GLOBAL HEALTH 2017

The Sixth International Conference on Global Health Challenges

ISBN: 978-1-61208-604-0

November 12 - 16, 2017

Barcelona, Spain

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GLOBAL HEALTH 2017

Forward

The Sixth International Conference on Global Health Challenges (GLOBAL HEALTH 2017), held between November 12 - 16, 2017, in Barcelona, Spain, continued a series of events taking a global perspective on population health, from national to cross-country approaches, multiplatform technologies, from drug design to medicine accessibility, everything under mobile, ubiquitous, and personalized characteristics of new age population.

Recent advances in technology and computational science influenced a large spectrum of branches in approaching population health. Despite significant progresses, many challenges exist, including health informatics, cross-country platforms interoperability, system and laws harmonization, protection of health data, practical solutions, accessibility to health services, and many others. Along with technological progress, personalized medicine, ambient assistance and pervasive health complement patient needs. A combination of classical and information-driven approach is developing now, where diagnosis systems, data protection mechanisms, remote assistance and hospital-processes are converging.

The event was very competitive in its selection process and very well perceived by the international scientific and industrial communities. As such, it has attracted excellent contributions and active participation from all over the world. We were very pleased to receive a large number of top quality contributions.

The conference had the following tracks:

- Mechanisms and features
- Application-oriented analytics
- Fundamentals for data analytics
- Healthcare Information and Management Systems
- PAPHOS

We take here the opportunity to warmly thank all the members of the GLOBAL HEALTH 2017 technical program committee, as well as all the reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors that dedicated much of their time and effort to contribute to GLOBAL HEALTH 2017. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

We also gratefully thank the members of the GLOBAL HEALTH 2017 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope that GLOBAL HEALTH 2017 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the area of global health challenges.

We also hope that Barcelona, Spain, provided a pleasant environment during the conference and everyone saved some time to enjoy the unique charm of the city.

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Smart Grip Prosthetic Hand

Vicken Tchangoulian[1],Vicken Daghlian[2], Ali Hage-Diab[1, 3], Bassam Hussein[2, 3], Hassan M. Khachfe[1, 3]
[1] Department of Biomedical Engineering
[2] Department of Industrial Engineering
[3] Lebanese Institute for Biomedical Research & Applications (*LIBRA*)
Lebanese International University
Beirut, Lebanon
e-mail: vickent9@gmail.com, e-mail: vicken.daghlian@gmail.com, e-mail: {ali.hagediab; bassam.hussein; hassan.khachfe}@liu.edu.lb

***Abstract*- In a fast paced world, an accident can happen to anyone of us, changing and impacting our lives negatively. Some of these accidents have irreversible consequences, like the amputation of a limb. Recent studies show that there are about 16 amputations per 100,000 people in Lebanon. Through the decades, engineers and scientists have come up with different solutions to make the lives of amputees somewhat easier, specifically transradial amputation. Unfortunately, fully functional prosthetic hands cost anywhere from $5000-$120000. The current project proposes a solution at a reasonably affordable cost for a highly durable prosthesis that can satisfy the needs of an amputee coming from any financial background. To manufacture a durable prosthesis, we used aluminum to machine the parts of the inner skeleton. To make the cover, we used fiberglass molding and finished it off with a glossy paint job. The aluminum parts are connected to each other by steel bearings and stainless steel rivets, nuts, and bolts. The fingers are actuated by steel cables, which are pulled by servo motors. The fingers are reset to their initial positions by spring loaded steel cables. The smart grip system, which is the main innovative characteristic of the prostheses, senses the presence and the slipping of an object between the fingers. The whole system is controlled by an Arduino microcontroller. In addition, the smart grip system can be used in many other industrial applications related to the fields of robotics. With this project, we managed to prove our concept of the smart grip system, but there is still room for improvement.**

I. INTRODUCTION

In an imperfect world, an accident can happen to anyone of us, changing our lives to worse. Some of these accidents may be severe and have irreversible consequences like the amputation of a limb. The ingenuity of humankind has led us to different solutions to problems that were thought to be unsolvable. Throughout history, people have come up with different methods to make the lives of amputees somewhat easier. For example, in the case of hand amputation, people used a hook to perform simple tasks, or a wooden hand for cosmetic reasons. Prosthetics have come a long way since then.

Nowadays, there are much more advanced methods to solve this problem, prosthetics can range from metal hooks and purely cosmetic hands to fully functional thought controlled prosthetics, and in between, there are still method to be explored in order to find the soft spot of prosthetics, that is, to find the method that can meet the requirements of an amputee at a reasonable price. Presently, the cost of a functional prosthetic hand can range from $4,000 to $12,0000 [1]- [4].

According to most human rights doctrines, all people should have an equal opportunity to a normal life. Unfortunately, this is not always the case as the privileged have the luxury to afford any solution to any problem since they have the financial means of doing so. In this paper, the researchers propose an optimal solution at the lowest cost for a highly durable prosthesis that can satisfy the requirements of an amputee, especially the ones with limited financial resources. To achieve this objective, a durable and affordable functional prosthetic hand will be presented. The durability of the prostheses will come from its lightweight aluminum skeleton with composite cover, and the functionality will be derived from a simple smart grip system integrated with the finger drive. Also, the smart grip system can be used in many other industrial applications in most of the robotic fields.

II. AMPUTATION AND PROSTHETICS

Knowledge of amputation and the history of prosthetics will help to emphasize the importance of the availability of prosthetics to amputees.

A. Amputation

Amputees can be found all over the world. Some people are born with a missing limb, but also limb loss can be the result of different types of accidents such as wars, vehicle accidents, diseases, or sports related accidents (mountain climbing, soccer, etc.).

According to the statistics done by Eastern Mediterranean Health journal [5], there are about 1.6 amputations per 10,000 persons in Lebanon. Amputations are categorized as upper limb amputations and lower limbs amputations, and each of these two types have different subcategories. Each of the above mentioned amputation types are usually handled by specific types of devices, which are called prosthetic devices. Transradial amputations, for example, were initially solved with wooden prosthetics, metallic prosthetics, cosmetic prosthetics, hook prosthetics and – today – myoelectric prosthetics. Nowadays, prostheses

 ISBN: 978-1-61208-604-0

Figure 1. Palm and Forearm

fall in different categories and they differ by quality, functionality, cost and other specifications.

