A Survey on sitting posture monitoring systems

Ferdews Tlili*, Rim Haddad*, Youssef Ouakrim†, Ridha Bouallegue*, Neila Mezghani†
* Laboratoire Innov´Com, Ecole Suprieure des Communications de Tunis, Université de Carthage
Email: ferdews.tlili@supcom.tn, rim.haddad@supcom.tn, ridha.bouallegue@supcom.tn
†Laboratoire de recherche en imagerie et orthopédie, TELUQ university, Montreal, Qc, Canada
Email: Youssef.Ouakrim@teluq.ca, neila.mezghani@teluq.ca
‡Centre de recherche du CHUM, Montreal, Qc, Canada

***Abstract*—Spinal pain caused by the bad sitting posture can affect adults and young people. The slouching and leaning for long hours using computers and portable electronic devices is the main cause of the back problems. Recently, in order to prevent the spinal pain, sitting posture monitoring systems have been developed in the literature to assess the posture of a seated person in real-time and improve sitting posture. The purpose of this study is to review the recent posture monitoring systems. The review is based on a literature search in PubMed, IEEE Xplore and Science Direct. We studied the main characteristics of the posture monitoring systems, the used technologies to identify the posture changes over time and the systems limits. The posture systems are classified according to their sensing technologies. This paper can be a valuable source of recent reference for future research in the field of sitting posture monitoring systems.**

***Index Terms*—monitoring systems, sitting posture monitoring, accelerometer, pressure sensors, flexible sensors, inductor sensors, optical fiber sensors**

I. Introduction

Nowadays the spine problems (neck pain, low back pain, kyphosis, etc.) are widely spread in population. According to Canadian studies in six months, five persons over ten are suffering from the low back pain [1], [2]. The workers and young people are the most exposed to the back diseases. In Canada, 85% of workers are affected by low back pain at any period of life [1], [3]. The sitting for long periods of time leads to the piling up of the spine disc causing the low back pain. Moreover, in a wide percentage range of adolescents (7 and 58%) with age range between 13 and 15 are suffering from a hyperkyphosis [4]. This spine deformation is caused by the bad posture during sitting for extended periods of time leaning over their computers, tablets and smart phones.

The back problems are still difficult to cure and usually need long duration therapy. Thus, in some cases, patients are obligated to leave their work or their studies for long hours in order to carry out their therapy with continues monitoring of the spine shape. Moreover, the back pain therapies is expensive. In Canada, the medical cost of low back pain is between 6 and 12 billion dollars annually [1] [5]. According to medical studies the posture correction and sitting straight are efficient to prevent and reduce the back pains [6]. That is why several researchers were interested to the development of patient posture monitoring systems.

978-1-5386-8173-2/18/$31.00 © 2018 IEEE

The easiest way to monitor people posture is to use vision cameras [7]–[9]. For instance, a photo training intervention using an innovative self-modeling webcam photo shows an efficiency to reduce musculoskeletal risk compared to traditional training methods [10]. The system consists to provide the worker in his computer screen a frequent feedback with two photos one for the current posture and the other one for the correct posture. This system is efficient to provide a quick feedback and help the person to improve his posture. The intervention had a great effect on office workers using computers and suffering from musculoskeletal pain. However, the vision based systems, can have blind spots because of the camera's position. In addition, they are faced to a privacy problem [7].

The evolution of sensing technologies and their low cost lead to be spread over healthcare technologies [11]. The sensing technologies are characterized by a variety of information collected by the sensors. The developed sensors can provide many information such as position, acceleration, aerospace orientation, etc. Thus, recently, many scientific research are focusing on studying and proposing systems to monitor and help person to improve and correct the bad posture habits without the invasion of user privacy. The posture monitoring systems aim to help users to autonomously monitor and correct bad posture over time. The collected information is useful for posture monitoring analysis systems to define the body posture and provide feedback for his bad posture cases. Hence, different solutions for posture monitoring systems have been proposed, recently, in the literature.

In this paper we present a literature overview on sitting posture monitoring systems with a focus on the used technologies. Indeed, we classify the posture monitoring systems according to the sensor technologies used and we discuss their corresponding characteristics and architectures. The paper is composed of four sections. In section II, we detail the description of the existing sitting posture monitoring systems and in section III, we compare and evaluate the different sitting posture monitoring systems aspects. Section IV, we conclude the review with the prospects for future work.

