Assessing Occupational Health with a Cross-platform Application based on Self-reports and Biosignals

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Keywords: Occupational Risks, Mobile Application, Sensors, Surveys, Assessment, Ergonomic.

Abstract: Occupational disorders have a significant impact on the health of office workers. This has even more relevance considering the increased population in this work modality and the recent shift to remote work. Efforts are needed to create worker awareness and reduce occupational hazards. Based on this motivation, an intuitive and easy to use application for the assessment of occupational risks was developed and it is presented in this paper. This application records risk factors in the biomechanical, psycho-social, and environmental domains through data collected with self-assessment tools and wearable sensors, contributing to a more complete, robust and personal assessment of risk exposure. This article presents the system architecture and its application interface. Examples of interaction with each module of the app are also provided.

1 INTRODUCTION

Work-related Diseases (WRDs) have significant implications for workers' well-being and quality of life, productivity, and absenteeism, thus having a big social and economic impact. According to data released by the International Labor Organization (ILO) (Peruničić, 2008), around 2.3 million men and women worldwide die annually from accidents or work-related illnesses. The most recent European Union Survey in 2013 revealed that three-fifths (60.1%) of all people who reported work-related health problems had musculoskeletal disorders (Wahlström, 2005). This was followed by problems related to stress, depression, and anxiety (15.9%), headaches and/or eye fatigue (4.8%), and cardiovascular diseases (4.5%) (Eurostat, 2017). In recent years, an increase of dependence on the use of computers to carry out daily work tasks has been observed. Thus, it is expected that the number of workers affected by WRD's will increase. Currently employed techniques for the assessment and evaluation of risk exposure have limitations. Observational techniques like the Owako Work Posture System (OWAS) (Hellig et al., 2018), Upper Limb Rapid Assessment (RULA) (McAtamney and Nigel Corlett, 1993), and Rapid Office Strain Assessment (ROSA) (Sonne et al., 2012) need to be evaluated by experts and require a long time to be implemented. These techniques also measure workers' exposure to risk using a risk score value based on a standard worker. This means that individual variability among workers, such as anthropometric variations, age, work experience, exercise practice, among others, is not taken into account. Furthermore, these instruments focus on documenting and quantifying the postures and behaviors observed during work, focusing on risk as a problem from a physical point of view. However, research suggests that environmental and psycho-social factors also contribute to the onset of WRDs, thus indicating that the etiology of WRDs consists of multiple contributing factors. Therefore, deriving the ergonomic risk associated with a worker, by solely basing it on physiological factors is insufficient as a complete analysis of the risk factors that contribute to an overall risk score (Santos et al., 2020).

In order to reflect the multifactorial nature of WRDs, we propose an application for monitoring a variety of dimensions in relation to occupational health. The application is structured around three potential risk domains, namely risks associated with psycho-social, biomechanical, and environmental factors. Each domain offers a multitude of assessments, that are considered as mini-apps, that collect data from the user by either employing self-assessment tools, such as questionnaires or by utilizing the sensors that are integrated into mobile devices, smartwatches, and wearable physiological sensors. The ap-

Silva, S., Cepeda, C., Rodrigues, J., Probst, P. and Gamboa, H.
Assessing Occupational Health with a Cross-platform Application based on Self-reports and Biosignals.
DOI: 10.5220/0010846700003123
In *Proceedings of the 15th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC 2022) - Volume 5: HEALTHINF*, pages 549-556
ISBN: 978-989-758-552-4; ISSN: 2184-4305

plication is intended to be intuitive, easy-to-use and accessible to everyone. Using this tool should help make people more aware of their working conditions, identify sources of risk factors and provide exposure reports to ergonomic risks, thus contributing to a more complete, robust and personal assessment of risk exposure. With this, the user has access to information that can help in understanding which risk factors are present, adapt their behavior and prevent the onset of occupational diseases.

The proposed application is being developed in the context of the PrevOccupAI (BiosignalsLibphys, 2020) project, which has as the main objective the promotion of occupational health through the identification of occupational risk and contribution to its mitigation. The project is carried out in collaboration with Portuguese public entities such as the *Direção Geral da Saúde* (DGS) and the *Autoridade Tributária e Aduaneira* (AT). Therefore the first version of the application was produced in Portuguese.