In this paper, a smart prosthetic hand with good grip is presented. Usually, the user needs to grab items that can have different textures and geometrical shapes. The smart grip system will provide the simplicity of grabbing any kind of object without the fear of loss of control over the item grabbed, be it a hot coffee mug, a plastic bottle, an egg, etc. A hot coffee mug, for example, will exert heat on the prosthesis, and hence the choice of materials that will be used to manufacture the prosthesis should be such that it will not be affected by temperatures that a normal human hand can withstand. Being smart does not mean that prostheses will be independent; the user interface will control different modes of operation that will satisfy the amputee.

In brief, the aim of proposed model is mainly to provide the average amputee with a prosthesis that is durable and functional, at an affordable price.

III. MATERIALS AND METHODS

The materials and methods chosen for this project have a direct effect on its success, thus they are discussed in detail in the subsections below.

A. Manufactring:

From a manufacturing point of view, the proposed model aims to achieve four main objectives: heat resistance, durability, weight, and mechanism.

- **Heat Resistance**: heat resistance is important, because it gives the user a wider range of activities that he/she can perform with the prosthesis, rather than being limited by a certain temperature range. By heat resistance we do not mean that the prosthesis must be totally fireproof, but it must be able to withstand the normal temperatures that a human being encounters in his daily life, e.g., holding a mug containing a hot beverage, an accidental spill of hot water, or getting your hand close to naked flame for a short period of time. The target temperature range will be up to 70˚C.
- **Durability**: durability is also a key factor in functionality and user satisfaction. Durability is important, because the user can encounter high forces through accidents and this can damage the prosthesis. By durability, it is meant that the prosthesis must endure certain rages and types of forces. This however, can limit the range of activities the user can perform with the device, for example, when a finger gets wedged in a doorway, or if a door is slam-closed on a finger.
- **Weight**: weight plays a big role in comfort and this is a major factor in functionality and user satisfaction. Simply, if the prosthesis is heavy, the user will not be comfortable carrying it around on his/her arm.
- **Mechanism**: the importance of the mechanism is indirect rather than direct in user satisfaction context. The smooth operation of the hand is crucial for a semi-humanlike motion of the fingers. The mechanism must be reliable to ensure accuracy, consistency, and repeatability.

B. Control

The device control can be divided into three parts: user interface, processing, and smart grip system.

- **User Interface**: a system that will allow the user to control the prosthesis through simple commands.
- **Processing**: a control module that must combine the smart grip system (mentioned below), the drive system, and the user interface.
- **Smart Grip System**: a unit that allows the person to actuate the right amount of force to provide sufficient grip to grab a given item depending on its weight, texture, and geometrical shape. The aim of having a smart grip system is to eliminate the margin of human error during the grabbing action. This system will be able to grab an object regardless of its shape, surface texture, or weight.

IV. IMPLEMENTATION

The manufacturing methods and implementation protocols are being filed for patenting and, thus, will not be disclosed now. In this paper, only the various phases will be mentioned and discussed briefly:

Phase 1

1.1 Machining (Figure 1)

The machining was done with a lathe and milling machine. The measurements, along with the 90 degree angles, had to be accurate to a tenth of a millimeter to ensure the smooth operation of the fingers.

1.2 Smart grip system design and testing

The smart grip system is a combination of three

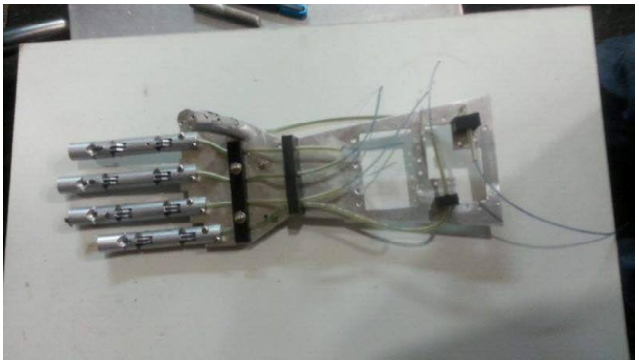

Figure 2. Assembled Aluminum Skeleton

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elements; object sensing, slip sensing, and data acquisition system. The object sensing is accomplished by micro switches in the fingertips. The slip sensing is accomplished by a modified optical mouse. The data acquisition is done by an Arduino microcontroller.

Phase 2

2.1 Assembling the aluminum skeleton (Figure 2)

After assembling the machined finger section together, the fingers were placed on the palm and forearm plate. Then the cable system was assembled on the plate.

2.2 Integrating the smart grip system (Figure 3)

The micro switches were fitted on the finger tips and the optical mouse was modified to fit into the composite cover of the index finger.

Phase 3

3.1 Integration of the drive system with the skeleton

After fitting the servo motors onto the palm and forearm plate and temporarily fixing the modified optical mouse on the tip of the index finger, the drive cables were connected to the arms of the servo motors and each finger preload was calibrated.

3.2 Further smart grip system testing

After integrating the mechanism with the smart grip system, tests were done on the system to find some coding bugs and fix them.

Phase 4

Composite cover design and testing

The composite cover design phase was dedicated mostly to find the right design that would be humanlike, proportional in size, strong, light weight, and big enough to contain all the elements of the system. This was done by hand laying fiberglass on positive and negative molds made of plaster of Paris and molding clay.

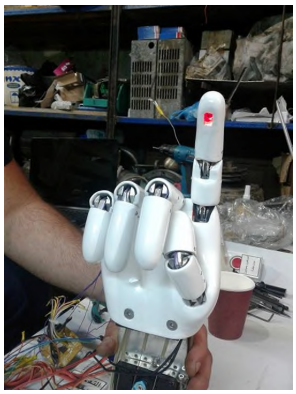

Figure 3. Integrating the Slip Sensor

Phase 5

Integration of the optical mouse in the index finger as shown in Figure 3

The most important aspect of this stage was to calibrate the exact distance of the lens of the optical mouse, from the surface of the hand. This distance has a direct effect on the information transmitted by the sensor.

Phase 6

Cosmetic finishing of the composite cover.

The cosmetic finish was handed over to a professional painter in a body shop.

V. CONLUSION

Although the current prototype, as shown in Figure 4, is not ready for the market and is in need of more research and testing to improve some aspects, it served as a “proof of concept” that can later be subjected to further development and amelioration.