II. Posture Monitoring Systems

In this section, we describe the different posture monitoring systems for seated people developed in literature. The systems are classified according to the sensing technologies.

A. Posture monitoring systems based on pressure sensors

The posture monitoring systems based on pressure sensors have been deeply investigated [14]–[16]. The pressure sensors provide weight information that are analyzed in order to define the body posture.

A new research by Jongryun et al [14] proposes a sitting posture monitoring system with a few embedded load sensors in the seat plate of the chair. The system is composed of four load cells that provide the weight data measurement to a computer via the Arduino board which is an open-source electronics platform based on easy-to-use hardware and software. The proposed system is able to classify sitting postures by inserting pressure sensors into backrest plate and seat plate. The system detects different types of sitting posture (as shown in Figure 1). The pressure sensor-based monitoring system developed by Jingyuan Cheng et al. [15] consists of four pressure sensors placed under the chair legs. The experimental results show that the system defines different sitting posture and detects, also, the hand and the head motion. Bilal El-Sayed et al [16] describe a posture monitoring systems equipped with a combination of inclinometer sensor and weight sensors. The inclinometer sensors are placed on the neck whereas the weight sensors are attached to feet. The system analyzes the weight data and defines the sitting postures and the body states (walking, sitting or standing).

The systems, we have just described, have a major limitation because they require a specific environment equipped with load cells in an office and cannot be used anywhere.

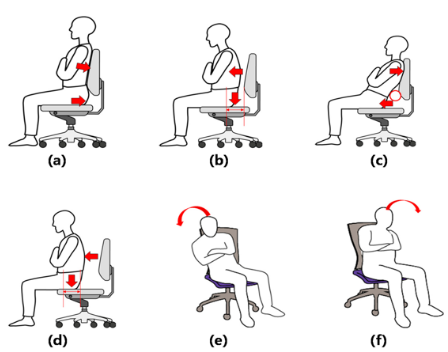

Fig. 1. Types of sitting postures : (a) upright sitting with backrest; (b) upright sitting without backrest; (c) front sitting with backrest ; (d) front sitting without backrest ; (e) left sitting ; and (f) right sitting [14].

B. Posture Monitoring Systems Based on Inertial Sensors

Inertial sensors have attracted the attention of several industrial [17], medical [18] and aerospace researchers [19] in recent years. This is due to their tiny size and high portability characteristics allowing them to be integrated directly into people clothing. The inertial sensors provide information about the tilting angle relative to the gravity and linear acceleration.

A posture monitoring system composed of three inertial tri-axial accelerometer sensors have been proposed by Wai Yin Wong and Man Sang Wong [20]. The sensing devices are placed in the upper trunk, mid trunk and the pelvic levels. These devices monitor the spinal curvature during the trunk movement on the sagittal and coronal planes.

In a recent research, the author introduces a Smart Rehabilitation Garment (SRG) for posture monitoring [21] composed of two inertial measurement units embedded in the patient clothes and controlled by an Arduino processor. A LilyPad Vibe Board is placed close to the sensor providing vibration feedback. The communication between the system elements is ensured by a wireless Bluetooth communication. The system aims to monitor the thoracic posture for slouching position and the compensatory movement during patient arm-hand training. The system identifies the slouching posture by placing sensors at C7-T1 spinal segment and at T4 and T5 vertebrae. The proposed system detects the compensatory movement by calculating the average of the sensor angle with respect to the vertical plane.

A wearable posture monitoring system have been proposed by Azin Fathi and Kevin Curran [22]. The system is composed by 3 inertial units stuck on the back using piezo-resistive fabric: the first sensor placed on the cervical spine part, the second one on the thoracic and the third one on the lower lumbar spine. The inertial units collect accelerometer and gyroscope data. Then the collected data is analyzed using classification algorithm in order to identify the hunched and slouching back posture. A user interface is implemented for recording and checking the user posture.

The inertial sensors, described previously, are characterized by the high portability. However, the system measurements accuracy is sensitive to the sensors position. Moreover, the systems are invasive as the sensing devices must be stuck to the human body.

