Artificial senses and computer wearable design for health and wellness

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Artificial senses and computer wearable design for health and wellness

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Abstract

This paper shows some of the outcomes of the ongoing research on Design for wellness and for medical devices carried out at the Polytechnic University of Bari.
Particularly it focuses on the role of the ICT and the wearable technology in in the orthopedic field for the skeletal muscle strengthening and postural correction.
Proprioception and posture are strictly connected because the proprioceptive sensibility allows to be conscious about the position of the articulation and of the skeletal, the muscle tensions and the movement (Kinaesthesia).
Posture is the expression of an inherited experience (such as personal experience, training and physical and emotional trauma) and a rehab training, as far as a medical treatment, needs to focus the emotional sphere of the user – patient.
So, the question behind the research presented is: could ICT systems and the IOT address product design towards the definition of a new generation of interactive systems able to perform a postural positive rehabilitation and correction trough the enhancement of the proprioceptive sensitivity? Could design practices and methods help in a new vison for medical scientific frameworks in order to give a positive value to the medical treatment and rehabilitation experience focusing on the patient? Could the empowerment of the patient be enabled by Iot and smart devices?
In order to give an answer to that question the paper shows a meaningful selection of devises and technology in the state of the art and the results of the experimental phase: a smart lumbar belt and an app.

Keywords: human center design, medical and wellbeing design, wearable technology

1. INTRODUCTION

1.1 LOGICAL PROBLEM: WELL-BEING AND DISEASE PREVENTION IN THE POSTURAL FIELD

In premise we observe that posture is the result of the functional interaction between the biomechanical, neurophysiological, psychological and psychomotor components of the individual, which is highlighted by the static and dynamic attitudes of the body segments, which are variable in relation to the objectives to be pursued and the stimuli of the environment [1].
Posture is, furthermore, the expression of an inherited experience, personal experience, training and physical and emotional trauma, the kind of life and stress we lead, the kind of work and sport we have subjected ourselves to over time.
Assuming a correct posture, allows muscles and organs such as abdomen and chest, to function and work in optimal conditions. Factors such as sedentary lifestyle, constitutional characteristics, daily work stress can influence postural attitude. Bad posture is nothing more than the result of bad habits, resulting from incorrect attitudes taken since childhood.

Fig. 1. In figure a general overview of the relationship between bad and god posture effect and the main treatment options

Educating your body to proprioception means acting on the awareness that posture is an essential part of our well-being. The set of sensory information that allows the body to recognize its position in space and within the external world, describes the proprioception [2]. At this connection, the Gibson's theory on

ecological perception is an excellent example. As is well known, according to Gibson proprioception should be conceived not as a specialized channel of sensations, but as “ego-reception”, as “self-sensitivity”. In this sense, Gibson writes, all perceptual systems are proprio-sensitive, but also foreign-sensitive, since all, in various ways, provide information on the activities of the observer [3].
The physical activity aimed at skeletal muscle rehabilitation requires the constant presence of a specialist re-educator and the feedback of an orthopedic specialist in order to offer the best outcome. However, the dynamics between doctors and patients is changing according to World Health Organization. WHO defines empowerment as “a process through which people gain greater control over decisions and actions affecting their health”? The tendency is to the greater responsibility of the patient in the care and in assuming correct lifestyles [4].
Empowerment implies awareness and skills: in order to increase that kind of conditions this paper focuses on the state of the art in smart devices for wellness and proposes an experimental prototype of a smart lumbar belt.

1.2 RESEARCH QUESTIONS

Starting from this premise, the following main research questions are defined: can nowadays technology support the skeletal and muscles rehabilitation and the disease derived from the sedentary lifestyle or traumas, preventing the onset of posture-related pathologies connected with the back pain or/and controlling and monitoring them? Can sensors be considered sensory amplifiers useful for proprioceptive re-education? Can the persuasive role of the technology be encouraging the correct lifestyle enhancing the wellbeing? To the end, could the Design practices and methodology centred on user-patient enhance a new vision based on the positive healthcare – rehabilitation experience?
In order to give answers to that questions the research aims, on the one hand, at defining the state of the art in the design of intelligent devices in the wellness field and, on the other hand, at developing an experimental prototype of a smart belt for postural disease and rehabilitation.

