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Experience in developing diagnostic insoles with resistive pressure sensors

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Abstract. The purpose of the article is to develop diagnostic insoles for the analysis of motor activity. Materials and methods. The selection and testing of various types of sensors is performed. The key parameters of the selected sensors are studied, and the most suitable sensors are selected. The technique of developing a hardware-software complex is defined. Results. Various sensors were tested, both for measurement accuracy and resistance to external influences. The need for additional modules when using sensors is revealed. Conclusion. As a result of the study, a finished product was developed that allows obtaining pressure data on various parts of the foot, which gives an initial assessment of the musculoskeletal system and diagnoses, for example, flat feet.

Keywords - insole, foot, resistive sensor, piezoelectric sensor, analysis of motor activity.

I. INTRODUCTION

Currently, according to the Ministry of Health of the Russian Federation, there are 57,836 cases of diseases of the musculoskeletal system per 100,000 of the total population, which makes up about 60% of the total population [4].

According to Pirogov Russian National Research Medical University from 40 to 60% of the population of Russia are subject to flat feet, women 4 times more often than men [5].

According to the Federal Service for Surveillance in Healthcare medical statistics: by the age of two years, 24% of children have the first signs of flat feet, by four years - 32%, by six years - 40%, by twelve years - 50% (every second teenager is diagnosed with flat feet), by twenty years - 60% [6].

Thus, the data of various studies come to almost the same result of 60% [1, 7, 9].

The obtained statistics clearly reflect the research problem, because the consequences of flat feet lead to disorders of the musculoskeletal system as a whole, which negatively affects the cardiovascular system of the human body.

Thus, it is necessary to identify such diseases in a timely manner for preventing their consequences. The device being developed is aimed at solving this problem.

This article discusses the feasibility of implementing a hardware complex that allows converting the pressure created by a person’s foot into data that can be further processed using data mining tools.

This study is the first step in creating a wearable device for the initial assessment of the musculoskeletal system; it considers the possibility of using various pressure sensors and materials that contribute to obtaining the most accurate data.

II. MATERIALS AND METHODS

As part of this study, it is necessary to select pressure sensors capable of withstanding high dynamic loads, since in the future they will be located in the insole, which entails increased shear and bending loads, while ensuring accurate data transmission over a wide pressure range from 5 g to 150 kg dynamic and passive load.

We selected and tested resistive, piezoelectric, and tensoresistive sensors. Table 1 shows the parameters of these sensors.

TABLE 1. COMPARATIVE ANALYSIS OF PRESSURE SENSORS BY KEY PARAMETERS

	Range of pressure	Measurement accuracy	Type of load	Min dimensions	Touch resistance
Resistive	1g – 300 kg	0.1 g	Dynamic/constant	15*15*1 mm	1 mln
Piezoelectric	10 g – 200 kg	5 g	Dynamic	10*12*2 mm	3 mln
Tensoresistive	10 g-1000 kg	1 g	Dynamic/constant	20*10*10 mm	10 mln

As can be seen from the table, the parameters of the sensors are very different, while all satisfy the initial condition for the range of pressure and possess sufficient accuracy for primary measurements.

Resistive sensors allow measuring the load on the foot in a dynamic and static position with maximum accuracy among the selected sensors, while their overall parameters, in particular thickness, allow using them in usual shoes. However, the sensor’s life is significantly lower compared to piezoelectric and tensoresistive sensors, i.e. not suitable for everyday use.

Piezoelectric sensors are capable of processing only dynamic loads, i.e. if the subject remains in the same place without movement, there will be no signal. This type of sensors is reasonable to use only in those cases when it is necessary to record the contact time of various parts of the foot and the force created.

The study also examined a tensoresistive sensor, the key feature of which is the ability to transmit information about the stretching of the material with an accuracy of 1 g. This means that by ensuring a sufficiently tight fit of the sensor to the foot, it becomes possible to assess the state of the foot, while the resource of such sensors is quite high.

