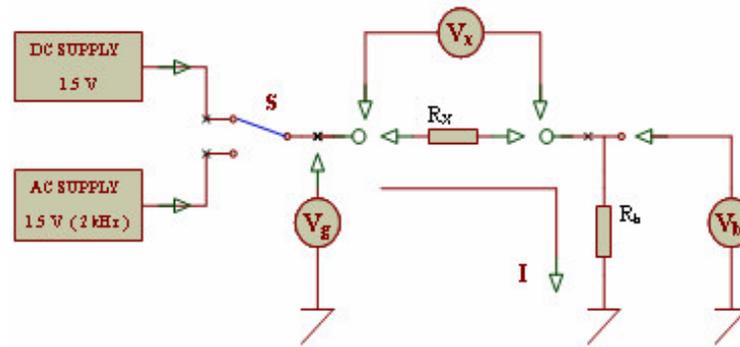


Figure 1. Block diagram of the measurement circuit.

numbness, or heavy swelling in deep tissues during manual acupuncture) (Liao et al., 1998).

The use of objective methods rather than subjective methods in the determination of diagnosis in low back pain will be more convenient. This study, it is aimed to develop a system which can evaluate the low back pain in an objective way. The developed system will assist the physical therapy clinic doctors in the diagnosis of low back pain.

## MATERIALS AND METHODS

### The design of the measurement system

The skin resistance measurement is achieved by connecting two probes on the interested skin area. By applying the Direct Current (DC) supply, the skin resistance level (SRL) of the epidermis can be assessed. Yet, by applying the Alternative Current (AC) supply, the skin impedance of the dermis can be measured (Christie, 1981; Jabbari et al., 2007). Therefore, both the DC and the AC supplies are preferred to carry out the current research. The circuit designed 1.5 V for DC and with an effective voltage level of 1.5 V at 2 kHz of sinusoidal, AC are applied to the skin (Li et al., 2003; Pliquet et al., 2005).

The measurement system is represented as black diagrams in Figure 1 and the main circuit is given in Figure 2. The circuit can be simplified with two resistors connected in series with each other. Here,  $R_x$  and  $R_b$  stand for the skin resistance and the known resistance, respectively. When voltage is applied, the current  $I$  flows through the resistances. This current creates a voltage  $V_b$  on the resistance  $R_b$ . The value of the voltage  $V_b$  is measured by the system. The current flowing through the skin is calculated using Equation (1):

$$I = \frac{V_b}{R_b} \quad (1)$$

where  $I$ ,  $V_b$  and  $R_b$  indicate the current flowing through the skin, voltage measured by the processor and the known resistance, respectively. At the same time, the value of the voltage across the skin is calculated as:

$$V_x = V_g - V_b \quad (2)$$

where  $V_x$ ,  $V_g$  show the voltage across the skin and the voltage applied to the circuit, respectively. Then the skin resistance is found to be:

$$R_x = \frac{V_x}{I} \quad (3)$$

### The software for the measurement system

In the system realized, as hardware, two microcontrollers are used. These microcontrollers are programmed with software for the measurement and processing stages. The program codes used in the microcontrollers have been produced in PARSIC. The 4-bit data output and 5-bit data selector output in the analog /digital converter, 16F628 (represented with U2 in Figure 2), of the two microcontrollers are used to be A port data input and B port data input selector, respectively. Namely, the corresponding microcontroller sends the data that are read regularly to the serial port. Briefly, the microcontroller 16F628 transfers the data in the output of analog/digital converter through the serial port to the other microcontroller 16F877 and to the computer.

