Prototype of Wearable Technology Applied to the Monitoring of the Vertebral Column

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Abstract—The main goal of this research is the development of a prototype of wearable technology that allows monitoring the vertebral column by recording movements in healthy individuals to assist the treatment of low back pain. Thus, a prototype of wearable technology with sensors that monitor the vertebral column movements and register the data in a smartphone application was developed in this research for later use by health professionals. The prototype was evaluated using a sample of 33 volunteers observing the functionality of the product, a clinical evaluation of the vertebral column, the identification of behavioral habits sample characterization. Computational embedded technologies feasibility in clothing products is evidenced by this research as a study field in evidence by facilitating the user's data collection day to day.

Keywords—Computational technology, textile technology, health, vertebral column.

1 Introduction

This research has interdisciplinary approaches and relates concepts of computer embedded technology in clothing product for application in healthcare. The process involved researchers from several fields, such as Information and Communication Technology, Computer Engineering, Textile Engineering and Physiotherapy. Demand arose from the study of low back pain and the possibility of application devices that allow the monitoring of the movements of the vertebral column in textile area, either in functional or static activity. It might allow the parameterization and monitoring of the evolution or regression of the treatment for pain proposed by health professionals. Movement monitoring prototype for the vertebral column was developed in distinct stages of design: electronic system and clothing product.

The main advance obtained in this research is evidenced by measuring instrument prototype developed to automate the information obtained with the aid of the goniometer, in other words, the angular variation of the spine when the individual performs a functional activity.

Analyzing the applying embedded computing technologies to clothing products feasibility is necessary to contribute to the technological development. Therefore, the subject of this research is related to the interface between health, computational technology and textile technology, showing the technologies involved may assist people in their daily activities and contribute to the efforts reduction suffered by the spine through health treatments.

2 Wearable Technology Applied to Health

Health data from 30 countries of the Organisation for Economic Co-operation and Development (OECD) show health expenditure as a proportion of the Gross Domestic Product (GDP) are high historical levels because of rising spending and a general economic downturn [1]. In this context, research and development of Smart Wearable Systems (SWS), which includes wearable technologies for health care, have increased both in academia and industry.

Prevention and health care as well as access to information contribute to the country's economy development. Thus, the problem of this research is evidenced by the contemporary lifestyle in which the lack or excess of physical activities prevails, the sedentarism, inadequate posture, work that requires little physical effort and a long time in the seated posture. All these activities are usually performed inappropriately with no proper monitoring causing damage in the vertebral column and low back pain. Thereunto, questions arise seeking to clarify whether a wearable technology is able to monitor the vertebral column movements of an individual, what may contribute to health professionals during the treatment of low back pain.

As stated in [2] "monitoring a patient’s natural motion for medical diagnosis and rehabilitation of postural disabilities is highly desirable, particularly outside the restricting volume of the laboratory environment". In this perspective, this research aimed at developing and evaluating a wearable technology feasibility that allows the monitoring vertebral column posture through recording the movements of healthy individuals and providing data which help in low back pain treatment.

The relevance of this research is evidenced by its contribution to the scientific community that studies wearable technologies, considering the information popularization and communication technologies that provide ease access to these technologies, also an increase in the number of people with problems of low back pain and the difficulty of health professionals, especially physiotherapists in obtaining data outside the laboratory environment which help in low back pain diagnosis and treatment.

As stated in [3], Smart Wearable Systems (SWS) have demonstrated potential to increase efficiency in monitoring and reduce health costs. Technological progress has fostered development of a variety of wearable devices and sensors for self-tracking health, including activity trackers, smart watches, smart clothing and smart implants [4]. As activity tracking devices become smaller, cheaper, and more consumer-friendly, they will be used more extensively in a wide variety of contexts. Therefore, Smart Wearable Systems become part of treatment (prescription) and may be used in behavior change programs to involve patients in self-management and best practices for clinical integration as defined as stated in Reference [4].

As stated in [3], it is empirically proven that an individual using a wearable technology for healthcare believes that whether the benefit gained from their use is greater than the risk of privacy with the data generated, he/she will be more prone to adopt the device. Otherwise, the device would not be adopted, since the risk of privacy perceived by individuals is formed by health information, sensitivity, personal innovation, legislative protection and prestige, and the benefit obtained is determined by perceived informativeness and functional congruence of the technology application used to monitor health care data.

As stated in [3] depending on the device used, the advantage in tracking and transforming health users' information in real time has been widely adopted in the health sector. So far, there are two main types of health care: devices in the fitness market and wearable medical devices. By adopting a device suitable for physical fitness such as Fitbit Flex and Jawbone UP, users may monitor their health conditions, sleep, calories burned, heart rate and distance traveled in real time.

The authors declare a recent report released by P & S Market presents data on research into a global wearable device for health care (which includes Fitness and wearable medical devices) valued at $157 million by 2014, and expected to reach 1,630.3 million in 2020, with a growth rate of 46.6% over the years 2015-2020. In this bias, the wearable devices have enormous potential for future development.

