Interreg Italia-Österreich
European Regional Development Fund
EUROPEAN UNION

AGEDESIGN

Milestone 6.2

Validation of AGEDESIGN research results

Interreg Italia-Österreich
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Index

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Introduction

The project consists of joint research activity (Veneto-Salzburg) oriented to the definition, development and testing of new "design concepts" of products and services for the ageing population: the main objective of the project is to provide suitable tools which in the near future can help the improvement and preservation of health and wellness for elderly people, and to prevent the emergency of physical and psychological issues.

The project starts from the definition of four research lines, then collected in three main issues to address considering the state of art of elderlies' lifestyle in both Italy and Austria. The research continues with the identification of the "design brief", then developed into the "design concepts" that will be realized in form of "kits" to be tested in laboratory and in an external environment with real users. The demonstrative panel of end-users is selected in both the regions for the check of the usability of the kits, composed of wearable devices and supporting software running on smartphones. The completion of the research implies the validation of the outcoming systems, the verification of the market appeal and the drafting of possible implementation of the research. The aim of the resulting kits is supporting the users to adopt a healthier lifestyle in a home-based environment.

The present document introduces the research areas addressed by the AGEDESIGN project, focusing on the design of the wearable devices by distinguishing them with the differentiation of the research lines of reference.

The first section describes the research lines and the premises for the brief, the following sections concern the process that drove from the brief to the concept development. Each section addresses the sketching phase, the definition of the electronics and the modeling, to synthesize the results into the prototypes of which consists AHAMS, the final kit subjected to the users.

The last section presents the development of the QUALIFEDESIGN platform.

1. The AGEDESIGN Project

1.1 Design brief

The future of wearable devices integrates existing technologies at affordable prices, encouraging the adoption of health monitoring technologies in everyday life. These facilitate home assistance during the performance of physical activities inside and outside the home perimeter in a friendly way, becoming tools that look like fashionable accessories and clothing which collect and manage specific physiological and behavioral data. By the term "design brief" we intend here the specification of the typology and the characteristics of the products on which the researchers have worked to address the four research lines introduced in the AGEDESIGN Project Agreement. The characterization implies the study of technical components, ergonomic aspects, performance, aesthetics and the interaction expected.

Despite the identification of four research lines into the Interreg Ita-Aus Agedesign agreed document (vascular circulation, muscular control and balance, sensory abilities and dehydration), the preliminary research phase has driven to the identification of two research lines as similar and addressable with the same technology: to avoid the design of products with analogous functions and features, "muscular control and balance" and "sensory abilities" have been merged in a single research line (Table 1). Once defined the typology of sensors the partners agreed upon the design brief to combine three aims – muscular control, balance and sensory abilities into a unique smart tracksuit. Eventually, the design brief and the concepts developed into the project are two:

- **vascular circulation and dehydration;**
- **muscular control, balance and sensory abilities;**

The first approach to the research lines has been oriented to a general identification of the physical parameter to monitor in order to get the relevant data that give an overview on the user's situation. The users have been identified as persons over 65, with an healthy lifestyle and without existing pathologies: they might have familiarity with diseases such as diabetes, high or low pressure, hypertension, arthritis, sarcopenia but they have not been diagnosed with any of these; therefore the use of medical terms in the development of the project shall not imply the treatment of the user as a patient but the goal of the research is to develop a product, or a series of products, that address the lifestyle of different personas in a programme of prevention of any disease that can occur in connection to the ageing process. The wearable devices designed through the project will provide support to the users for reaching a healthier lifestyle in an home-based environment, therefore they won't be registered as medical devices.

The second step after the identification of the parameters has been the research on the existing technologies that monitor such parameters. The decision to work towards the prevention of the disease instead of the treatment of the same has oriented the researchers to exclude the technologies that require invasive monitoring techniques. A brainstorming phase was necessary to understand and define aims and electronic components for each project's lines. A list of possible sensors to use for the development of the project has been provided by SRFG and PLUS in the document "First sensors assessments" shared with the partners in June 2017.

The details of the two research concepts will be exploited in the following paragraphs.

Table 1 - Definition of the design concept (WP3.2)

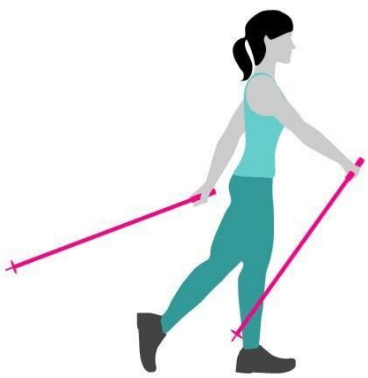
Research lines	Vascular circulation	Dehydration	Muscular control and balance	Functional abilities
Design Brief	to monitor heart beat and detect cardiac anomalies	to monitor the dehydration during the day	to monitor physical activities, lack of balance and loss of muscular tone	to monitor the lack of balance during physical activities
	Photoplethysmograph	Bioimpedance sensor	Inertial measurement units sensors	Inertial measurement units sensors

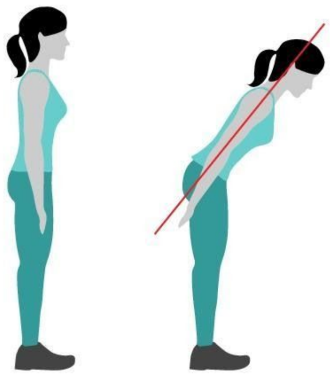
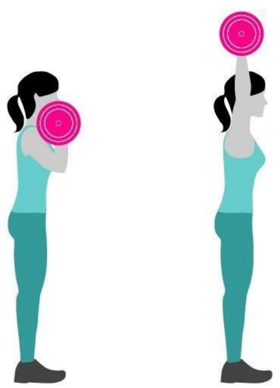
Concept	wristband + hub	smart suit

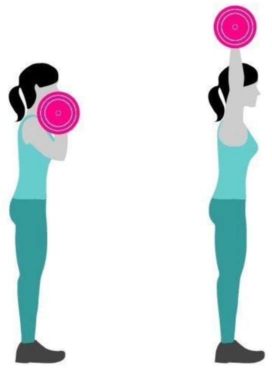
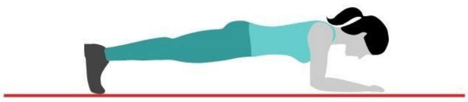
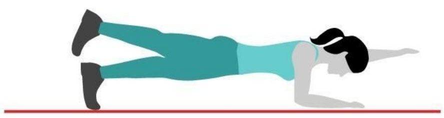
1.2. Premises for the smart suit development

The concept of the suit arises from the need to monitor and encourage physical activity in the elderly. At first, it was necessary to define precisely which exercises are best suited to strengthen the musculoskeletal system and improve muscular control. Thus, SRFG and PLUS defined the physical exercises to be monitored in June 2017 and afterward, the exercises were verified and confirmed by the ULSS 1 Dolomiti in July 2017 (Table 2).

Table 2 - Excerpt from exercise selection

Exercise	Sensors	Measurement Variables
Nordic Walking *(or Brisk walking, jogging, running)* 	• Ambient • IMU • LVL	• heart rate • breathing hard and fast (pulmonary expansion) • knee angle • knee angle velocity • knee angle acceleration • varus/valgus • use of the sticks (impact forces) • gait cycle (e.g. asymmetries)
Squat (*Kniebeuge*) 	• Kinect • Ambient • IMU • LVL	• heart rate • breathing hard and fast (pulmonary expansion) • knee angle • knee angle velocity • knee angle acceleration • varus/valgus • lumbar spine

Exercise	Sensors	Measurement Variables
Hinge (*Kreuzheben*) 	• Kinect • Ambient • IMU • LVL	• heart rate • breathing hard and fast (pulmonary expansion) • knee angle • knee angle velocity • knee angle acceleration • varus/valgus • lumbar spine
Lunge *(Ausfallschritt)* 	• Kinect • Ambient • IMU • LVL	• heart rate • breathing hard and fast (pulmonary expansion) • knee angle • knee angle velocity • knee angle acceleration • varus/valgus • lumbar spine
Military press *(Schulterdrücken)* 	• Kinect • Ambient • IMU • LVL	• heart rate • breathing hard and fast (pulmonary expansion) • height of shoulders • extended elbows

Exercise	Sensors	Measurement Variables
Military press *(Schulterdrücken)* 	• Kinect • Ambient • IMU • LVL	• heart rate • breathing hard and fast (pulmonary expansion) • height of shoulders • extended elbows
Plank *(Unterarmstütz)* 	• Kinect • Ambient • IMU • LVL	• heart rate • breathing hard and fast (pulmonary expansion) • shoulder blades • long neck • lumbar spine
Plank (*Unterarmstütz*) remove feet/hands from floor 	• Kinect • Ambient • IMU • LVL	• heart rate • breathing hard and fast (pulmonary expansion) • shoulder blades • long neck • lumbar spine
Standing on one leg 	• Kinect • Ambient • IMU • LVL	• heart rate • breathing hard and fast (pulmonary expansion) • hip

In agreement with all the project partners, two of the listed exercises have been selected for the development of the smart suit: squat and lunge. These exercises have been identified as the most effective for their completeness in the engagement of the entire body, in terms of balance and musculoskeletal strengthening. SRFG and PLUS suggested the Inertial Measurement Units as the most appropriate sensors to monitor the body during physical activities. They might be placed all over the body and, through the produced data, it is possible to recognise the exercises performed by the wearer and verify if these have been acted in a correct way.

The correctness of the performed exercises is a key index of the improvement of balance control and muscular tone: the more exercises are correct, the more the user is strengthening his musculoskeletal system.

As a matter of fact, the smartphone application is designed to provide to the users a guided experience in performing the exercises and, at the end of the session, they can see the result of the performance: the app shows the number of the exercises performed correctly and those performed incorrectly. Furthermore, users can also see what was incorrect during the exercise (like wrong back posture, or wrong knee bending, etc.).

1.3 Premises for the wristband and hub development

To address the vascular circulation and dehydration research lines, partners agreed on the development of a wristband to be worn on a daily basis, which monitors constantly the wearer's heartbeat and, at regular intervals during the day, the body hydration. As shown in table 3, the most suitable sensors for the detection of the mentioned parameters are photoplethysmograph for the former, and bioimpedance sensor for the latter. Besides the measurement of the blood pulsation, what is important to detect are the cardiac anomalies (bradycardia, tachycardia and arrhythmia). Thus, the system will send alerts to the user when cardiac anomalies and body dehydration are detected through the smartphone application (see 2.3 APP). In addition, ULSS1 Dolomiti highlighted the relevance of the cardiac frequency and the blood saturation as parameters to be measured in order to have a complete framework of the vascular circulation status of the user. Following these recommendations, it has been agreed to develop an additional non-wearable device: the hub, a self standing desk-device designed to accomplish the daily measurement of blood saturation and cardiac frequency.

Table 3 - Definition of the sensors and parameters to be measured

Research lines	Vascular circulation	Dehydration	Muscular control and balance	Functional abilities
Design Brief	to monitor heart beat and detect cardiac anomalies + Blood saturation and cardio frequency	to monitor the dehydration during the day	to monitor physical activities, lack of balance and loss of muscular tone	to monitor the lack of balance during physical activities
	Photoplethysmograph + ECG plates	Bioimpedance sensor	Inertial measurement units sensors	Inertial measurement units sensors

Heartbeat and blood saturation are detected by the same technology: the photoplethysmograph, an unobtrusive optical sensor which needs to be in contact with the skin to reliably detect the parameters. In spite of this, the body position for the detection of these parameters are different: wrist is the most suitable body part for the detection of heartbeat and finger phalanges for the blood saturation. The bioimpedance sensor, instead, which consists of two copper plates positioned at a certain distance to one another, detects the electrical resistivity of the skin. It needs to be in contact with the skin as well, but it does not require ti he positioned on a specific body part.

For the reasons mentioned above, the sensors have been merged into a single device which can be removed from the wristband to be inserted into the hub (the table-device), allowing the measurement of the blood saturation.

For the detection of the cardiac frequency, it has been opted to the implementation of two silver plates in the external shell of the hub. Therefore, the hub is the tool that allows the measurement of blood saturation and cardio frequency. Besides these two functionalities, it also works as a charger for the sensor.

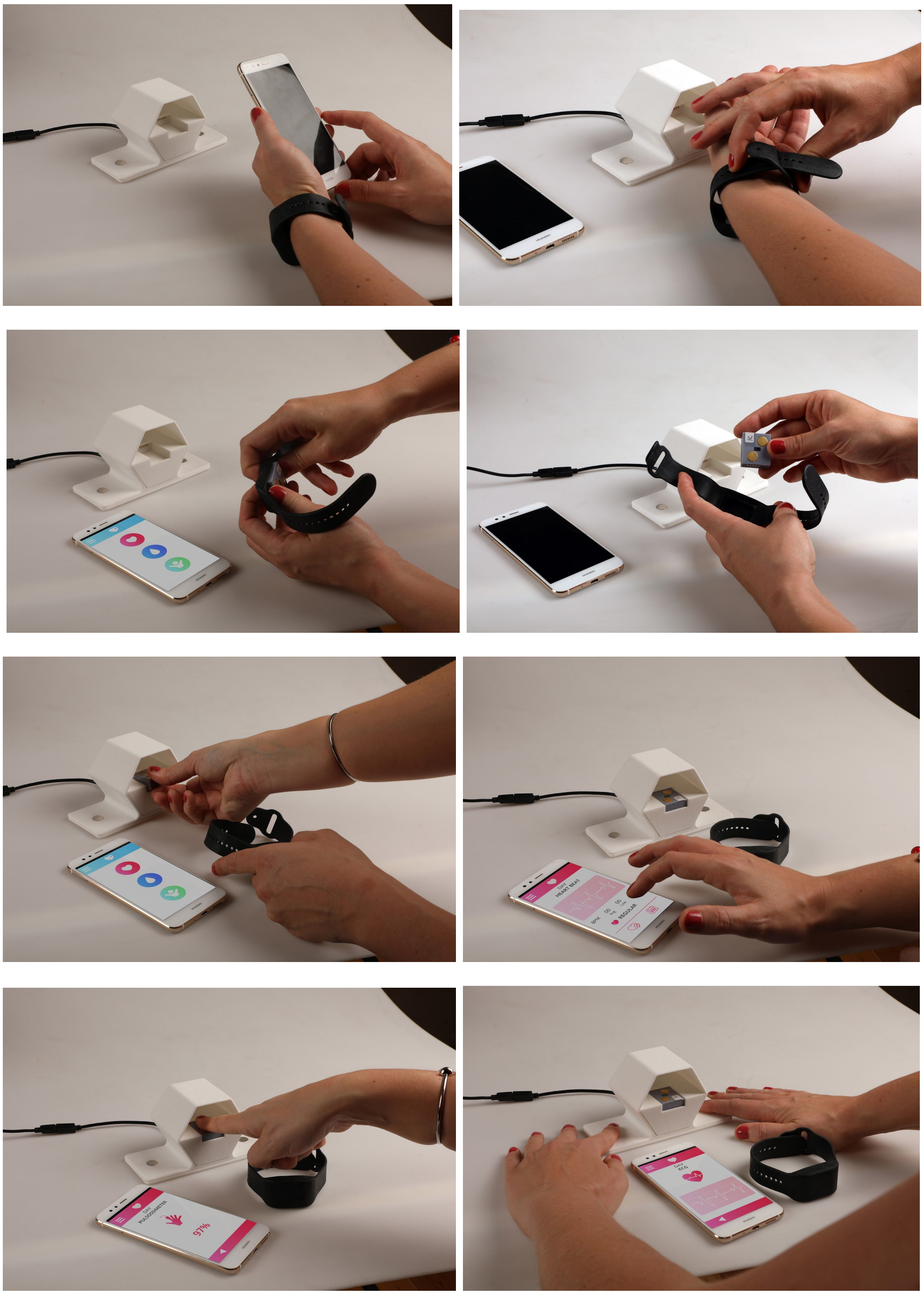


FIG.1 - How to use the system.

1.4 Design development

In order to satisfy the above mentioned premises, the design concepts of the different research lines have been developed. Starting from the sketches, then moved on the development of the electronics, and finally to the implementation of 3D models.

Dehydration and circulation system (wristband and hub)

I. Sketches

The sketches were designed to investigate the morphology of the hub and the technical structure of the different devices. While drawing, the researchers make hypothesis on the possible materials and the interaction with the users. The drawings are made with different techniques, and their elaboration allowed the discussion of the team on the possible alternative designs.

The sketches included different levels of development, from shape studies to assembly techniques. Color variations have also been investigated following the references identified with a research of the competitors and a moodboard collection.

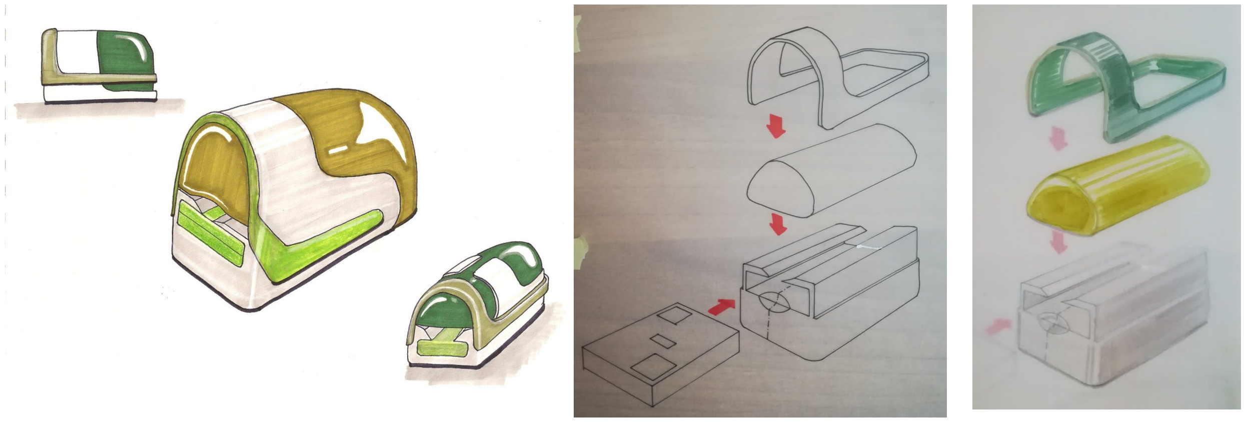


FIG.2-3-4 - Preliminary sketches of the hub development.

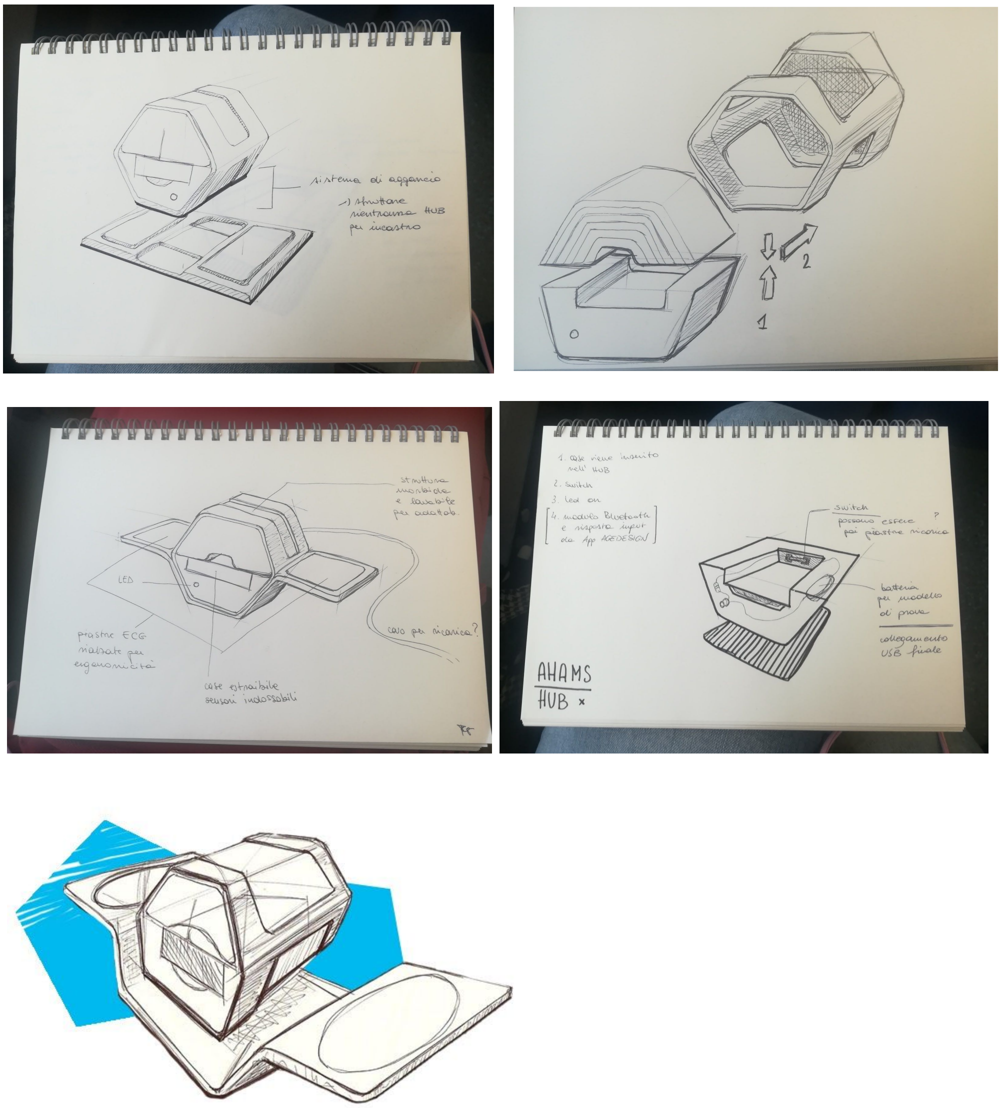
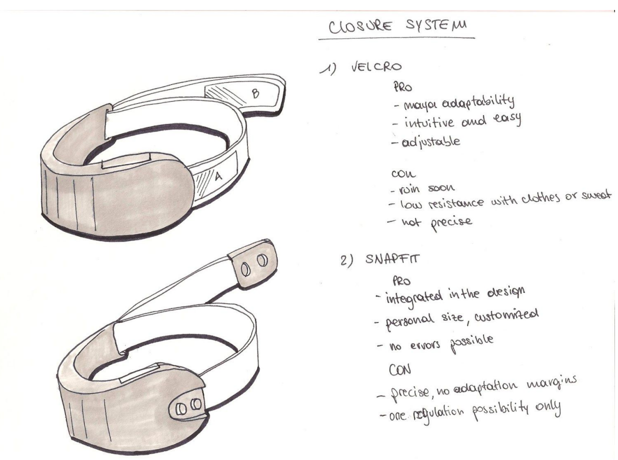
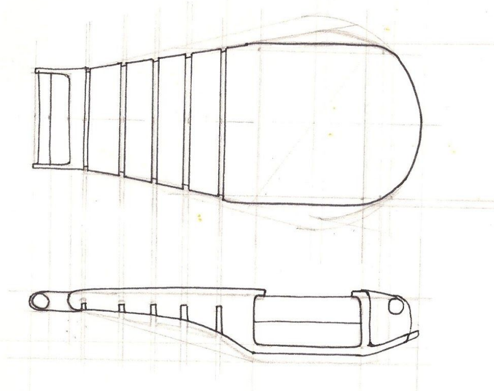
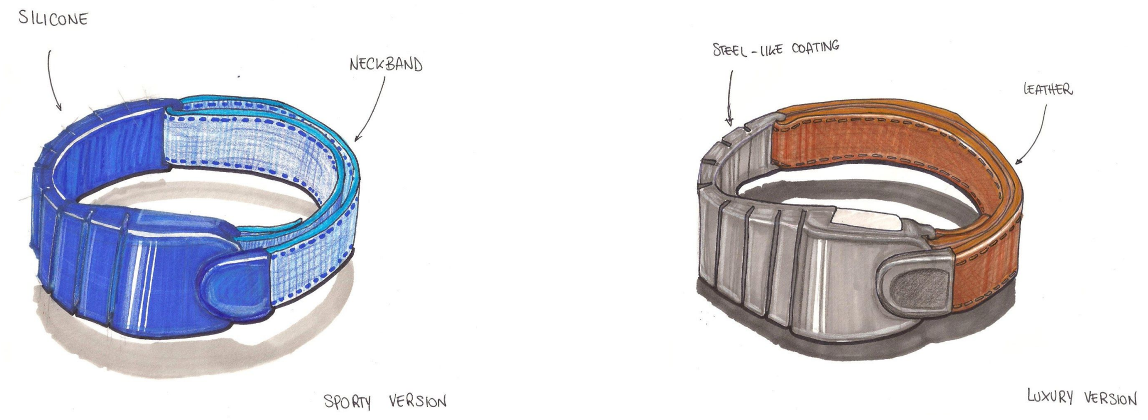