C. Posture monitoring systems based on flexible Sensors

The flexible sensors are fabricated of materials which are malleable to a certain extent without changing its properties [23]. Based on polyvinylidene fluoride, which is a flexible piezoelectric material, the resistance of the flex sensors changes in case of bent which is useful for defining the body posture. The flex sensors are characterized by a low cost and long life [24].

Manju Gopinath and Angeline Kirubha [25] implemented a posture monitoring system using flexible sensors which define the spine bend. This is supported by a load cell composed of weight sensors to detect the spine stress. The flexible sensor is placed on the mid-thoracic region whereas the load cell is placed between platforms on which the subject can stand. The optimal position of the flex sensor to detect the bad posture is the mid-thoracic region. However the bad postures are never detectable when the flex sensor are placed on the lumbar or the lower thoracic.

The flex sensors are sensitive to the sensor position. As presented in [25], the bad postures are detected for specific sensor position. In addition, the flex sensors demonstrate a lower sensitivity to define the shape, curvature and small bent angle [24].

D. Posture Monitoring Systems Based on Inductor Sensors

The principle of posture monitoring systems based on inductance sensors consists in measuring inductance as a function of geometric deformation. The deformation is caused by the lengthening and straightening of the body. An electronic circuit measures the impedance value and outputs a voltage. Thus, the sensor elongation variation gives indication about the spine shape when the sensor is stuck on the back and front [26] (as shown in Figure 2).

Emilio Sardini et all [26] describe a posture monitoring T-shirt used for rehabilitation exercises based on inductor sensor. The system is composed of one inductor sensor stitched to the T-shirt throughout the user back and chest. The lengthening and straightening of the body led to sensor shape deformation, then the inductance variation. A readout unit collects the inductance values. Then this information is sent to a PC for matching the inductance value to the correspond posture. Besides a feedback system composed of two vibro-feedback sensors to alert users in bad posture cases.

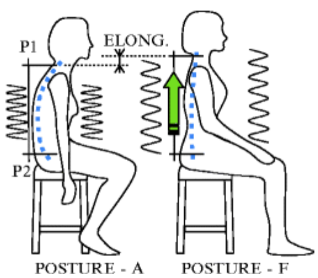

Fig. 2. Principle of a posture monitoring systems inductor-based [26].

The described posture monitoring system based on Inductor are limited on sagittal geometric deformation and do not give information about the body posture inclined left or right.

E. Posture Monitoring Systems Based on Optical Fiber Sensor

The optical fiber sensing systems are usually composed of light sources and light sensors. The fiber curvature is determined by the amount of light detected between the light source and the light sensor. A posture monitoring system based on optical fiber sensor has been developed by Dunne et al [27]. The system consists of a light source and a light sensor stuck to the two optical fiber ends. This system is integrated to a garment. The spine curvature is assessed by the amount of light detected between the light source and light sensor. The voltage values are converted to digital data that are sent to the computer via a serial Bluetooth. The received information is evaluated according to a predefined threshold. A warning message is displayed in the software interface to alert the bad posture cases.

The posture monitoring system based on optical fiber is sensitive to the sensor position. Any slippage of optical fiber position leads to erroneous posture evaluation.

III. Discussion

At a glance, the problematic of sitting posture monitoring system is relatively a recent subject since all identified studies are in the 21st century. The studied systems characteristics are summarized in the Table I and II below in order to analyze and compare, respectively, their architecture and their accuracy. Thirteen systems are analyzed. The systems are classified according to the sensors technologies: 3 systems based on pressure sensors, 7 systems based on inertial sensors, 1 systems based on flexible sensors, 1 system based on inductor sensors and 1 system based on optical fiber sensor.

The aim of researches related to the posture monitoring is to improve the system's efficiency in terms of measurement accuracy, portability and ease of use.

The system portability is an important aspect to evaluate the system's reliability. Only the systems with pressure sensors [14] [15] do not satisfy the portability aspects while the sensors are mounted under the chair legs and on the seat plate. The posture monitoring based on the inertial sensors, flexible sensors, inductor sensors, and fiber optical sensor are considered portable systems. However, these systems are related to the readout unit that collects the information and sends them to the analyzer system using Bluetooth which is limited in communication range. The subjects motion must conserve Bluetooth connectivity. The portability aspect remains an open issue to study in future works.