3 Materials and the Experiment

In order to evaluate the functionality of wearable technologies applied to the health of the vertebral column, this research was classified as applied one. Regarding the objectives as descriptive and the procedure as experimental, it aims at verifying whether the knowledge area in wearable technologies applied to the vertebral column health is configured as a field to be explored [5].

The research is divided into four phases: the first one establishes bibliographical research with the purpose of guiding the planning and design process of a technological clothing product (vertebral column monitoring device) in order to establish the best tools and methodologies available to carry out the next steps. The information served as a basis for defining the visual characteristics and the layout of the proposed application for the clothing product. In the second phase, the clothing product able to monitor and record the variation of the movements was developed, as well as the thoracic trunk angulation to assist health professionals regarding postural analysis of the spine. In the third phase, the postural monitoring instrument validation was performed by comparing the data obtained by the measurement between the wearable technology and the goniometer. In the fourth and last phase, an experimental research was carried out with a qualitative and quantitative approach, characterized by the execution of the previously developed project. A qualitative approach is necessary in order to identify behavioral habits and the individuals' characteristics. Quantitative approach applies regarding the functionality and efficiency of the proposed product to the participants necessary for the analysis of results.

The measurement items in this study were developed based on previous studies according to [6] and checked for reliability and validity. The project was divided into three preliminary stages:

- The clothing product development
- Electronic system embedded to the clothing (hardware)
- Software application program

The wearable technology prototype was designed to allow the placement of the sensors along the vertebral column, allowing the sensors localization adapted to the vertebrae of the individual's spine.

Three accelerometer sensors were used in the wearable monitoring product investigation. The sensors were positioned near the height of the vertebrae: C7, 7th cervical vertebra; T12, 12th thoracic vertebra; L5, 5th lumbar vertebra.

Figure 1 shows the components for electronic system elaboration, namely: accelerometer sensor MPU 6050; Bluetooth HC 05; PIC 18F258 processor and mobile application software. The accelerometer sensor was used to monitor vertebral column movements of right and left lateral tilt, extension, flexion and speed of spinal movement in a healthy individual.

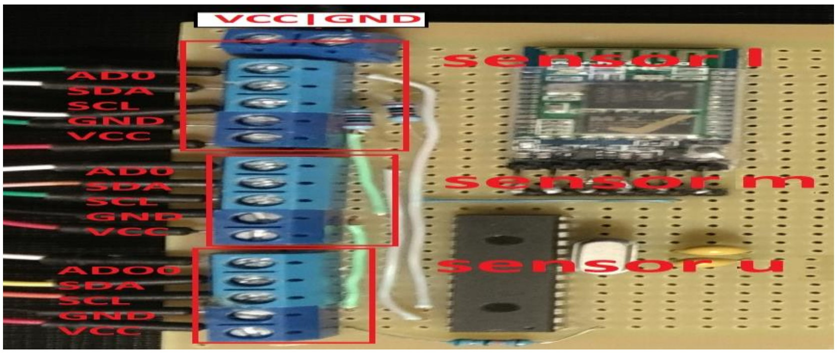

Fig. 1. Column Card Monitoring Electronic System.

Figure 2 shows schematically the electronic system shipped to clothing. In the image, the input represents the signal generated by the sensors attached to the garment that are emitted to the smartphone, and the output represents the information generated by the application software which is displayed on the mobile phone screen.

Figure 3 demonstrates how the application presents the generated data. When installing the system in the mobile phone, it generates a folder called Postural Control, in which the files are saved, and the name represents the date and time the worksheet was generated.

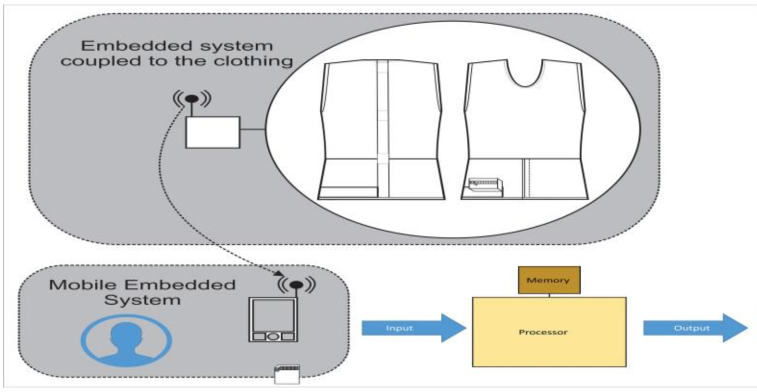

Fig. 2. Embedded System Coupled to the Clothing.

Each worksheet records information regarding the spine angular movements by the three sensors, both for the front view and the side view.