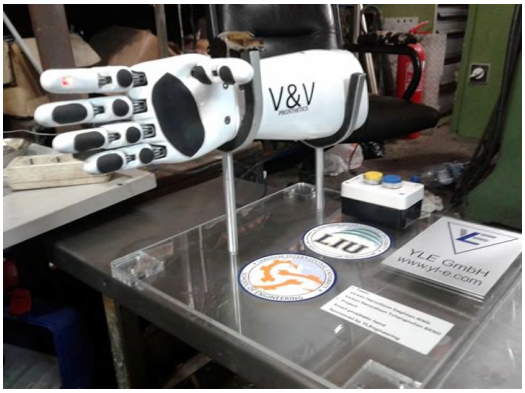

Figure 4. The Prosthetic Hand

From a manufacturing point of view, the researchers had four main objectives: 1) Heat resistance, 2) Durability, 3) Weight, and 4) Mechanism, all but one – weight – were achieved. From an electronic systems point of view, two of the three main objectives: 1) User interface (not achieved), 2) Processing, and 3) were achieved. The two objectives that were not successfully completed were the expense of durability and time limitation. These incomplete objectives will be the target of future work.

ACKNOWLEDGMENT

The researchers would like to acknowledge and thank Mr. Fadi Lama, Mr. Farris Al Hajj, Dr. Ardaches Tchangoulian, Mr. Garo Mateosian, Mr. Joseph Al Haybe, Mr. Edward Hassoun, Mr. David Slikhanian, and Mr. Harout Enichteian for their priceless help and support. This project was funded by a generous grant from YLEngineering.

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 ISBN: 978-1-61208-604-0

Impaired Hand Training Device with Wireless Data Communication

Majd Gahreeb[1] Rabah Yehya[1] Ali Hage-Diab[2] Ali Bazzi[1] Hassan M. Khachfe[3]
[1] Department of Computer and Communication Engineering
[2]Department of Biomedical Engineering
[3]Center for Quality Assurance, Institutional Assessment, & Scientific Research
International University of Beirut, Beirut, Lebanon
Corresponding author's email: majd.ghareeb@b-iu.edu.lb

Abstract— **In this paper, we aim at combining assistive technology with the Internet of Things in order to create a system with an important health impact on the quality of life of people with disabilities. In this system, an impaired hand training device with real time data transactions has been designed and developed. This device allows patients to practice their hand rehabilitation routine daily at home avoiding the exhausting transportation to the clinic or the hospital. Then, it will wirelessly and automatically send the acquired data to a Web system accessed by the physician and the patient as well. Consequently, the physician will be able to view, monitor, and adjust the requested routines for each patient and communicate this information with him/her in order to achieve the best results in the shortest possible time.**

Keywords-assistive technology; stretching sensor; hand rehabilitation; Arduino Wireless communication; Web.

I. INTRODUCTION

"Based on the Hebbian theory, Siegrid Löwel claims that "Cells that fire together, wire together" [1]". The neuroscience Hebbian theory explains the ability of synapses to strengthen or weaken over time, in response to the increase or decrease in their "synaptic plasticity", which is the ability of synapses to strengthen or weaken over time, in response to increases or decreases in their activity. Hence, this insures that neurons are able to adapt with the correct learning process and clarifies how intensive training can help patients in many clinical cases to overcome their impairments [1]. Relying on this finding, a lot of research has been applied in the domain of assistive technology. Assistive technology includes any item, tool, device or study that is designed for assisting, adapting, and rehabilitating people with disabilities. Wheelchairs, hand helpers, reaching tools, prosthesis, etc., are all examples that could be included under this umbrella. Nevertheless, research goes far beyond these traditional pieces of equipment to follow the technology revolution with many assisting smart devices.

In the last decade, these devices have been seen on the market and continue to develop. However, each of them still raises concerns, such as, reliability, ease of use, weight, the relatively expensive cost of such technology, the lack of a database that stores the acquired information and the smooth interface between the patient and the physician.

Approximately 315,000 patients in Canada live with the after effects of strokes and it costs around 3.6 billion dollars per year in hospitals and rehabilitation centers, and more than 4.5 million days in a rehabilitation center and 639,000 days in the hospital [2].

A lot of research has already been done to develop a hand rehabilitation glove. One solution was proposed in [3], in which the angle achieved by the finger is observed. In this work, in case of a slow or lacking healing process, a physician can add a routine that may be considered as a missing part of the system. This draws the attention to the importance of having a flexible system that updates the patient with the daily exercise routine to promote the healing process.

Another solution is proposed by Panagiotis Polygerinos et al. [4] and it is an automated glove for people with practical handle pathologies to help improve the catch movement. The results obtained were very promising in this work and also in the work presented in [5] by Dominic E. Nathan et al. This latter examines the design, development and validation of a custom-made sensorized glove system and its custom grasp prediction model. The validation studies helped show the capability of this glove for real-time tracking. However, both presented gloves need the direct observation of the physician during the exercises and do not provide any means to communicate remotely with him or to save the obtained results into a database for future use and analysis. Many commercial hand rehabilitation gloves are available on the market. On the other hand, different other proposed gloves are inefficient or relatively expensive [6]. Additionally, the noticeable wiring on some glove models can be a problem [7].

Furthermore, patients, such as children and elderly, might not be able to attend physical therapy due to the exhausting road trips to and from the medical facilities and that might hinder their healing process. We believe the "specificity of learning" principle should be ensured [8], which predicts that the learning of a new skill is improved when conditions of practice match those of the task in real life [9]. Hence, home-based rehabilitation could prove to be more advantageous than hospital based or outpatient treatment based since it permits a repeated practice of occupationally embedded tasks in the individual's own environment [10]. Many works have been done with the objective of moving the clinic to the home whenever possible. CNNTECH [11] is a biomedical oriented company that developed a smart glove that helps

 ISBN: 978-1-61208-604-0

stroke patients rehabilitate. However, the clinical studies are still at an early stage. Another training device called "RAPAEL Smart Glove for Hand Rehab [6]" was released by NEOFECT and it is a sensory technology that captures the patient's hand movement data and transfers it via WiFi. However, the cost is too expensive for many hand impaired individuals since it costs $15,000 according to the digital trend [6]. A recent low cost and light weight device [12] like ours was developed by our colleagues in the Lebanese International University in 2016. However, it lacked wireless interface and real time data transmission.