FIG.5-6-7-8-9 - Sketches of the hub







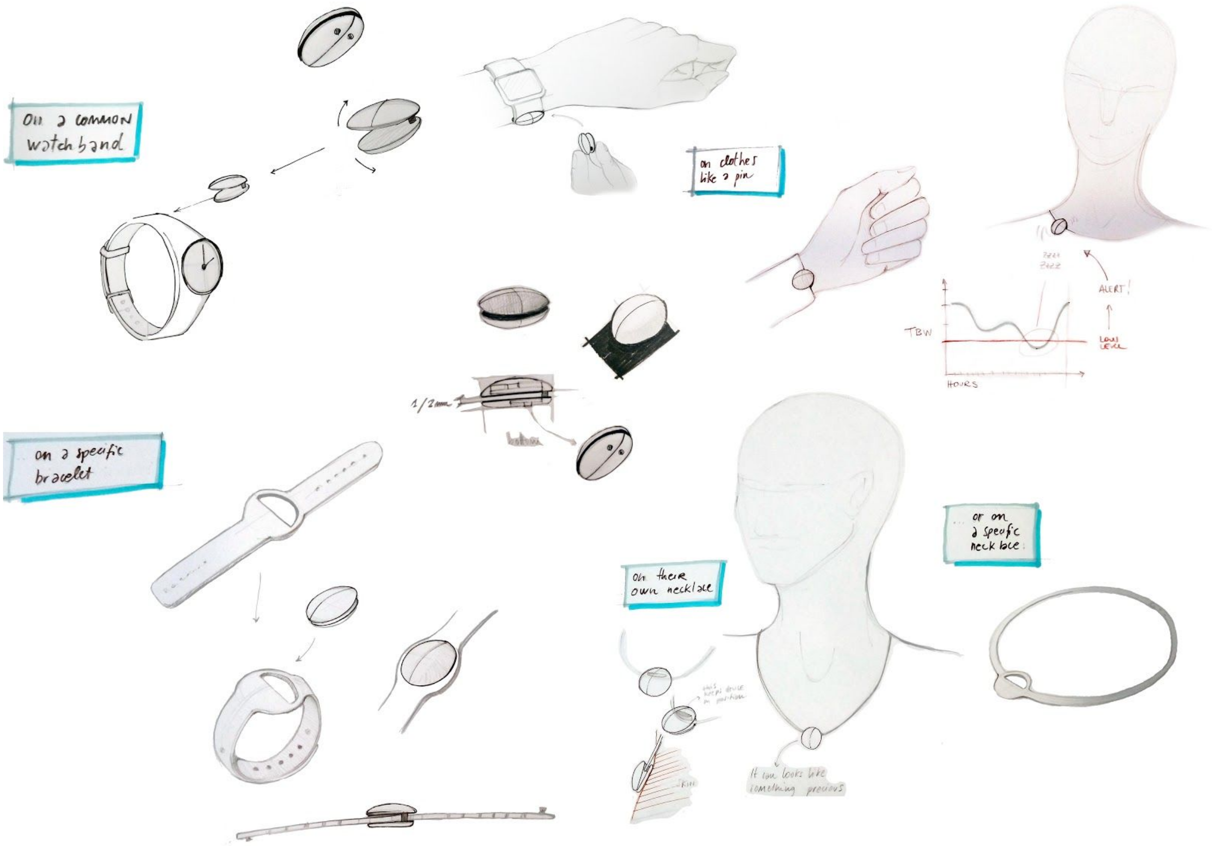


FIG.10-11-12-13-14 - Sketches of the wristband development

II. Development of the electronics

After the literature study on the technologies used for the monitoring of dehydration and circulation, the researchers have required the production of a specific board including a bioimpedance sensor and a photoplethysmograph. The first version of the board mounting these sensors resulted cumbersome, since the board itself measured 39x28 millimeters and a case was needed to allow any use. A further issue emerged with the positioning of the case on the wrist, for which the relation within the minimum dimension for the adult wrist resulted too thin to accommodate the element and allow a perfect contact between the bioimpedance plaques and the user's skin. While the first production ended in a non-functioning element, an implementation has followed with the involvement of the tech start-up Re:Lab, whose engineers were able to provide a miniaturized component that allowed the reduction of the case dimensions and the access to the lab testing phase conducted by ULSS 1 Dolomiti.

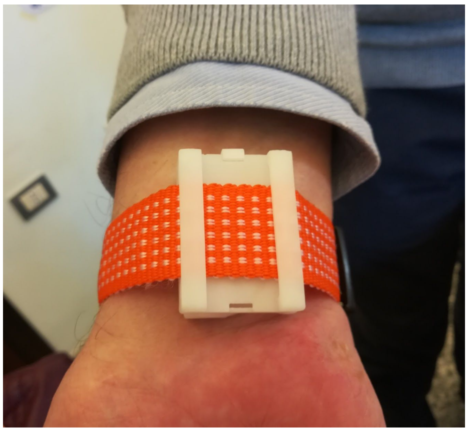
FIG.15-16-17 - Stages of the development of the electronics components

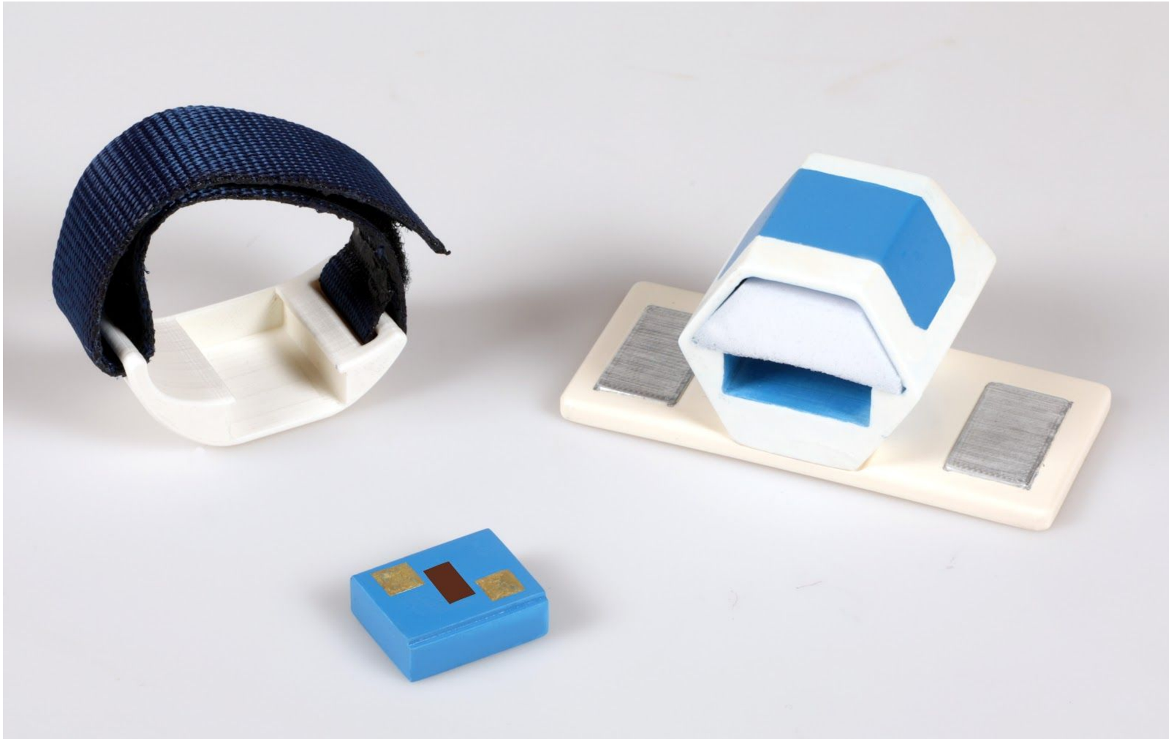
III. Models

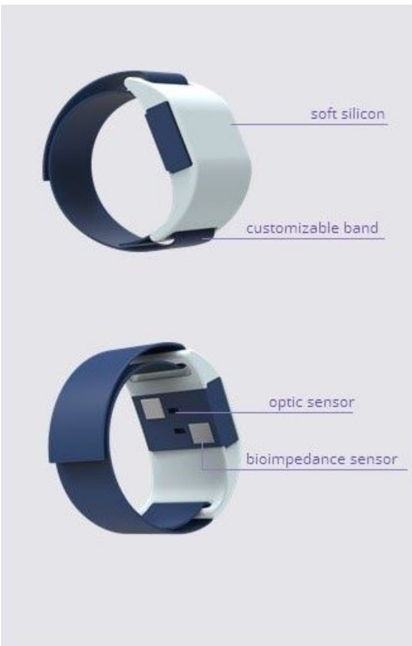
The definition of the electronics and their size has been a compulsory step to define the shape and the dimensions of the other elements of the system, plus the interaction needed within the user and the same system.

To investigate dimensions and interactivity, different study models have been prepared using poor materials and then advanced prototyping techniques (3D printing), testing the resistance of the material, the appropriateness for the intended use and the overall usability of the resulting designs. The models included an evolution of the sensors' case, the study of joints to applique it on the wristband, a study on the wristband and its closure, the design of the charging station and the inclusion of the cardiac frequency monitoring plaques base as additional service provided through the board.

Colors and textures have also been investigated, driving to the choice of polished white finishing for hub/charging station prototype and of a soft, dark plastique for the wristband, designed in an unique solution with the space to integrate the sensor.



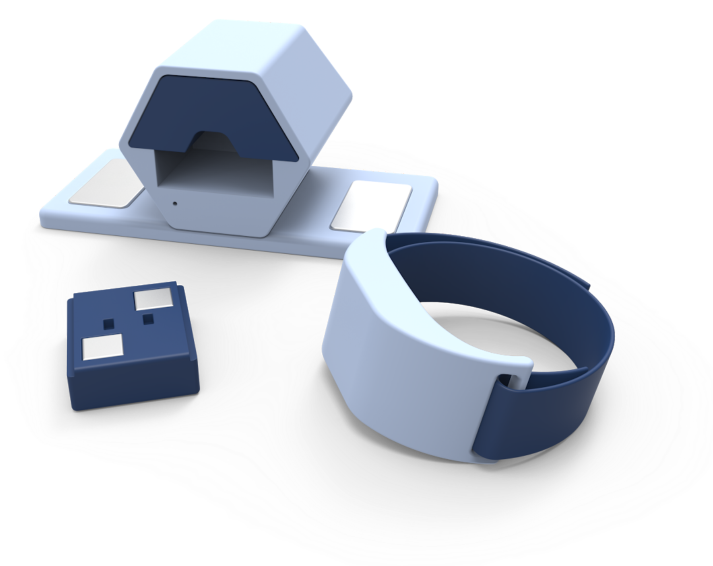


FIG.18-19-20-21-22-23-24-25 - Development of the models

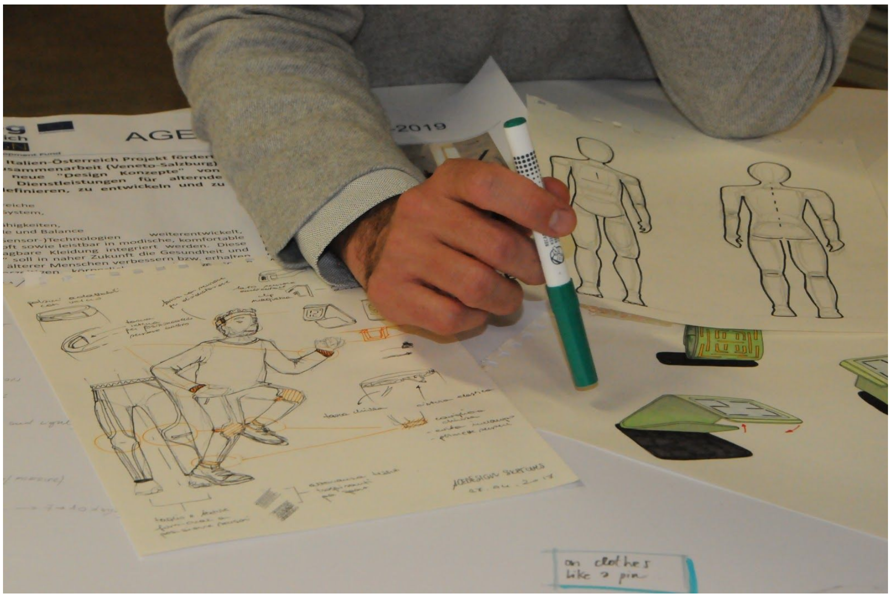
Smart Suit

I. Sketches

The sketches were designed to investigate the wearability of the smart suit and the most adequate fabric to use. While drawing, the researchers made a hypothesis on the possible materials and investigated the best positioning and the most effective coupling of the sensors in relation to human morphology.

The target of the project implied the specificity of a body shape and tone that required the researchers to design an element that empowers the users instead of wrapping and embarrass them, as the majority of training cloths on the market do. To reach the aim, natural elements, bright colors and a combination of textures were investigated.

The need of positioning the sensors on the suit was also matter of analysis during the sketching phase: the need of placement for a variable number of electronic devices on different parts of the body required the evaluation of adjustable elements to fit different body shapes and dimensions, plus at the early stage of the research it was not yet possible to define the specificity of the sensors' position neither their final number. To allow the maximum flexibility and to provide the textile material as soon as possible in the project for the laboratory testing, the system studied comprehended the design of perforated bands in which the cases could have been moved as needed, preferring the solution to reduce the number of components and external elements on the suit itself: other solutions included the sewing of buttons on the suit, limiting the range of shift, the positioning of hooks in specific points of the suit, reducing the comfort of the user, or the use of belts to be positioned without evident constraints and therefore industrious and not precise.



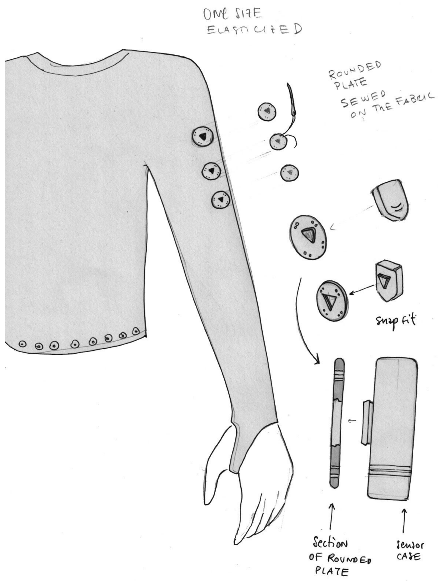


FIG.26-27-28-29 - Preliminary sketches of the smart suit development

II. Development of the electronics

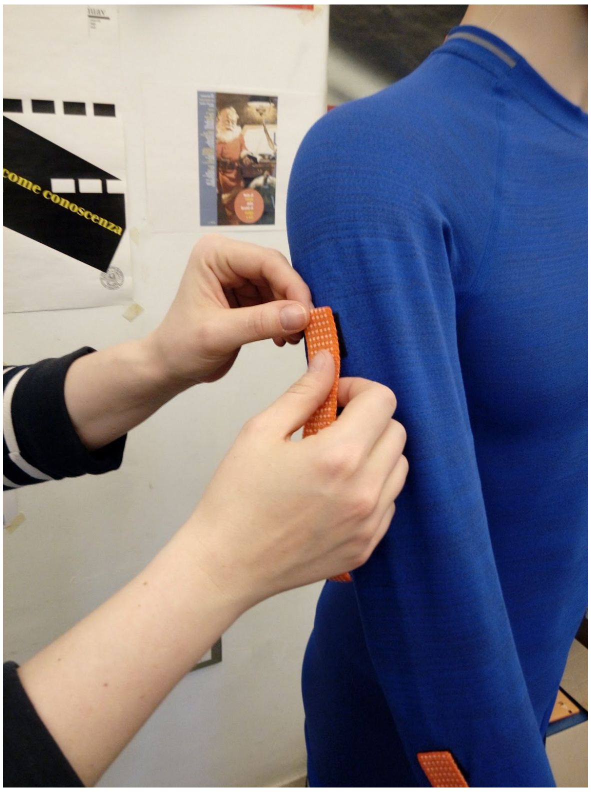
The research line on motion control was developed based on an existing IMU system, MetaMotionR, selected by the Austrian partners of the project, who had the expertise to test, implement and verify their effectiveness compared to other motion tracking devices.

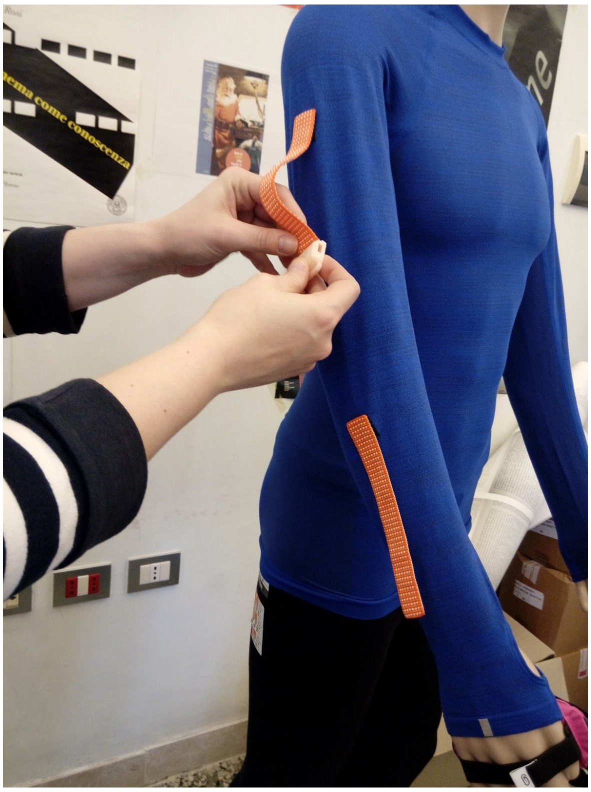
The main qualities that resulted relevant for the design of the physical user interface were the dimensions, which required a specific design of the cases, then implemented according to the suit design and the need to attach them on it, the accessibility of the charging plug and the evidence of the visual feedback represented by the LED positioned on the board.

FIG. 30-31-32-33 - Development of the electronics components

III. Models

The initial models focused on the attachment of the IMU cases on the suit, therefore the first models implies the use of existing sport textiles to study the wearability and the ease of insertion of the devices on the system. The major step in the design of the casings and on the definition of the suit has been reached with the identification of WKS by Cifra s.r.l. as a producer of specific textile technology that allows to influence the flexibility and the resistance of the textile through the knitting technique: thanks to the expertise of the company, it has been possible to combine different consistencies in the same garment within a singular production process. The first models included a study on the sewing finishing and the distribution of rigid and soft areas according to the male and female body shape, in compliance with the physical changes due to the aging that are still perceived as flaws.





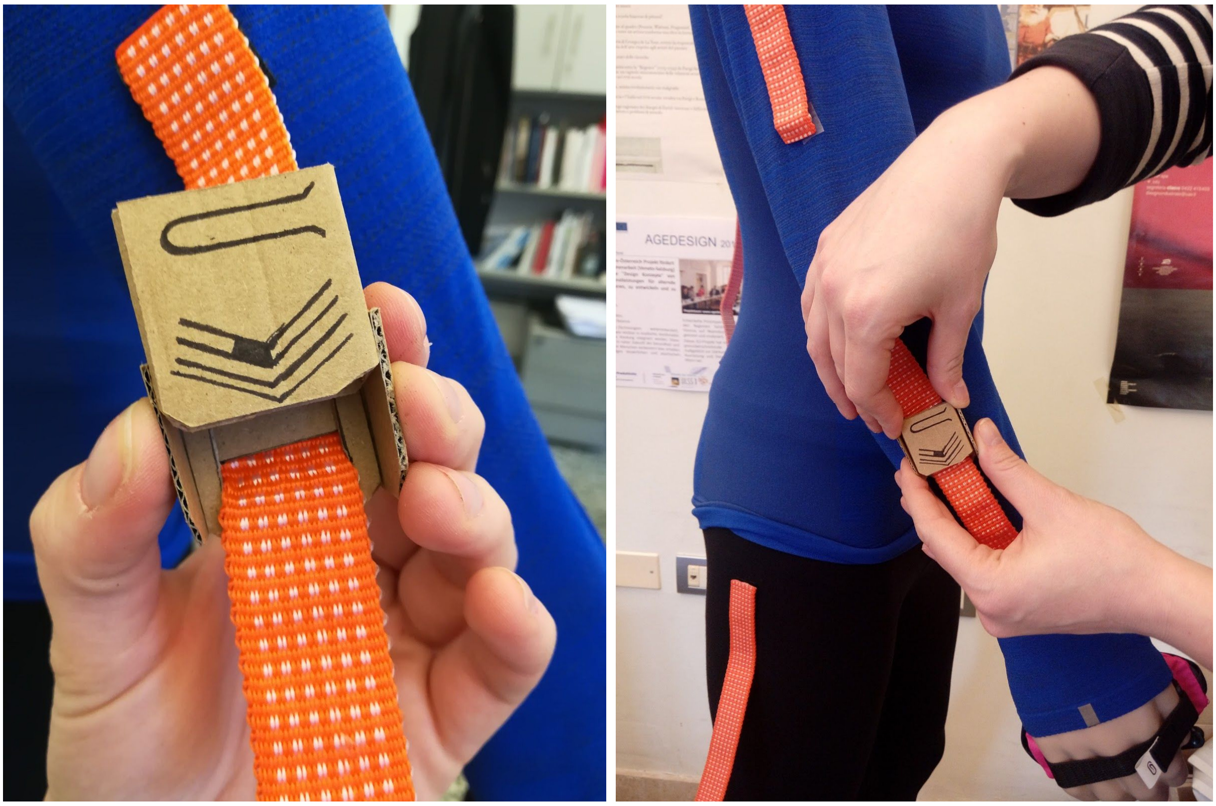


FIG. 34-35-36-37 - Development of the smart suit

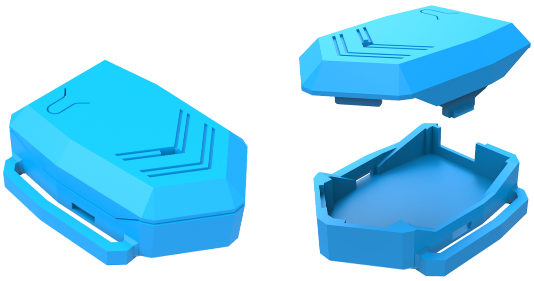


FIG. 38 - Development of IMU case 3D model

FIG. 39 - Development of IMU case 3D printed model

1.5 The final kit

The final kit consists of a set of wearable devices connected through a smartphone app, following the project requirement. To address the system in its totality, the acronym AHAMS has been coined: it is the union of the initials of the aim of the project result itself, "Active and Healthy Ageing Monitoring System ''.
The prototypes simulate the final morphology of the different designed elements and includes working electronics, still foresee the possibility to implement the design after the user review. The project's aim was to obtain functioning devices to access the testing phase, plus the prototypes allows the discussion with investors for further developments.

FIG. 45 - The final kit

The kit allows us to address the three research lines represented by the icons on the app's homepage, that provide the visualization of the data monitored through the suit plus the IMUs, the wristband and the hub.

The motion control kit is composed of a suit and a set of sensors. The suit prototypes have been produced in Male version, sizes M and L, and Female version, sizes S and M. As a result of laboratory testing conducted by the SRFG and PLUS partners, the IMUs were reduced to a number of 6 sensors for each user.