The accuracy measurement units are different in the proposed systems. As shown in Table II, the system's accuracy can be measured by the percent of tests for which the system correctly identifies the subject posture and by the root mean squared error of the posture tilt angle. Moreover the tests are performed with different scenarios. Thus, it is difficult to compare the posture monitoring systems accuracy. All systems presented in Table II have good accuracy values. However these accuracy measurements are related to a simple test and limited number of postures. As shown in [15], the error depends on the tasks. The accuracy decreases in complex cases. It is important in future works to propose systems that cover the dynamic and complex tasks with good accuracy.

As shown in Table I, different sensing technologies are used to define the persons sitting posture. The most used technology for the posture monitoring systems is the inertial sensors (accelerometer). The accelerometers are tiny and wearable. They are simple and easy to install on the subject clothes. However, the inertial sensors are sensitive to the sensor position and orientation [28]. In fact an erroneous result can be generated because of the accelerometer changing position during the posture monitoring. The wrong orientation of the accelerometer leads to errors that distorted the posture results.

Moreover, the flex sensors and optical fiber-based systems accuracy is related to the sensor position [25] [27]. In [25] the poor postures are not detectable when the sensors are placed on the lumbar or the lower thoracic. In [27] the slippage of sensor position tends to posture monitoring errors.

Some posture monitoring systems are based on the combination of two sensing technology, i.e., inclinometer sensor and load sensors [16], flex sensors and load sensor [25]. This technology combination gives more information about the subject posture and the spine deformation. Using more than technology for posture assess is an open issue to improve the efficiency of the posture monitoring systems.

As the posture monitoring systems are medical systems offering a human being assesses, the ethical or moral aspects should be considered in these systems implementation. A healthy system is needed for human use. The tiny electrical devices integrated in the human clothes use magnetic signal to define and transmit the posture information. Using signal frequencies that match the human being physiological property is a challenging issue for the tiny technology development used for medical care.

A biological feedback of the posture monitoring systems is studied in some literature works [29] in order to provide a learned posture correction aspect to the system user. Furthermore, the posture monitoring systems based on sensing technology maintain the person privacy all the time. However, the data transmission and database store must develop techniques to secure the user information.

IV. Conclusion

We report a survey on the recent posture monitoring systems existing in the literature. These systems define the body posture using sensing technologies and provide feedback to the user in order to improve the body posture. For the patient posture correction systems and rehabilitation systems, the accuracy of the posture information remains the challenging research subject to improve the posture monitoring systems.

In the future work, we will develop and design a wearable posture monitoring system that is comfortable, easy to use and efficient in terms of the posture accuracy, the time-system treatment and feedback.

References

[1] Canadian Chiropractic Association Team, “Canada Low Back Pain Epidemic,” Blog Chiropractic Expertise Low Back Pain, Mai 2018.

[2] GBD 2015 Disease and Injury Incidence and Prevalence Collaborators, “Global, regional, and national incident, prevalence, and years lived with disability for 310 diseases and injuries, 19902015: a systematic analysis for the Global Burden of Disease Study 2015“, THE LANCET, pp. 1545-1602, October 2016.

[3] Hoy D, Bain C, Williams G, March L, Brooks P, Blyth F, Woolf A, Vos T, Buchbinder R, “A systematic review of the global prevalence of low back pain. Arthritis Rheum,” Arthritis and Rheumatology, June 2012

[4] Altaf F, Heran MKS, Wilson LF, “Research Review: Back pain in young patients,” Bone and Joint Journal, 2014.

[5] Church J, Saunders D, Wanke M, Pong R, Spooner C, Dorgan M, “Citizen participation in health decision-making: past experience and future prospects,” J Public Health Policy, 2002.

[6] DeokJu Kim, MiLim Cho, YunHee Park, and YeongAe Yang, “Effect of an exercise program for posture correction on musculoskeletal pain,” Journal of Physical Therapy Science, pp. 17911794, June 2015.