This manuscript explores the creation of the application describing the system architecture and the technological systems used in data acquisition. The interface of the application is also presented.

2 RELATED WORK

Several tools that aim to assess occupational risk in the office work context are found in the literature. These are mainly based on observational techniques that consist in a visual inspection of the physical load at work and/or by means of self-reporting, reflecting the worker's perception of physical and biomechanical exposure (David, 2005).

One such tool is the Rapid Office Strain Assessment (ROSA), developed by Sonne et al. in 2012 (Sonne et al., 2012). It is an instrument to assess the occupational risk of desk work with computer usage based on observational assessment and provide information to the user about the necessary changes based on reports of worker discomfort. For the development of this tool, the postures outlined in the CSA Z412 guidelines for office ergonomics, developed by a group of experts, were used. This method is constructed so that risk factors can be grouped into several different sections, namely chair, monitor, telephone, keyboard, and mouse. The score is assigned to each risk factor representing an individual posture and equipment, and modeled based on deviations from a defined neutral posture given by the CSA. The final score is obtained by combining scores from all subsections. The ROSA has a final score ranging from 1 to 10, which is divided into three risk levels, where each successive score means an increase in the presence of risk factors.

The European Agency for Safety and Health at Work (EU-OSHA) has launched a qualitative occupational risk assessment tool called Online Interactive Risk Assessment (OiRA) (European Agency for Safety and Health at work (EU-OSHA), 2019). OiRA is a web application that provides a set of risk assessment tools for various work sectors, including the office work sector. This tool assesses the risks associated with the office workstation, office layout, office environment, workers, and work organization. The questionnaires are in a simple format and are organized to provide the user with information about hazards in the work area, which the user assesses. After completing the questionnaire, an action plan is generated with recommendations on how to reduce the risk and a schedule of when measures against possible risks should be implemented. In the end, a report is produced that contains all the results obtained during the evaluation.

In addition to these, MUEQ (Maastricht Upper Extremity Questionnaire) (Eltayeb et al., 2007) is a reliable and consistent self-report tool that assesses the occurrence and nature of CANS (Arm, Neck and Shoulder Complaints) in office workers. The tool has the advantage of combining physical, psycho-social, and environmental factors in one assessment.

All these tools provide relevant solutions for the evaluation of occupational exposure to several domains. The proposed application is inspired by these solutions and integrates several of their ideas to provide a more complete assessment. The integration of such ideas also come from the *microErgo* concept, which suggests that the combination of several risk factors, associated with their incidence factor can be made to provide an intuitive risk score and increase the perception of the user over how to change his/her working environment to improve his/her health in the long run (Rodrigues et al., 2021). This work goes beyond the presented literature by (1) combining multiple dimensions of risk factors, such as biomechanical, psycho-social and environmental; (2) provide an accessible, easy-to-use and personal tool for occupational assessment and (3) using both direct and qualitative measures to quantify all dimensions of the occupational exposure.

3 SYSTEM ARCHITECTURE

Figure 1 presents an overview of the application's system architecture. The backbone of the application consists of a content and a form server that are installed on an Amazon Web Services (AWS) virtual machine. Both servers are used to create the content that is displayed within the application. By employing the servers as the content providers it is possible to offer a cross-platform approach that allows for large parts of the application to be accessed by either a mobile device or a desktop PC.

The application is structured in a modular way, so that each assessment is considered as a mini-app that targets specific ergonomic risk factors. Depending on the type of data acquired, the application integrates Surveys and Sensing mini-apps. Survey mini-apps are used to acquire information about the users through questionnaires. These surveys could be either psychological, biomechanical, or of environmental nature. Sensing mini-apps are used to acquire biosignal, motion, or environmental data from the subjects during work.

All the included elements are described and explained throughout this section.