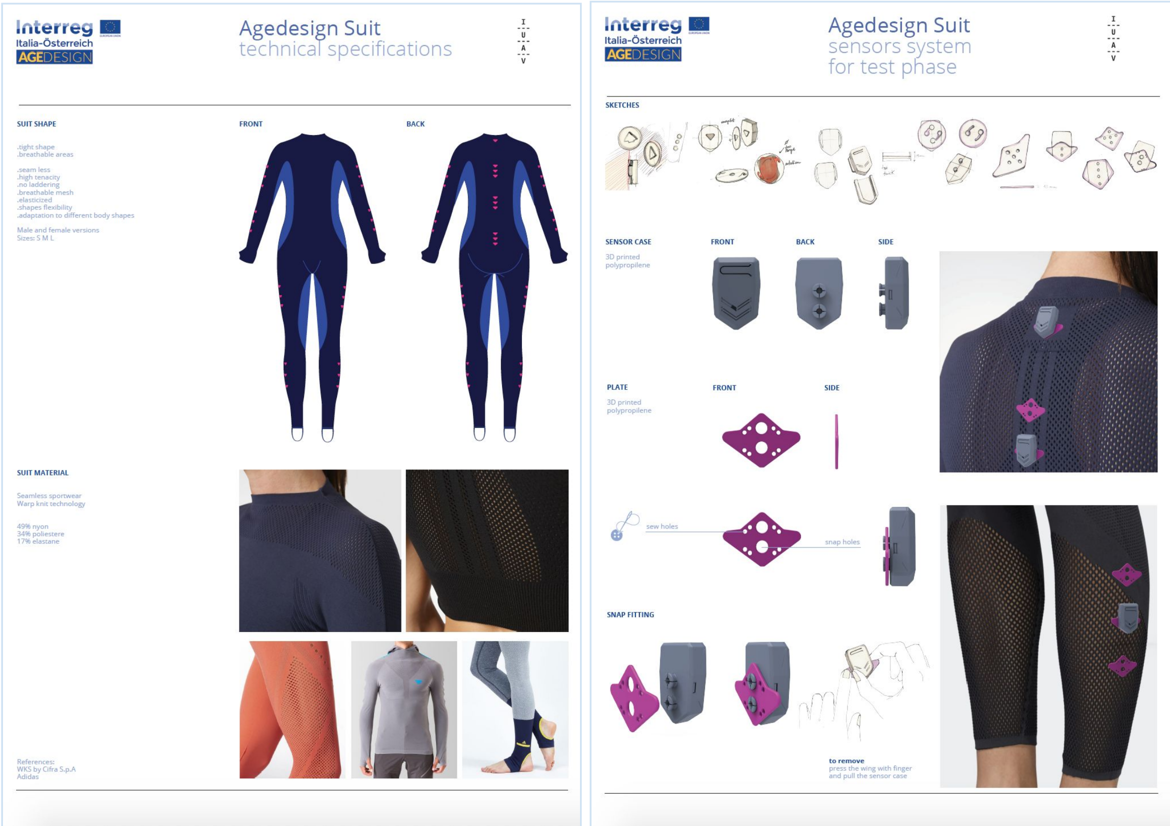


FIG. 46 - First draft of the smart suit (before the reduction in number from 12 to 6)

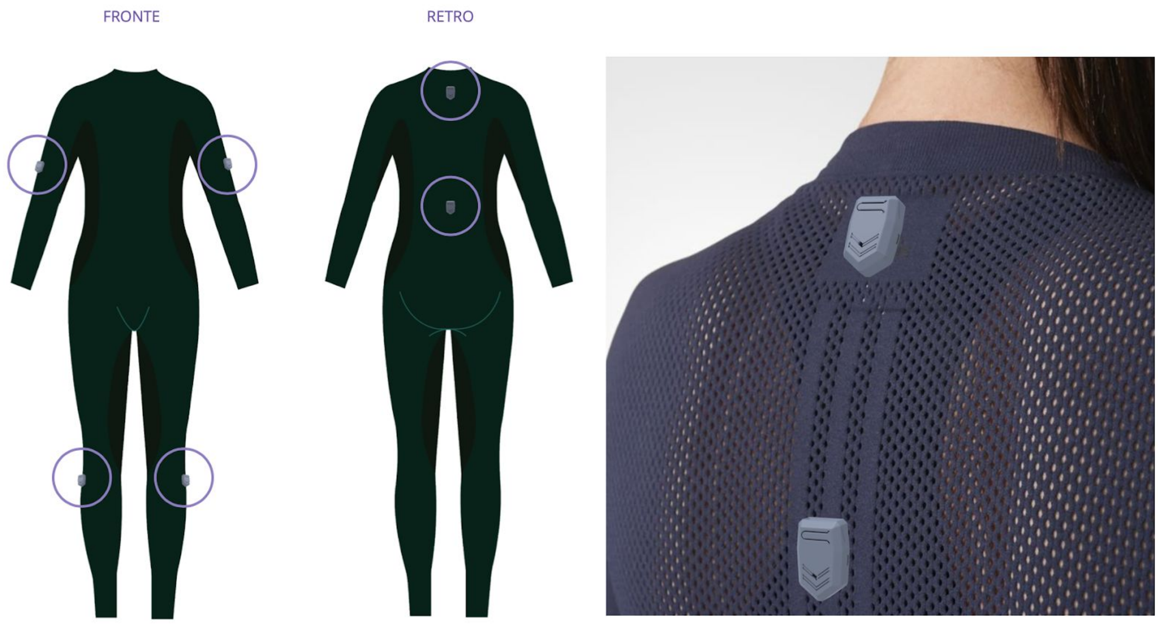


FIG. 47 - The final version of the smart suit

The dehydration and circulation monitoring kit consists of the wristband and the hub.

The wristband is designed to fit a variety of wrist dimensions, following a one-size-fit-all dynamic, therefore the holes distributed on the strap allow the regulation of the adherence of the sensor to the skin. The hub comes in a single size and it is designed to allow further implementations to become a telemonitoring deck.

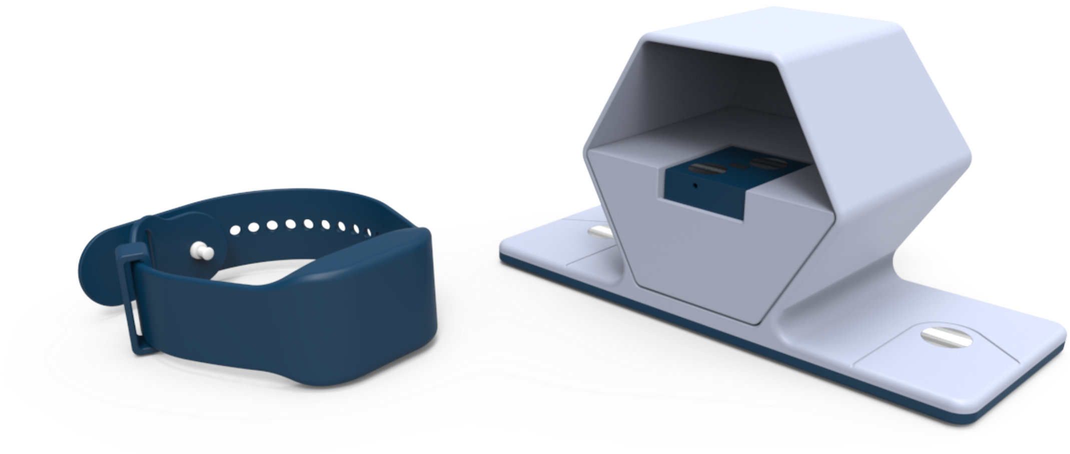


FIG. 48 - The final version of the wristband and hub

APP

I. First version

The smartphone application has been designed to be as simple as possible. Since the project's target consists of users over sixty years old, we seek to provide a user interface and a user experience that are intuitive and linear. Bearing in mind this consideration, we opted to divide the functions into three different topics, related to heart, body water and physical exercise. The three functions are represented into the homepage of the app, the main screen, in form of three buttons: a red heart, a blue drop and a green silhouette to recall the physical activity. To land in the home screen, it is required an initial phase of logging in, in which the user has to register his profile filling the form with personal data - this is required just the first time, when the user downloads the application from GooglePlay (so far, the application runs only into Android devices). The home screen also shows the button for the dropdown menu in which are listed further options, like for instance settings of the sensors.

The figure below (fig. 34) shows the first wireframe of the application, which is the navigation map of the user interface. In the orange box, it is shown the alert screens which occur when the sensors detect cardiac anomalies, low level of body hydration or the bluetooth is not connected.

Entering into the heart section, a graph illustrates the heartbeat trend and the values in BPM in real time. At the bottom of the screen, two buttons are placed: one for further cardiac measurements (those above mentioned) and the other for checking the history of the cardiac measurements where, touching on a single day all the measurements carried out on that day will occur. Touching the former, the app allows the user to choose between pulse oximetry, cardiac frequency and blood pressure (this last one is not included in the research project, thus we have not developed a digital sphygmomanometer, but in order to have a comprehensive framework of the cardiac status of the user, we opted to provide the chance to manually insert the blood pressure values). As regards the pulse oximetry measurement, the user has to touch the "measure" button and place the index finger of the other hand on the sensitive area of the sensor (previously inserted in its hub location) when a red light occurs. The values will be displayed on the smartphone application (fig. 1, p.11). For what concerns the cardiac frequency, the user has to touch the "measure" button and place both index fingers on the silver plates on the outer side of the hub's shell. As for the previous function, the collected values are displayed by the app (fig. 1, p.11).

To check the body hydration level, the user has to enter into the drop section, where an illustration shows the level of body hydration (it is not shown the value but an indicative level). As already mentioned, when the level is too low the user will receive an alert in which it is suggested to drink water as soon as possible. And, as for the heart section, a calendar-shaped button is touchable to check the history of the hydration levels.

Last but not least, the section for physical activity has been developed by SRFG and PLUS, and it is designed to work along with the support of the smart suit. At first, the user can choose whether to check the history of activities or to start a new session. Before selecting the new session, the user has to wear the suit and place the sensors on it. After that, a quick calibration is required, then the application allows the user to choose the exercises and the number of repetition. A video shows how to perform the exercise. When the session is complete, the application displays the results, and specifically the number of the exercises performed correctly and those incorrectly (it is also possible to check what has been done wrongly). As the user progresses, a congratulation message occurs which means that the user is improving in performing the activities and so he is strengthening his musculoskeletal system.

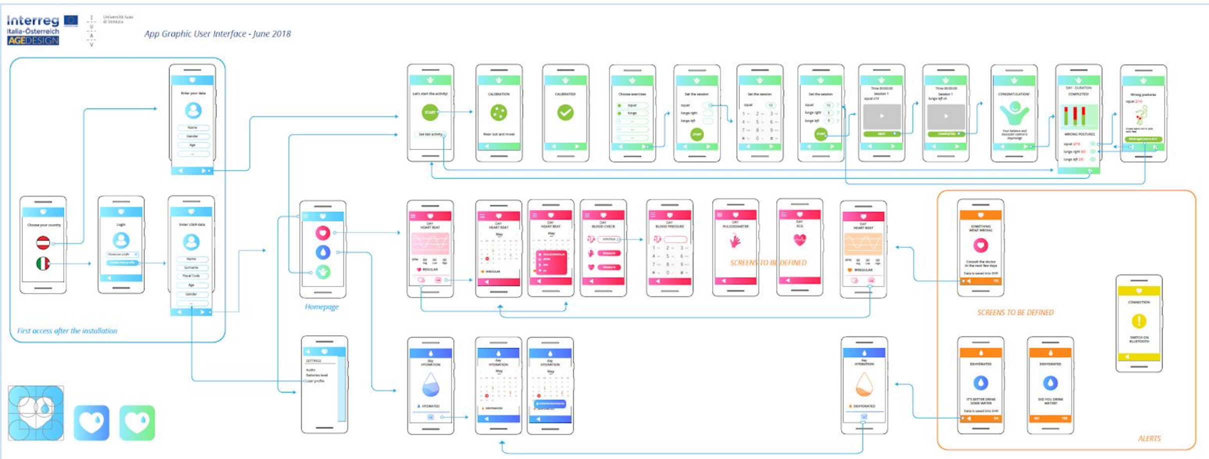


FIG. 40 - APP wireframe

II. Implemented version

FIG. 41 Initial screens of the APP.

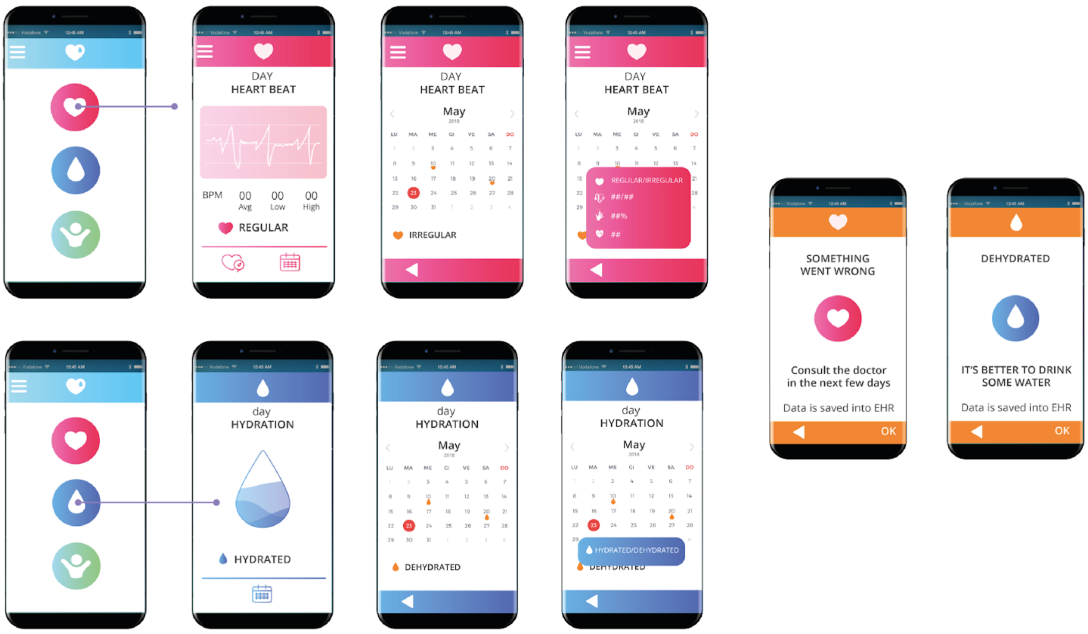


FIG. 42 Final version of the APP (heart and body water sections)

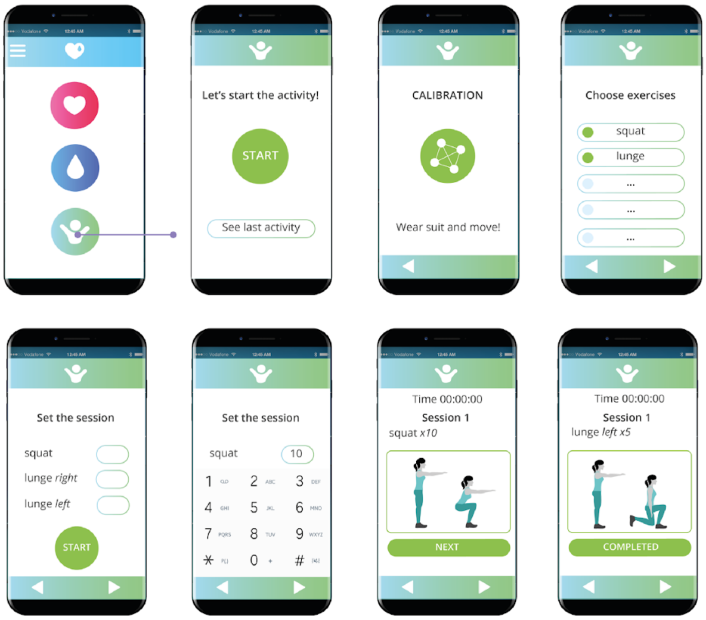


FIG. 43 Final version of the APP (physical activity section)

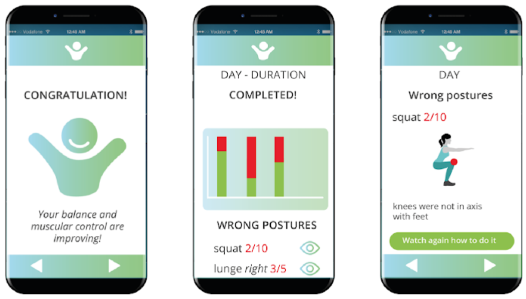


FIG. 44 Results shown by the APP (physical activity section)

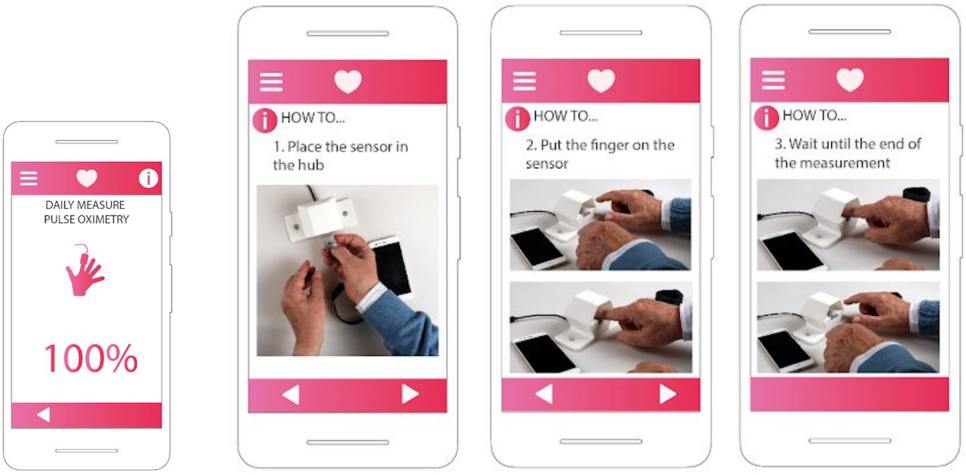


FIG. 49 - Instructions for the use of the pulse oximeter

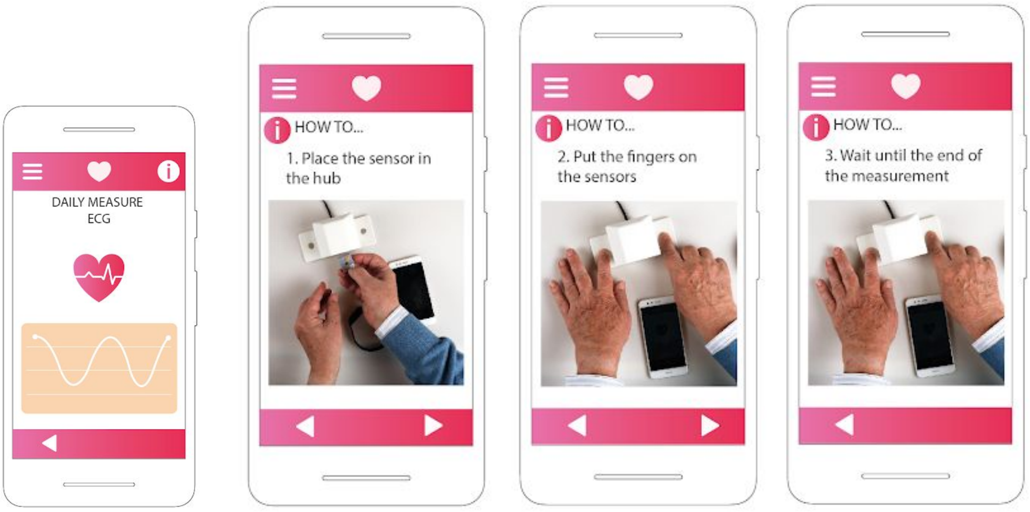


FIG. 50 - Instructions for the use of the cardiac frequency detection

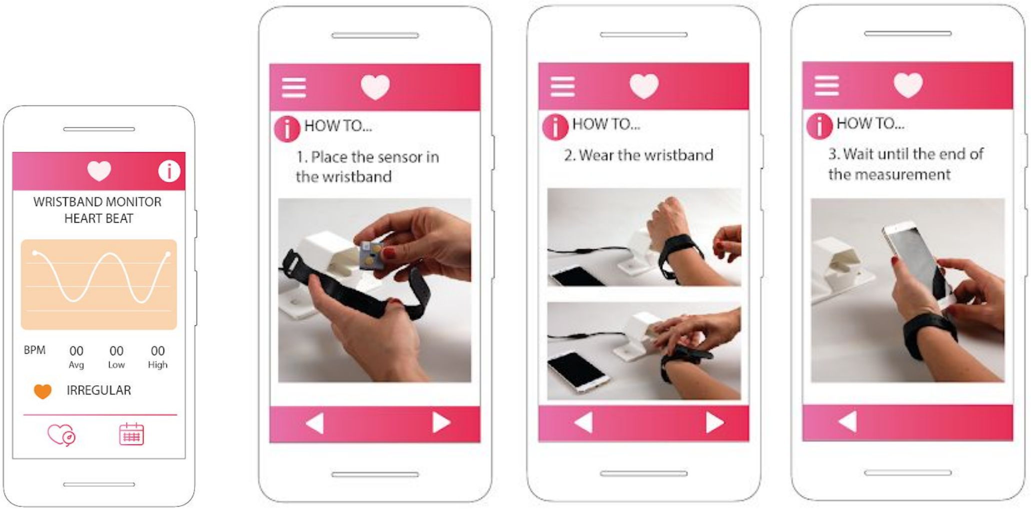


FIG. 51 - Instructions for the use of the bioimpedance sensor and heartbeat detector in wearable mode

The final kit was distributed to the Austrian and Italian partners in order to conduct the user testing, for which the wearability of the devices and the interaction with the system were points of interest.

The usability testing has been designed to include the collection of qualitative data through the User Experience Questionnaire (UEQ) and the Mobile App Rating Scale (MARS).

FIG. 52, 53 - Cardiac frequency monitoring mode

1.6 QUALIFEDESIGN Platform

Qualife design is a web platform focused on the promotion of design projects and in creation of networks between students, young designers and companies. On the platform, designers can publish their projects in search of interested companies or lenders, while companies can look for new projects and instantly propose a collaboration to the designers in order to create new solutions (software or hardware development).

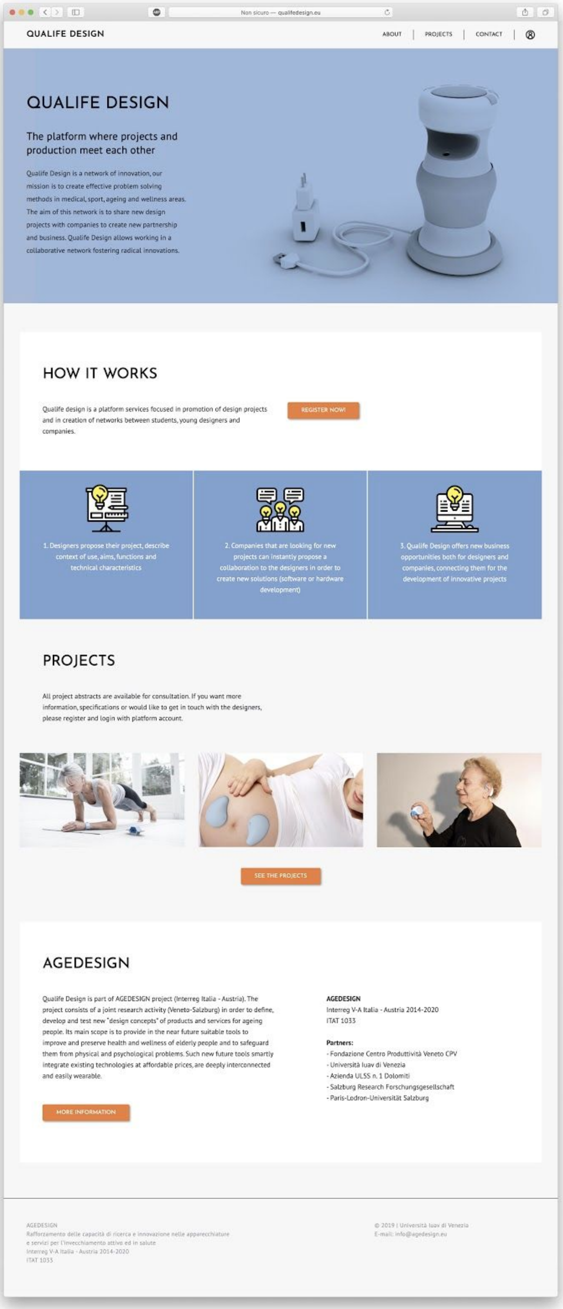


FIG. 54 - Homepage of the QUALIFEDESIGN Platform

All project abstracts are available for consultation.