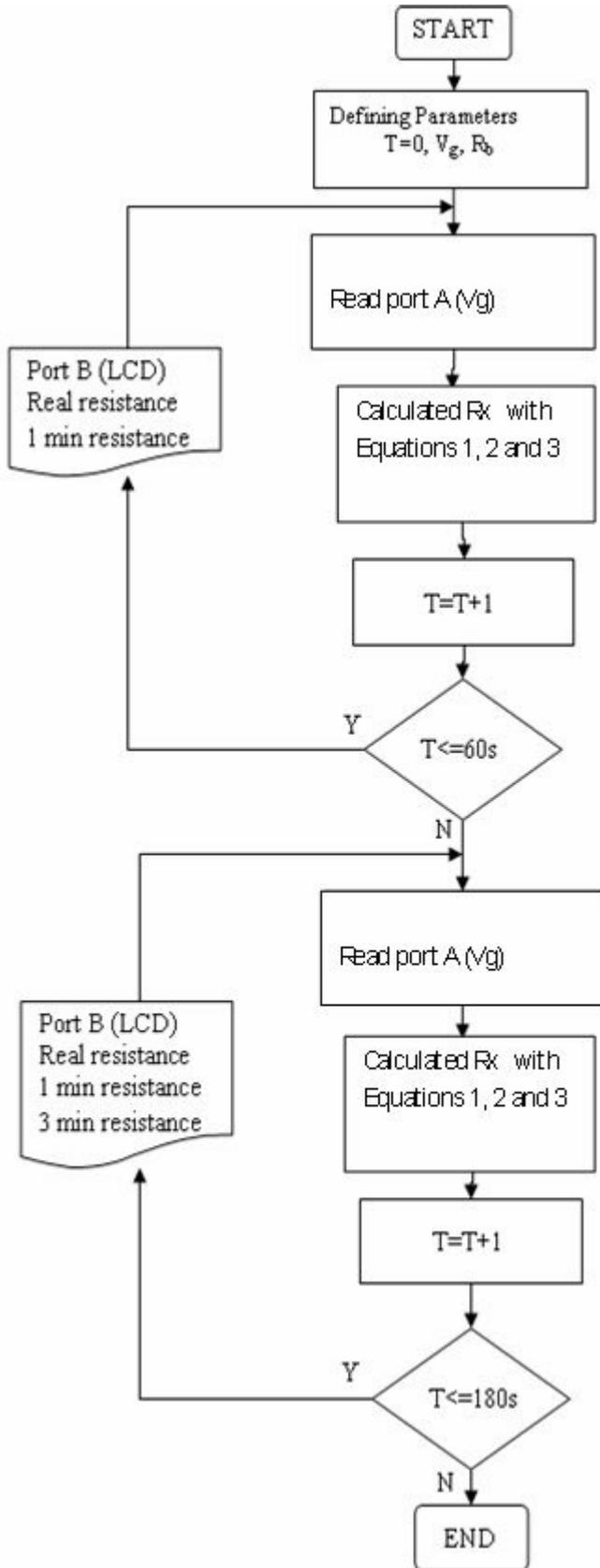
The second microcontroller, 16F877 (represented with U1 in Figure 2), takes the data from the output of the first microcontroller 16F628, calculates the quantities given in Equations (1), (2), (3) and sends the computed results onto the LCD screen. The data on the LCD screen shows the resistance values which are calculated at the 1<sup>st</sup> and 3<sup>rd</sup> min of the measurements. The flow chart of the developed program for microcontroller 16F877 is given in Figure 3. This is due to the fact that the resistance values are not stable and rise continuously with the start of measurement process. It is seen from the experimental results that the measured values were stabilize approximately for 2 min (Figure 4). In the light of this information, microcontroller was instructed to show the values in the 1<sup>st</sup> and 3<sup>rd</sup> min.

The data from the output of the microcontroller 16F628 is transferred to a computer via serial port. To receive and process the data via the serial port, software in Visual Basic programming language has been developed; programming flow chart is given in the Figure 5. The developed program continuously receives the resistance values via serial port and displays them visually on the monitor. When the measurements are completed, then the resistance values are recorded in graphical form (Figure 4).

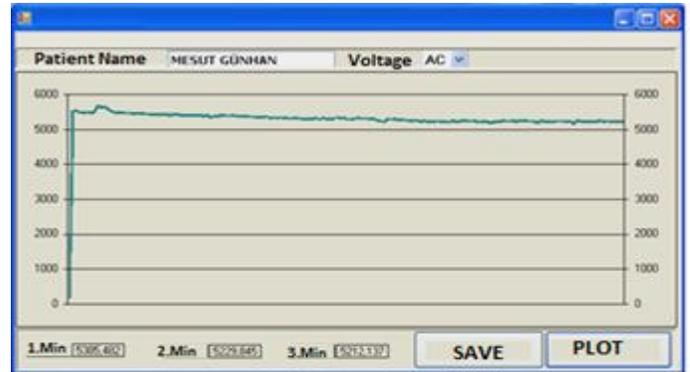
### Stability of measurement instruments

To determine the stability of our equipment used for measurement,





**Figure 3.** The flow chart of the developed program for microcontroller 16F877.



**Figure 4.** The developed software interface.

pre-treatment and post-treatment are given in Table 2. The level of significance is also examined in Table 2. When the results for the pre-treatment and post-treatment were considered in the case of AC, it was observed that there was no significant difference between the measured resistance values ( $p > 0.05$ ).

For the DC supply, the skin resistance values and comparative results of the experimental and the control groups are presented in Table 3. When the results for the post-treatment and the control group were considered in the case of DC supply, it was observed that there was significant difference between the measured resistance values in the first and the third minutes ( $p < 0.05$ ). However, statistically, there is no difference between the measurements of the pre-treatment and the control group in the first and the third minutes ( $p > 0.05$ ). Given the significance level, the criterion value is very close to 0.05. If the number of subjects would be increased, a statistical difference may emerge.