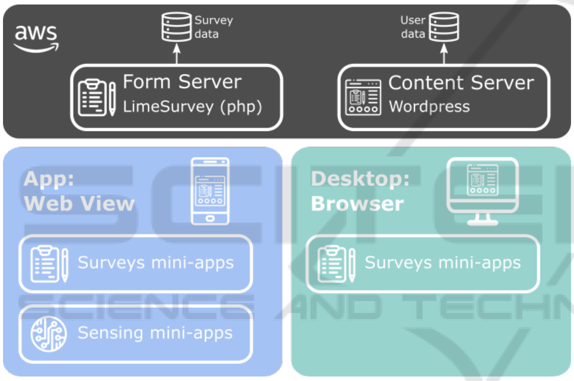


Figure 1: System architecture.

3.1 AWS Cloud

The application is hosted on the Amazon EC2 instance web server, with a minimal Linux operating system. On this web server, we installed and configured WordPress as a content server.

WordPress (WordPress, 2016) is an open-source content management platform that can create websites, blogs, or applications. This system is based on PHP with a MySQL database running on a server. The application layout can be organized from widgets or by editing PHP or HTML codes. WordPress facilitates the integration of new content in the application by non-programmers users, which is an important functionality given that the project has multidisciplinary collaborators.

Since this application has mini-apps based on forms, a Form server was also installed and configured: LimeSurvey. LimeSurvey (LimeSurvey, 2009) is a free and open-source online survey application software written in PHP. With LimeSurvey it is easy to create, develop and publish online surveys and collect responses from them, without doing any coding and scripting. The system provides statistical analysis based on survey responses. The generated questionnaires can be public or with controlled access.

Both WordPress and LimeSurvey use a MySQL database. Data related to WordPress, including its users, and data related to LimeSurvey, including the output of the surveys, are all stored on the virtual machine.

3.2 Cross-platform Functionalities

The questionnaires implemented in LimeSurvey are embedded as an iFrame into the HTML document produced by WordPress. Since WordPress is hosted on a web server, it is possible to access it through both a mobile device or a desktop PC, thus allowing the user to choose the device of their choice according to their circumstances and needs. Using a desktop PC, the surveys mini-apps can be simply accessed by using any browser. For android mobile devices, a native app was developed that accesses the content on the web server through an Android WebView component that allows to embed a browser into an application. This WebView is limited to just access the web server and is integrated into the application in such a way that users are not aware that they are using a browser.

In addition to survey mini-apps, the mobile application offers sensing mini-apps that run locally on the mobile device to acquire data from external devices. These mini-apps are accessed through a JavaScript interface that was embedded into WordPress. The Interface checks if the website is accessed through a mobile device that has the application installed and if this is true, then the sensing mini-app is launched locally on the phone. The process was implemented in such a way that the transition between WebView and local sensing mini-app is seamless and the user is not aware of which content is run in the web or locally on the mobile device. The next section describes what data could be acquired by the sensing mini-apps and explains how the systems are integrated into the app.

3.3 Android Native Components

The presented system is prepared to acquire data from a smartphone, a smartwatch and from a wearable device that acquires real-time electromyography, the muscleBAN (muscleBAN, 2020). The combination of these three devices includes a wide range of sensors, which are presented in Table 1. These sensors

Table 1: Onboard sensors on devices.

Sensor	Category	Android OS	Wear OS	muscleBAN
Accelerometer	Motion	X	X	X
Linear Accelerometer	Motion	X		
Gravity	Motion	X		
Gyroscope	Motion	X	X	
Rotation Vector	Motion	X		
Significant Motion	Motion	X		
Step Detector	Motion	X		
Step Counter	Motion	X		
Magnetometer	Position	X	X	X
Proximity	Position	X	X	
Ambient Temperature	Environment	X		
Light	Environment	X	X	
Pressure	Environment	X	X	
Relative Humidity	Environment	X		
Temperature	Environment	X		
Microphone	Environment	X		
Optical Heart Beat	Special		X	
Electromyography	Special			X

are useful to evaluate ergonomic risks, such as the worker posture, his psychological state and also to evaluate the working environment.

The acquisition of data from these sensors is, at this moment, only available with smartphones and smartwatches running on an Android operating system.