From all the above mentioned needs and issues in the existing work, we could observe the vital need for a reliable, affordable, light-weighted, and portable hand assistive device that can help patients to perform their hand repetitive therapeutic routines at home and that can also provide an interface between patients and their physicians.

In this paper, we present a prototype of an assistive glove that can help patients in practicing their hand rehabilitation routine daily at home. Via a Web based application and a wireless communication, the system will automatically transfer and save the achieved results of each exercise. Hence, physicians can from their part approve or ask to improve the followed routine by the patient to guarantee faster recovery.

The rest of the paper is structured as follows. Section II presents the general overview of our idea. Then, Section III contains the user requirements and specifications of the system. Section IV presents the tools used to implement the system with a few important details about the implementation steps. Finally, we conclude the article in Section V.

Figure 1. System architecture design

II. SMART GLOVE SYSTEM ARCHITECTURE

In addition to a previous work done by our colleagues at the Lebanese International University last year [12], different approaches have also explored the use of assessment devices to monitor the impaired hand function during daily life activities. However, even in the work presented in [12], monitoring and data saving is basically done over an SD card, an ultra-small flash memory card designed to provide high-capacity memory in a small size, which makes data reading, searching and retrieval a complicated mission, especially for patients and physicians who are not familiar with recent technology advances. Most of the already existing solutions are to be used in clinics under physician supervision. Nevertheless, we benefited from them to create a standalone system that could be used by the patient, with no need to go to the clinic or to be under the direct supervision of an expert since all the needed utilities could be managed by the patient at home.

The objective of the project presented in this paper is to develop a smart assistive glove that will monitor the improvement of the impaired hand, and save this information directly into a permanent storage that could be accessed remotely by the physician and the patient for review and edit.

As shown in Figure 1, our system is composed of the assistive glove that is mounted by the same stretching sensors used in [7][13]. These sensors are basically made from elastic rubber and graphite, which have lower cost and lighter weight compared to other existing sensors with the high accuracy required to monitor the movement of the hand. Moreover, these stretch sensors have a role in converting the physical parameters into an electric signal, allowing them to reflect the finger's motion and angles as the individual moves his/her digits.

The glove will be connected wirelessly to the Internet via a node MCU (ESP8266) WiFi wireless module which is an open source IoT platform. This node includes a firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems and hardware which is based on the ESP-12 module. In addition, the sensor readings will be shown on an LCD (Liquid Crystal Display) screen in order to help the patient directly see his achieved results. Accordingly, the results will be transmitted wirelessly to a website that will be connected to a database which organizes all the requested information by the physician and performed by the patient for future monitoring and reviewing.

This real-time reading will allow the physicians to make better treatment plans and optimize the given routines in order to increase the number of patients who improve their condition in a short period of time. Moreover, it will allow easy access for both physicians and patients to check the progress of the daily routines requested for rehabilitation and to facilitate and declare the aforementioned missions by each one of them according to their roles.

Patients can access the website by logging in their specific page where they are able to check what they have to do and their progress. This process will help in improving patient health, since it is proved that integration of augmented feedback and exercises can stimulate the learning process in rehabilitation therapy by making patients more

 ISBN: 978-1-61208-604-0

conscious of their performance [14]. An additional feature of the smart glove system is to communicate with the patient via SMS (Short Message Service) messages from the website to inform him about his progress or about any urgent issues.

Finally, the cost of our system is very low taking into account the parts used to build it, the expected delivered service, and the flexibility of use in different aspects.

III. USER REQUIREMENTS AND SPECIFICATIONS

Our proposed system consists of two main components that are the assistive glove used by the patient at home to rehabilitate his routines, and the website that could be used by the physicians and the patients as well, each according to his/her role. Below, we list the requirements of each component of the system. This is also shown in the use case diagram presented in Figure 2.

A. Glove (Patient side):
- Easily wearable with hidden wires and flexible stretch sensors.
- Easy to change the battery by simply plugging the corresponding cable into the box.
- Enable monitoring the angle value using an LCD.
- Wirelessly connected to the WiFi router at home in order to send the corresponding information to the server.

B. Website (Physician side):
- Ability to login/out, change/reset the password.
- Ability to add to the patient's list their patients and their general information that will be directly saved in the database.
- Ability to submit a mission or, in other words, the tasks the patients should try to do in the routine process by adding a specific routine to each patient.
- Ability to check all their patients' routines that they have submitted.
- Ability to check the routine progress analysis of their patients (advancement) in a table and in a graphical form.
- Ability to send an SMS text directly from the website to their patients' mobile phone according to the phone number that has been registered in the patient page.

C. Website (Patient side):
- Ability to login/out, change/reset their password.
- Ability to check his routine only and the remarks added by the physician.
- Ability to check his routine progress analysis (advancement) in a table and graphical form.

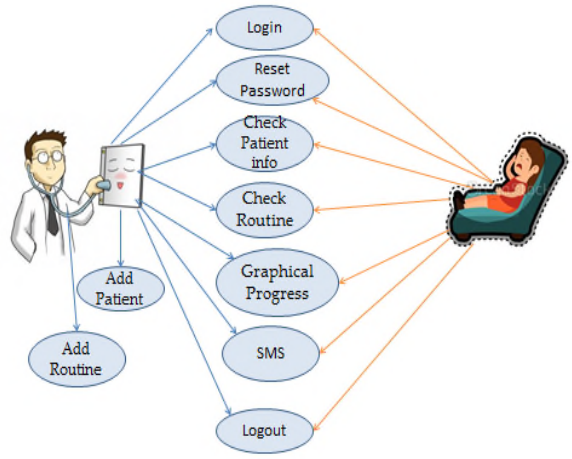

Figure 2. Use case diagram of the system

IV. IMPLEMENTATION TOOLS AND SUMMARY

As indicated in Section III, the smart assistive glove system consists of two major components that are the glove and the website. We will start this section by listing the technical tools that we used for creating these components. Then, we present the details followed to implement the glove. A summary of the main pages of our website are then listed and explained.