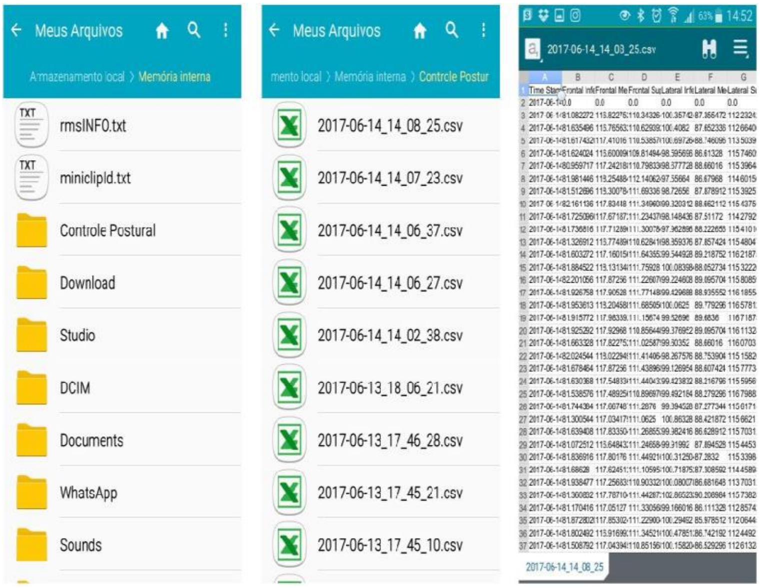

Fig. 3. Screen and the presentation form of the data generated by the postural monitoring application.

During the research the participants used the wearable technology (measuring instrument), and simultaneously filled in the questionnaires. The instrument was turned on and remained in operation while the participants answered the questionnaires in a seated posture, and later, at the end of filling in the questionnaires, when they performed the functional activity of picking up a pen on the table, placing it on the floor, getting up, picking up the pen on the floor and placing it on the table.

Initially, the following questionnaires were filled out by the volunteers participating in this research in a position of sedestation: a) lumbar spine physiotherapy evaluation card (collection of sociodemographic data and interview to verify health conditions); b) health-related quality of life questionnaire (SF-12), a questionnaire developed for the purpose of assessing quality of life from physical and mental components through two domains known as PCS (physical health) and MCS (mental health) [7]; c) International physical activity Questionnaire - Short Form (IPAQ), used for sample standardization consisting of global instrument that determines the physical activity level of the individual and the ranks: very active, active, irregularly active A, irregularly active B, and sedentary [8]; d) Oswestry Disability Index (ODI): a questionnaire developed to define lumbar incapacity degree; e) Questionnaire of Fears and Beliefs - Fear - Avoidance Beliefs Questionnaire (FABQ-Brazilian Version): questionnaire consisting of 16 items divided into two subscales; (i) FABQ-Work, which addresses fears and beliefs of individuals regarding to work [9].

At the end of the five questionnaires, the volunteers still had their functional activity performed. Subsequently, the monitoring product was disconnected from the power source and the volunteers answered a final questionnaire regarding the performance evaluation of wearable technology (visual and functional evaluation of ergonomic and technical performance). All data, added to the monitoring application results, served as a basis for the decision-making by the physiotherapist to help in the low back pain diagnosis.

Thirty-three male and female adult volunteers with anatomical measures proportional to the manikin average size and age between 17 and 58 years participated in this study.

4 Experimental Result Discussions

Through the tabulation data of the previously described questionnaires and the clinical evaluation of the vertebral column, individuals participating were classified into two groups, experimental and control. Statistical analysis defined 17 individuals did not present low back pain, then forming the control group ($1 - p = 0.52$), and 16 individuals presented nonspecific low back pain ($p = 0.48$), forming the experimental group.

Considering the distribution of the 33 participants in the study conducted in Araranguá town in 2017, 72.7% ($n = 24$) were women and 27.3% ($n = 9$) were men. The mean age among women was 34.63 years old, considering a margin of error ($E = 4.93$ years), and among men, the mean age was equal to 29.33 years ($E = 5.26$). The minimum and maximum ages were 17 and 58 years old for women and 19 and 40 years old for men.

Considering the participants, 100% answered they had not performed a surgical procedure in the spine. When asked if they had already undergone any type of treatment in the spine, 9.1% answered yes, and 90.9% answered no. Among who underwent treatments in the spine ($n = 3$), 67% of the participants underwent Physical Therapy and 33% Pilates.

When asked if they had spinal pain at that moment, 42.4% answered they did not have pain at the time (n = 14). Among those who declared that they had pain at the time of the activity, 18.2% declare they had pain intensity 1 (n = 6), 15.2% answered they had pain intensity 2 (n = 5), 6.1% (n = 2) reported they had pain intensity 4 (n = 2), 6.1% reported had pain intensity 5 (n = 2) and 6.1% (n = 2). When questioned about what increases pain, 12% declared physical exercises, 30% standing posture, 24% posture seated, 21% posture lying down, 9% declare not having pain and 3% all the options. When questioned about what alleviates pain, 18% answered specific medication, 27% exercise, 42% rested, 3% reported nothing softens their pain and 9% did not answer this question.