1.3 ROLE OF ICT AND AI IN THE WELLNESS AND MEDICAL DESIGN FIELD

The design that uses advanced technology to improve the user experience places its methodological bases in the context of the human center design sharing knowledge and practices with the medical and Engineering scientific area [5].The new class of high-tech artifacts recalls design to a direct dialogue with the sciences: as a result of rapid technological advancement, today we are witnessing an extreme fragmentation of processes and systems that requires an organic human centric vision. More than this, the holistic approach in Human center design [6] (due to the amount of data (big data) coming from user in the IOT environment can address a more defined definition of the user – patient, thanks to all that kind of information coming from the real interaction with the devices and the user questionnaire associated to the APP.
This process, started with the digital revolution at the beginning of the 80’s, has at the beginning introduced the concept of a class of artifacts intended as prosthesis of the human body, enabling the enhancement or replacement of the performance capabilities of the human body, through the so-called medical devices; today it is increasingly impacting the theme of customization, focusing on new performances that relate to the life style, artistic performance and the visual communication [7].
The miniaturization of technology (micro and nano electronics, nano materials) has, in fact, made possible the implementation of interaction

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and data exchange systems, able to interconnect man to machine, through clothing [8]. In the medical field, the application of sensors to devices was aimed at the development of "data receptors" able to communicate health status (heartbeat, blood pressure, insulin level, etc.). But the most interesting developments of the contemporary world lie in the possibility of managing input and output data by acting directly on digital information.

So, the premise for the development of this study is that the development of wearable technologies and IoT in the industrial product field can be a fertile field of experimentation in order to improve living standards. In fact, medical design aimed at the design of wearable devices, currently allows to examine in real time what could be the conditions of comfort and what could be the right supports, interactive or not, to propose to users in order to improve their well-being. The reporting of data framing the user's medical parameters, if properly processed and addressed to wearable devices, can lead to the prevention of disease outbreaks and the improvement of lifestyles that include an adequate physical activity plan to be carried out. Ergonomics, well-being and comfort, properly parameterized and included as constraints of the design process, represent a real tool for innovation in the design of devices useful to meet the user's needs. The research has required a transdisciplinary approach in which the design has operated a synthesis between the needs of the users, the instances coming from medical and physiotherapeutic sciences, the technologies implemented by computer engineering.

Design that exploits technologically advanced systems to improve the user experience lays its methodological foundations in the context of systemic design and methodologically refers to human center design.

With reference to systemic design, Maldonado states that the designer, in addition to giving objects a shape, function and meaning, must have a broad knowledge of existing technology in order to improve the user's living conditions [9]. Chiapponi also argues that the designer's role is becoming that of a problem finder, or rather a critical interpreter, capable of identifying the user's needs [10].

Nowadays the informatic environment provides many opportunities to improve the quality of life in the ICT field: augmented reality, nanotechnology, smart materials, Internet of Things, wearable computer and wearable technology [11].

This research considers, in particular, wearable devices, intelligent objects and textiles, which allow the creation of new products, services and interactions, designed for the sharing of information, knowledge and experiences through supports that provide stakeholders, through a smart interaction, the increase of physical and social awareness and the world around them. The use of smart technologies, in fact, allows to collect a huge amount of data and information about the user.

At this connection Norman summarizes three different types of design: industrial design, interaction design and user experience design. Industrial design deals with the creation and development of concepts and specifications to optimize the functionality, value and appearance of products and systems, to the mutual benefit of users and manufacturers. Interaction design, on the other hand, focuses on how people interact with technology. The aim is to improve their understanding of what can be done, what happens and what has just happened, based on psychological, technical and aesthetic principles. The design of the user experience, which deals with the design of products, processes, services and environments, aiming above all at the quality and pleasantness of the overall experience [12].