The Projects section shows the list of all loaded projects, divided into 3 topics: Medical & Diseases, Rescue & Emergency, Sport & Wellness. Projects abstracts can also be filtered by technological components in order to speed up the search.

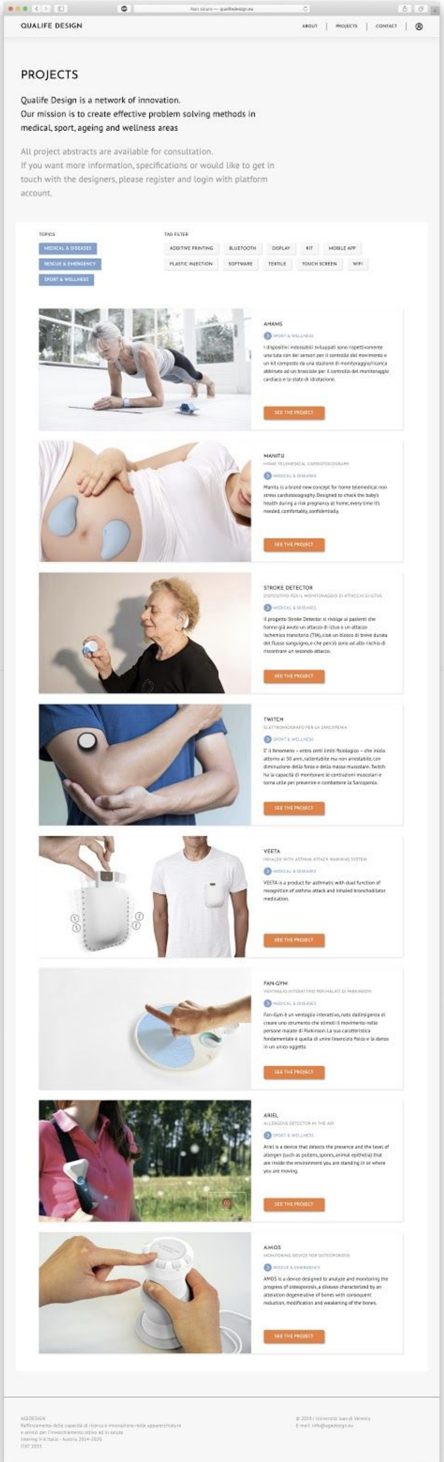


FIG. 55 - Overview of the list of projects

The pages of the individual projects can be consulted in two different ways, public or private (subject to registration). In the public view it's possible to see a photo of the project, a short descriptive text and the name of the designer.

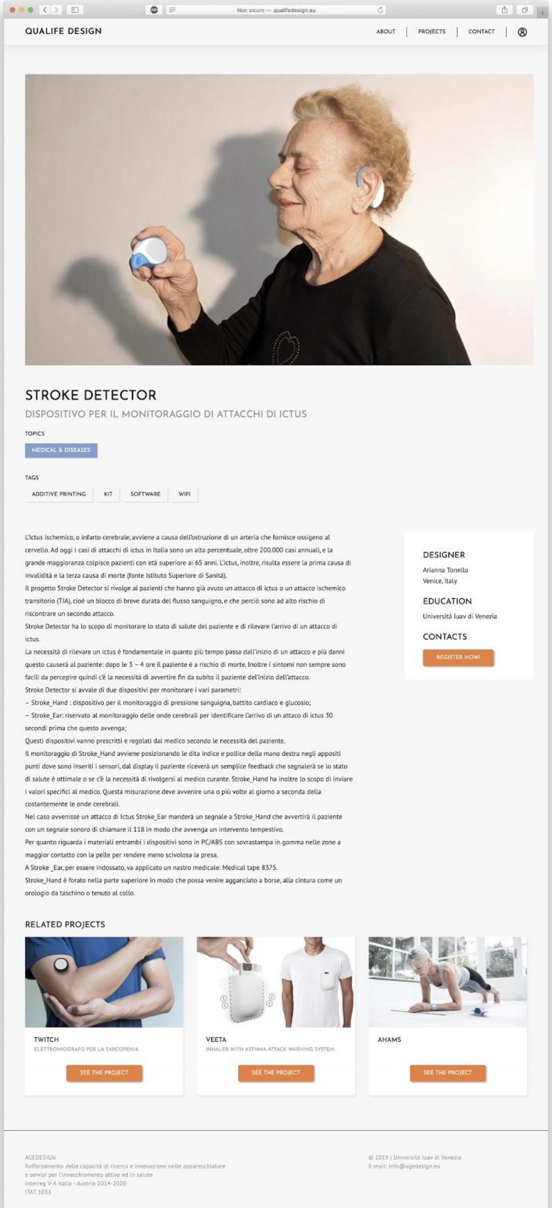


FIG. 56 - Example of a project's page

After registering the user will see much more information related to the individual project: other photographs, videos, technical drawings and the electronic components used. In this section a company can contact the designer to propose a collaboration for the development of the project (hardware or software).

2. Validation protocols and usability

2.1 Exercise monitoring concept - AUSTRIA

As mentioned above, the AgeDesign project aimed to define, develop and test novel "design concepts" of products and services for older people. The technologies are designed to promote the health and quality of life of the elderly and to counteract early physical and mental health problems. The requirements for these product prototypes and services are

- Integrate available technologies
- Moderate price
- Wearable
- Support physical activity indoors and outdoors
- Integrated into clothes
- All sensors connected

The interoperability of the concepts was targeted by providing the services in an AgeDesign app with three distinct service areas:

1. Dehydration monitoring (dehydration)
2. Heart rate monitoring (vascular circulation)
3. Exercise monitoring (muscular control & balance; functional abilities)

The following protocol summarizes the background and characteristics of the exercise monitoring functionality of the AgeDesign app. This area was implemented by Salzburg Research and included the connection to an Inertial Measurement Unit (IMU)-based sensor network attached to the AgeDesign smart suit designed by the partners IUAV in cooperation with Salzburg Research and the University of Salzburg.

In the following sections, details of the smart suit and the exercise monitoring on the app are provided. Furthermore, the validation results concerning the validation of the system and the target group are given. The results in the text are related to the Austrian outcomes. In the end, the validity and market potential of the concept is mentioned and market attractiveness is given. The other two service areas (dehydration and heart rate monitoring) and the corresponding devices are described in additional documents. The Italian assessment of the usability testing is added in the appendix since it was not yet ready for publication while writing this report.

2.1.1. Problem description

Promoting physical activity in older people reduces the risk of common age-related diseases such as diabetes and cardiovascular diseases (Egger & Dixon, 2014; Griebler, Geißler, & Winkler, 2013; Knoops et al., 2004; Park et al., 2009). In the field of Active and Assisted Living (AAL), projects aim at promoting physical activity through technological support. Examples for such projects are fit4AAL (www.fit-mit-ilse.at) or StayFitLonger (www.stayfitlonger.eu). The two projects have in common that they provide, among other functionalities, exercise service areas on a smartphone app in which the users can select their training program. Videos of exercises are shown to the users in order to make them familiar with the correct execution and as a guide through their workout. In fit4AAL, additionally, an exercise monitoring based on a depth camera system is provided. The Orbbec Persee (3D camera system) uses depth imagery and skeletal tracking in order to analyze the human body movements. Hints of movement quality are given in real-time via the app on the Persee that is connected to the TV monitor at home.

The focus on exercises can be observed in many other projects. The technological support ranges from the provision of a training program on a tablet over gesture recognition, counting to exergaming [5–7]. Nevertheless, the specialization on motion quality assessment has not yet entered the application at home. Fit4AAL contributes to this direction but still on a hint-based level (e.g., "Take care of a straight back during this exercise"). However, biomechanical studies are using joint tracking in order to analyze human movement [8]. The technologies range from camera-based to miniaturized sensor-based systems. In particular, inertial measurement units (IMUs) are of interest for the latest research on human movement analytics [7,9]. Nevertheless, the use of IMU-based sensor networks is still challenging.

2.1.2. Exercise monitoring

The exercise monitoring consists of the smart suit with at least four attached IMU sensors and the app service area. The following is a manual overview of the functionalities.

The exercise monitoring service area in the app guides users through the new training experience. Initially, people are instructed to put on the smart suit and attach two IMU sensors on their back and one sensor each to their left and right thighs. After connecting the sensors with the app, calibration starts during which the user has to maintain in a resting, standing position. After this process, the users or coaches will select the exercise and number of repetitions for the current workout. In the prototype version, squats and lunges can be selected (see Fig. 1).

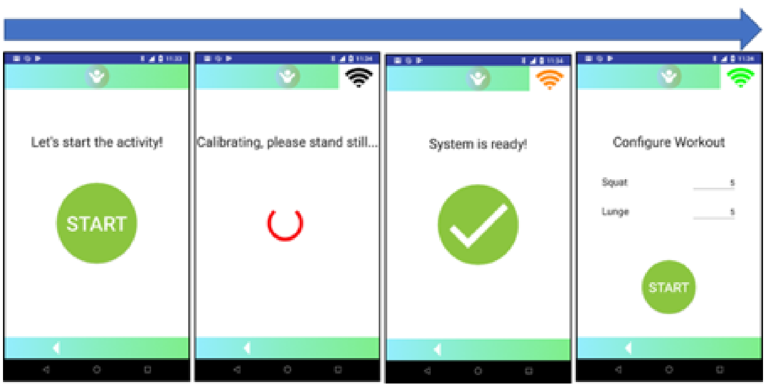


Figure 1 User interface of app for setup and configuration of the workout

Researchers of the University of Salzburg selected the available exercises. The aim was to represent functional fitness exercises for muscular control and balance with various variations in terms of execution and level of physical effort. Hence, an exercise can be both strength and/or balance training. However, the marker position, the sensors used, and the parameters to describe and control the correctness of the movement were the same within a particular exercise. The selected squats and lunges cause a high activation of the large muscle groups of the lower limb.

After this configuration procedure, the workout can be started. Each exercise will be accompanied by a video tutorial with instructions for correct executions. When the users finish an exercise, they confirm it and continue with the next exercise. During the exercises, the sensors on the smart suit send data to the app to monitor the leg axis.

At the end of each workout, the user will be given a summary of exercises performed and the number of correctly or incorrectly performed repetitions. The sensors can be removed, and the suit washed in a washing machine.

The user interface of the training app is shown in Fig. 2. The smart suit and the casings of the IMUs that are to be attached to the suit are depicted in Fig. 3 and Fig. 4. The suit can be worn under regular sportswear or even replace it. Where the IMUs can be attached, there is another texture or rather holes in the regions of interest such as the thigh and the back.

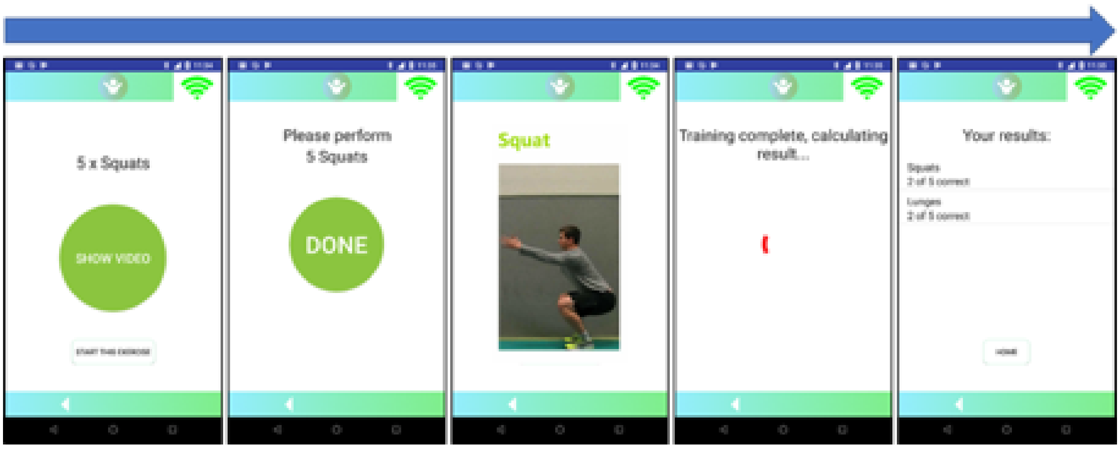


Figure 2 User interface of app for execution of workout and workout results at the end

Figure 3 Sensor suit prototype

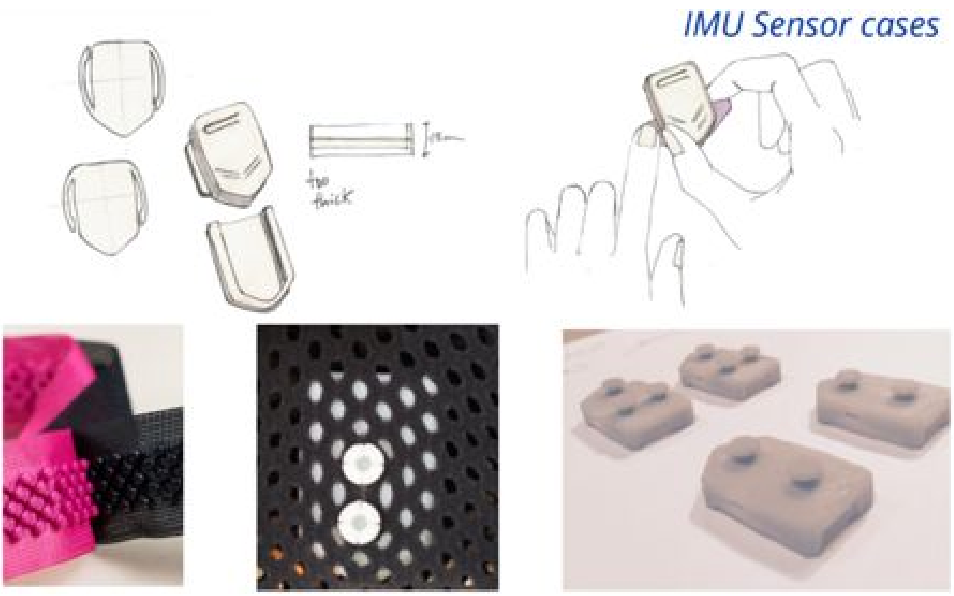


Figure 4 3D printed sensor casings for attachment onto the suit

Validation

This validation study aimed to test the validity of the developed algorithms. Thereby, the technological results of the AgeDesign project included a training monitoring app with two instruction videos and detailed feedback on performance, the sensor network of the suit, and the algorithm for dynamic detection of the leg axis of the knee and back stability.

Before validation, the algorithms were developed and implemented based on lab measurements of three volunteers performing squats and lunges with back and leg axis instabilities. The dynamic knee valgus (i.e., inwards leaning of the knees during execution) was simulated for leg axis instabilities. For simulating back instabilities, the volunteers performed round backs. In the lab tests, the sensors were directly attached to the human bodies via tape in order to guarantee a marker-based collection of data.

The process of data analysis and instability detection is depictured in Fig. 5. After preprocessing, the exercises are segmented in order to have annotated or instead labeled data (e.g., ten repetitions of squats, ten repetitions of lunges). Based on these labels, the repetitions and other relevant features such as range of motion and decision signals for the instability detection are determined. The instability detection focuses on identifying leg axis and back instabilities within the repetitions of exercises.

Based on the available data, an accuracy of 94% in counting or recognizing the repetitions of the exercise and an accuracy of 93% in detecting errors could be achieved. The algorithms are to be evaluated based on further laboratory measurements and a higher number of volunteers. Examples of the results of the instability detection are given in Fig. 6, Fig. 7, Fig. 8 and Fig. 9. Each of the figure pairs represents repetitions of either correct performance or repetitions correctly identified as incorrect. The decision signals of the algorithms are shown in the plots.

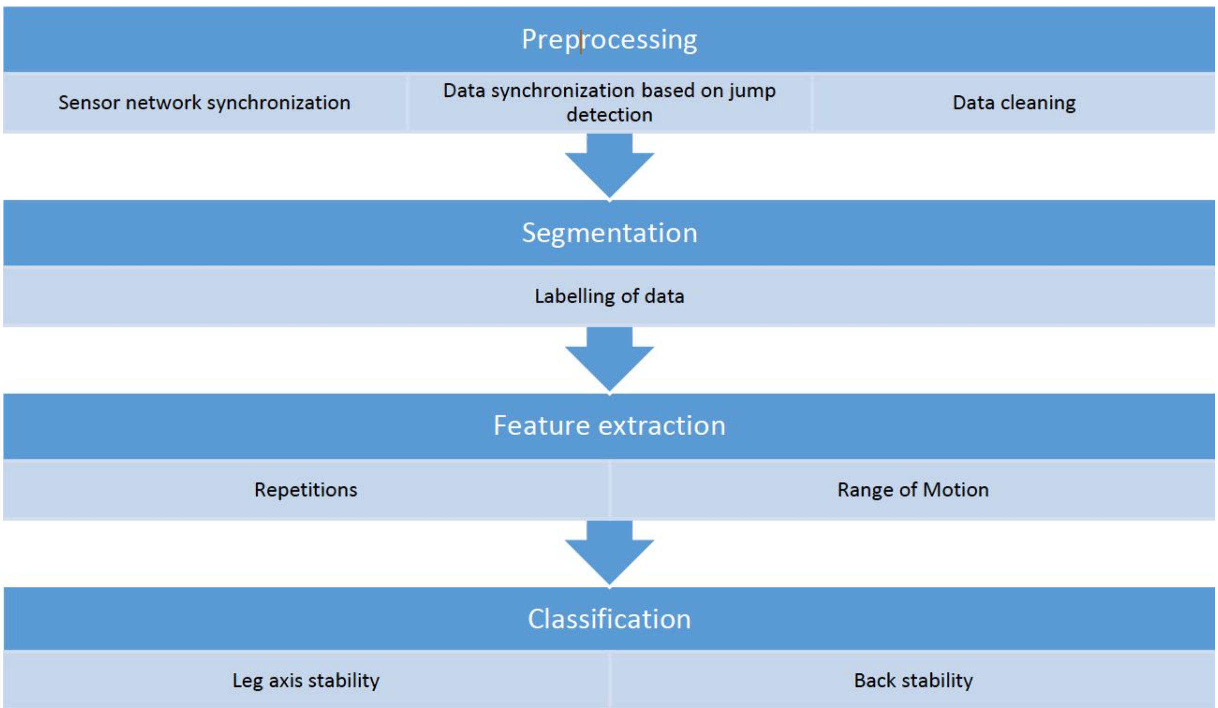


Fig. 5:Data processing and error detection process.

Correct

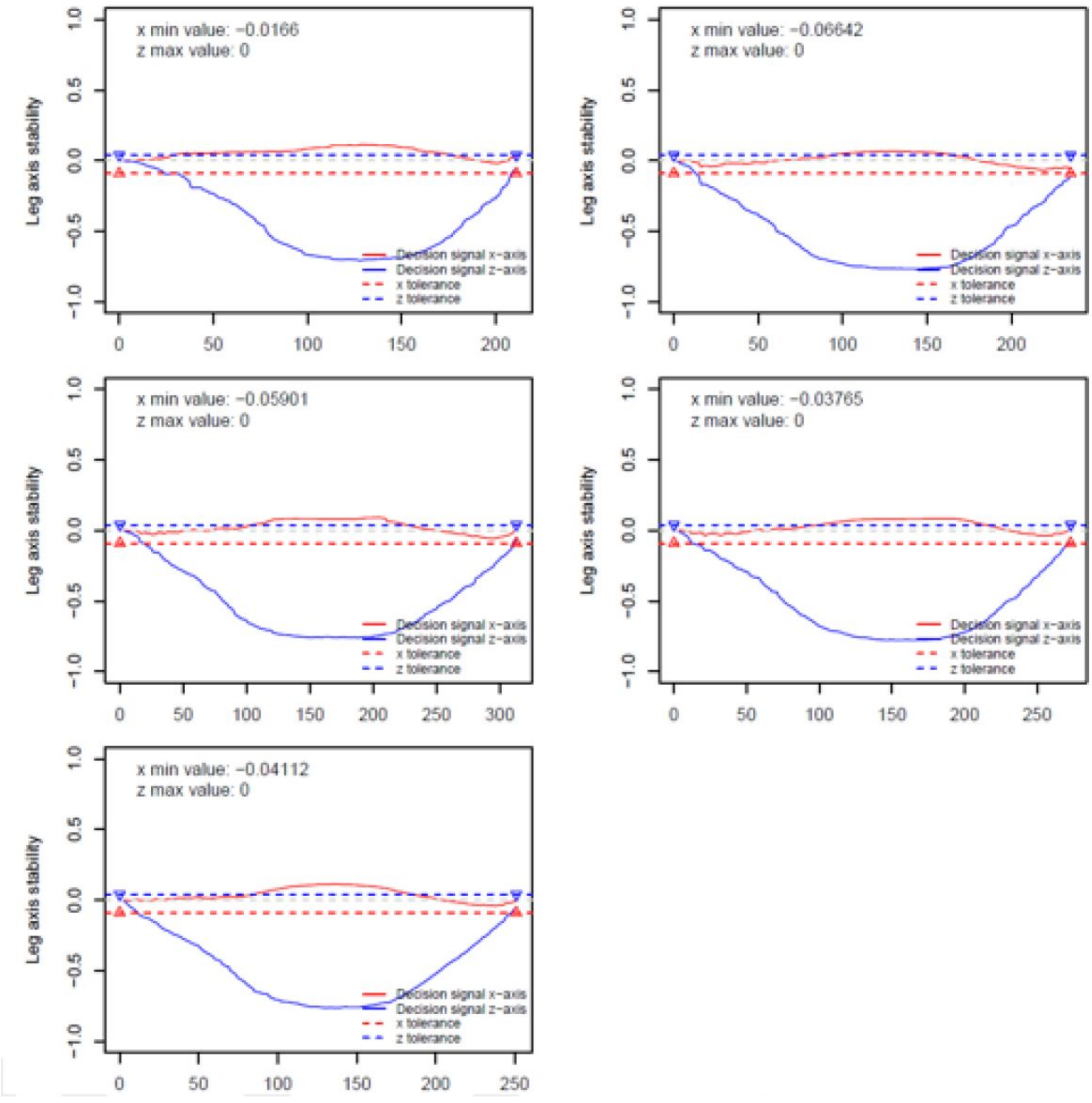


Fig. 6: Example of leg axis instability during squatting; five correct repetitions

Incorrect

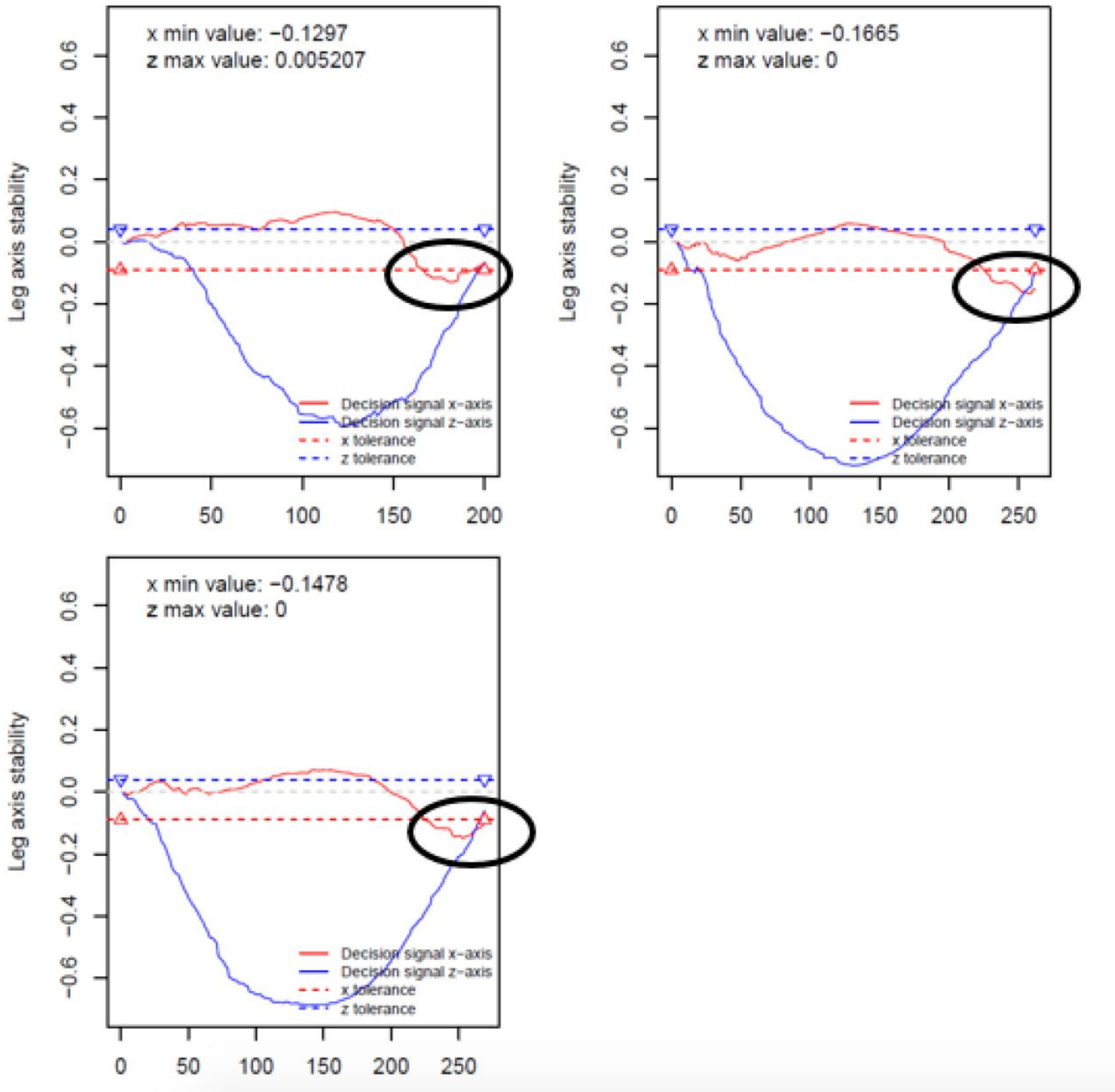


Fig. 7: Example of leg axis instability during squatting; three incorrect repetitions