The vertebral column monitoring instrument was used by all the participants of this study. Participants took an average of 23 minutes to respond the five questionnaires and perform the functional activity using the spinal monitoring instrument.

All data files have been transformed into spreadsheets for calculation. Some analyzes were necessary to understand the data obtained through sensor monitoring and to define the significance of the results. Thereunto, the "results in module" of the variable "angular mean" were analyzed using the IBM SPSS Statistics Version 22 Program, in which the following tests were performed: Normal test - Kolmogorov-Smirnov test, considering a sample N < 30; the T-Test (T-TEST) for comparison of independent samples; and Levene Test for equality of variances.

Figure 4 presents an organizational chart of the data structure of the comparative analysis performed by sensor: between the Side (S) and Frontal (F) views; positioning among Lower (L), Medium (M) and Upper (U) sensors; between Seated Posture (SP) and Functional Activity (FA); and between groups, experimental (PL) and control (WP). The purpose was to verify whether the means of the movements were the same or different and the respective significance. For comparative analysis among the angular means, the comparative test between the mean of independent samples was chosen, because the sample group is N < 30, the experimental group was formed by 16 individuals and the control group by 17 individuals, and also due to the fact that only one data sample per individual was collected.

Table 1 contains the T-test result analysis of independent samples and Levene's test for equality of variances performed with values of the angular means of the sensors between the front views in relation to the lateral view.

The results observed were the same for both the Experimental and Control groups. In other words, the mean sensor located in the thoracic region of the spine obtained the same average for the variables (Average_Angle_WP_FA_M_FS and Average_Angle_PL_FA_M_FS) frontal and lateral view. However, the significance degree was different. For all other variables, the means of the frontal versus the lateral views were different, so presumed non-assumed equal variances. It means the signal received by the sensor transmits different information referring to the angles for the front view and for the side view, in other words, the means are different.

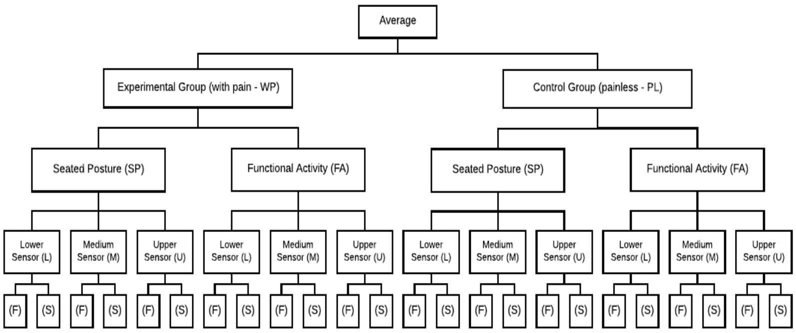

Fig. 4. Organization chart of the comparative analysis data structure

Table 2 contains the analysis of the results of the T-Test of independent samples and Levene Test for equality of variances by comparing the angular means among the positioning of the sensors, i.e. lower sensor in relation to the average sensor; lower sensor in relation to the upper sensor and, mean sensor in relation to the upper sensor for the Experimental group.

Table 1. Comparative test between the average of the independent samples for the sensors: Frontal (F) view in relation with Side (S) view

Group Statistics						
Category	***Sensor Variable***	***N***	***Aver-age***	***Standard Deviation***	***Hypothesis Test***	
					Average	***Variance***
Average_Angle_WP_SP_L_FS	Frontal (F)	16	91.58	3.16	$\bar{\bar{x}}F \neq \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$
	Side (S)	16	85.26	6.45		
Average_Angle_WP_SP_M_FS	Frontal (F)	16	103.76	3.58	$\bar{\bar{x}}F \neq \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$
	Side (S)	16	108.63	6.19		
Average_Angle_WP_SP_U_FS	Frontal (F)	16	101.47	2.79	$\bar{\bar{x}}F \neq \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$
	Side (S)	16	134.26	4.85		
Average_Angle_WP_FA_L_FS	Frontal (F)	16	91.68	1.70	$\bar{\bar{x}}F \neq \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$
	Side (S)	16	77.56	8.43		
Aver-age_Angle_WP_FA_M_FS	Frontal (F)	16	102.75	1.83	$\bar{\bar{x}}F = \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$
	Side (S)	16	100.41	8.43		
Average_Angle_WP_FA_U_FS	Frontal (F)	16	100.39	2.68	$\bar{\bar{x}}F \neq \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$
	Side (S)	16	124.49	7.63		
Average_Angle_PL_SP_L_FS	Frontal (F)	16	91.31	3.73	$\bar{\bar{x}}F \neq \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$