So, the IoT, summarizes at best the new phase of artificial intelligence applied to objects and places.

The term (IoT) refers to all those technologies that allow to connect to an Internet network any type of device. In essence, the purpose of this connection is to monitor, control and transfer information so that the appropriate actions can be taken. In recent years, the use of objects connected to the Internet has become increasingly widespread, both in people's daily lives (wearable devices, connected household appliances, etc.) and in work (digitized production lines, Industry 4.0, etc.).
One of the key segments of this IoT revolution is precisely the industrial one, so much so that we specifically talk about Industrial IoT, which is nothing more than the application of the Internet of Things to the industrial world [13]. Today, wearable computers represent the new world of electronic devices.
When worn directly by humans, they create the so-called human-machine interaction.

2. METHOD AND PHASE

Human centered approach – postural disease modelling

As this research investigated the boundary of design with medical - physiotherapeutic disciplines, computer engineering and materials technology, a multidisciplinary approach needed.

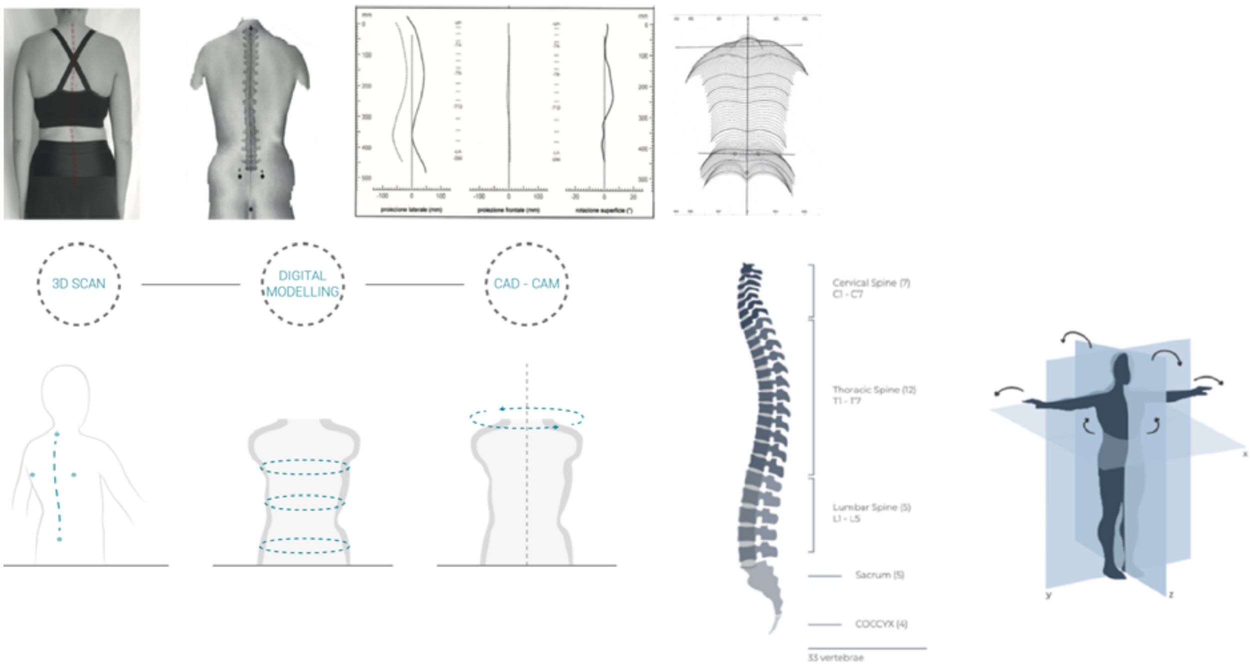

Fig. 2. In the postural correction, diagnostic and rehabilitative care, based on the spinometry and the rx ray, have been implemented by the systems based on laser scanning detection and cad cam production. Starting from medical postural dysfunctions in real case study (Federica). In the first stage analysis it was performed on the assumption of repositioning of the sensors on the human body. The second phase includes the person's relief, the study of his posture and the reinterpretation of the human model. Finally, data overlap was performed to understand how to make them interact with the App.