Correct

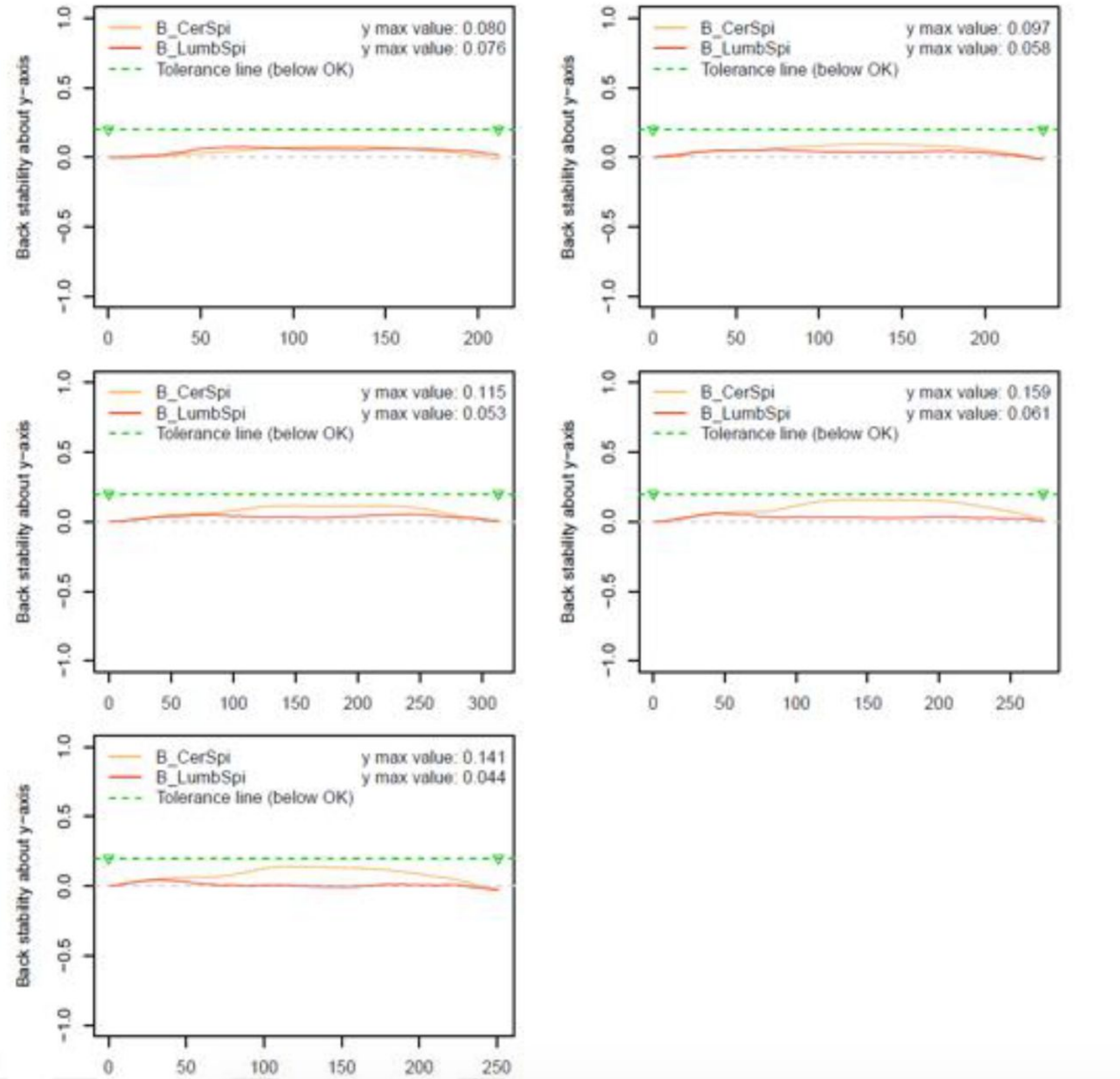


Fig. 8: Example of back instability during squatting; five correct repetitions

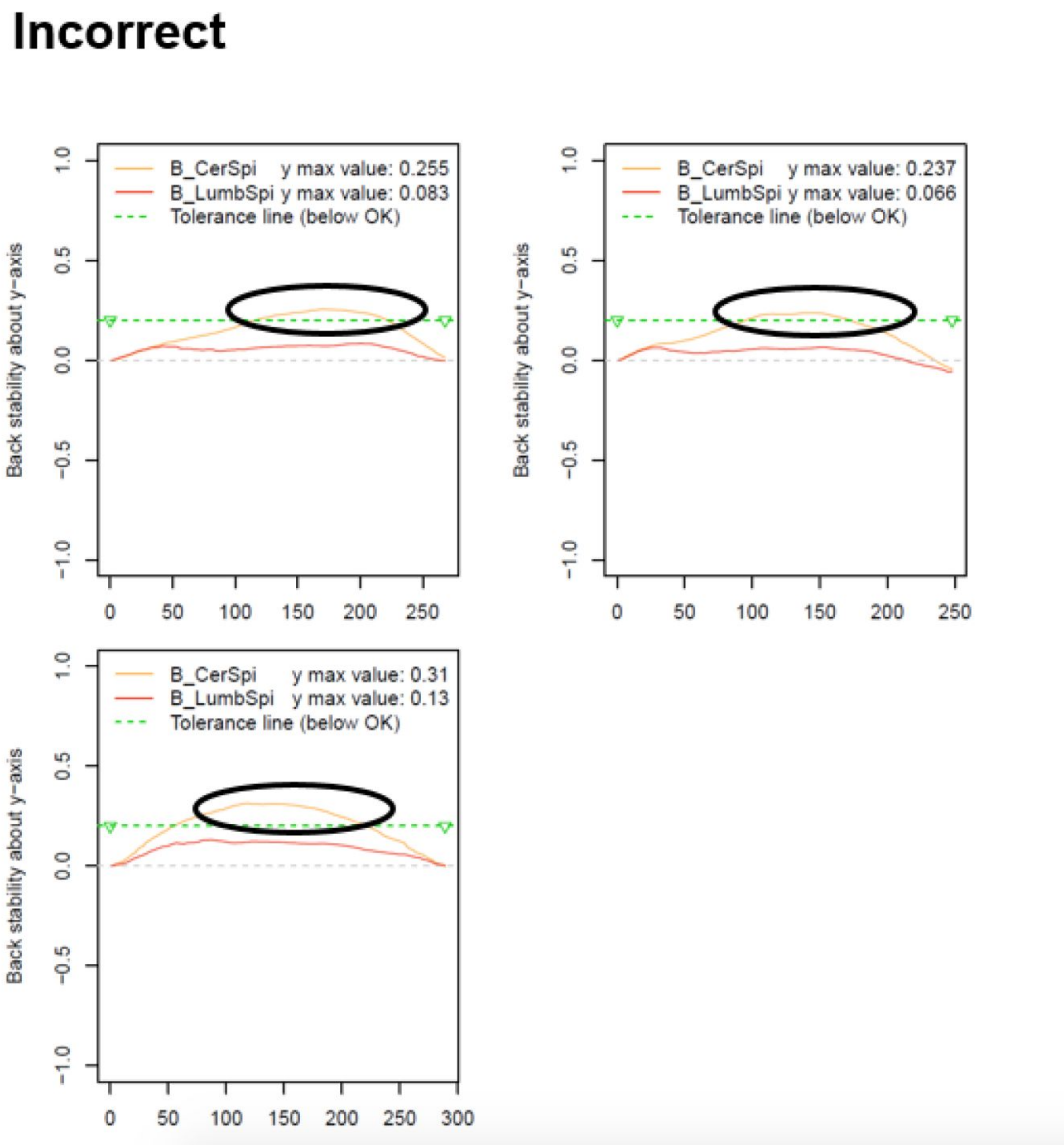


Fig. 9: Example of back instability during squatting; three incorrect repetitions

2.1.4 Subjects for functionality testing

Nine healthy male employees from the University of Salzburg and Salzburg Research (age 31 ± 3yrs) volunteered to participate in the validation measurements. Exclusion criteria were knee or ankle injuries that impeded squat and lunge exercise from various correct and incorrect executions. Self-reports by the participants showed no cardiovascular disorders, medical history of diabetes, respiratory and neuromuscular diseases. All subjects were verbally contacted, and the purposes, benefits, and risks of testing procedures were given prior to obtaining written informed consent. The study was approved by the Ethics Committee of the University of Salzburg (EK-GZ: 23/2018) and was conducted in accordance with the Declaration of Helsinki.

2.1.5 Experimental Design

The validation study consisted of a single laboratory session for motion detection of lunges and squats. Lower and upper body segment kinematics were simultaneously tracked using a gold-standard motion capture system (Oqus 7+, Qualisys AB, Göteborg, Sweden), the Xsens MTw Awinda IMU sensors (Xsens Technologies B.V., Enschede, The Netherlands), and a wireless IMU sensor-framework (MetamotionR; mbient, Inc. San Francisco California) developed in this project. The test order was kept constant across all participants and started with the lunges before squats — five correct executions, followed by three sets of five repetitions with specific, predefined errors. An experienced training therapist evaluated the correct execution of the exercise and if necessary, the entire set was repeated. Participants familiarized themselves with the testing procedures a few days before the validation session.

2.1.6 Data collection and analysis

Validations sessions were preceded by 10 minutes of supervised cycling at 1.5 W kg−1 at a cadence of ~70 rpm on a stationary ergometer (Heinz Kettler GmbH and Co. KG). Kinematic data were obtained from the 3D trajectories of a twelve camera, whole-body marker-based motion capture system with a sampling rate of 250 Hz. One camera of the motion capture system was set up to capture video footage of the sagittal plane of each subject. Reflective markers (diameter: 15 mm) were positioned according to the Cleveland Clinic Marker set (Motion Analysis Corp, Santa Rosa, USA) (Figure 10A). IMUs were mounted to participants'body to calculate the angle between the lumbar and the thoracal spine and hip and knee joint angles, in real-time. IMU positions were half the distance between the fifth lumbar vertebrae (L5) and the twelfth thoracic vertebrae (Th 12), half the distance between the Th12 and the sixth thoracic vertebrae (Th 6) and on the backside (upper third) of the left and right thigh. The Xsens sensors were placed right beneath the IMU positions (see Figure..B). Besides, a video camera (JVC GC – PX100BEU at 50Hz) was placed perpendicular to the frontal plane and all repetitions were rated offline by an experienced sports scientist before retaining for further analysis. The videos contained both frontal and sagittal plane of the subject, and the items rated were "straight back", "knee valgus" and "knee over toes" and "overall". A three-level rating was conducted for all of the items using 1 (completely wrong), 2 (more wrong than correct) and 3 (correct). The number of correct repetitions was solely derived from repetitions labeled with 3 (correct).

All squats and lunges were performed on a force plate (AMTI, Advanced Mechanical Technology Inc., Watertown, Massachusetts, USA; 1000 Hz), and subjects completed a short calibration routine, including for temporal synchronization of kinematics. Once calibrated, orientation estimates of IMUs accelerometer, gyroscope, and magnetometer were transmitted to a smartphone (Samsung Galaxy S5). All data records were synchronized and processed offline and further processed using Visual 3D (Cmotion, Inc) and Matlab R2018b (Mathworks). Dynamic knee valgus detection and the back instability detection were assessed by using confusion matrix metrics. Besides the standard confusion matrix, precision, recall, and F1-score were determined. The repetition counting algorithm was assessed by comparing the actual versus the expected number of repetitions to get an amount of accuracy.

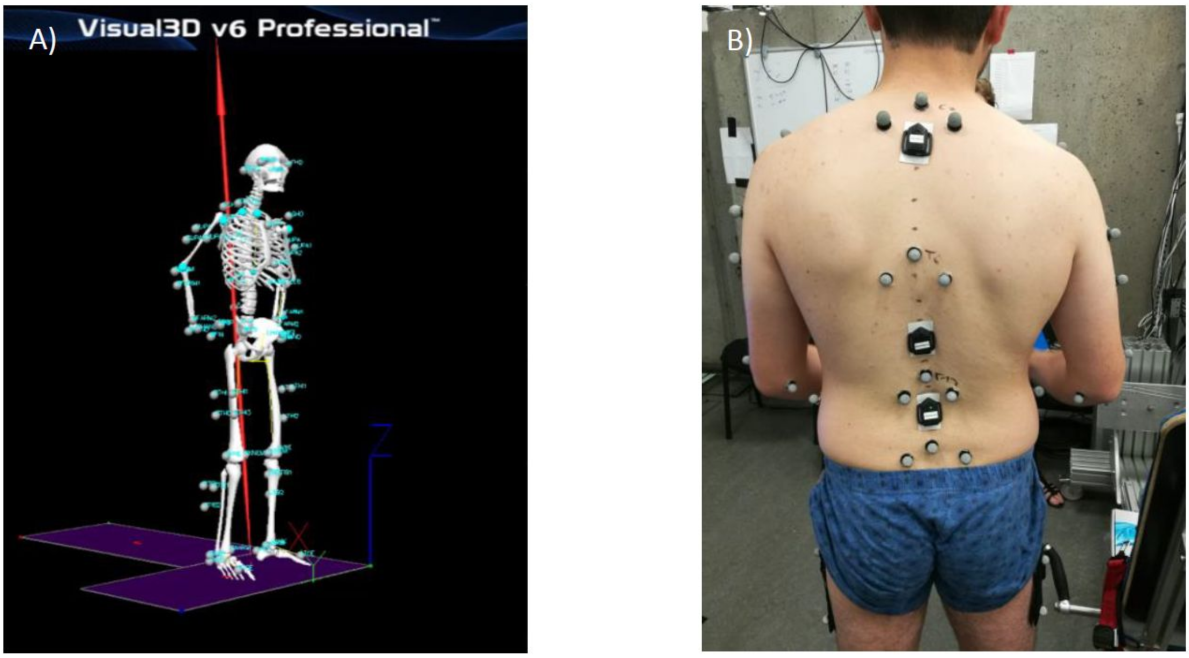


Fig. 10: Illustration of the measurement setup of the gold standard motion capture system (A) and inertial measurement units (B)

The process of data analysis and error detection can be seen in Figure 2. The data blocks are divided into segments using data preprocessing to receive annotated data (e.g. 10x squats, 10x lunges,...). It will then detect the repetitions and eventually create other properties such as joint range of motion and decision signals for error detection. The error detection itself focuses on the leg axis stability and the trunk stability during the exercises.

2.1.7 Results

Data from four subjects had to be excluded following the screening of sensor-network recordings because of connection errors. All other data also included at least some defective signals in at least one of the devices used.

The following table shows the data collection issue by illustrating the availability of datasets for validation. Orange cells indicate data from all four AgeDesign smart suit sensors were available, light grey ones that at least one of the sensors did not collect data or the connection was lost. The dark grey areas indicate that none data was collected.

Movements	#1	#2	#3	#4	#5	#6	#7	#8	#9
30 squats									
10 squats (valgus)									
10 squats (back)									

Although steady further optimization of the sensor network, the immature hardware, and software of the MetaMotionR sensors for sensor networks could not be overcome. The Xsens data collection also failed some times. For comparison, we show in the following table again the data availability from this mature sensor network with the same color-coding:

Movements	#1	#2	#3	#4	#5	#6	#7	#8	#9
30 squats									
10 squats (valgus)									
10 squats (back)									

We used the Xsens data to crop the entire signal of the available MetaMotionR data into exercise segments. A local extreme points search derived the repetition segments with various reliability.

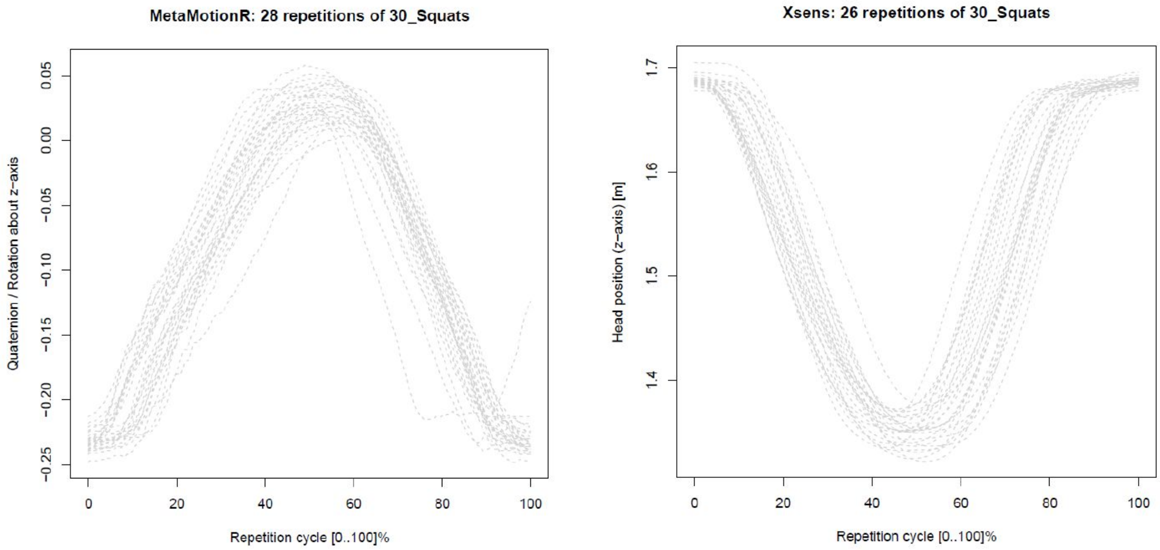


Fig. 11: Sometimes, the MetaMotionR counting algorithms failed to correctly recognize repetitions, at the beginning or end of the repetition. This lack of detection can be prevented in the future by applying more rules to the segmentation method. An example is given in Figure where 11 instead of 10 repetitions were recognized:

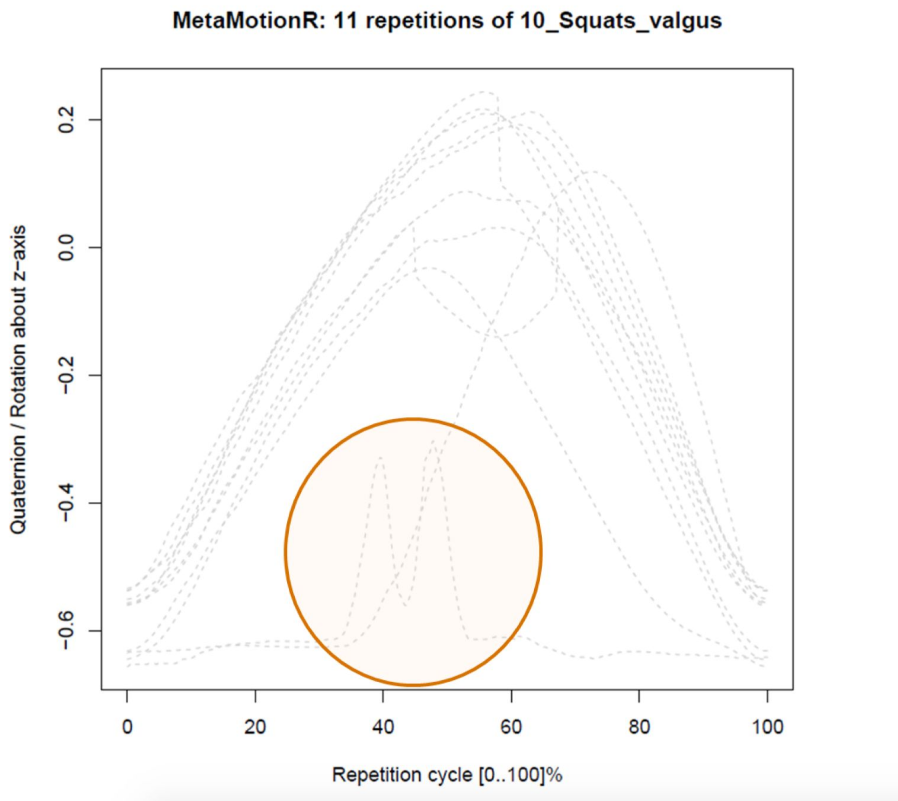


Fig. 12: Incorrect counting with MetaMotionR sensor signal; 11 instead of 10 repetitions were recognized.

Due to incomplete data, a scientifically valid validation could not be performed. This analysis would require more data, in particular, annotated data. A need for changing the used sensor is given. Nevertheless, a comparison of the results will be given for the first subject due to data completeness and the first comparison between Xsens and the AgeDesign smart suit.

For the first subject, the dynamic knee valgus detection was applied to the data coming from the AgeDesign smart suit and the Xsens setup. The result of the AgeDesign smart suit is 28 and of the Xsens setup is 26 from 30 squat repetitions. The AgeDesign smart suit incorrectly detects three as valgus repetitions, where the Xsens setup classifies all counted repetitions as incorrect ones. From ten squat repetitions with nine repetitions performed with dynamic knee valgus, the AgeDesign smart suit counts eight and detects four of them as incorrect repetitions. The Xsens setup wrongly identifies ten correct repetitions. For the aim of a generic quaternion-based dynamic knee valgus, the results are less promising than in the development phase. Further investigation leads to the assumption that for each subject, a blueprint of correct repetitions is necessary in order to derive the thresholds for the detection. Furthermore, dynamic thresholds should be considered for future developments.

An example of a wrongly detected repetition and a correctly detected repetition of the AgeDesign MetaMotionR suit can be found in Figure 14.