[7] Supriya Sathyanarayana, Ravi Kumar Satzoda, Suchitra Sathyanarayana, Srikanthan Thambipillai, “Vision-based patient monitoring: A comprehensive review of algorithms and technologies,“ Journal of Ambient Intelligence and Humanized Computing, pp. 225251, November 2015.

[8] Damien Brulin, Yannick Benezeth, Estelle Courtial, “Posture Recognition Based on Fuzzy Logic for Home Monitoring of the Elderly,“ IEEE Transactions on Information Technology in Biomedicine, pp. 974 - 982, July 2012.

[9] Obdrzlek S1, Kurillo G, Ofli F, Bajcsy R, Seto E, Jimison H, Pavel M., “Accuracy and robustness of Kinect pose estimation in the context of coaching of elderly population,“ International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 11881193, September 2012.

[10] Taieb-Maimon M1, Cwikel J, Shapira B, Orenstein I, “The effectiveness of a training method using self-modeling webcam photos for reducing musculoskeletal risk among office workers using computers,” j.apergo, 2011.

[11] Kendall Ho, Christopher Yao, Helen Novak Lauscher, “Part2: Health apps, wearable, and sensors: The advancing fraintier of digital health,“ BC medical Journal, pp. 503-506, December 2017.

[12] Wen-Yen Lin, Wen-Cheng Chou, Tsai-Hsuan Tsai, Chung-Chih Lin, Ming-Yih Lee, “Development of a Wearable Instrumented Vest for Posture Monitoring and System Usability Verification Based on the Technology Acceptance Model,”Sensors (Basel), 2016.

[13] Wen-Yen Lin, Ming-Yee Lee, Wen-Cheng Chou, “The design and development of a wearable posture monitoring vest,” IEEE International Conference Consumer Electronics (ICCE) on Las Vegas, Janvier 2014.

[14] Roh J, Park HJ, Lee KJ, Hyeong J, Kim S, Lee B., “Sitting Posture Monitoring System Based on a Low-Cost Load Cell Using Machine Learning,” Sensors (Basel). 2018.

[15] Jingyuan Cheng, Bo Zhou, Mathias Sundholm, Paul Lukowicz, “Smart chair: What can simple pressure sensors under the chairs legs tell us about user activity?,” IARIA XPS Press, 2013.

[16] Bilal El-Sayed, Noura Farra, Nadine Moacdieh, Hazem Hajj, Rachid Haidar, Ziad Hajj , “A novel mobile wireless sensing system for real-time monitoring of posture and spine stress,” 1st Middle East Conference Biomedical Engineering (MECBME), 2011.

[17] E.Hedberg, J.Norn, M.Norrlf, S.Gunnarsson, “Industrial Robot Tool Position Estimation using Inertial Measurements in a Complementary Filter and an EKF,“ IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd, pp. 12748-12752, July 2017.

[18] A. Linkel, K. Daunoraviciene , J. Griskevisius, J. Ziziene, A. Juocevicius, I. Raudonyte, “Applications of inertial sensors in medicine: towards model-based rehabilitation of stroke,“ IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd, pp. 442-447, 2015.

[19] Paul D. Groves, “Navigation using inertial sensors,“ IEEE Aerospace and Electronic Systems Magazine, pp. 42 - 69, April 2015.

[20] Wai Yin Wong, Man Sang Wong, “Trunk posture monitoring with inertial sensors,” Eur Spine J, 2008.

[21] Q. Wang, W. Chen, A.A.A. Timmermans, C. Karachristos, J.B. Martens, P. Markopoulos, “Smart Rehabilitation Garment for posture monitoring,” 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 2015.

[22] Azin Fathi, Kevin Curran, “Detection of spine curvature using wireless sensors,” Journal of King Saud University Science, pp. 553560, 2017.

[23] Anindya Nag, Subhas Chandra Mukhopadhyay, Jrgen Kosel, “Wearable Flexible Sensors: A Review,“ IEEE Sensors Journal, pp. 3949 - 3960, May 2017.

[24] Giovanni Saggioab, Giancarlo Orengo, “Flex sensor characterization against shape and curvature changes,” Sensors and Actuators A Physical, pp. 221-231, April 2018.

[25] Manju Gopinath, Angeline Kirubha, “Real Time Monitoring of Posture to Improve Ergonomics,” Journal of Biomedical Engineering and Medical Imaging, 2015.