In the tradition of the studies that are focused on person in the way in which "needs" are at the center of the Research action of Design. We have to state that this research is focused on Human Centre Design, more than on User Centre Design as far as Norman the methodological approach is not focused on "product" in itself with the necessary market implication, but it is based on the human interaction and experience [13], particularly in the postural disease rehabilitation. As this premise has been done this study is based on an interdisciplinary team of researcher including orthopedic doctor and physiotherapist, as well as designers, informatic engineers, and material engineers. The medical diagnostic practice based on imaging techniques for posture correction was compared with reverse engineering techniques through laser scan and three-dimensional reconstruction of the musculoskeletal model, in order to identify the areas stressed during rehabilitation practice.
If we examine the medical and physiotherapeutic field aimed at postural correction, diagnostics and rehabilitative care have implemented detection systems by laser scanning and CAD/CAM production systems for the production of that devices useful for postural correction (such as bust, lumbar belt, etc.). In this context, the sharing of digital design and manufacturing protocols has defined a dynamic of disciplinary interaction that shares the human-centric approach starting from the patient scan [14].
The biometric data are overlapped to the biomechanical modelling in order to define a numerical model useful for all that kind of parametrization useful for the richest on person model. At this connection this study has been developed in its experimental phase (desk) thanks to one patient, Federica, that allow the test of the whole process.
Particularly, a spinometry has been performed on Federica. A spiniometry is a non-invasive but reliable postural analysis that analyzes the data obtained by reconstructing three-dimensionally the conformation of the back, the column and the position of the pelvis. Significant was the anatomical study of the muscle extension and the areas involved in the exercise phase, useful to understand what signals the fascia will have to transmit to the App and to monitor the reports The design process finalizes, also, the possibility of customizing the device both for what concerns orthopedic corrections, and for what concerns the features of comfort and style of device. Customization takes place through an interface managed in contemporary from the medical and patient side. It allows to manage data and interact with the final model of the belt.
From an analytic point of view the research is based on the comparison scientific literature, the research on technology and market positioning of the already in use devices for fitness and wellness. Particularly such studies have been classified using the Kiviat diagram based on a star diagram that takes in account 5 different factors: software, usability, price, aesthetic value, technology.

2.2 DESK PHASE

During the desk phase of the study it was possible to identify the devices already in use (already on the market or in the prototype testing phase) that inspire part of the project developed.
In particular, 4 devices are examined: Upright, Icaros, Microsoft Kinect and the Myo from which it has been possible to draw the informal information on the technologies implemented and the general operation.

2.3 FIELD PHASE

The main objective is to provide the user with a wearable kit that is able to improve proprioceptive state.
The user will be offered a diagnostic training, monitored by the sensors inside the kit,

supported by an App. Being interconnected, they provide the user with continuous feedback on the performance of the physical activity.

3. RESULTS

3.1 STATE OF THE ART MAIN RESULT

This research, based on the analysis and comparison of the state of the art on ITC technology and intelligent textiles, comes to a first experimental approximation through a wearable kit that provides the user with a postural experience. The research and analysis of the various case studies taken into consideration, led to the project development to obtain the results listed below:

- study of the different design methods, useful to understand the necessary phases for the development of a good medical product;
- drafting of a wide state of the art, which highlights which technologies, shapes and materials should be implemented to ensure a perfect kit realization;
- study of a graphic interface (App), which is able to provide the user with an alternative to the classic postural gymnastics, to be carried out comfortably at home, but at the same time can provide medical support and feedback;
- identification of the necessary sensors, given by careful research carried out in the field of e-textiles and wearable devices.

Fig. 3. Analyzed devices and kit for wellness and fitness training. They have been classified using the Kiviat diagram on the base of software, usability, price, aesthetic value, technology.