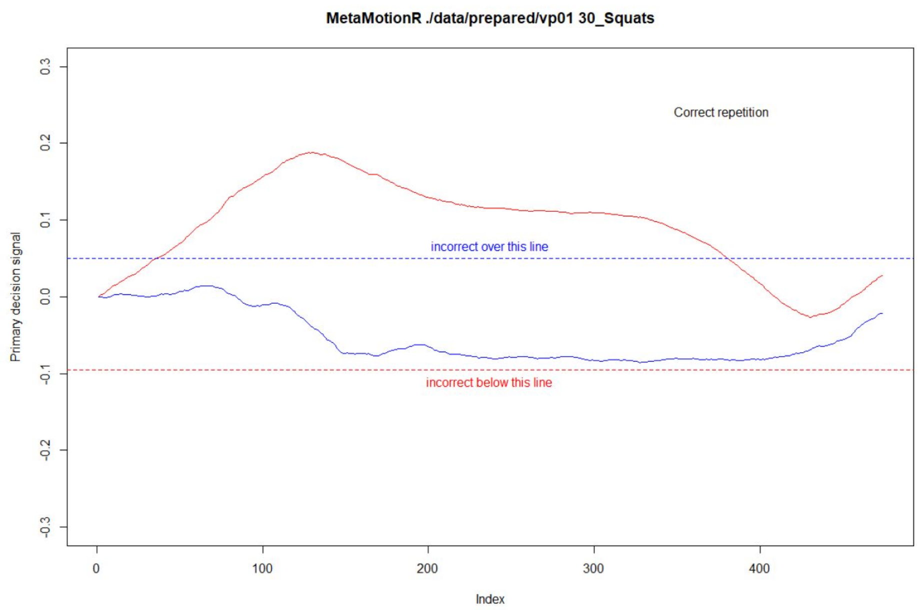


Fig. 13: Correctly detected repetition

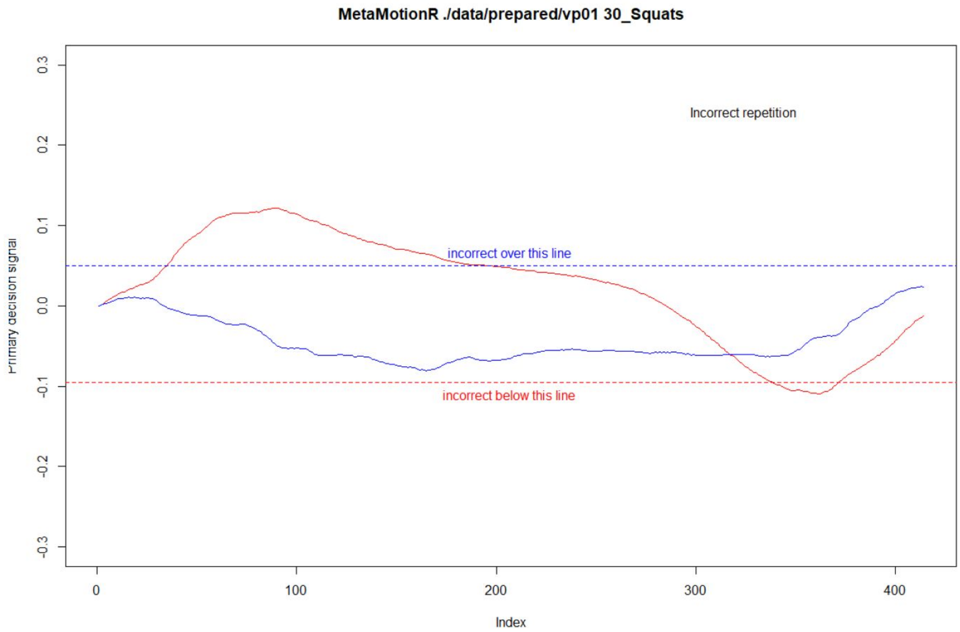


Fig. 14: Wrongly detected incorrect repetition

2.1.8 Discussion

The innovative aspect of the exercise monitoring lies in the vision of performing unsupervised workouts at home or outdoors without the fear of doing something wrong or rather guidance on the movement performance. It is crucial to include personal trainers or similar professionals in the future to guarantee the maintenance of the workout section. Personal coaching is essential in order to create a workout plan. Exercise monitoring apps integrating sensor devices are available on the market when it comes to quantifying movement (e.g. FitStar). However, the qualifying movement is still rare with trackers. Sensors attached to the suit on the points of interest is the first step into qualifying movement, at home, and outdoor.

The technological results of the AgeDesign project include the exercise monitoring app with two exercise videos with detailed information on correct performance, the sensor network on the suit, and the algorithm applied on the collected data to assess dynamic knee valgus and back stability. Validation measurements of the systems used suggest that more established sensors, such as e.g. Xsens MtW, should be used. The application of the given technology causes some connection problems and possibly more data loss. Nevertheless, further development of the detection methods is necessary. Machine learning algorithms could be a solution. However, they require more annotated data.

Last but not least, we seize the opportunity to mention future potentials and limitations of the current prototype:

- **Selection of affordable sensor networks:** The mbientLab MetaMotionR sensors were selected based on Venek et al. [11]. At this point, the evaluation and selection of IMUs, the performance of single IMUs were compared to each other. In the future, it is crucial to select and use validated sensor networks rather than base the selection on a single performance of IMUs. Examples for existing and validated sensor networks providing body model features are Xsens or Notch. By avoiding immature hardware, more analytics due to reliable data quality would have been possible. Much time was lost due to conflicts between specification, documentation and reality.
- **Machine learning as a classifier for correct/incorrect:** Different classification methods could be applied to the collected data, for example, machine learning methods. These require more data, in particular, more labeled data and, thus, a large-scale study, which was not the aim within AgeDesign.
- **Recommendations for future developments and/or co-operations:**
    - Include project partner with competence in hardware development
    - Include business project partner with economic interests (e.g. CIFRA) to ensure distribution
    - Include ecosystem, such as personal trainers to guarantee the maintenance of the exercise monitoring.

2.1.9 Usability

Subjects:

Healthy active seniors, aged between 60-75 years, who do not perform regular exercise, volunteered to participate in this pilot study. That means no history of regular "high loads" activities such as resistance training, ball or racquet sports, and no regular (>1/week) endurance training like e.g. biking, running or hiking for more than 30 minutes. Thus, the international classification (ICF-levels) developed by the World Health Organization (WHO) was used as a unified classification of health and health-related states. Exclusion criteria were apparent cardiovascular diseases, not monitored hypertension, cardiac pacemaker, uncontrolled angina pectoris, stroke, lower extremity injury or operations within a year, acute inflammatory disorders of the musculoskeletal system, hernia, lager-area wounds, epilepsy, multiple sclerosis.

All subjects received a printed tutorial that resulted in a complete training session. Besides, they were supervised by a coach and further instructed as needed. The subjects were first asked to securely fasten the four sensors on the intended places on the suit and then put on the pant and shirt. The supervisor checked the correct sensor positions before the subjects started the app, connected and calibrated the sensors, and did a trial with five squats and five lunges. Before each exercise, the subjects watched a video with instructions for correct execution. With no further instructions, the exercises were performed and evaluated by the app. Afterward, all subjects completed a modified questionnaire (UEQ) containing questions about user experience and usability of the system.

Each question is linked to a specific part of the system and split into different characteristics. Due to this design, the questionnaire provides useful but straightforward insights into the way the users experience the different aspects of the system. Those insights help to improve the early staged system further.

Results Usability Testing

The outcome of the modified usability questionnaire of the seven subjects is reported in Figure 17.

Question 1. How do you feel the shirt worn in static position?								
Uncomfortable	0	1	0	1	1	1	3	Comfortable
Unpleasant	0	0	0	0	1	3	3	Pleasant
Large	0	0	0	0	0	4	3	Tight
Rough	0	0	0	0	0	3	4	Soft
Cold	0	0	0	0	0	0	7	Warm
Heavy	0	0	0	0	3	1	3	Light
Ugly	0	0	0	3	1	1	2	Charming

Question 2. How do you feel the trousers worn in static position?								
Cold	0	1	0	1	2	0	3	Comfortable
Unpleasant	0	0	0	0	1	2	4	Pleasant
Large	0	0	0	0	0	4	3	Tight
Rough	0	0	0	0	0	3	4	Soft
Cold	0	0	0	0	0	0	7	Warm
Heavy	0	0	0	1	1	2	3	Light
Ugly	0	0	0	3	1	1	2	Charming

Question 3. How do you feel the shirt during the exercise?								
Uncomfortable	0	0	0	0	0	3	4	Comfortable
Unpleasant	0	0	0	0	1	3	3	Pleasant
Large	0	0	0	0	1	2	4	Tight
Rough	0	0	0	0	1	2	4	Soft
Cold	0	0	0	0	0	0	7	Warm
Heavy	0	0	0	0	1	3	3	Light
Ugly	0	0	0	2	0	3	2	Charming
Falling	0	0	0	0	1	4	2	Stable

Question 4. How do you feel the trousers during the exercise?								
Uncomfortable	0	0	0	0	0	3	4	Comfortable
Unpleasant	0	0	0	0	1	3	3	Pleasant
Large	0	0	0	0	1	2	4	Tight
Rough	0	0	0	0	1	2	4	Soft
Cold	0	0	0	0	0	0	7	Warm
Heavy	0	0	0	0	1	3	3	Light
Ugly	0	0	0	2	0	3	2	Charming
Falling	0	0	0	0	1	4	2	Stable

Question 5. How would you judge the sensor cases?								
Hard to insert	0	3	2	1	0	1	0	Easy to insert
Hard to place	0	1	1	1	3	0	1	Easy to place
Small	0	0	0	5	1	0	1	Big
Ugly	0	0	0	3	0	1	3	Nice
Hard to recharge	0	0	0	0	1	1	5	Easy to charge
Unstable	0	0	1	1	1	1	3	Stable
Uncomfortable	0	0	0	1	1	1	4	Comfortable

Question 6. How would you evaluate the instruction provided by th								
Unuseful	0	0	0	1	2	0	4	Useful
Incomplete	0	0	0	0	2	2	3	Complete
Not clear	0	0	0	0	1	2	4	Clear
Hard to understand	0	0	0	0	2	1	4	Intuitive
Not accessible	0	1	0	2	1	1	2	Repetitive

Question 7. How would you evaluate the video?								
Unuseful	0	0	0	1	2	0	4	Useful
Incomplete	0	0	0	0	0	2	5	Complete
Not clear	0	0	0	1	0	2	4	Clear
Too long	0	1	1	1	1	1	2	Right length
Boring	0	0	2	0	2	1	2	Involving
Too slow	0	0	0	5	2	0	0	Too fast
Not enough information	0	0	0	5	1	1	0	Too much infor
I didn't emphasize	0	0	0	1	3	1	2	I emphasized a
I liked the music	0	0	0	2	0	2	3	I hated the mu

Question 8. How would you evaluate the feedback from the ap								
Too early	0	0	0	6	0	0	1	Too late
Cannot hear it	0	0	0	6	0	0	1	Too loud
Confusing	0	0	0	0	3	2	2	Clear
Not understandable	0	0	0	0	3	2	2	Understandabl
Distracting	0	0	0	4	2	0	1	Involving

Question 9. How would you evaluate the data collected from the								
Unuseful	0	0	0	0	2	1	4	Useful
Hard to understand	0	0	0	0	3	0	4	Well represent
Not clearly communicated	0	0	0	0	2	1	4	Clearly commu
Hard to access	0	0	0	2	2	0	3	Easy to access
Hard to find	0	0	0	3	1	0	3	Easy to find
Not enough	0	0	0	4	2	0	1	Too many
Made me anxious	0	0	0	3	2	0	2	Made me confi

Fig. 15: Results of usability testing (n=7).

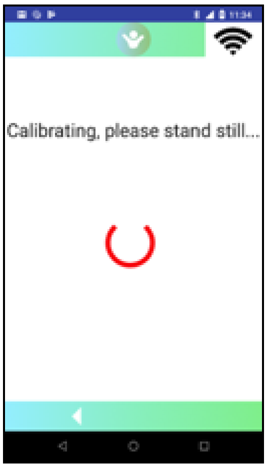
Report created by:
Hans-Peter Wiesinger & Christoph Gressenbauer (PLUS)
Verena Venek & Wolfgang Kremser (SRFG)

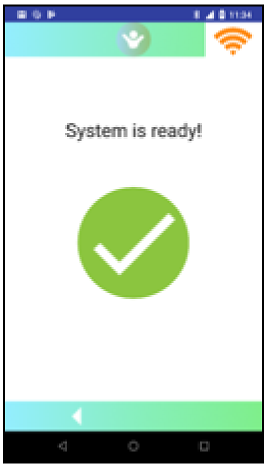
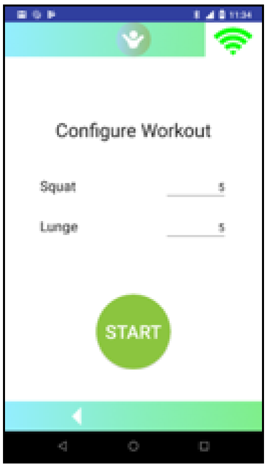
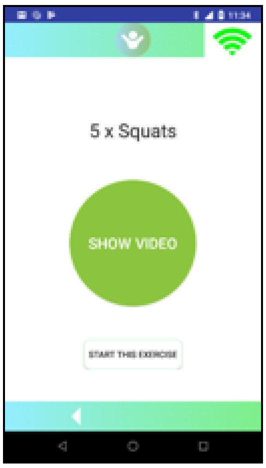
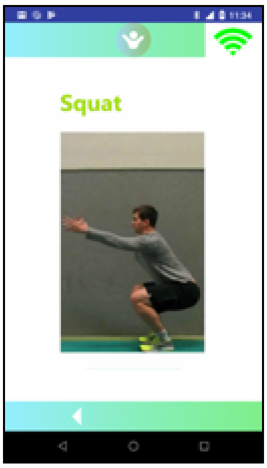
2.1.10 Market Appeal

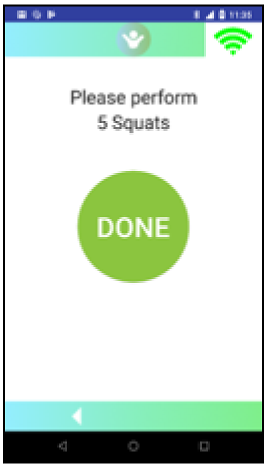
As mentioned before, the concept of the AgeDesign project was presented to numerous companies in the health sector during the Salzburg Sportphysio Therapy Symposium (e.g. SüssMed https://www.suessmed.com/, Storz Medical Alliance https://www.storzmedical-alliance.de/, Synaptos https://synaptos.at/).
There was great interest in motion detection and recording in particular. Some manufacturers considered how to connect the IMU-based sensor technology directly to the screens of fitness equipment instead of an additional app (cell phone/tablet). However, the thoughts also went in the direction of implementation in the health sector about insurance. For example, the amount of the self-contribution for various medical expenses could be linked to the compliance of the given exercise programs. The project would allow with a few extensions an objective collection of such personal data.
Clearly, these are visions. Nevertheless, some exhibitors were amazed at how inexpensive, miniaturized, and equipped with high storage capacities these sensors are. There was enthusiasm for easy integration into clothing without impairing the movement requirements, but still capturing relevant movement properties.
Another appointment was planned with at least one company after the end of the project.

Annex 1 Manual

In the following, the app's user interface of the exercise monitoring is described and the steps to go through the app.

User Interface	Tasks
	• Put on the suit and attach the sensors (or vice versa) • Open app • Click START
	• Stand still and wait until next screen appears

	• Now the system is ready
	• Select number of repetitions for the exercises • Click START
 	• You can watch the video of the exercise, then click SHOW VIDEO • If you want to perform the exercise, click START THE EXERCISE

<table>
<tr>
<td>
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- Confirm execution of exercise by clicking DONE

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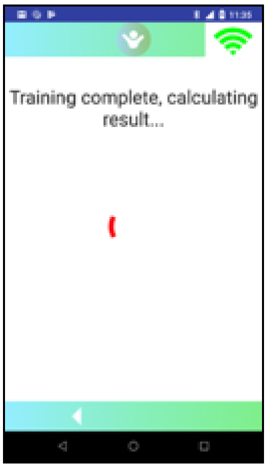
<td>
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- After the workout, the results are calculated
- Wait until next screen appears

</td>
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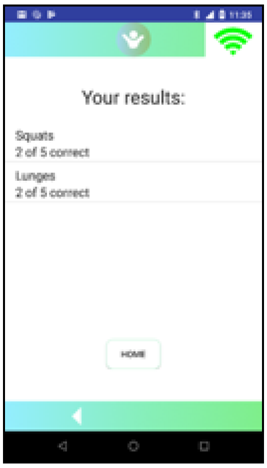
<td>
</td>
<td>

- Watch your results
- Return to start with HOME

</td>
</tr>
</table>

2.1.11 References

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6. Venek, V.; Kremser, W.; Schneider, C. Towards an IMU Evaluation Framework for Human Body Tracking. Stud. Health Technol. Inform. 2018, 248, 156–163.

2.2 Regular heart-beat monitoring concept

2.2.1 Problem description

Heart-beat monitoring is really relevant in order to detect arrhythmia early and prevent severe consequences. Arrhythmia could happen suddenly and in a non-regular mode, for this reason it is important to analyze the heart beats during the whole day. Moreover the heart-beat monitoring can help people who is practicing physical activities to avoid excessive hard-training.

2.2.2 Validation

The device has been tested on a 31-year old healthy man and monitored parameters compared with other devices. The parameters that have been considered were: saturation O2 (%), heat beat frequency (BPM), arrhythmia (yes/no) and graphically. The results has been discussed with a cardiology in order to assess the relevance of the data collected from a medical perspective.

2.2.3 Subjects for functionality testing

The device has been tested on a 31-year old healthy man. No exclusion criteria was applied. All subjects participated voluntarily in this test and were verbally contacted and informed on purpose, benefits and risks of this testing procedure. No risks have been spotted by the medical doctors for subjects.

2.2.4 Data collection and analysis

To ensure greater grip of the sensors to the skin, the bracelet was worn with the upward closure and the sensors on the lower as shown in Figure 16.

Figure 16 Indication of how the device was worn

The test has been performed in a single session wearing the bracelet for ten minutes and comparing data collected with the data collected with other wearable device:

1. Measurement of parameters with APP.
2. Measurement of parameters with other devices.
3. Comparison of the data collected by different device with a cardiologist.

The user has not been subjected to an ECG since the data from APP was not comparable with date collected with medical device.

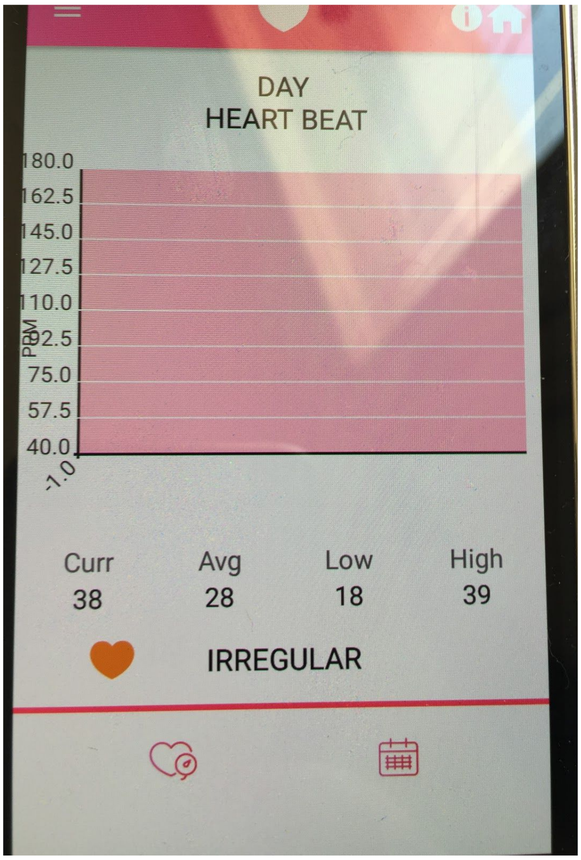
2.2.5 Results

The devices measured the parameter and the results are presented in the APP section.

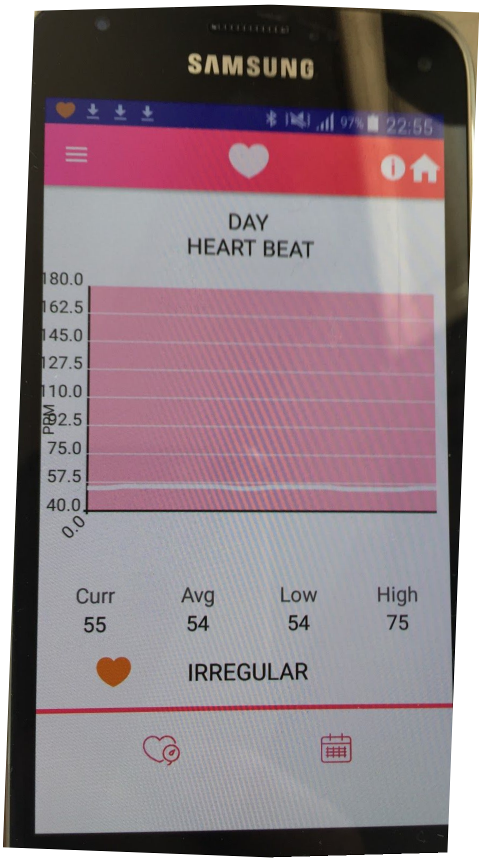
Beat monitoring:

The data collected by the APP is not stable, its change quite rapidly and the data collected is lower compared to the data collect with other device. The Cardiologist said that the value is to low to be considered plausible and moreover is not common to have a suddenly change in the measurement in healthy people with no motivation (the change registered is about 10 BPM).

As shown in figure 17 part A the beats are 38 BPM, the value measured with other devices were 75 BPM, in part B is 55 BPM vs 77 BPM measured using other device. In both session has been detected an irregular situation.



A



B

Fig 17 heat beast measured with APP and device

ECG:

the graphical representation of the beats is not clinically useful. Is not possible seen the graphical representation of the beats and the picks are not comparable. The problem could be related to the bluetooth connection because if the sensor is connected directly to the APP (as done by prof. Prati) the signal is more clean even if has no clinical relevance. Some tolerance has been noted since the APP takes 5 to 10 seconds after the fingers have been put on the sensors to show the measure.

Fig 18 ECG performed by a medical device

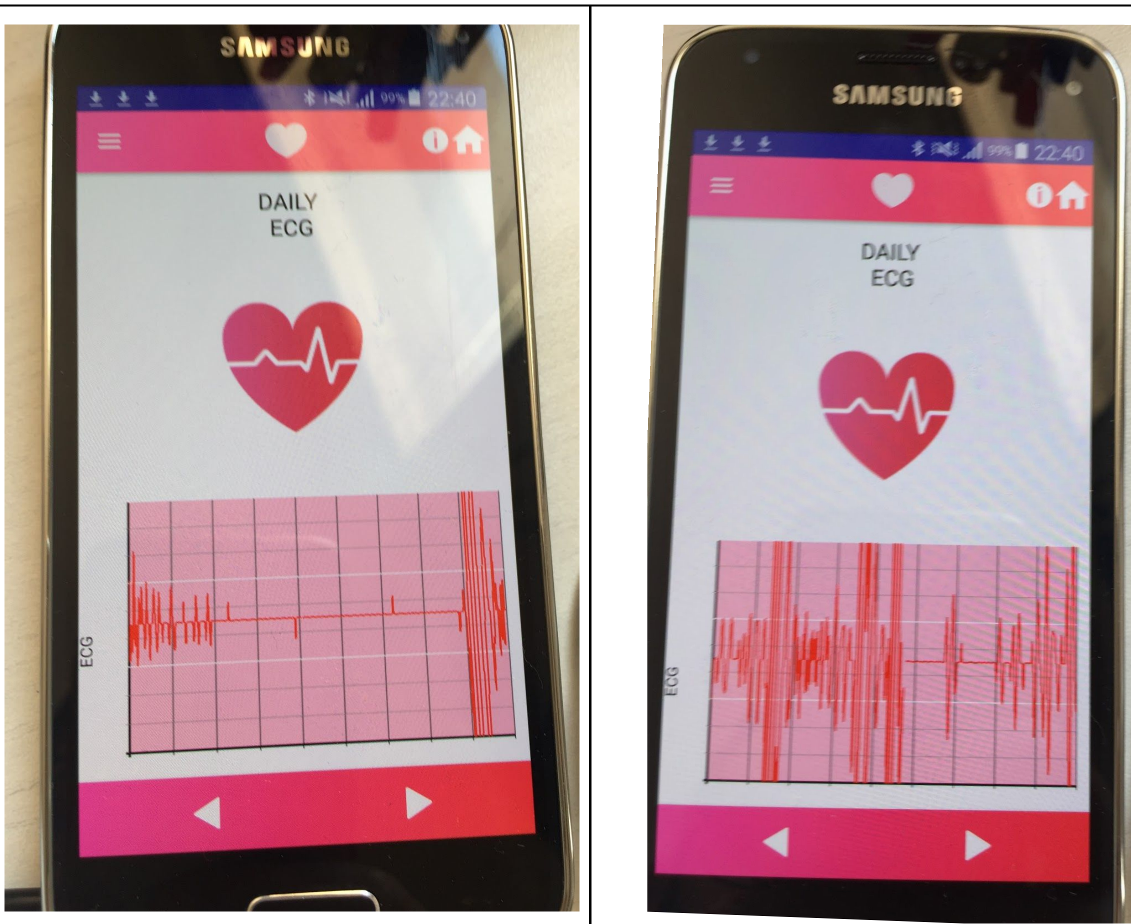


Fig 19 ECG measured with APP and device

Saturation is almost in line with the saturation measured with other devices

2.2.6 Discussion

Data collected with the APP were compared with results collected with other device.