A. Implementation tools:

➢ Glove:
- Arduino -Node mcu 0.9 (ESP8266 – 12 Module)
- Accelerometer ADXL 345.
- Stretch sensor.
- LCD monitor 16 x 2.
- A light-weighted medium thickness glove
- Connecting wires, resistors, a 10K potentiometer, regulators, and a 9V battery.

➢ Web application:
- Use XAMP to run the servers APACHE [15] and MYSQL [16].
- Use PHP for server side programming [17]
- Use PHP MyAdmin and MYSQL to create database [18]
- Use Arduino Software [19].
- API for SMS.

After listing the technical tools used in the development, we briefly explain below the steps followed to implement the system.

B. Glove Implementation

As presented in the previous work in [12] and [13], the stretch sensors are made from elastic rubber dipped in finely

 ISBN: 978-1-61208-604-0

grated graphite-alcohol mixture, then dried out and fixed with a thin layer of white glue to keep the graphite from falling off the rubber. Since graphite is a good electrical conductor, the nonconductive rubber will turn into a stretch sensor that converts the physical parameter into an electrical signal to be acquired by the board for monitoring and control.

A voltage divider is used to convert the change of the resistance into an electric analog voltage readable by the Node MCU module. This voltage will be mapped into angles indicating the flexion or extension of the digits. The patient should reach the desired angles set by the physician during each routine and repetition, so in order to do that, an LCD monitor will display the values of the angles and the position of the patient's hand indicated by the attached accelerometer on the wrist.

In order to map the stretch sensor, one must wear the glove, extend his/her fingers and note the measured value as zero, then flex the fingers to the maximum point and note the obtained value as 90. Mapping these two values will serve as a range for the voltages with their corresponding angles.

The stretch sensor is connected to another resistor of similar resistance to create a voltage divider, thus converting the changes in resistance into changes in voltages. Then, the voltage divider's output is connected to the only analog pin A0 of the Node MCU to acquire the data.

An accelerometer is also connected to the Node MCU input digital pins to measure the wrist's acceleration and map it into an angle. The LCD is connected to the Node MCU in order to display the values of the stretch sensor and accelerometer clearly visible to the patient.

C. Website Implementation

The implemented website consists of two main users that are the physician and the patient. Each can access the system using his own credentials. Below, we list for each of the two roles the main activities and actions that could be implemented.

- **Physician's Side**

When the physician logs into his page, a list of his patients appears with their information (name, phone number, gloveID and email address). Moreover, a button for each patient will take him to this latter corresponding page to display every patient's routine separately, add routine to every patient, check his routine progress analysis (advancements) in a table and in a graphical form and send him/her an SMS to the number saved in the database for that patient.

Figure 3 shows the "Add routine" page where the physician is supposed to submit the routine (the required angle that the patient is supposed to practice with, the number of times he is supposed to repeat the exercise, etc.). On the other hand, the patient will be able to see this information directly and hence could start his routine on the given date.

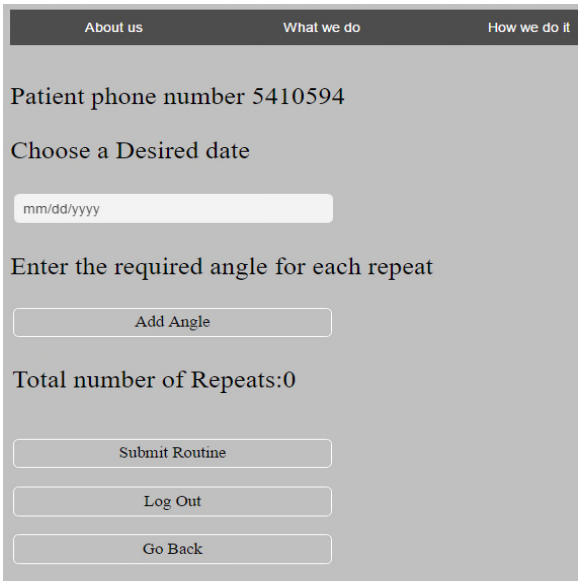

Figure 3. Add Routine

- **Patient Side**

When the patient logs into his page, his achievements records appear with a well specified number of repeats and desired angle for every repeat that he is supposed to do during a certain period of time, as shown in Figure 4.

We notice from this figure how routines are organized according to the date of their occurrence, with the required angle to be done by each requested repeat and the achieved angle that could be reached by the patient during practice time. Moreover, the system automatically generates these records in graphical form to make result observation easier for the patient and the physicians as well, since both are able to show the results as presented in Figure 5.

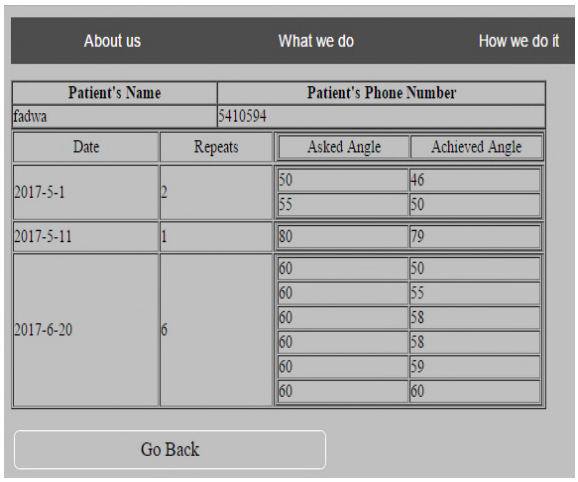

Figure 4. Data transferred saved in a table form

Figure 5 shows graphically the comparison between the asked and the achieved angles.