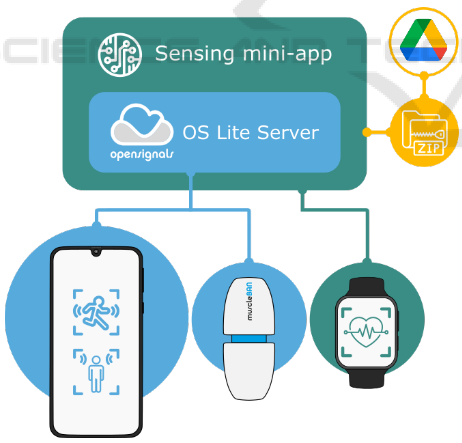


Figure 2: Sensing mini-apps acquisition system.

The acquisition of the aforementioned devices is currently achieved by two different means as shown in Figure 2. Mobile device internal sensors and the muscleBAN data are acquired through OS Lite server. OS Lite server is an experimental module developed by PLUX (PLUX, 2021) that allows for data acquisition from multiple PLUX devices and Android internal sensors at the same time. Acquired data is stored on a local folder as *.txt* files. OS Lite also allows for uploading the acquired data to a google drive folder. This is done by compressing the folder that holds the acquired data into a *.zip* file and then using the Google Drive API to upload the file to a defined google drive repository. As OS Lite server does not allow for the acquisition of the sensors that are integrated into a smartwatch, a module was implemented within the android application that makes this possible. The module was written in such way that the acquired data is written to *.txt* files that are saved into the same folder that OS Lite server uses. Thus, the smartwatch data is sent to the google drive repository together with the other sensor data.

4 USER INTERFACE

To create a first version of the application, several mini-apps were integrated considering the various classes of risk that made up this occupational health control system, filling in the gaps and flaws found in other existing tools. The main objectives of this first version is to: (1) include more than one mini-app associated to the main three domains (biomechanics, environment and psycho-social) and (2) gather most of the existing risk factors in office work. The assessment mini-apps are able to collect information regarding risk exposure through questionnaires or sensors provided by the acquisition systems, as it was described in the previous section, depending on the risk module selected. The questionnaires come from existing tools, available and validated in the Portuguese

Table 2: Mini-apps included in the application first version and respective assessment tool, organized by category. [1](Sonne et al., 2012); [2](Lima and Coelho, 2011); [3](de Souza, 2012); [4](European Agency for Safety and Health at work (EU-OSHA), 2019); [5](Silva et al., 2000); [6](Eltayeb et al., 2007); [7](Miranda, 2015); [8](Simões, 2016).

Category	Mini-App	Assessment Tool
Biomechanical	Office Design	ROSA[1]; Lima and Coelho's Checklist[2]
	Equipments	ROSA[1]; Lima and Coelho's Checklist[2]
	Pain	Nordic Musculoskeletal Questionnaire[3]
	Posture	Smartphone; Smartwatch; muscleBAN
Environmental	Workstation	OiRA[4]
	Office Organization and Privacy	Lima and Coelho's Checklist[2]
	Noise	Smartphone
Psycho-social	Labor Requirements	COPSOQ II[5]; MUEQ[6]
	Work Organization and Content	COPSOQ II[5]; Work Design Questionnaire[7]
	Social Relations and Leadership	COPSOQ II[5]
	General Well-Being	COPSOQ II[5]
	Values in the Workplace	COPSOQ II[5]
	Personality	An adaptation of the Big Five Inventory[8]

language, to determine exposure to the hazards posed by the mini-app.

The application structure, including the general risk categories, the mini-apps that assess each of them, and the tools that each mini-app is based on, is presented in Table 2.

Figures 3a, 3b and 3c show an example of user interaction with the application for a psycho-social, biomechanical and environmental assessment, respectively.

At the home page, the three main categories are presented: psycho-social, biomechanical, or environmental assessment. In Figure 3a, the user selects the Psycho-social Assessment (*Avaliação Psicossocial*) and the app presents the mini-apps that evaluate different risk factor categories (see "Mini-App" of "Psyco-social" category in Table 2). In this example, the user wants to evaluate how he is exposed to the risk of WRDs due to the demand of the work, the impossibility of deciding or planning breaks, or even a reduced or non-existent number of intervals. Bearing this in mind, he selects the mini-app Labor Requirements (*Exigências Laborais*). This example shows a survey mini-app, created with LimeSurvey, that the worker fills in the questionnaire and submits the answers that are automatically stored in the database.