	Side (S)	16	85.60	8.24		
Average_Angle_PL_SP_M_FS	Frontal (F)	16	105.25	4.22	$\bar{\bar{x}}F = \bar{\bar{x}}S$	$\bar{\bar{s}}2F = \bar{\bar{s}}2S$
	Side (S)	16	107.29	7.34		
Average_Angle_PL_SP_U_FS	Frontal (F)	16	102.41	2.36	$\bar{\bar{x}}F \neq \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$
	Side (S)	16	132.99	6.08		
Average_Angle_PL_FA_L_FS	Frontal (F)	16	89.49	2.70	$\bar{\bar{x}}F \neq \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$
	Side (S)	16	79.00	10.06		
Average_Angle_PL_FA_M_FS	Frontal (F)	16	102.31	2.87	$\bar{\bar{x}}F = \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$
	Side (S)	16	102.10	8.54		
Average_Angle_PL_FA_U_FS	Frontal (F)	16	99.50	2.00	$\bar{\bar{x}}F \neq \bar{\bar{x}}S$	$\bar{\bar{s}}2F \neq \bar{\bar{s}}2S$
	Side (S)	16	126.06	5.37		

The general behavior obtained was of different means and equal significances, what means there was an equal stimulus to generate the movement among the three sensors, regardless the positioning, but with different means. The exception is for the variable (Average_Angle_WP_SP_MU_F) that obtained equality between mean and variance. In other words, the medium and superior sensors received the same stimuli during the seated posture regarding the frontal view.

Table 3 contains the analysis of the T-test result of independent samples and Levene test for equality of variances by comparing the angular means between sensor positioning, that is lower, middle and upper sensors for the control group.

Table 2. Comparative test among the averages of the independent samples from the Experimental Group for the sensors: Lower (L), Medium (M) and Upper (U) regarding the spine

Group Statistics						
Category	***Sensor Variable***	***N***	***Average***	***Standard Deviation***	***Hypothesis Test***	
					Average	***Variance***
Aveage_Angle_WP_SP_LM_F	Lower (L)	16	91.58	3.16	$\bar{x}L \neq \bar{x}M$	$\bar{s}2L = \bar{s}2M$
	Medium (M)	16	103.76	3.58		
Average Angle_WP_SP_LM_S	Lower (L)	16	85.26	6.45	$\bar{x}L \neq \bar{x}M$	$\bar{s}2L = \bar{s}2M$
	Medium (M)	16	108.63	6.19		
Average_Angle_WP_SP_LU_F	Lower (L)	16	91.58	3.16	$\bar{x}L \neq \bar{x}U$	$\bar{s}2L = \bar{s}2U$
	Upper (U)	16	101.47	2.79		
Average_Angle_WP_SP_LU_S	Lower (L)	16	85.26	6.45	$\bar{x}L \neq \bar{x}U$	$\bar{s}2L = \bar{s}2U$
	Upper (U)	16	134.26	4.85		

Average_Angle_WP_SP_MU_F	Medium (M)	16	103.76	3.58	$\bar{x}M = \bar{x}U$	$\bar{s}2M = \bar{s}2U$
	Upper (U)	16	101.47	2.79		
Average_Angle_WP_SP_MU_S	Medium (M)	16	108.63	6.19	$\bar{x}M \neq \bar{x}U$	$\bar{s}2M = \bar{s}2U$
	Upper (U)	16	134.26	4.85		
Average_Angle_WP_FA_LM_F	Lower (L)	16	91.68	1.70	$\bar{x}L \neq \bar{x}M$	$\bar{s}2L = \bar{s}2M$
	Medium (M)	16	102.75	1.83		
Average_Angle_WP_FA_LM_S	Lower (L)	16	77.56	8.43	$\bar{x}L \neq \bar{x}M$	$\bar{s}2L = \bar{s}2M$
	Medium (M)	16	100.41	8.43		
Average_Angle_WP_FA_LU_F	Lower (L)	16	91.68	1.70	$\bar{x}L \neq \bar{x}U$	$\bar{s}2L = \bar{s}2U$
	Upper (U)	16	100.39	2.68		
Average_Angle_WP_FA_LU_S	Lower (L)	16	77.56	8.43	$\bar{x}L \neq \bar{x}U$	$\bar{s}2L = \bar{s}2U$
	Upper (U)	16	124.49	7.63		
Average_Angle_WP_FA_MU_F	Medium (M)	16	102.75	1.83	$\bar{x}M \neq \bar{x}U$	$\bar{s}2M = \bar{s}2U$
	Upper (U)	16	100.39	2.68		
Average_Angle_WP_FA_MU_S	Medium (M)	16	100.41	8.43	$\bar{x}M \neq \bar{x}U$	$\bar{s}2M = \bar{s}2U$
	Upper (U)	16	124.49	7.63		

Similarly, the behavior obtained was of different means and similar meanings. It means there was an equal stimulus to generate the movement among the three sensors regardless the positioning, but with different means. The exception is for the variable (Average_Angle_PL_FA_LU_S) that obtained difference between mean and variance. It means the lower sensor receives different stimulus from the upper sensor during the accomplishment of the functional activity regarding the lateral view.