Particularly useful for the desk field research are:
RingFit: has two accessories that detect and measure the movements of players in the real

world and turn them into actions in the virtual world. For example, to correct the place it is possible to advance the character, while it includes attacks and attacks are made. In addition, this device monitors the heart rate via a motion sensor

Levis jacket: it is smart jacket that connects wirelessly with the phone. On the left sleeve there is a conductive, touch-sensitive fabric. This jacket inside contains a tactile motor, a led, a motion sensor, bluetooth and battery.

Nadi X: is a leggings that allows you to practice yoga in a technological way. Inside there are sensors, tactile feedback and a battery. The exercise that the user will carry out through the installed app will guide him through the update, on which parts of the body he must concentrate to carry out this specific exercise.

Upright Go: is a device that can be applied directly to the skin, which helps the user to assume a correct posture. To be able to use it, you need to use the app on your device, enter your Bios data in order to better track your posture. Inside there is a LED, a BLE, a USB port and a vibration motor, useful for generating signals in case of incorrect posture.

Icaros: a VR device that projects the user into a 3D space. The latter is shown to the user through an augmented reality viewer connected to the Icaros handlebar. Through a single device, the user is able to optimize his therapy rehabilitation phase.

Cutecircuit: consists of a sound t-shirt (for deaf users) able to transform the sounds perceived from the outside and send them to the user in the form of vibrations. The presence of 16 micro actuators, present inside it, allows to capture the different sound intensities and to transfer them to the user according to different degrees of sound intensity.

Myo: is a bracelet that acquires myoelectric signals produced by the muscles of the forearm and transform them into commands. Being Hi-tech it allows to control devices of various kinds. It is equipped with 8 EMG electrodes, the IMUs, and the vibration sensors.

Microsoft Kinect: it is a sensor capable of detecting 3D images, facial and vocal recognition. It is composed of a camera, a microphone, a motorized pin, a depth sensor, a software capable of detecting movements and gestures.

3.2 THE "SMART BELT" EXPERIMENTATION

The experimental prototype is a kit for postural exercise training in the absence of a specialized operator (doctor, physiotherapist, etc.). The kit composed of two devices passively receives the dynamics of the movement and the tensor state and translates it into a series of outputs interpreted in the context of a dedicated App. The reading of these data lends itself to a double interface: patient, physiotherapist/medicine. For both users, suitably processed reading levels are offered that offer the picture of the course of physical rehabilitation and the picture of errors made during the training routine.

This kit, as it is adjustable on the patient's body by means of a Velcro belt, can be readjusted and reused by several people from the same family. The sensor technology applied inside the kit does not require personal calibration, as it is able to detect muscle extension and movements of people with different physicality. The easy adaptability is given by the presence of highly elastic and high-performance materials such as Lycra for the band, which provides additional properties such as breathability, excellent fit and freedom of movement, and silicone for the bracelet, also adaptable and elastic, so that it can also be used as an ankle. The user will be offered a diagnostic training, monitored by the sensors inside the kit, in turn supported by an App. Being interconnected, they provide the user with continuous feedback on the progress of physical activity.

It is a wearable kit that is able to provide medical

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support to the user, and which leads to the growth of muscle tone. Starting from scientific bases that interface with medical diagnostics, the kit will be able (unlike the already existing Apps that only partially monitor movement) to detect whether the user is able to reactivate, through movement, that part of the injured muscle that needs strengthening. that improves the physical condition.

The prototype consists of a device that aims to provide the user with a wearable kit that is able to improve his proprioceptive state through exercise.
This training is continuously monitored by the devices we provide, thanks to the presence of sensors inside it; these send output signals to an App, able to provide an external person (doctor-physiotherapist) with continuous feedback on the performance of postural correction.