Thus, according to the stated requirements, the tensoresistive pressure sensor best meets them, since it allows obtaining the most accurate data, occupying the minimum space. Therefore, resistive sensors will be used to create the test product.

III. RESULTS AND DISCUSSION

To obtain reliable data with a tensoresistive sensor, it is necessary to provide a tight and at the same time flexible contact with the foot, since in the future it is planned to use sensors in the insoles. Thus, it is necessary to select the material that is most closely adjacent to the surface of the foot, which will require the creation of an individual insole for each individual product.

To test the sensors, we used the FizioStep method for creating insoles [2, 3] (Fig. 1).

Figure 1. FizioStep insoles 3D-model

According to the technology, the eco-leather layer is fixed to the base of two-component silicone. This design allows to more evenly distribute the pressure of the foot on the surface. The technology also allows placing sensors in the insole so that the contacts of the sensors are tight and the wires do not affect the foot.

When creating a product, there are a number of important points that have a strong influence on the data from the sensors.

Firstly, it is extremely important that at the moment of filling the mold the sensor fits tightly the upper layer, otherwise, voids may form, and the sensor will move from the tracking area. Therefore, it is necessary to tightly fix the sensor on the lower part of the upper layer of the insole before filling the mold with silicone.

Secondly, when the form is ready and molding is carried out, it is necessary to provide such a degree of pressure at which the sensor will give a minimum signal level, otherwise the sensor may be under constant pressure, even without a load of the foot, which will not allow to obtain its data. To solve this problem, pressure was measured on each of the sensors at the molding stage (Fig. 2).

Figure 2. Installation of sensors in the insole

The following test sample was obtained to check the touch resistance and sensor data (Fig. 3):

Figure 3. Test sample for checking the performance of sensors

Data from this sample was taken with a multimeter, one of the significant drawbacks is the lack of factory calibration of the sensors for a given load. This means that with the same load, different sensors give different resistance, which can be eliminated by selecting additional resistors. However, this solution will require more space in the insole itself, so this option is not suitable even when using SMD components. Therefore, this problem must be solved programmatically.

Also, one of the upcoming tasks is to obtain accurate data from each of the sensors by setting the load / resistance correspondence, since the output data is non-linear.

In addition, for the correct performance of the sensors, a stable voltage is required, since when voltage changes, the sensor parameters significantly change.

It was decided to eliminate these disadvantages with the help of the hardware-software complex.

The signals from the sensors are transferred to the analog input of the microcontroller. However, since this microcontroller only had one analog input, the multiplexer was additionally used, which made it possible to obtain identical data to the one that would be obtained when replacing the controller.

At the next stage, software was developed to correct the received data, i.e., the problem with the factory calibration of the sensors was solved. Moreover, the multiplexer allows using a less efficient controller, which leads to a cheaper design and, in the case of using a wireless interface, increases the autonomy of the device.

Since we are developing a universal monitoring platform, at the first iteration we only visualized data from the sensors (Fig. 4).

Figure 4. Visualization of data from the sensors

The disadvantages of such a solution were revealed: uneven distribution of pressure on a separate sensor is observed, since the lower supports made of silicone exert uneven pressure. This problem can be solved either by increasing the area or by changing the carrier. One of the solutions is the use of 3D printing, which will allow taking into account the position of each sensor already at the design stage. This solution is significantly more compact and simpler, but requires careful selection of material, since most plastics will not work, due to the lack of flexibility of the final product, which will lead to discomfort and possible damage to the plastic.

IV. Conclusion

In general, the selected sensors are suitable for the task. However, their correct performance requires the appropriate environment, which implies the creation of both software and hardware [8], as well as a careful selection of the material of the final product with the necessary flexibility and strength.

The developed hardware-software complex allows eliminating the disadvantages of the selected sensors.

Thanks to this study, a number of upcoming tasks were identified for a subsequent creation of a portable diagnostic equipment.

At the moment, the device is being tested on the premises of the Research Center for Sports Science of the Institute of Sport, Tourism and Service (South Ural State University).

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