Table 3. Comparative test among the averages of the independent samples from the Control Group for the sensors: Lower (L), Medium (M) and Upper (U) regarding the spine

Group Statistics						
Category	***Sensor Variable***	***N***	***Average***	***Standard Deviation***	***Hypothesis Test***	
					Average	***Variance***
Average_Angle_PL_SP_LM_F	Lower (L)	17	91.31	3.73	$\bar{x}L \neq \bar{x}M$	$\bar{s}2L = \bar{s}2M$
	Medium (M)	17	105.25	4.22		
Average_Angle_PL_SP_LM_S	Lower (L)	17	85.60	8.24	$\bar{x}L \neq \bar{x}M$	$\bar{s}2L = \bar{s}2M$
	Medium (M)	17	107.29	7.34		
Average_Angle_PL_SP_LU_F	Lower (L)	17	91.31	3.73	$\bar{x}L \neq \bar{x}U$	$\bar{s}2L = \bar{s}2U$
	Upper (U)	17	102.41	2.36		

Average_Angle_PL_SP_LU_S	Lower (L)	17	85.60	8.24	$\bar{x}L \neq \bar{x}U$	$\bar{s}2L = \bar{s}2U$
	Upper (U)	17	132.99	6.08		
Average_Angle_PL_SP_MU_F	Medium (M)	17	105.25	4.22	$\bar{x}M \neq \bar{x}U$	$\bar{s}2M = \bar{s}2U$
	Upper (U)	17	102.41	2.36		
Average_Angle_PL_SP_MU_S	Medium (M)	17	107.29	7.34	$\bar{x}M \neq \bar{x}U$	$\bar{s}2M = \bar{s}2U$
	Upper (U)	17	132.99	6.08		
Average_Angle_PL_FA_LM_F	Lower (L)	17	89.49	2.70	$\bar{x}L \neq \bar{x}M$	$\bar{s}2L = \bar{s}2M$
	Medium (M)	17	102.31	2.87		
Average_Angle_PL_FA_LM_S	Lower (L)	17	79.00	10.06	$\bar{x}L \neq \bar{x}M$	$\bar{s}2L = \bar{s}2M$
	Medium (M)	17	102.10	8.54		
Average_Angle_PL_FA_LU_F	Lower (L)	17	89.49	2.70	$\bar{x}L \neq \bar{x}U$	$\bar{s}2L = \bar{s}2U$
	Upper (U)	17	99.50	2.00		
Average_Angle_PL_FA_LU_S	Lower (L)	17	79.00	10.06	$\bar{x}L \neq \bar{x}U$	$\bar{s}2L = \bar{s}2U$
	Upper (U)	17	126.06	5.37		
Average_Angle_PL_FA_MU_F	Medium (M)	17	102.31	2.87	$\bar{x}M \neq \bar{x}U$	$\bar{s}2M = \bar{s}2U$
	Upper (U)	17	99.50	2.00		
Average_Angle_PL_FA_MU_S	Medium (M)	17	102.10	8.54	$\bar{x}M \neq \bar{x}U$	$\bar{s}2M = \bar{s}2U$
	Upper (U)	17	126.06	5.37		

Table 4 contains the analysis of the T-test result of independent samples and Levene's test for equality of variances by comparing the angular means between the sitting position for the movement of functional activity regarding the frontal and lateral views of the sensors lower, middle and higher.

Table 4. Comparative test among the averages of the samples for the independent sensors: Lower (L), Medium (M) and Upper (U) regarding the spine and for Seated Posture (SP) in relation to the Functional Activity (FA)

Group Statistics						
Category	***Sensor Varia-ble***	***N***	***Average***	***Standard Deviation***	***Hypothesis Test***	
					Average	***Variance***
Average_Angle_WP_SPFA_L_F	(SP)	16	91.58	3.16	$\bar{x}SP \neq \bar{x}FA$	$\bar{s}2PS = \bar{s}2FA$
	(FA)	16	100.39	2.68		
Average_Angle_WP_SPFA_L_S	(SP)	16	85.26	6.45	$\bar{x}SP = \bar{x}FA$	$\bar{s}2PS = \bar{s}2FA$
	(FA)	16	77.56	8.43		
Average_Angle_WP_SPFA_M_F	(SP)	16	103.76	3.58	$\bar{x}SP = \bar{x}FA$	$\bar{s}2PS \neq \bar{s}2FA$