In the presence of AC supply, the skin resistance values and comparative results of the experimental and the control groups are given in Table 4. When the results for the pre-treatment and the control groups were considered in the case of AC supply, it was observed that there was a significant difference between the measured resistance values in the first and the third minutes ( $p < 0.05$ ). At the same time, there is a statistically difference between the measurements of the pre-treatment and the control group in the first and the third minutes ( $P < 0.05$ ).

## DISCUSSION

In this study, a device for evaluating the low back pain objectively has been developed. The developed system has been justified using the AC and DC supplies and the correlation of the results delivered by the calibration curves were found to be excellent. Moreover, with the aid of the developed software, the resistance measurements were visualized in graphical form. At the same time, since it has non-invasive usage, there is no requirement for any

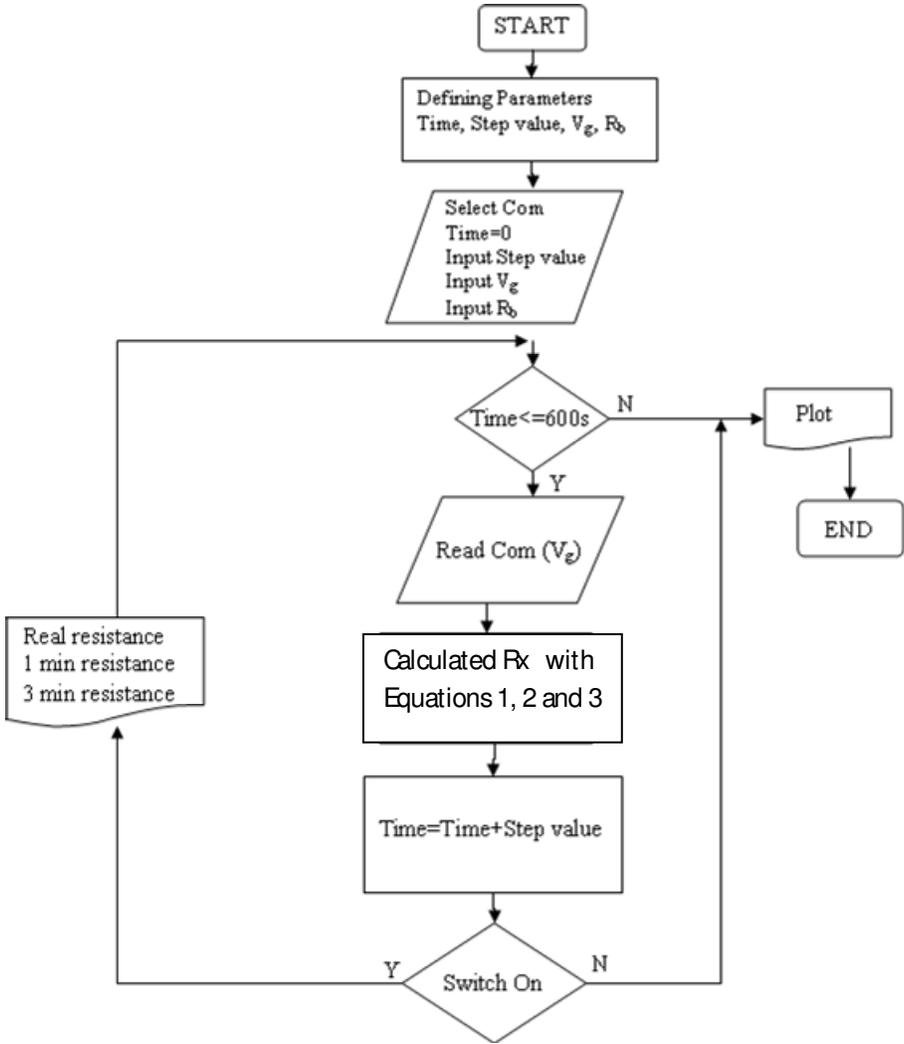


Figure 5. The flow chart of computer interface program.

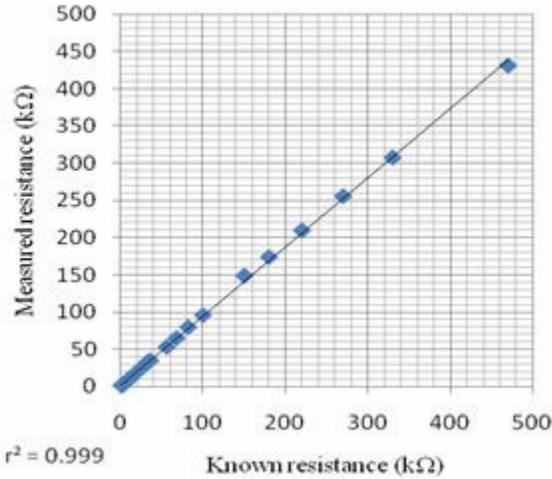


Figure 6. Calibration curve of measurement equipment in the presence of DC supply.