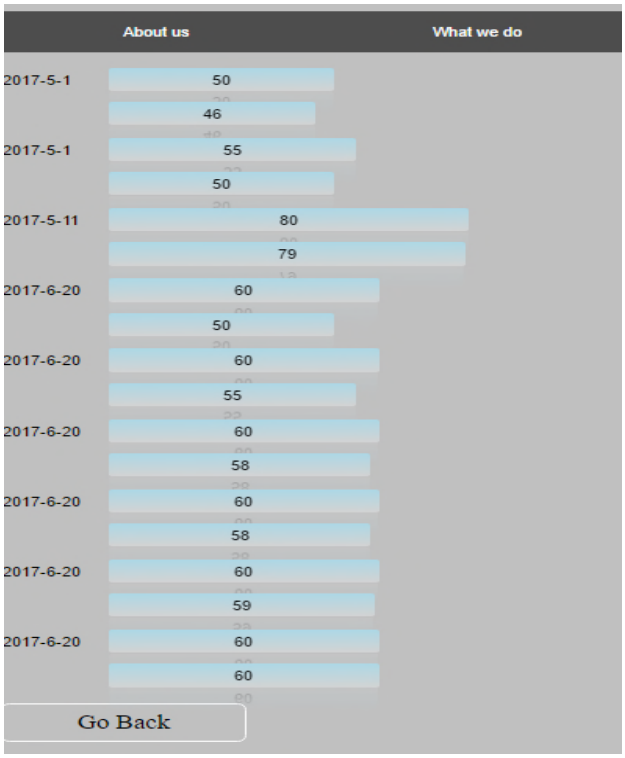

Figure 5. Data transferred shown in a graphical format.

V. CONCLUSION AND FUTURE WORK

The proposed system could save a lot of time and effort for all involved users. This can be achieved by spending less time at the clinics, analyzing patient's activities and planning. These activities could be done at home where patients are more comfortable, thus increasing the benefits of the session.

Physicians can take their time interpreting the results and conducting a detailed analysis of the data obtained and taking the appropriate next steps. In addition, the system is based on a database that will always be reachable and secured. Physicians and patients can easily access this website that is clear enough and simple to use.

The contribution proposed in this paper is the preliminary step towards a more developed and stable system that would surely take its place among other existing conventional devices in terms of accuracy, speed, etc.

Smart assistive glove is a very helpful device for people with impaired hands and there will always be room for improving system functionality. The accuracy of the stretch sensor can be improved by using more stretch sensors. The standard deviation can be computed after conducting many experiments and improving the calibration of the sensors.

Moreover, the website could be improved and augmented in different pages. Besides, all the trails on the website were done locally and it should be tried on a real domain to make sure everything is working perfectly to be prepared for using the smart glove on the market.

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 ISBN: 978-1-61208-604-0

Cervical Cancer Prevention in Rural Nicaragua - An Ambassador Model

Nicole Wood, Anaisy Pargas, Stephanie Romero
University of South Florida Morsani College of Medicine
Tampa, FL, U.S.A.
Email: nicolew1@health.usf.edu, anaisy@health.usf.edu, stephanieromero@health.usf.edu

Abstract -- **Cervical cancer prevention is dependent on frequent Pap smear screening based on national guidelines and recommendations. Several identified barriers to health access may prevent women in several Latin American countries from receiving the consistent care necessary to prevent cervical cancer. The objective of this study was to evaluate the effectiveness of a peer-education based women's health program in increasing Pap screening adherence and cervical cancer awareness in a rural Nicaraguan community. In this community trial, researchers created an ambassador model for community education and evaluated the effects by way of surveys and chart review at a local clinic.**

Keywords-global health; Human Papillomavirus (HPV); cervical cancer; health education; women's health.

I. INTRODUCTION

In Nicaragua, cervical cancer is the leading cause of cancer-related deaths, with an estimated 18.43 deaths per 100,000 females in 2011 [1]. Prevention of cervical cancer is largely dependent on periodic Pap smear screening. The nature of this test makes it highly specific, but only moderately sensitive, requiring periodic testing to ensure results remain accurate [2]. Access to consistent health care is difficult in many Latin American countries due to educational, socioeconomic, and cultural barriers [3][4]. There is a larger difference in the mortality of cervical cancer than the incidence of cervical cancer when comparing these numbers between developed and developing nations [5]. This supports the idea that the greatest risk factor leading to death from cervical cancer is the lack of regular screening or health care intervention.

The objective of this study is to evaluate the effectiveness of a peer-education based women's health program in increasing Pap screening rates and cervical cancer awareness in a rural Nicaraguan community.

In section II, we describe the methods used by researchers to establish the education program and perform the 2 separate chart reviews. In section III, we present a summary of the pertinent raw data from both the survey assessments and chart reviews. In section IV, we present the qualitative data obtained from education sessions. In section V, we combine quantitative data and qualitative data and discuss limitations and future indications for this investigation.

II. METHODS

Investigators used an educational model and materials previously validated by Moffitt Cancer Center [6] on a rural US Hispanic population to develop a health education ambassador system. Community leaders (n=11) in a small rural Nicaraguan community were identified via collaboration with a local non-governmental organization (NGO), recruited, trained, and then instructed to educate other women (n=29) in a session-based manner. These sessions were organized by the ambassadors in local homes, and the participants in attendance were friends or family members recruited by the ambassadors. Sessions were held in small groups in living rooms or private terraces to encourage conversation amongst participants. Data was collected through questionnaires and structured discussion.

Eligibility for both ambassador and participant groups was dependent on age (21-70), gender (female), and location (living within the community of Cedro Galan). Specific eligibility for community leaders to serve as ambassadors included ability to be contacted via phone, attendance to training sessions, and willingness to host independent sessions.

The success of this education, and community perceptions of Pap screening and cervical cancer, were measured through a survey (n=40). This survey contained both true/false items for evaluation of knowledge and scaled health prevention readiness measurements.

All discussion topics were archived by researchers and coded for categories for qualitative analysis.

A chart review was performed at the local clinic in order to establish baseline community Pap screening adherence (n=564). Eligible charts from women ages 21-70 were reviewed and recorded based on age, smoking status, Pap screening history and records, and available comorbidities.

III. QUANTITATIVE DATA

A. Survey Results

Comparisons made between pre-session survey and post-session survey are presented in Table 1. For the two questions presented in Table 1, the results were consistent with p values of p=0.09, and p=0.61, respectively. These results are further discussed in the conclusions section below.

 ISBN: 978-1-61208-604-0

TABLE I. PRE- AND POST- SESSION SURVEY RESULTS

	Question Category					
	Awareness of HPV			*HPV causes cervical cancer*		
	Total	*Incorrect (%)*	*P-value*	*Total*	*Incorrect (%)*	*P-value*
Pre-test	34	6 (17.6%)	p=0.09	36	1 (3.7%)	p=0.61
Post-test	27	2 (5.6%)		33	1 (3%)	

B. Chart Review Results

Baseline chart review data for the 564 patients reviewed, the mean age was 38.6 years (+/- 12.4 years) with a minimum of 21 years and a maximum of 70 years. The review indicated that 498 (88.3%) of eligible women lacked positive Pap screening information in their clinic chart. Of the 66 (11.7%) women that had Pap screening on record, 2 (3%) had an abnormal result possibly indicative of cancer. Of the charts reviewed, smoking data was only available for 34 (6%) patients. Of these patients, 4 (11.8%) were listed as current or past smokers.