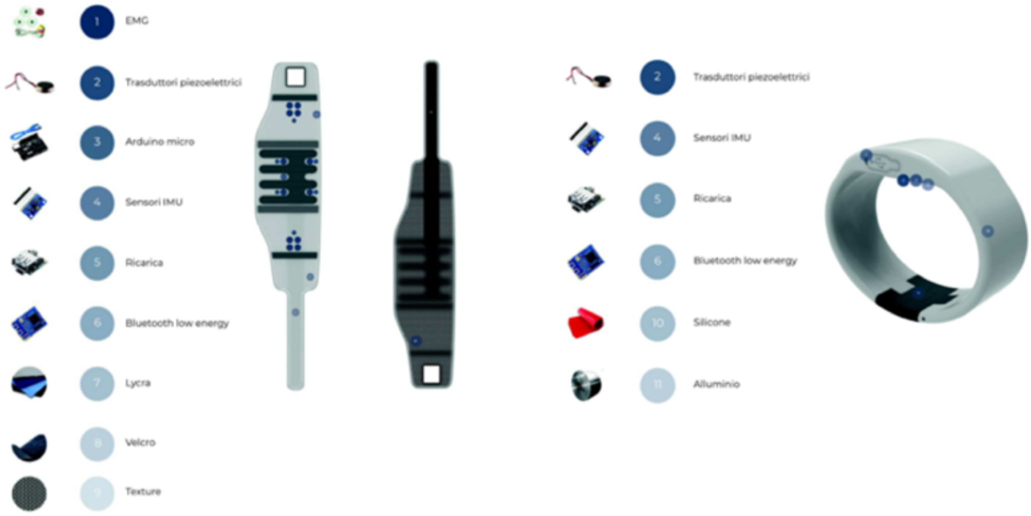
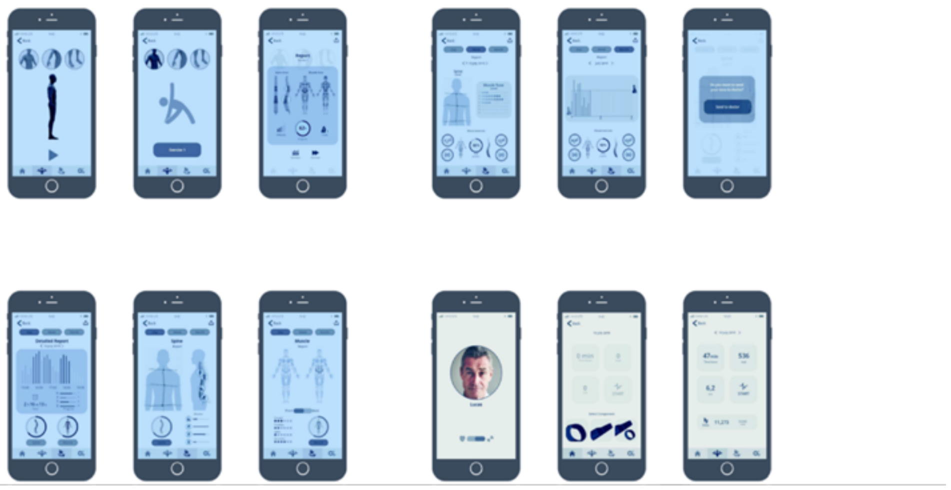


Fig. 4. Here, we can see the position of sensors. The position of these is the result of an anatomical study. To position the sensors in the best way, a muscular analysis was necessary to understand the correct positioning of the EMG sensors.