	(FA)	16	102.75	1.83		
Average_Angle_WP_PSFA_M_S	(SP)	16	108.63	6.19	$\bar{x}SP \neq \bar{x}FA$	$\bar{s}2PS = \bar{s}2FA$
	(FA)	16	100.41	8.43		
Average_Angle_WP_PSFA_U_F	(SP)	16	101.47	2.79	$\bar{x}SP = \bar{x}FA$	$\bar{s}2PS = \bar{s}2FA$
	(FA)	16	100.39	2.68		
Average_Angle_WP_PSFA_U_S	(SP)	16	134.26	4.85	$\bar{x}SP \neq \bar{x}FA$	$\bar{s}2PS = \bar{s}2FA$
	(FA)	16	124.49	7.63		
Average_Angle_PL_PSFA_L_F	(SP)	16	91.31	3.73	$\bar{x}SP = \bar{x}FA$	$\bar{s}2PS = \bar{s}2AF$
	(FA)	16	89.49	2.70		
Average_Angle_PL_PSFA_L_S	(SP)	16	85.60	8.24	$\bar{x}SP \neq \bar{x}FA$	$\bar{s}2PS = \bar{s}2FA$
	(FA)	16	79.00	10.06		
Average_Angle_PL_PSFA_M_F	(SP)	16	105.25	4.22	$\bar{x}SP \neq \bar{x}FA$	$\bar{s}2PS = \bar{s}2FA$
	(FA)	16	102.31	2.87		
Average_Angle_PL_PSFA_M_S	(SP)	16	107.29	7.34	$\bar{x}SP = \bar{x}FA$	$\bar{s}2PS = \bar{s}2FA$
	(FA)	16	102.10	8.54		
Average_Angle_PL_PSFA_U_F	(SP)	16	102.41	2.36	$\bar{x}SP \neq \bar{x}FA$	$\bar{s}2PS = \bar{s}2FA$
	(FA)	16	99.50	2.00		
Average_Angle_PL_PSFA_U_S	(SP)	16	132.99	6.08	$\bar{x}SP \neq \bar{x}FA$	$\bar{s}2PS = \bar{s}2FA$
	(FA)	16	126.06	5.37		

The variables (Average_Angle_WP_SPFA_L_F, Average_Angle_WP_PSFA_M_S, Average_Angle_WP_PSFA_U_S, Average_Angle_PL_PSFA_L_S, Average_Angle_PL_PSFA_M_F, Average_Angle_PL_PSFA_U_F and Average_Angle_PL_PSFA_U_S) obtained different mean for equal variances. It means a same pulse occurs from the sensor to seated position posture compared to functional activity.

The variables (Average_Angle_WP_SPFA_L_S, Average_Angle_WP_PSFA_U_F, Average_Angle_PL_PSFA_L_F, and Average_Angle_PL_PSFA_M_S) obtained averages and equal variances when compared to the seated position regarding the functional activity.

The variable (Average_Angle_WP_SPFA_M_F) obtained the same means, but with different variances. It means the stimuli perceived by the mean sensor were different for the seated posture when compared to the functional activity for the average sensor, frontal view. An inversion was observed in the behavior of the Experimental Group's sample data, in which the variable (Average_Angle_WP_SPFA_M_F) obtained equal mean and different variances for the average sensor, frontal view, when compared to seated posture with functional activity regarding the Control Group, which for the variable (Average_Angle_PL_PSFA_M_F) obtained different mean and equal variances for the average sensor, frontal view, and compared the seated posture with the functional activity.

Table 5 contains the analysis of the T-test result of independent samples and Levene Test for equality of variances by comparing the angular means between the experimental group and the control group for the frontal and lateral views of the lower, medium and higher.

Table 5. Comparative test between the average of the independent samples for the sensors: Control Group (PL) regarding the Experimental Group (WP)

Group Statistics						
Category	***Sensor Variable***	***N***	***Average***	***Standard Deviation***	***Hypothesis Test***	
					Average	***Variance***
Average_Angle_WPPL_SP_L_F	(WP)	16	91.58	3.16	$\bar{x}WP = \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$
	(PL)	17	91.31	3.73		
Average_Angle_WPPL_SP_L_S	(WP)	16	85.26	6.45	$\bar{x}WP = \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$
	(PL)	17	85.60	8.24		
Average_Angle_WPPL_SP_M_F	(WP)	16	103.76	3.58	$\bar{x}WP = \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$
	(PL)	17	105.25	4.22		
Average_Angle_WPPL_SP_M_S	(WP)	16	108.63	6.19	$\bar{x}WP = \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$
	(PL)	17	107.29	7.34		
Average_Angle_WPPL_SP_U_F	(WP)	16	101.47	2.79	$\bar{x}WP = \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$
	(PL)	17	102.41	2.36		
Average_Angle_WPPL_SP_U_S	(WP)	16	134.26	4.85	$\bar{x}WP = \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$
	(PL)	17	132.99	6.08		
Average_Angle_WPPL_FA_L_F	(WP)	16	91.68	1.70	$\bar{x}WP \neq \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$
	(PL)	17	89.49	2.70		
Average_Angle_WPPL_FA_L_S	(WP)	16	77.56	8.43	$\bar{x}WP = \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$
	(PL)	17	79.00	10.06		
Average_Angle_WPPL_FA_M_F	(WP)	16	102.75	1.83	$\bar{x}WP = \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$
	(PL)	17	102.69	2.78		
Average_Angle_WPPL_FA_M_S	(WP)	16	100.41	8.43	$\bar{x}WP = \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$
	(PL)	17	102.10	8.54		
Average_Angle_WPPL_FA_U_F	(WP)	16	100.39	2.68	$\bar{x}WP = \bar{x}PL$	$\bar{s}2WP = \bar{s}2PL$