IV. QUALITATIVE DATA

Participants identified multiple barriers to effective cervical cancer prevention in their community based on personal experience. Qualitative data was assigned to categories to develop the following themes shown in Table 2 below. All participants agreed with the need to prevent cervical cancer and increase awareness in their community.

V. CONCLUSIONS

The overarching goal of this multi-part study was to increase cervical cancer awareness and identify a method for effective community education. While the survey data did not provide evidence of a change in cervical cancer awareness following participation in the educational program, researchers identified several confounding factors, including the unfamiliarity of the population with the survey format. The formatting used included several categories with answers coded in a graduated format (very likely, somewhat likely, etc.), which weren't familiar to this patient population despite repeated instruction by researchers. This finding may be useful for future studies in similar communities and an additional long-term study should be completed to test a reformatted and more intuitive survey with simplified questions coded with only two or three predetermined answers. Future studies may test follow-through with cervical cancer prevention information learned during educational sessions by way of increased Pap screening adherence in the population. Follow-through might be monitored by way of further chart review and survey at the local clinic. With regards to the low screening rates indicated by the chart review, it must be considered that women do have some access to public healthcare, and may have obtained their screening at more remote healthcare locations. Future study via survey will measure prevalence of screening regardless of clinic location.

TABLE II. THEMES AND CATEGORIES

Themes	
Category	***Related Concern***
Education Barriers	Poor Health Literacy
Financial or physical barriers	Travel and clinic availability
Familial, marital, religious barriers	Community stigma
Fear or diagnosis of cancer	n/a

Significant value was found in the formatting of this program to provide a small, safe space for discussion of sensitive topics, to encourage questions, and for the sharing of knowledge. The identified themes suggest that barriers to adequate cervical cancer prevention encompass several aspects of daily living for women in rural Nicaragua. These themes identified during this study may be used to create additional opportunities for future educational sessions on other health topics identified by the community.

ACKNOWLEDGMENT

We would like to thank Manna Project International for assistance in-country, University of South Florida Morsani Scholarly Concentrations Program for guidance, and Dr. C.D. Meade, Dr. C.K. Gwede, and K.F. Fleming with Moffitt Cancer Center/National Cancer Institute/Tampa Bay Community Cancer Network for use of materials from their pilot project.

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 ISBN: 978-1-61208-604-0

Effects of Aerobic Training Combined with Inspiratory Muscle Training on Cardiopulmonary and Skeletal Muscle Function, Dyspnea and Quality of Life in Patients with Chronic Heart Failure

Zahra Sadek/ Said Ahmaidi
Laboratory EA 3300 (APERE) « Adaptations Physiologiques à l'Exercice et Réadaptation à l'Effort »
Picardie de Jule Vernes University
Amiens, France
Zahra.sadek@etud.u-picardie.fr
Said.ahmaidi@u-picardie.fr

Wissam Jomaa / Fadia Shebbo
Laboratory « PhyToxE Physio-toxicité environnemental »
Faculty of Sciences, Lebanese University
Nabatieh, Lebanon
wjoumaa@ul.edu.lb
Fadia.shebbo@gmail.com

Mahmoud Youness
Medical Research Center
Beirut Cardiac Institute
Beirut, Lebanon
Myouness55@yahoo.com

Wiam Ramadan
Lebanese Institutes for Biomedical Research and Application (LIBRA)
Lebanese International University (LIU)
Beirut, Lebanon
Wiam.ramadan@liu.edu.lb

Abstract - This randomized controlled study aims to determine the additive effects of combining Aerobic Interval Training (AIT) with Inspiratory Muscle Training (IMT) in subjects having chronic heart failure and inspiratory muscle weakness. 32 patients were enrolled, and underwent a 3 months training program each allocated to one of three different exercising groups comprised of IMT, AIT and a combination of both. IMT training involved a 15 minutes inspiratory training at 60% maximal inspiratory pressure, AIT involved a 30 minutes treadmill exercising at 60% to 90% of maximum heart rate, and the combined group performed both types of training separated by a rest period. Pulmonary function, respiratory and skeletal muscles function tests were performed as well as Quality of Life (QoL) and functional capacity before and after interventional periods. Our results showed the benefits of using the combination of the two training types on inspiratory muscle and skeletal muscle function. Also, additional improvements in functional capacity were observed using the 6 minutes' walk test and by evaluating the patients' QoL.

Keywords: Heart failure; Aerobic interval training; Inspiratory muscle training; Inspiratory muscle weakness; Cardiac rehabilitation; Quality of life.

I. INTRODUCTION

The main obstacle that heart failure patients face is exercise intolerance, usually manifested by fatigue and dyspnea during the daily living activities. Thus, these symptoms might contribute to physical impairment and reduce the autonomy of individuals. Exercise training has been shown to be safe and beneficial in heart failure patients. Thus, the non-pharmacologic strategy guidelines recommended exercise training to relieve symptoms, improve exercise tolerance, quality of life and reduce the rate of hospitalization.

II. REVIEW

Exercise training is highly recommended in patients with Chronic Heart Failure (CHF) [1][2][3]. The significant improvements on patients Quality of Life (QoL) and functional capacity have been proven by many researchers after Aerobic Interval Training (AIT) [1] and Inspiratory Muscle Training (IMT) [4][5]. The combination of both modalities has been promising and proved to be more beneficial than each training modality taken alone. Two recent studies have confirmed the additional effects of combining IMT and AIT in CHF patients. Winkelmann et al. [6] reported additional improvements in cardiorespiratory response in the combined group when compared with aerobic training group. Adamopoulos et al. [7] reported additional benefits in serum biomarkers and dyspnea sensation in the combined group patients compared to the aerobic training group. Both studies did not measure the benefits at the level of skeletal muscle function, and did not compare their combined group patients to IMT group or to a control.