[26] Sardini, auro Serpelloni and Viviane Pasqui, “Wireless-wearable T-shirt for posture monitoring during rehabilitation exercises,” IEEE Transactions on Instrumentation and Measurement, pp. 439-448, 2015.

[27] L.E. Dunne, P. Walsh, B. Smyth, and B. Caulfield, “A System for Wearable Monitoring of Seated Posture in Computer Users,” 4th International Workshop on Wearable and Implantable Body Sensor Networks (BSN 2007), pp 203-207, 2007.

[28] Harsh Gupta, “Smartphone Based Cervical Spine Stress Prevention,” Smartphone Based Cervical Spine Stress Prevention. Journal of Software Engineering and Applications , pp 110-120, 2018.

[29] Da-Yin Liao, “Collaborative, Social-networked Posture Training (CSPT) through Head-and-Neck Posture Monitoring and Biofeedbacks,” 19th International Conference on Enterprise Information Systems (ICEIS 2017), pp 158-165, 2017.

[30] Maheswaran Shanmugam, Sunilvignesh Nehru, Sathesh Shanmugam, “A wearable embedded device for chronic low back patients to track lumbar spine position,” Biomed Res 2018 Special Issue, 2018.

[31] Jullia Birsan, Diana Stavarache, Maria-Iuliana Dascalu, Alin Moldoveanu, “SpiMO - Sitting Posture Monitoring System,” RiCHI 2017 Proceedings, 2017.

TABLE I
POSTURE MONITORING SYSTEMS ARCHITECTURE

Papers	Sensor Type	Information provided by sensors	Number of sensors	Sensors placement	Communication technology	Battery Performance
Jingyuan Cheng et all.2013 [15]	Pressure sensors	The total weight and the distribution of weight and force exercised to the four legs	4	Under chair legs	A 2.4 GHz Zigbee module for data transfer	5500mAh battery with 36 hours autonomy
Roh J et all.2018 [14]	Load sensors	Body weight ratio	4	Mounted on the seat plate	1 Hz frequency via the Arduino board	NA
Jullia Birsan et all.2017 [31]	Pressure sensors	Weight distribution	11	9 pressure sensors on the pillow and 2 pressure sensors on the back	Bluetooth	NA
Bilal El-Sayed.2011 [16]	Inclinometer Sensor and load sensors	Posture angle and weight	3	The inclinometer sensor positioned at the neck + load sensors placed on the feet soles	Wi-Fi data acquisition device	the battery used to power the sensors and DAQ module.
Wai Yin Wong et all.2008 [20]	Inertial sensors: 1 3D accelerometer and 3 gyroscopes	Tilting angles and trunk angles of the thoracic and lumbar regions	3	Sensors embedded on the garment on the upper and trunk and in the pelvic level	NA	4 AAA size rechargeable batteries (Ni-MH type, 1,100 mAh, 1.2 V) for operational 8 hours.
Q. Wang et all.2015 [21]	Inertial sensors	Thoracic angle	2	Vertebrae T1 and T5 of spine	Bluetooth	NA
Azin Fathi, Kevin Curran.2017 [22]	Inertial unit: accelerometer and gyroscope	Acceleration and angles change rate	3	Cervical spine, thoracic spine and lower lumbar spine.	NA	The shimmer sensor battery life is not to be recharged for running days.
Maheswaran Shanmugam et all.2018 [30]	Gyroscope and accelerometer	Acceleration angle converted to the bend angle	1	The sensor unit is placed on the lower back or at the shirt pocket.	Bluetooth	NA
Da-Yin Liao.2017 [29]	Accelerometer	Tilt angle	1	Earhook device	NA	NA
Harsh Gupta.2018 [28]	Accelerometer	Tilt angle	1	Smartphone accelerometer	NA	NA
Manju Gopinath and Angeline Kirubha.2015 [25]	Flex sensor and cell load	Voltage value caused by resistance variation during spine bending and body load	2	The Flex sensor placed on the mid-thoracic region and the load cell is placed between platforms on which the subject can stand	NA	NA
Emilio Sardini et all.2015 [26]	Inductive sensor	Inductance value	1	sticked to the T-shirt throughout the patient back and chest	Bluetooth	9 V batteries and about 1200mAh allowing continuous functioning of a few hours
L.E. Dunne et all.2007 [27]	Plastic optical fiber (POF) sensor	Bend degree	1	Plastic optical fiber (POF) integrated to the garment. A light source and light sensors are placed at the edges of the POF. The POF is stuck to the subject back	Bluetooth	NA