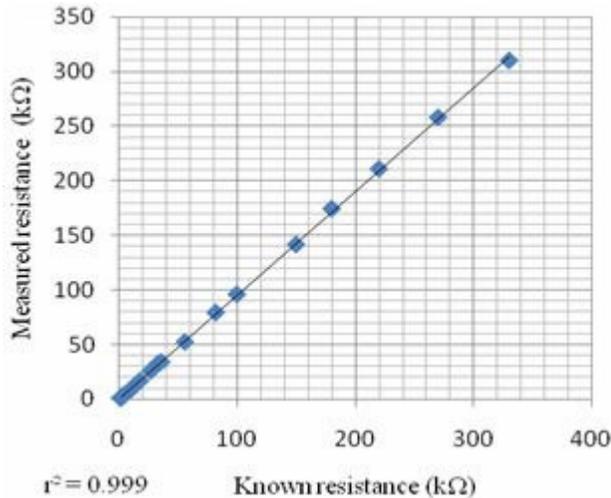


Figure 7. Calibration curve of measurement equipment in the presence of AC supply.



**Figure 8.** Developed skin resistance measurement system has been tested on patients.

**Table 1.** VAS values of the experimental group.

At rest		At active		At night	
Pre-treatment	Post-treatment	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
4.00 ± 1.00	1.00 ± 1.00	8.33 ± 0.58	4.00 ± 1.00	5.33 ± 1.15	1.67 ± 0.58
p < 0.05		p < 0.05		p < 0.05	

**Table 2.** DC and AC voltage values measured at the skin resistance and comparison results.

Measuring time (min)	Measuring status	DC voltage		AC voltage	
		Skin Resistance ( $\Omega$ )	Significant (p)	Skin resistance ( $\Omega$ )	Significant (p)
1	Pre-treatment	292491.50 ± 155890.88	1.00	7735.67 ± 2284.41	0.827
	Post-treatment	310290.00 ± 137766.10		6764.33 ± 2217.90	
3	Pre-treatment	436666.50 ± 356786.99	0.56	7127.33 ± 1757.85	0.827
	Post-treatment	390529.33 ± 257752.08		6553.67 ± 1728.57	

**Table 3.** Resistance comparison values between control and experimental groups under DC supply.

Measuring time (min)	Measuring status	Skin resistance ( $\Omega$ )	Significance (P)
1	Pre-treatment	292491.50 ± 155890.88	0.096
	Control group	729453.00 ± 397551.50	
3	Post-treatment	310290.00 ± 137776.10	0.048
	Control group	729453.00 ± 397551.50	
3	Pre-treatment	436666.50 ± 356786.99	0.096
	Control group	702887.00 ± 346189.00	
3	Post-treatment	390529.33 ± 257752.08	0.048
	Control group	702887.00 ± 346189.00	

**Table 4.** Resistance comparison values between control and experimental groups under AC supply.

Measuring time (min)	Measuring status	Skin resistance ( $\Omega$ )	Significant (P)
1	Pre-treatment	7735.67 $\pm$ 2284.41	0.017
	Control group	4856.78 $\pm$ 1777.42	
3	Post-treatment	6764.33 $\pm$ 2217.90	0.017
	Control group	4856.78 $\pm$ 1777.42	
3	Pre-treatment	7127.33 $\pm$ 1757.85	0.017
	Control group	4711.78 $\pm$ 1557.77	
3	Post-treatment	6553.67 $\pm$ 1728.57	0.017
	Control group	4711.78 $\pm$ 1557.77	

In determining the low back pain disorders, a statistically significant difference between the resistance values of the pre-treatment and post-treatment and the control group of the patients with the AC measurements was found. Similarly, the differences between the resistance values of the post-treatment and the control group with the DC measurements were observed. However, the difference is very close to the limit value, being between the resistance value of the control group and the pre-treatment in the DC measurements. While DC supply skin resistance values are increasing, the AC supply skin resistance values decreased. This situation can be explained by skin electrical model. This model included, basically, capacitor and the parallel resistor (Schaefer and Boucsein, 2000). Resistance of capacitor in the DC current has infinitive values, and an increasing equivalent resistance.

The obtained result has proved that the developed device is very successful in diagnosing low back pain. Thus instead of the VAS method which is a subjective method, the presented objective method may be used for the scaling of the low back pain.

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