	(PL)	17	99.50	2.00		
Average_Angle_WPPL_FA_U_S	(WP)	16	124.49	7.63	$\bar{x}$WP = $\bar{x}$PL	$\bar{s}$2WP = $\bar{s}$2PL
	(PL)	17	126.06	5.37		

In the general behavior of the variables, averages and equal variances were obtained, except for the variable (Average_Angle_WPPL_FA_L_F) where the means were different for equal variances. Therefore, the samples behavior was similar for both groups.

Inferential analysis indicated the differences and similarities of the behavior for the mean angular variable obtained through the three garment sensors, located in the lumbar region (lower sensor), thoracic region (middle sensor) and cervical region (upper sensor) for the Experimental Group, which presents nonspecific low back pain and Control Group. So, it is up to health professionals to apply this wearable technology in the health area.

Here it is important to rescue the problem of this research, which is based on the contemporary lifestyle where individuals, due to excessive or lack of physical activity, sedentary lifestyle, work-related issues that require hours in sitting posture cause lumbar damages. They may be monitored through the wearable technology presented here to help in the data collection concerning the functionality of human beings' spine.

This research aimed at verifying the possibility of monitoring the spine movements and organizing the information from the postural analysis in health people in order to allow the wearable technology individual user to prevent future back injuries

The use of technological devices in clothing products may be applied to health, which corroborates the hypothesis of this study. Whether it is used properly, wearable technology contributes to the treatment of low back pain by monitoring the spine angular movements.

Through this research, the importance of incorporating New Technologies of Information and Communication (NTICs) into clothing products is realized, allowing to start a niche market with products that facilitate the monitoring spine movements, further to perform related research in order to automate the data referring to the angles and vertebral movements of the human being for the other body joints.

This study shows that intelligent textiles and wearable technology contribute to the low back pain diagnosis because it facilitates data collection of angular movements performed by the spine, whether static or in motion and with the advantage the sensors are not directly fixed in the individual's body. It also allows a follow-up on the treatment advancement or regression proposed by the health professional for the patient who has low back pain.

The real need to apply new information and communication technologies (NICTs) to the garment is identified because the viability is evidenced by the automation possibility of measures the spine functional movements.

The real advantage of wearable technologies is the contribution to health care, facilitating the data collection. The disadvantage lies in the lack of electronic products and technological textiles available in the market, further qualified professionals for this product production.

The risks of producing wearable technology are practically none because it serves a promising market niche and fills an existing gap, i.e. wearable technologies capable of monitoring spinal movements and registering the data in a mobile application, enabling the follow-up by health professionals.

5 Conclusion

The spinal monitoring system may provide angles comparable to those obtained with the goniometer and relevant for lumbar assessment treatment, i.e. for the low back pain diagnosis. The system consists of three accelerometer measuring sensors, respectively connected and calibrated to the cervical, thoracic and lumbar regions, based on the frontal and lateral anatomical planes of the individual.

The sensor output is transformed into significant flexion, extension and lateral inclination clinical parameters of each body segment, regarding the calibrated global reference space. Monitoring the spine in a functional activity allows the dynamic measurement of three-dimensional spine movement, which may be animated and monitored in real time. Firstly, when comparing the device to the goniometer when it comes to the device developed, it provides movement real-time reading, as well as passing the data directly to the worksheets, avoiding manual and inaccurate annotations.

Secondly, the device is embedded in a garment in contrast to traditional applications where sensors are attached directly to the body. Its embedding in a garment facilitates the device placement on the body avoiding issues for people with contact allergy, further making the device easily adaptable to the individuals' routine.

In order to extend the study to the people daily life with the possibility of continuously using the devices coupled in the clothing, and continuing the study for a week or a month for example, this research continuation is suggested. There are great possibilities in uniting clothing technology and designers should explore this marketplace, which encompasses needs such as comfort, sustainability, energy reuse, physical protection and body chemistry that may be obtained through advances in new textile products, like intelligent fibers, conductive wires and technological textiles.

In order to continue the study of this promising theme for the development of scientific research in related areas, some recommendations for future studies follow:

- Developing wearable technologies using sensors capable of measuring heart rate, body temperature, displacement, brain activity (neurotransmitter);
- Improving the software and developing a system capable of data recording of all the evaluations in order to enable analyzing statistically and calculate an values overlap showing the differences, such as success or failure for the low back pain diagnosis and treatment;
- Developing new wearable technologies, shipping sensors in all the human body joints, and thus assess the angular variation for any joint, citing fingers, arms, legs,

feet and head. An example is a coverall with modular technological couplings capable of recording individual angular movements.

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