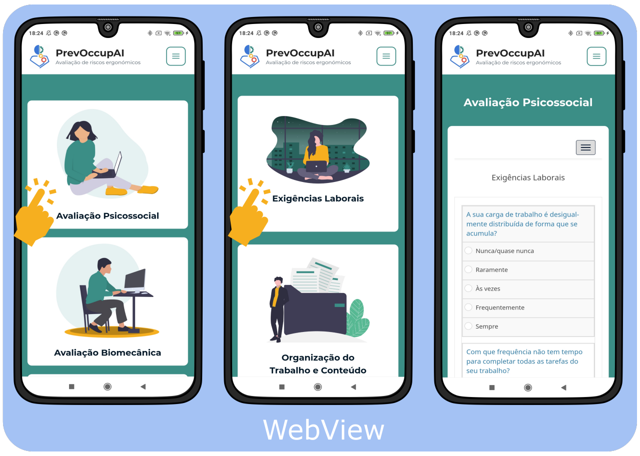
Figure 3b explains how to carry out the postural assessment, which is a mini-app of the Biomechanical category (*Avaliação Biomecânica*). The user accesses the posture mini-app (*Postura*), in which are presented information about how to setup the sensors (*Como montar os sensores?*) and what data is acquired during this procedure (*O que irá ser adquirido?*). When the user is ready, he presses the button to start the acquisition (*Começar Agora*). Then, the application shows the time of acquisition and also the connected devices, from which data is acquired. This acquisition can be interrupted anytime by the user, by clicking the button *Terminar Avaliação*. The data will be available in the end a Google Drive folder.

The last example, presented in Figure 3c, uses the microphone of the smartphone to record environmental noise (*Ruído Ambiente*), which is part of the Environmental Assessment (*Avaliação Ambiental*). After selecting that mini-app, the user could verify what data is acquired during this procedure (*O que irá ser adquirido?*) and then start the acquisition (*Começar Agora*). While acquiring the noise level, the decibel value is displayed in real-time. This acquisition can be interrupted anytime by the user, by clicking the button *Terminar Avaliação*. The data will be available in a Google Drive folder.

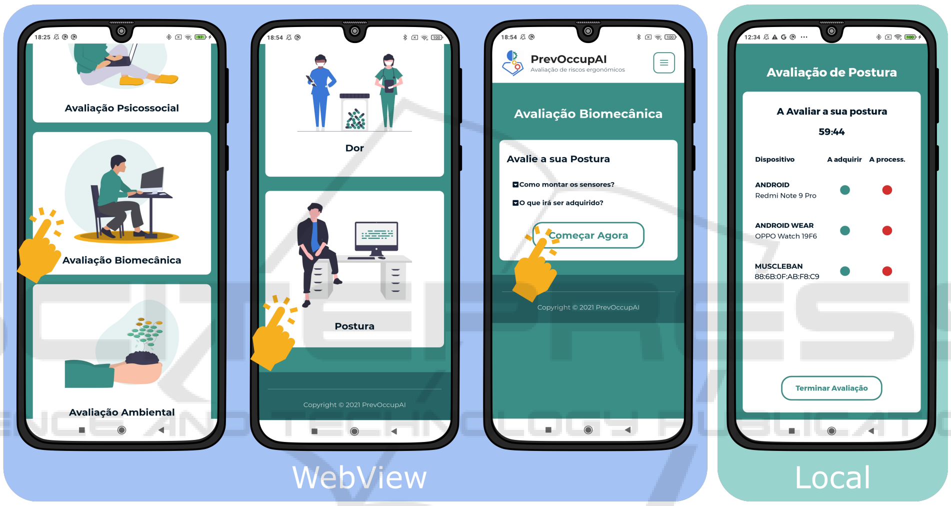
5 CONCLUSIONS AND FUTURE WORK

In this article, we intend to present and describe an application that goes beyond the current available tools, by combining various dimensions of risk factors through different assessment tools to provide a broader and more robust risk assessment, contributing for a greater user awareness and promoting the decrease of the occupational risk. The examples provided in this manuscript show that the user has the ability to decide over which assessments he/her wants to perform and are more adjusted to the user's goals or needs.