Only results related to the saturation (02) were in line and comparable.

The sensors is not able to detect the heartbeat correctly, The value has been defined as “non reliable” by the cardiologist.

From the ECG side the test has not been fully performed since the graphical representation of the data collected by the sensor is not comparable with standard ECG graph as shown in Fig 19.

2.2.7 Usability

Twelve healthy people aged 55+ has been involved in the usability tests, 6 male and 6 female. More details on people involved in test phase is available at section 2.4.

People tested all the devices and the APP in the same session at the end of the testing phase the User Experience Questionnaire has been submitted to subjects who tested the concepts.

The outcome of the questionnaire is reported below:

Question 1. How would you judge the wristband?		
Uncomfortable	0 0 1 0 2 1 8	Comfortable
Unpleasant	0 0 0 1 2 1 8	Pleasant
Large	0 0 0 11 0 0 1	Tight
Rough	0 0 0 1 6 1 4	Soft
Cold	0 0 0 5 6 1 0	Warm
Heavy	0 0 0 1 1 3 7	Light
Ugly	0 1 2 2 1 2 4	Charming
Embarassing	0 1 0 6 2 2 1	Stilish
Small	0 0 1 9 1 1	Big
Question 2. How would you judge the deck?		
Small	0 0 1 8 2 0 1 0	Big
Ugly	0 1 0 6 3 2 0	Nice
Not intuitive	1 0 0 0 0 0 11	Intuitive

Complex	0 0 0 0 0 1 11	Simple
Unuseful	0 0 0 1 0 1 10	Useful
Hard to clean	0 0 0 0 0 0 12	Easy to clean
Question 3. How do you feel the wristband during the day?		
Uncomfortable	0 0 0 1 1 3 7	Comfortable
Unpleasant	0 0 0 2 1 6 3	Pleasant
Large	0 0 0 11 1 0 0	Tight
Rough	0 0 0 2 5 4 1	Soft
Cold	0 0 0 3 6 2 1	Warm
Heavy	0 0 0 0 2 3 7	Light
Ugly	0 0 1 6 1 1 3	Charming
Falling	0 0 0 1 1 2 8	Stable
Question 4. How do you feel about the insertion/removal of the case to/from the devices?		
Uncomfortable	0 0 0 1 0 3 8	Comfortable
Unpleasant	0 0 0 5 1 4 2	Pleasant
Unuseful	0 0 1 3 3 2 3	Useful
Not intuitive	1 0 0 0 0 1 10	Intuitive

Forgetful	0 0 0 1 1 3 7	Easy to remember
Too short	0 1 1 10 0 0 0	Too long
Hard	0 0 0 1 0 0 11	Easy
Question 5. How would you judge the sensor case?		
Hard to insert	0 0 0 1 0 1 10	Easy to insert
Easy to lose	2 1 1 2 1 1 4	Easy to remember
Hard to place	0 0 0 2 0 2 8	Easy to place
Small	1 1 0 8 0 0 2	Big
Ugly	0 0 2 5 0 1 4	Nice
Hard to recharge	0 0 0 0 0 1 11	Easy to charge
Unstable	0 0 0 1 0 2 9	Stable
Uncomfortable	0 0 0 4 0 2 6	Comfortable
Question 6. How would you evaluate the instruction provided by the app?		
Unuseful	0 0 0 1 1 4 6	Useful
Incomplete	1 0 2 4 0 1 4	Complete
Not clear	0 0 2 2 2 2 4	Clear
Hard to understand	0 0 0 1 3 3 5	Intuitive

Not accessible	0 1 2 7 0 1 1	Repetitive
Question 7. How would you evaluate the alert?		
Noisy	0 0 1 0 1 3 7	Soft
Made me anxious	5 2 0 3 1 0 1	Made me confident
Unuseful	0 0 0 2 0 5 5	Useful
Question 8. How would you evaluate the feedback from the app?		
Too early	0 0 2 7 1 0 2	Too late
Cannot hear it	0 0 4 5 1 0 2	Too loud
Confusing	0 0 4 4 0 1 3	Clear
Not understandable	0 0 2 5 1 1 3	Understandable
Distracting	0 0 2 7 0 0 3	Involving
Question 9. How would you evaluate the data collected from the app?		
Unuseful	0 0 0 0 0 3 9	Useful
Hard to understand	0 0 0 0 0 1 11	Well represented
Not clearly communicated	0 1 0 0 0 4 7	Clearly communicated
Hard to access	0 0 0 0 1 5 6	Easy to access
Hard to find	0 0 0 0 0 4 8	Easy to find

Not enough	0 1 0 5 4 2 0	Too many
Made me anxious	0 0 3 7 1 0 1	Made me confident

2.2.8 References

User Experience Questionnaire (UEQ - https://www.ueq-online.org/).

2.3 Dehydration checking concept

2.3.1 Problem description

Elderly lose the sense of thirst and forget to drink water, for this reason they easily get dehydrated. Therefore, dehydration is a physiological parameter to be measured every day and not only in a workout session. Moreover elderly people who suffer of heart disease need to monitored the hydration status in order to avoid water retention that may cause several trouble.

Monitor the dehydration from a clinic prospective is not simple because the impact of a lot of factors may change the reliability of the measures.

In order to monitor the dehydration condition in a noninvasive way it is necessary to focus on these parameters: skin humidity, body temperature, mucous membrane humidity, weight and intake liquids. The measurement/monitor of one or more of these parameters allows a preliminary evaluation of the dehydration condition. In medical sector dehydration is monitored via medical device or by medical doctor visiting the subject in case of severe dehydration.

2.3.2 Validation

The validation phase aimed to test and validate the sensors, through a comparison between device measurements and medical device measurements. The sensors tested by ULSS 1 measured the body resistance expressed in Ohm Medical devices instead measured resistance (Ohm/m) and reactance (Ohm/m).

The test procedure has been the following:

- measurement with medical device before starting dialysis treatment
- monitoring with the wearable device
- measurement with medical device at the end of the dialysis treatment

Hardware and software were provided by Relab.

Lab tests tried to investigate the correlation between the resistance measured by the sensor and the dehydration status.

2.3.3 Subjects for functionality testing

Three people tested the sensors, one 31-year old healthy man and 2 men in dialysis treatment. No exclusion criteria was applied. All subjects participated voluntarily in this test and were verbally contacted and informed on purpose, benefits and risks of this testing procedure. No risks have been spotted by the medical doctors for subjects. The test involved people in active dialysis treatment in order to highlight the hydration status of the subjects that usually lose kilos of liquids in few hours.

2.3.4 Data collection and analysis

To ensure greater grip of the sensors to the skin, the bracelet was worn with the upward closure and the sensors on the lower as shown in Figure 1

Figure 1 Indication of how the device was worn

The tests were performed on people in active dialysis treatment as follow:

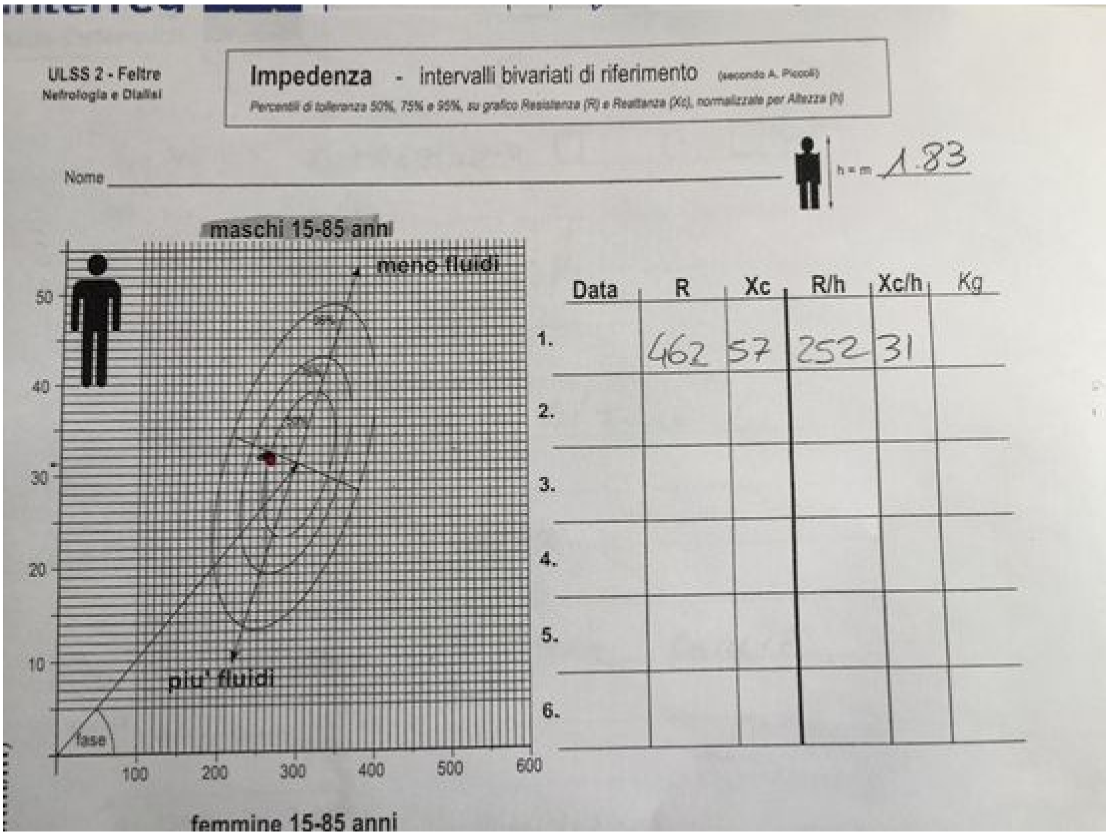
4. Hydration status detection with medical device supplied UOC nephrology and dialysis of Feltre pre dialysis
5. Starting dehydration status monitoring with the bracelet
6. Hydration status detection with medical device supplied UOC nephrology and dialysis of Feltre post dialysis (some hours later)

For user 1 the test procedure consisted only in step 1 and 2.

2.3.5 Results

User 1- 31 year-old healthy man

Resistance(ohm)	Reactance (ohm)	R/h (ohm/m)	Xc/h (ohm/m)
456	57	252	31



The result of the bracelet oscillates between 1,085 - 1,071 ohm.The result remains stable over time.

User 2 65 year-old man in active dialysis treatment

	Resistance (ohm)	Reattanza (ohm)	R/h (ohm/m)	Xc/h (ohm/m)	Peso (kg)
Pre dialysis	449	39	272	24	74,8
Post dialysis	520	51	315	31	71,7

The subject lost 3.1 kg in about 4 and a half hours.

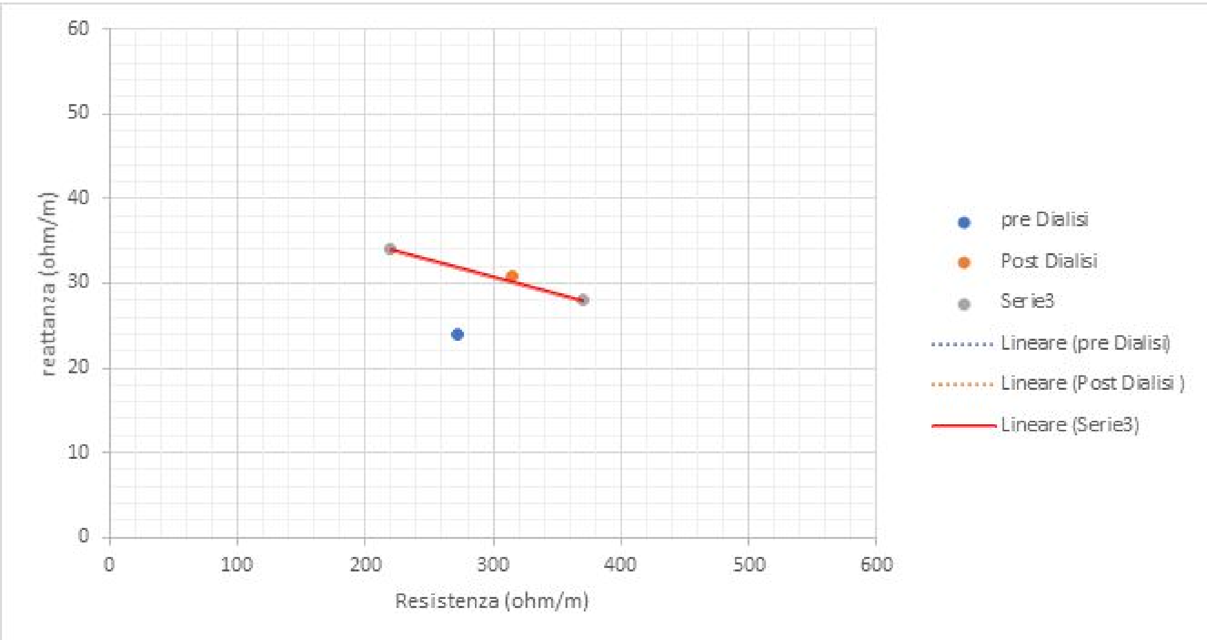


Figure x Detail Measurements Taken Pre and Post Dialysis.

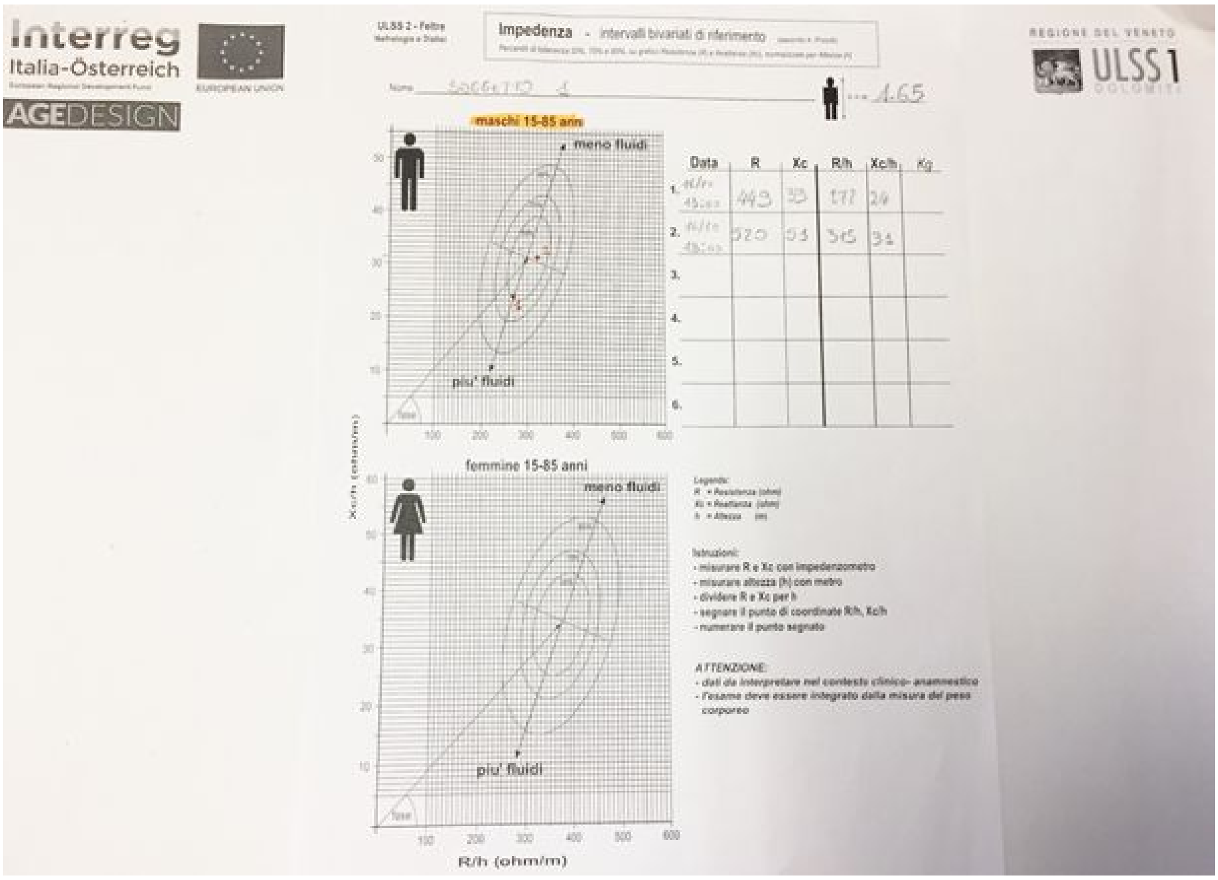


Figure 4 Graphical representation of the detections made with the pre and post dialysis medical device.

After the measurement of the impedance with the medical device the subject wore the bracelet and resistance was detected at three different times as shown below:

STEP 1

The monitoring of the surveys was done at intervals from 13:04 to 13:08. Figure 5 Step 1 shows the findings. It should be noted that by pressing the bracelet on the wrist the detected resistance drops rapidly (around 13:04:48). Detection is unstable as values decrease more or less rapidly throughout the detection phase

STEP 2

The monitoring of the surveys was done at intervals at 14:51 and 17:49 at 17:54 The value is stable and oscillates by some ohm. The readings taken at 17:49 coincide with the end of dialysis

STEP 3

Impedance was measured with medical device. The bracelet is removed and put back to the subject, this operation strongly impacts on the detection of the data since the only operation involves (at the green bar) the increase of about 4,000 ohm. For the following minutes, the detected resistance gradually declines.

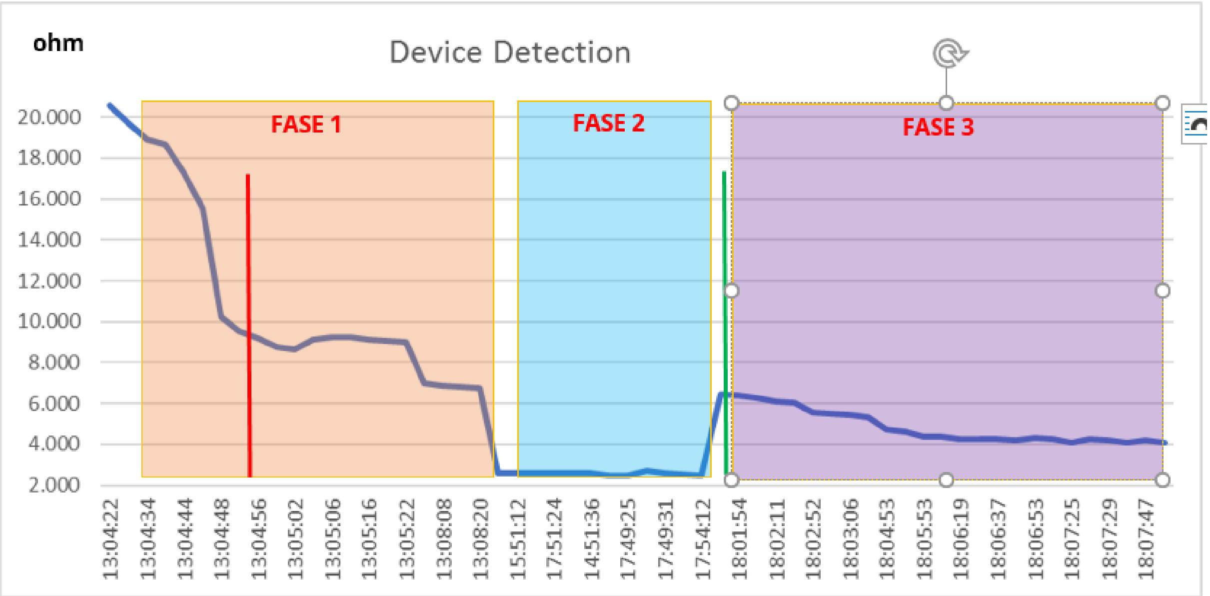


Figure Graphical representation of the measurements taken with the device to be tested.

User 2

Test mode:

1. Hydration status detection with medical device supplied UOC nephrology and dialysis of Feltre pre and post dialysis

2. Starting dehydration status monitoring with the bracelet

	Resistenza (ohm)	**Reattanza (ohm)**	**R/h (ohm/m)**	**Xc/h (ohm/m)**	**Peso (kg)**
Pre dialisi	465	30	291	19	70,6
Post dialisi	504*	32	315	20	69,7

The subject lost 0.9 kg in about 4 hours.

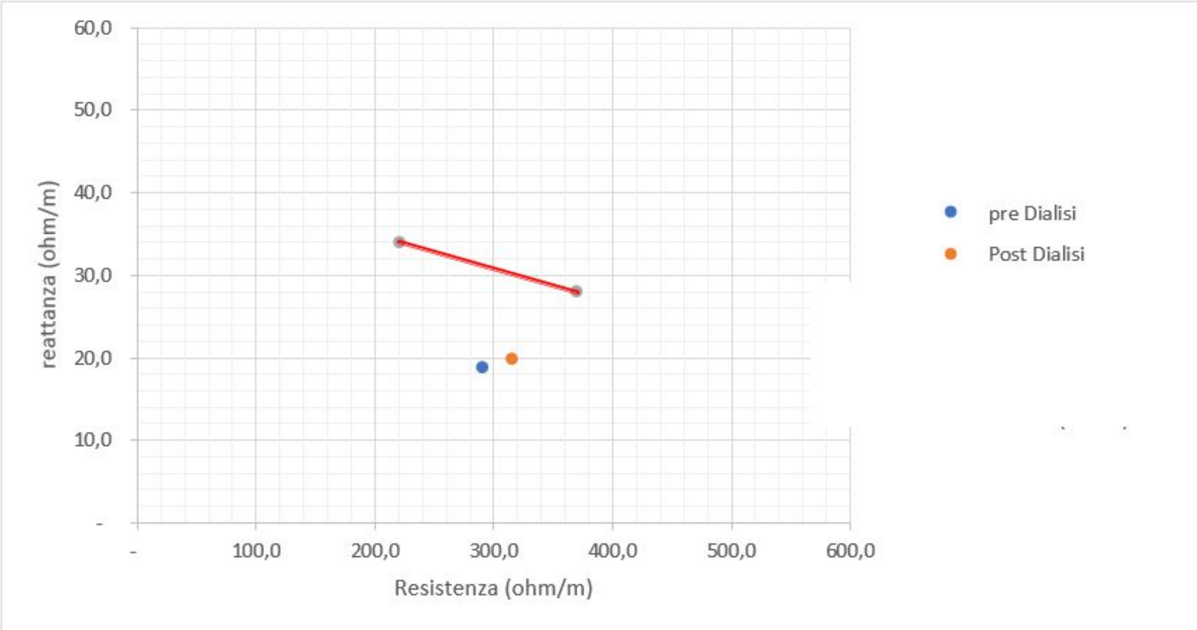


Figure Detail Measurements Taken Pre and Post Dialysis Subject 2

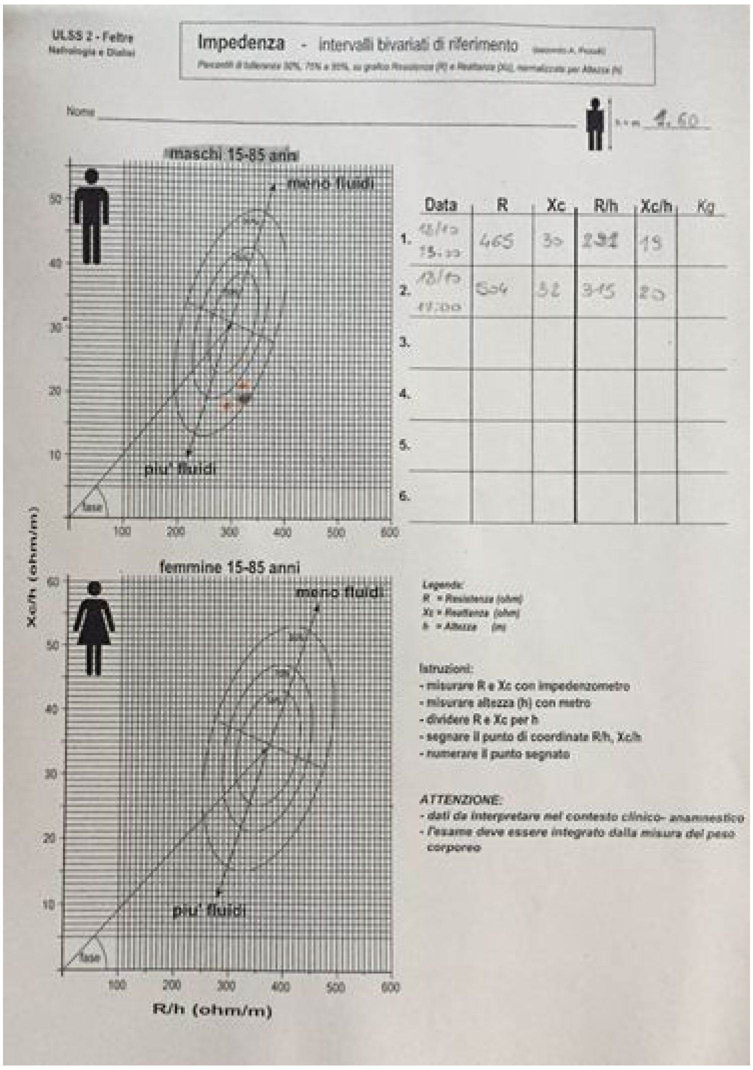


Figure: Graphical representation of the detections made with the pre and post dialysis medical device

After the impetuousness with the medical device the subject wore the bracelet and resistance was detected at three different times as shown below:

STEP 1

The monitoring of the surveys was done at intervals from 13:09 to 13:19. Figure 8 Phase 1 shows the findings. It should be noted that by pressing the bracelet on the wrist the detected resistance drops rapidly (around 13:09:36). The detection is unstable as the values decrease more or less rapidly throughout the detection phase. The peaks represented occur as the subject moves the arm, following a settling phase.