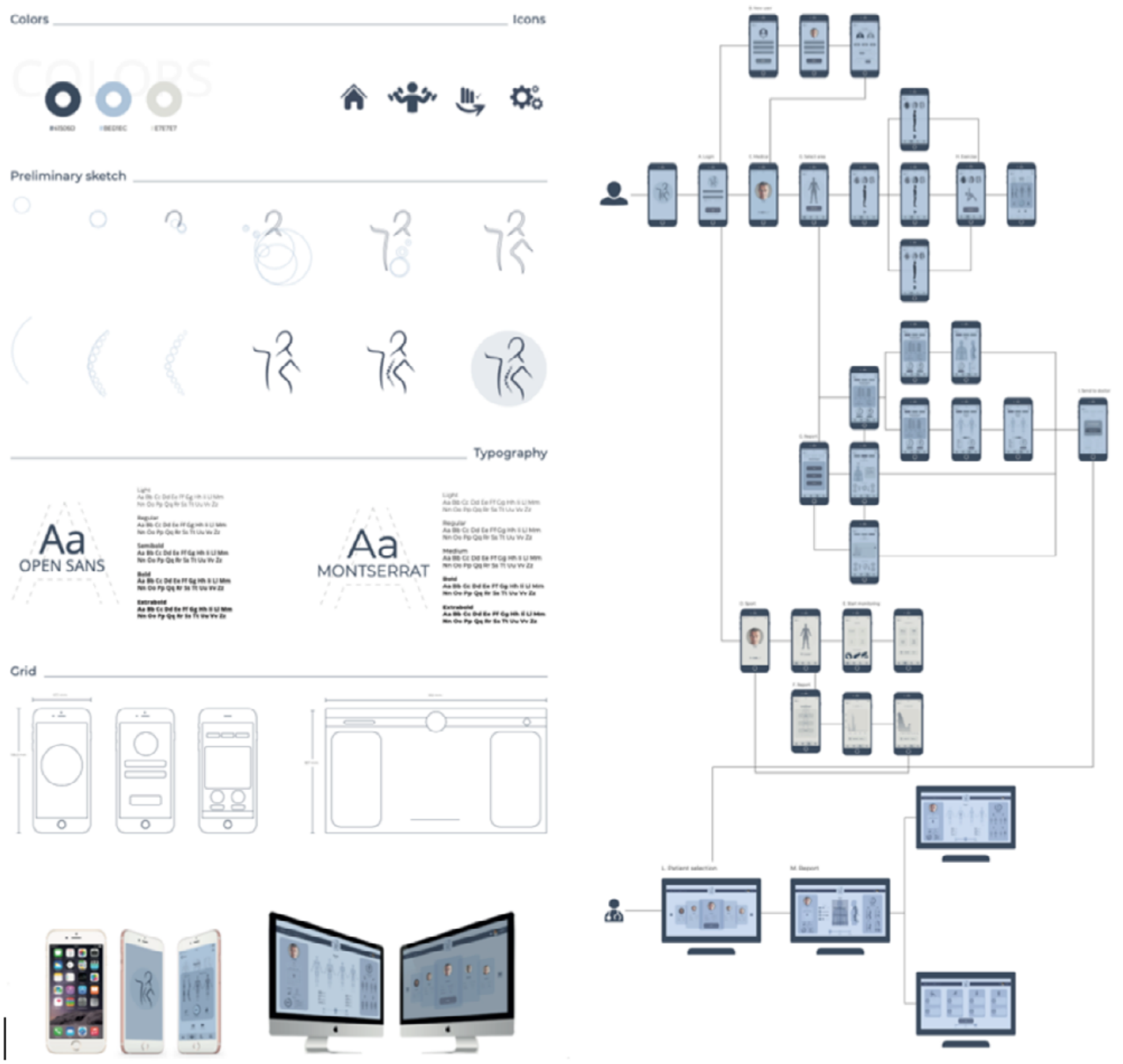


Fig. 5. Here represented the App that has the function to reading the data, monitoring them and also offers the possibility of sending the progress made during training to the physiotherapist. The App leds itself to a double two interface: patient, physiotherapist/ doctor, Both users are offered appropriately processed reading levels that provide the state of the rehabilitation progress and gives feedback related with errors and postural detection during exercises. The doctor/physiotherapist, once received the data, could correct the errors directly by the software.