TABLE II
POSTURE MONITORING SYSTEMS ACCURACY

Papers	Posture Accuracy Evaluation	Test Scenarios	Subjects Criteria	Number of Postures
Jingyuan Cheng et all.2013 [15]	Accuracy of the posture classification: - 82.6% for the experimental tests - 78.3% for the daily activities	- Experimental tests: the subject seated in the chair repeat 12 postures and actions 20 times. - Tracking daily activities: the subject is asked to sit for at least 8 hours during 3 days and perform normal work routine.	5 healthy subjects: 1 female, 4 males, aged between 23 and 34 years.	7 sitting postures
Roh J et all.2018 [14]	The average of posture classification rate: 97,2%.	2 tests evaluation: - Preliminary tests: posture changing with instruction. - Main tests: posture changing randomly.	24 healthy adult males (15 in the preliminary tests and 9 in the main tests): age: 27.6 ± 5.6 years, height: 174.5 ± 6.2 cm, and body weight: 71.9 ± 8.7 kg	6 sitting postures
Jullia Birsan et all.2017 [31]	Users satisfaction: 65% of participants consider the system is efficient to improve lifestyle	Tracking sitting posture	8 subjects: 4 males and 4 females, age 20-50	NA
Bilal El-Sayed.2011 [16]	NA	Sitting posture scenario: Beginning with a correct posture, then bent over, then straightened up for short time, then going through a period of fluctuation.	NA	3 sitting postures
Wai Yin Wong et all.2008 [20]	The averaged root mean squared differences between the measurements of the system and the reference system: $\leq 1.5°$ for dynamic measurement, $< 3.1°$ for the sagittal plane and $\leq 2.1°$ for the coronal plane	Track the posture during daily activities	4 females and 5 males: age: 25.2 ± 4.8 years, weight: 50.5 ± 7.2 kg, height: 1.7 ± 0.09 m and BMI: $18.4 \pm 1.1 kg\ m^{-2}$	NA
Q. Wang et all.2015 [21]	Root mean squared error of the thoracic angle compared to the commercial optical tracker (PST-55/110 series): 3.57	Stand straight to calibrate the system. Then bend forward different angles: $15°, 30°, 45°, 60°$ and $75°$ randomly. This exercise is repeated three times.	7 subjects: 4 females and 3 males	NA
Azin Fathi, Kevin Curran.2017 [22]	Classification accuracy according to the training data (the number of system training to distinguish between two incorrect posture (Hunch Back and Slouch Back) using prerecorded data) : accuracy 85% (1 Training data), 95% (5 Training data), 100% (20 Training data)	10 tests of hunched back and 10 tests of slouched back	5 subjects:2 males and 3 females aged between 25 and 60	2 sitting postures
Maheswaran Shanmugam et all.2018 [30]	Accuracy of bad posture recognition:95%	Begin with straight posture then posture change over time.	10 subjects	NA
Da-Yin Liao.2017 [29]	NA	The teenagers are asked to wear the training headset for at least sixty minutes a day during 10 days	6 teenagers	NA
Harsh Gupta.2018 [28]	NA	The subject is asked to keep the application working for as long as he use his smartphone during a week	100 people of ages 10-60	NA
Manju Gopinath and Angeline Kirubha.2015 [25]	NA	Posture variation: bending the spine to mimic poor posture	3 subjects	NA
Emilio Sardini et all.2015 [26]	Uncertainty of lengthening values: 4.9 mm	The subject is sitting and slowly performs lengthening and straightening of the body.	4 subjects: mean age 25.6 years, mean height 178 cm	NA
L.E. Dunne et all.2007 [27]	A mean value error of spinal bend degree: 0.64 degrees A mean time error: 0.53 seconds	The subject changes his bend degree over time.	9 healthy subjects.	NA