STEP 2

The monitoring of the detections was done at intervals at 2:44 pm The value is stable and oscillates by a few hundred ohm.

STEP 3

The monitoring of the detections was done at intervals, between the two green lines the subject is subjected to impetuousness with medical device. The bracelet is not removed. The peaks represented occur as the subject moves the arm, following a settling phase. Off-scale spikes are likely due to a temporary loss of grip with the skin as the detected values are entirely in line with those recorded with the unworn device.

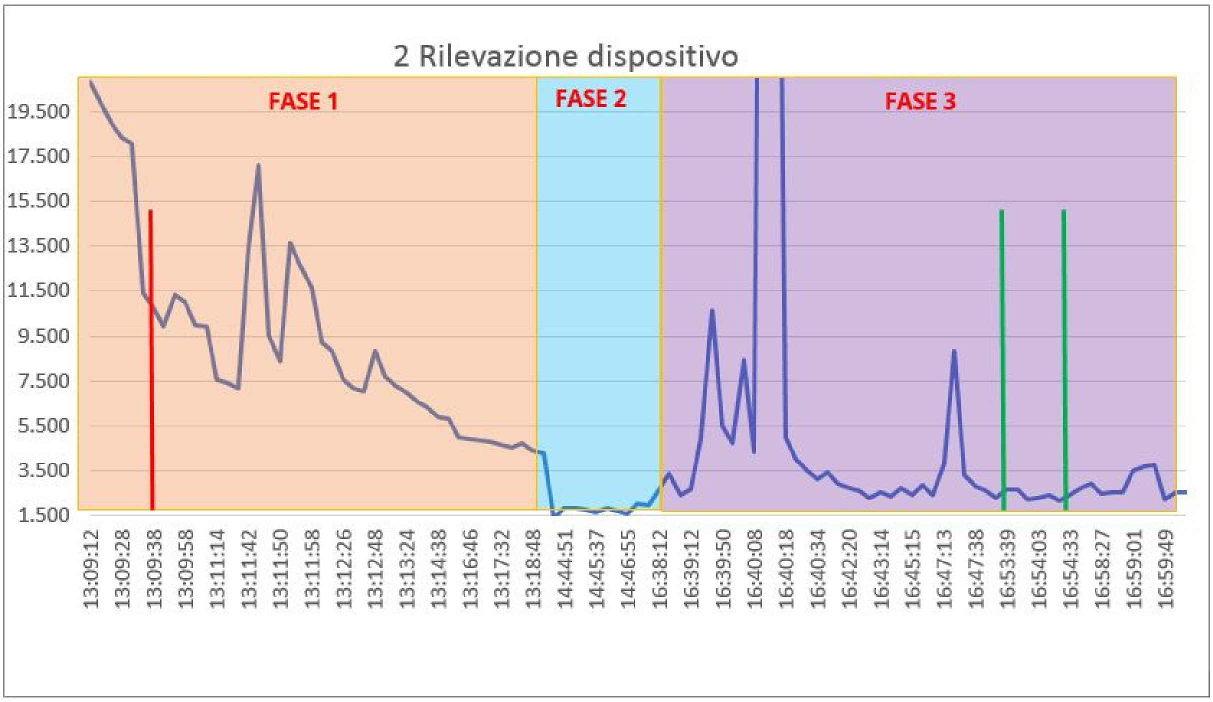


Figure Graphical representation of the measurements taken with the device to be tested.

2.3.6 Discussion

User 1

The resistance remains stable between 14:51 and 17:50 although at the same time the body weight of the subject suffers a significant reduction due to the subtraction of fluids. The resistance detected does not allow you to grasp this aspect.

From the test conducted it seems that the sensor needs a period of "settling" before stabilizing the value of a few ten minutes.

User 2

During the monitoring phase, stability is around 1500-2000 ohm in phase two and between 2,000 and 3,000 ohm in phase 3 except for the peaks detected due to the movement of the subject.

The data collected by the device are not allowed to determine the hydration status of the subject since the resistance is less than half dialysis compared to the final stage (since the subject lost about 900g of liquids between start and end). The patient was hyper-hydrated before and remains so at the end.

From the test conducted it seems that the sensor needs a period of "settling" before stabilizing the value of a few ten minutes.

Final conclusion

From the first analysis it is impossible to determine the hydration state through the APP, the resistance detected by the medical device is on a different order of magnitude (1/10), not even the re-referring resistance to ohm/m values are comparable.

Between subject 1 and 2 the detected resistance is in the same range even if subject 2 is normohydrated and the 2 hyperhydrated. Between subject 1 and subject 2 there are 1,000 ohm of difference despite being both normohydrated.

2.3.7 Usability

twelve healthy people aged 55+ has been involved in the usability tests, 6 male and 6 female. More details on people involved in test phase is available at section 2.4.

People tested all the devices and the APP in the same session at the end of the testing phase the User Experience Questionnaire has been submitted to subjects who tested the concepts.

The outcome of the questionnaire is reported below:

Question 1. How would you judge the wristband?		
Uncomfortable	0 0 1 0 2 1 8	Comfortable
Unpleasant	0 0 0 1 2 1 8	Pleasant
Large	0 0 0 11 0 0 1	Tight
Rough	0 0 0 1 6 1 4	Soft
Cold	0 0 0 5 6 1 0	Warm
Heavy	0 0 0 1 1 3 7	Light
Ugly	0 1 2 2 1 2 4	Charming
Embarassing	0 1 0 6 2 2 1	Stilish
Small	0 0 1 9 1 1	Big
Question 2. How would you judge the deck?		
Small	0 0 1 8 2 0 1 0	Big
Ugly	0 1 0 6 3 2 0	Nice
Not intuitive	1 0 0 0 0 0 11	Intuitive
Complex	0 0 0 0 0 1 11	Simple
Unuseful	0 0 0 1 0 1 10	Useful

Hard to clean	0 0 0 0 0 0 12	Easy to clean
Question 3. How do you feel the wristband during the day?		
Uncomfortable	0 0 0 1 1 3 7	Comfortable
Unpleasant	0 0 0 2 1 6 3	Pleasant
Large	0 0 0 11 1 0 0	Tight
Rough	0 0 0 2 5 4 1	Soft
Cold	0 0 0 3 6 2 1	Warm
Heavy	0 0 0 0 2 3 7	Light
Ugly	0 0 1 6 1 1 3	Charming
Falling	0 0 0 1 1 2 8	Stable
Question 4. How do you feel about the insertion/removal of the case to/from the devices?		
Uncomfortable	0 0 0 1 0 3 8	Comfortable
Unpleasant	0 0 0 5 1 4 2	Pleasant
Unuseful	0 0 1 3 3 2 3	Useful
Not intuitive	1 0 0 0 0 1 10	Intuitive
Forgetful	0 0 0 1 1 3 7	Easy to remember
Too short	0 1 1 10 0 0 0	Too long

Hard	0 0 0 1 0 0 11	Easy
Question 5. How would you judge the sensor case?		
Hard to insert	0 0 0 1 0 1 10	Easy to insert
Easy to lose	2 1 1 2 1 1 4	Easy to remember
Hard to place	0 0 0 2 0 2 8	Easy to place
Small	1 1 0 8 0 0 2	Big
Ugly	0 0 2 5 0 1 4	Nice
Hard to recharge	0 0 0 0 0 1 11	Easy to charge
Unstable	0 0 0 1 0 2 9	Stable
Uncomfortable	0 0 0 4 0 2 6	Comfortable
Question 6. How would you evaluate the instruction provided by the app?		
Unuseful	0 0 0 1 1 4 6	Useful
Incomplete	1 0 2 4 0 1 4	Complete
Not clear	0 0 2 2 2 2 4	Clear
Hard to understand	0 0 0 1 3 3 5	Intuitive
Not accessible	0 1 2 7 0 1 1	Repetitive
Question 7. How would you evaluate the alert?		

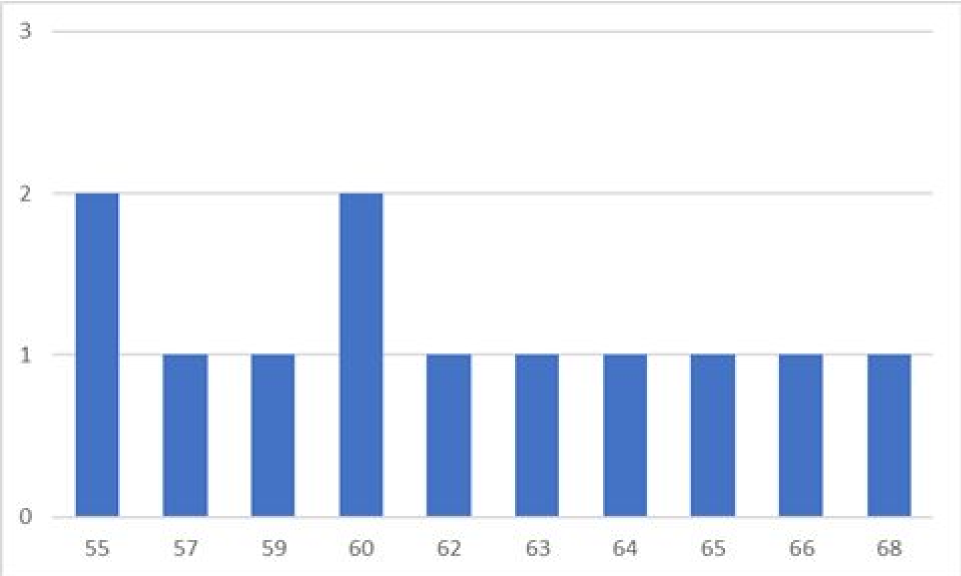
Noisy	0 0 1 0 1 3 7	Soft
Made me anxious	5 2 0 3 1 0 1	Made me confident
Unuseful	0 0 0 2 0 5 5	Useful
Question 8. How would you evaluate the feedback from the app?		
Too early	0 0 2 7 1 0 2	Too late
Cannot hear it	0 0 4 5 1 0 2	Too loud
Confusing	0 0 4 4 0 1 3	Clear
Not understandable	0 0 2 5 1 1 3	Understandable
Distracting	0 0 2 7 0 0 3	Involving
Question 9. How would you evaluate the data collected from the app?		
Unuseful	0 0 0 0 0 3 9	Useful
Hard to understand	0 0 0 0 0 1 11	Well represented
Not clearly communicated	0 1 0 0 0 4 7	Clearly communicated
Hard to access	0 0 0 0 1 5 6	Easy to access
Hard to find	0 0 0 0 0 4 8	Easy to find
Not enough	0 1 0 5 4 2 0	Too many
Made me anxious	0 0 3 7 1 0 1	Made me confident

2.3.8 References

User Experience Questionnaire (UEQ - https://www.ueq-online.org/).

2.4 APP usability

twelve healthy people aged 55+ has been involved in the usability tests, 6 male and 6 female.



Age distribution of people involved.

Remarks: People involved in the testing phase reported that they have limited experience with smartphones and APPs related to health status monitoring therefore the answers are based on their own perception of the APP only.

Some questions were not asked due to the type of test performed.

The APP is still unstable that may have affected the test's results.

The outcome of the questionnaire is reported below:

Section A		
Engagement – fun, interesting, customisable, interactive (eg, sends alerts, messages, reminders, feedback, enables sharing), well-targeted to audience		
1	**Entertainment: Is the app fun/entertaining to use? Does it use any strategies to increase engagement through entertainment (eg, through gamification)?**	
□	Dull, not fun or entertaining at all	0

◻	Mostly boring	1
◻	OK, fun enough to entertain user for a brief time (< 5 minutes)	2
◻	Moderately fun and entertaining, would entertain user for some time (5–10 minutes total)	7
◻	Highly entertaining and fun, would stimulate repeat use	2
2	**Interest: Is the app interesting to use? Does it use any strategies to increase engagement by presenting its content in an interesting way?**	
◻	Not interesting at all	0
◻	Mostly uninteresting	0
◻	OK, neither interesting nor uninteresting; would engage user for a brief time (< 5 minutes)	3
◻	Moderately interesting; would engage user for some time (5-10 minutes total)	7
◻	Very interesting, would engage user in repeat use	2
3	**Customisation: Does it provide/retain all necessary settings/preferences for apps features (eg, sound, content, notifications, etc.)?**	
◻	Does not allow any customisation or requires setting to be input every time	0
◻	Allows insufficient customisation limiting functions	2
◻	Allows basic customisation to function adequately	5
◻	Allows numerous options for customisation	1
◻	Allows complete tailoring to the individual’s characteristics/preferences, retains all settings	4

4	**Interactivity: Does it allow user input, provide feedback, contain prompts (reminders, sharing options, notifications, etc.)? Note: these functions need to be customisable and not overwhelming in order to be perfect.**	
◻	No interactive features and/or no response to user interaction	0
◻	Insufficient interactivity, or feedback, or user input options, limiting functions	1
◻	Basic interactive features to function adequately	7
◻	Offers a variety of interactive features/feedback/user input options	1
◻	Very high level of responsiveness through interactive features/feedback/user input options	3
5	**Target group: Is the app content (visual information, language, design) appropriate for your target audience?**	
◻	Completely inappropriate/unclear/confusing	0
◻	Mostly inappropriate/unclear/confusing	0
◻	Acceptable but not targeted. May be inappropriate/unclear/confusing	5
◻	Well-targeted, with negligible issues	3
◻	Perfectly targeted, no issues found	4
Section B		
Functionality – app functioning, easy to learn, navigation, flow logic, and gestural design of app		
1	**Performance: How accurately/fast do the app features (functions) and components (buttons/menus) work?**	

◻	App is broken; no/insufficient/inaccurate response (eg, crashes/bugs/broken features, etc.)	1
◻	Some functions work, but lagging or contains major technical problems	0
◻	App works overall. Some technical problems need fixing/Slow at times	5
◻	Mostly functional with minor/negligible problems	3
◻	Perfect/timely response; no technical bugs found/contains a 'loading time left' indicator	3
2	**Ease of use: How easy is it to learn how to use the app; how clear are the menu labels/icons and instructions?**	
◻	No/limited instructions; menu labels/icons are confusing; complicated	0
◻	Useable after a lot of time/effort	0
◻	Useable after some time/effort	0
◻	Easy to learn how to use the app (or has clear instructions)	6
◻	Able to use app immediately; intuitive; simple	6
3	**Navigation: Is moving between screens logical/accurate/appropriate/uninterrupted; are all necessary screen links present?**	
◻	Different sections within the app seem logically disconnected and random/confusing/navigation/is difficult	0
◻	Usable after a lot of time/effort	0
◻	Usable after some time/effort	2
◻	Easy to use or missing a negligible link	8

☐	Perfectly logical, easy, clear and intuitive screen flow throughout, or offers shortcuts	2
4	**Gestural design: Are interactions (taps/swipes/pinches/scrolls) consistent and intuitive across all components/screens?**	
☐	Completely inconsistent/confusing	0
☐	Often inconsistent/confusing	0
☐	OK with some inconsistencies/confusing elements	0
☐	Mostly consistent/intuitive with negligible problem	9
☐	Perfectly consistent and intuitive	3

Section C		
Aesthetics – graphic design, overall visual appeal, colour scheme, consistent style		
1	**Layout: Is arrangement and size of buttons/icons/menus/content on the screen appropriate or zoomable if needed?**	
☐	Very bad design, cluttered, some options impossible to select/locate/see/read device display not optimised	0
☐	Bad design, random, unclear, some options difficult to select/locate/see/read	0
☐	Satisfactory, few problems with selecting/locating/seeing/reading items or with minor screen size problems	0
☐	Mostly clear, able to select/locate/see/read items	3
☐	Professional, simple, clear, orderly, logically organised, device display optimised. Every design component has a purpose	9

2	**Graphics: How high is the quality/resolution of graphics used for buttons/icons/menus/content?**	
☐	Graphics appear amateur, very poor visual design – disproportionate, inconsistent style	0
☐	Low quality/low resolution graphics; low quality visual design – disproportionate, stylistically inconsistent	0
☐	Moderate quality graphics and visual design (generally consistent in style)	0
☐	High quality/resolution graphics and visual design – mostly proportionate, stylistically consistent	5
☐	Very high quality/resolution graphics and visual design - proportionate, stylistically consistent throughout	7
3	**Visual appeal: How good does the app look?**	
☐	No visual appeal, unpleasant to look at, poorly designed, clashing/mismatched colours	0
☐	Little visual appeal – poorly designed, bad use of colour, visually boring	0
☐	Some visual appeal – average, neither pleasant, nor unpleasant	0
☐	High level of visual appeal – seamless graphics – consistent and professionally designed	6
☐	As above + very attractive, memorable, stands out; use of colour enhances app features/menus	6

Section D
Information – Contains high quality information (eg, text, feedback, measures, references) from a credible source. Select N/A if the app component is irrelevant.

1	**Accuracy of app description: Does app contain what is described?**	
☐	Misleading. App does not contain the described components/functions or has no description	n/a
☐	Inaccurate. App contains very few of the described components/functions	
☐	OK. App contains some of the described components/functions	
☐	Accurate. App contains most of the described components/functions	
☐	Highly accurate description of the app components/functions	
2	**Goals: Does app have specific, measurable and achievable goals (specified in app store description or within the app itself)?**	
☐	N/A Description does not list goals, or app goals are irrelevant to research goal (eg, using a game for educational purposes)	0
☐	App has no chance of achieving its stated goals	0
☐	Description lists some goals, but app has very little chance of achieving them	0
☐	OK. App has clear goals, which may be achievable	11
☐	App has clearly specified goals, which are measurable and achievable	1
☐	App has specific and measurable goals, which are highly likely to be achieved	0
3	**Quality of information: Is app content correct, well written, and relevant to the goal/topic of the app?**	
☐	N/A There is no information within the app	1
☐	Irrelevant/inappropriate/incoherent/incorrect	0

◻	Poor. Barely relevant/appropriate/coherent/may be incorrect	1
◻	Moderately relevant/appropriate/coherent/and appears correct	5
◻	Relevant/appropriate/coherent/correct	4
◻	Highly relevant, appropriate, coherent, and correct	1
4	**Quantity of information: Is the extent coverage within the scope of the app; and comprehensive but concise?**	
☐	N/A There is no information within the app	1
☐	Minimal or overwhelming	0
☐	Insufficient or possibly overwhelming	0
☐	OK but not comprehensive or concise	4
☐	Offers a broad range of information, has some gaps or unnecessary detail; or has no links to more information and resources	6
☐	Comprehensive and concise; contains links to more information and resources	1
5	**Visual information: Is visual explanation of concepts – through charts/graphs/images/videos, etc. – clear, logical, correct?**	
☐	N/A There is no visual information within the app (eg, it only contains audio, or text)	0
☐	Completely unclear/confusing/wrong or necessary but missing	1
☐	Mostly unclear/confusing/wrong	1
☐	OK but often unclear/confusing/wrong	1

☐	Mostly clear/logical/correct with negligible issues	4
☐	Perfectly clear/logical/correct	5

These questions were not asked to final users.

6	**Credibility: Does the app come from a legitimate source (specified in app store description or within the app itself)?**	
☐	Source identified but legitimacy/trustworthiness of source is questionable (eg, commercial business with vested interest)	
☐	Appears to come from a legitimate source, but it cannot be verified (eg, has no webpage)	
☐	Developed by small NGO/institution (hospital/centre, etc.) /specialised commercial business, funding body	
☐	Developed by government, university or as above but larger in scale	
X	Developed using nationally competitive government or research funding (eg, European Union, WHO,...)	
7	**Evidence base: Has the app been trialled/tested; must be verified by evidence (in published scientific literature)?**	
X	N/A The app has not been trialled/tested	
☐	The evidence suggests the app does not work	
☐	App has been trialled (eg, acceptability, usability, satisfaction ratings) and has partially positive outcomes in studies that are not randomised controlled trials (RCTs), or there is little or no contradictory evidence	

☐	App has been trialled (eg, acceptability, usability, satisfaction ratings) and has positive outcomes in studies that are not RCTs, and there is no contradictory evidence	
☐	App has been trialled and outcome tested in 1-2 RCTs indicating positive results	
☐	App has been trialled and outcome tested in > 3 high-quality RCTs with positive results	

Section E		
App subjective quality		
1	**Would you recommend this app to people who might benefit from it?**	
☐	**Not at all** – I would not recommend this app to anyone	0
☐	There are very few people I would recommend this app to	0
☐	**Maybe** – There are several people whom I would recommend it to	3
☐	There are many people I would recommend this app to	4
☐	**Definitely** – I would recommend this app to everyone	5
2	**How many times do you think you would use this app in the next 12 months if it was relevant to you?**	
☐	None	0

☐	1 - 2	0
☐	3 - 10	0
☐	11 - 50	1
☐	> 50	11
3	**Would you pay for this app?**	
☐	Yes	3
☐	Maybe	2
☐	No	7
4	**What is your overall star rating of the app?**	
☐	★ One of the worst apps I've used	0
☐	★★	1
☐	★★★ Average	6
☐	★★★★	3
☐	★★★★★ One of the best apps I've used	2

Section F

App-specific. These added items can be adjusted and used to assess the perceived impact of the app on the user's knowledge, attitudes, intentions to change as well as the likelihood of actual change in the target health behaviour.

1 Awareness: This app is likely to increase awareness of the importance of addressing the monitoring of physical exercise, heartbeat and dehydration status in elderly

Strongly disagree				Strongly agree
1	2	3	4	5
0	**0**	**1**	**6**	**5**

2 Knowledge: This app is likely to increase knowledge/understanding of monitoring physical exercise, heartbeat and dehydration status in elderly

Strongly disagree				Strongly agree
1	2	3	4	5
0	**0**	**2**	**4**	**6**

3 Attitudes: This app is likely to change attitudes toward improving physical exercise and hydration status in elderly

Strongly disagree				Strongly agree
1	2	3	4	5
0	**2**	**0**	**4**	**5**

4 Intention to change: This app is likely to increase intentions/motivation to address physical exercise and hydration status in elderly

Strongly disagree				Strongly agree
1	2	3	4	5
0	**0**	**2**	**3**	**7**

5 Help seeking: Use of this app is likely to encourage further help seeking for monitoring health improvements

Strongly disagree				Strongly agree
1	2	3	4	5
0	**1**	**2**	**5**	**4**

6	Behaviour change: Use of this app is likely increase/decrease physical exercise and hydration status in elderly

Strongly disagree				Strongly agree
1	2	3	4	5
0	**0**	**2**	**3**	**5**