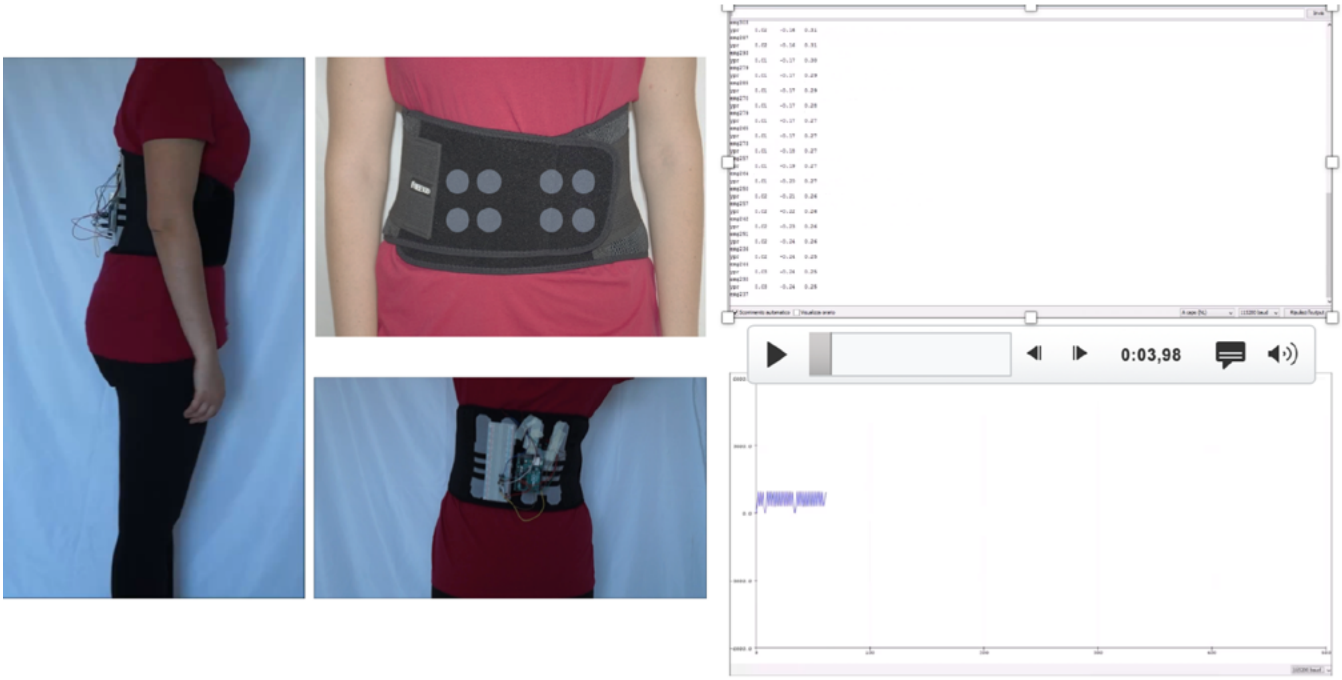


Fig. 6. This image captures the functioning of the prototype. On the right you can see the IMU sensor data movement and the muscle extension monitoring by EMG sensors.

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CONCLUSIONS

The design that interfaces with the scientific medical field, computer science and nanoelectronics represents an important area of reflection that directs design practices to the sharing of protocols and approaches, in order to humanize the experience of rehabilitation in its complex medical dynamics .
The in-depth analysis of the state of the art of IoT devices, wearable devices and sensors currently in use has led to the development and subsequent prototyping of the smart lumbar belt.
In order to carry out the smart lumbar belt, some rx ray and a spinometry was present, a non-invasive but reliable postural analysis that analyzes the data developed reconstructing the shape of the spine, the spine and the position of the pelvis in three dimensions.
The anatomical study of the muscular lengthening and of the areas involved in the physical exercise execution phase was significant, useful to understand which are the signals that the device must transfer through the App and for the monitoring of the reports.
The proposed device therefore assumes the presence of sensors, which are able to verify and monitor the posture and movements performed during the exercise.
Regarding the already existing Apps, which are more than less able to monitor the movements in part, the designed kit probably will be able to detect if the user is able to reactivate, through constant exercise, that strengthening muscle part and the effect of physical condition. This will be defined after the second experimental phase which includes a number of trial on different patient.

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