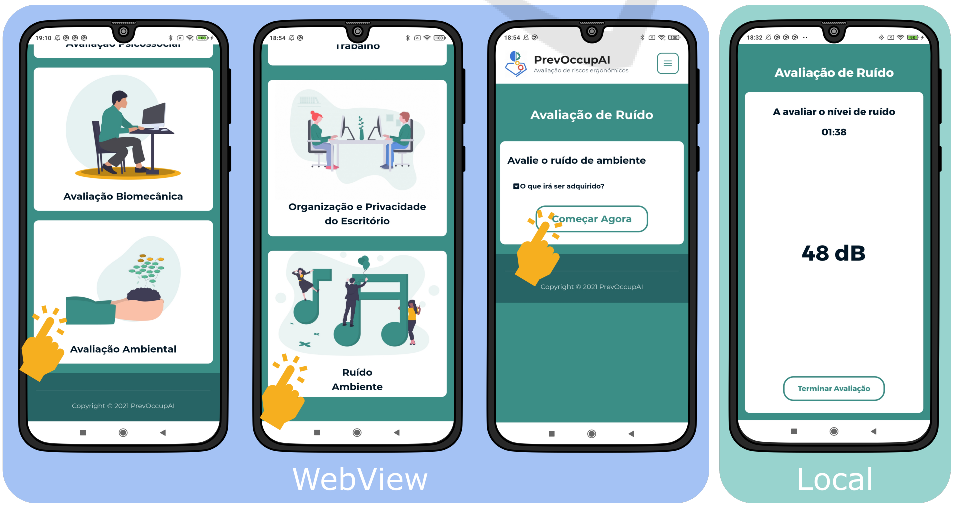
The integration of assessments based on sensors suitable for monitoring certain risk factors is an as-



(a) Example of the steps to do a psycho-social assessment.



(b) Example of the steps to do a biomechanical assessment.



(c) Example of the steps to do an environmental assessment.

Figure 3: Application interface in three different examples. Additionally it is shown which parts of the application are run in the WebView and which are run locally on the mobile device.

set, since these techniques are more accurate and potentially more reliable than the others (David, 2005). Furthermore, using sensors instead of observational methods promotes time-efficient assessments that do not rely on video inspection. Also, creating a combined system that uses direct methods and questionnaires to assess occupational exposure represents progress and improvements compared to the tools that have already been developed.

Ethical and privacy issues may be regarded while defining the mini-apps that integrate the acquisition of data from sensors. For example, data from the microphone could expose environmental risk factors while being acquired during the whole usage of the application, however continuous audio recordings at the workplace arise significant privacy concerns, and therefore, the way this information is stored and the periods at which it is acquired, should be well defined.

In the future, there are three main objectives: (1) calculate the user's ergonomic risks; (2) provide recommendations to reduce them; and (3) create users' profiles to (a) keep historical records of users and (b) extrapolate the assessment to new similar cases.

To calculate the scores from the information gathered in each mini-app, the data obtained from the responses of the questionnaires and from the sensing assessments is processed and combined to obtain a single risk measure converted into a well-defined scale, as proposed by (Rodrigues et al., 2021). In addition to this, other risk factors that constitute the variability between workers, such as age, gender, alcohol and smoking habits must also be included in the application.

It would be extremely important to present the results of each mini-app to the user in a way that is easily interpretable and allows them to be made aware of their exposure to WRDs and the risks that contribute to them. According to a study (Silva, 2012), these assessments have proven to increase worker comfort and reduce risk factors in their offices. Associated with this, it is planned to incorporate a set of recommendations that can be presented to the user based on the identified risks.

With the continuous acquisition of data over time, historical information can be stored and used to create a more detailed and robust assessment of the occupational exposure experienced by the user. In addition, with historical records of multiple users, it is possible to create relevant profiles. Newly incoming users that fit into these can have better answers even when little data is available.

ACKNOWLEDGEMENTS

This work was partly supported by Science and Technology Foundation (FCT), under the project PREVOCUPAI (DSAIPA/AI/0105/2019). The authors have no conflicts of interest to report.

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