III. AIM

The first aim of this study is to determine the effects of combined training on skeletal and respiratory muscle function, exercise capacity, left ventricular remodeling, dyspnea and quality of life in CHF. The second aim is to find the best training exercise that could have additional benefits on measured parameters.

IV. METHODS

32 patients with stable CHF and inspiratory muscle weakness were randomly assigned to a training program for 12 weeks (3 times / week). The patients were divided, thereafter, into four different groups: controls (n=8), aerobic

 ISBN: 978-1-61208-604-0

interval training AIT (n=8), inspiratory muscle training IMT (n=8), and combined AIT+IMT (n=8). AIT consisted of treadmill exercise at 60% to 90% of Maximum Heart Rate (MHR). Interval training was chosen for its confirmed benefits over continuous training [8]. The treadmill exercise included 5 minutes warm-up period, followed by four bouts, each of 4 minutes at high intensity (60%-90% of MHR) interspaced by five low intensity bouts (50% of high intensity), each of 2 minutes, and ended by 5 minutes cool-down period. IMT was performed for 15 minutes using the PowerBreathe device [4]. It included 4 bouts, each of 3 minutes at high intensity (60% of maximal inspiratory pressure (MIP) with a warm-up and cool-down periods each of 1 minute at low intensity (50% of maximum intensity). The combined group training consisted of AIT followed by IMT session, with 5 minutes rest in between. The controls were instructed to maintain their habitual daily living activities. At baseline and after the training period, patients underwent pulmonary function test by Spirometry, respiratory muscle function assessment by electronic pressure transducer, echocardiography, stress test, skeletal muscle function test using hand-held dynamometer, and 6-min walk test. Dyspnea, according to Borg scale, and QoL, according to Minesotta living with heart failure questionnaire, were also assessed.

V. RESULTS

Exclusively, skeletal muscle strength and endurance improved significantly in all three training groups. The combined group was shown to be the best group at the level of all improved parameters. Compared to the control, the combined group had 11% improvement in the maximal voluntary isometric force (kg) and a 30% improvement in the quadriceps muscle endurance capacity ($p < 0.05$). Compared to the control, this training has shown a 96% improvement in inspiratory muscle strength ($p < 0.01$) and 87% improvement in inspiratory muscle endurance ($p < 0.001$). Quality of life score, functional capacity, exercise time and dyspnea sensation had been improved in all three groups with the combined training being the most beneficial. No significant differences were reported between groups on spirometric and cardiac structure variables, forced vital capacity, forced expiratory volume and left ventricle ejection fraction.

VI. DISCUSSION

In this study, we have reported significant improvements in CHF patients after exercise training. We proved that combined exercise training has beneficial results on the respiratory muscle strength and endurance, as well as functional capacity and QoL. These results were previously shown by Winkelmann et al. in 2009 and Adamopoulos et al. in 2014. Skeletal muscle function that had not been assessed by these two studies, have also been significantly improved in our patients. Such beneficial effects in skeletal muscle, strength and endurance, might be due to improved skeletal muscle intrinsic properties.

VII. CONCLUSION

Combined AIT and IMT was safe and more effective in improving exercise capacity, skeletal muscle function, inspiratory muscle strength and endurance, pulmonary function, and QoL in CHF patients. Since no improvements have been detected in the cardiac function, we recommend that future studies must include a higher number of patients and assess for cardiac related improvements after combined training.

FUNDING ACKNOWLEDGMENT

This research was supported by *National Council* for Scientific Research (CNRS), Beirut, Lebanon.

ETHICS

The study is approved by the ethics committee of Beirut cardiac institute, Beirut, Lebanon.

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 ISBN: 978-1-61208-604-0

Evaluation Phase of a Novel Blood Pressure Monitor Device

Adhurim Hajzeraj, Marco Belcastro, Davide Alfieri, Brendan O'Flynn
Tyndall National Institute
University College Cork
Cork, Ireland
E-mail: adhurim.hajzeraj@tyndall.ie; marco.belcastro@tyndall.ie; davide.alfieri@tyndall.ie; brendan.oflynn@tyndall.ie

***Abstract*—Blood pressure (BP) has always been one of the most important parameters in monitoring cardiovascular system conditions and coronary artery diseases (CAD), such as angina and myocardial infarction (commonly known as a heart attack). This is due to the fact that many of the changes within the cardiovascular system, like clogged arteries for example, are reflected by changes in BP. A number of methods and devices that can measure BP are available on the market for both clinical and consumer use. However, being able to measure one's own BP non-invasively, with the required frequency (even continuously) in a comfortable fashion remains an unsolved problem using currently available systems. To date, the Pulse Transit Time (PTT) measurement method has been seen as a feasible approach to help bring current blood pressure monitoring systems to a stage where non-invasive, continuous measurements are viable. However, developing a system which uses the PTT method for blood pressure measurement is as yet an unsolved problem and it remains a challenging way to achieve accurate BP results despite considerable research in the past decade. In this paper, we present the first step in building a smart sensing system that overcomes the technical difficulties associated with accurate measurement of PTT. The novel hardware developed incorporates multi modal sensing capability to explore and quantify the relationship between blood pressure and PTT in clinical tests.**

Keywords - blood pressure; pulse transit time; ECG; PPG; calibration; real time data.

I. INTRODUCTION

According to statistics, cardiovascular diseases (CVD) are the main cause of deaths in Europe with 45% of all deaths caused by CVDs. The overall estimated cost to the EU economy is €210 billion a year [1]. The motivation for this research is to reduce these statistics by finding a better method of monitoring real time blood pressure (BP). This will help clinicians to monitor, diagnose and improve the condition of the cardiovascular system [3].

The current state of the art in BP measurement utilises a number of different methods and devices including catheterization, auscultation, oscillometry, volume clamping, and tonometry, with catheterization being the most accurate standard currently [2]. In general, the accuracy of the measurements using existing devices is acceptable, but they have a number of drawbacks. Firstly, where inflatable cuffs are used, they tend not to be comfortable for the user and as a result are inappropriate for long term continuous monitoring. Secondly, clinical grade systems need to be operated by doctors, which causes a phenomenon called 'white coat syndrome', where BP readings are inaccurate due to the presence of the clinicians.

A system which would enable clinicians to take accurate, real time and continuous BP measurements would be invaluable to doctors in diagnosing CVDs at an early stage [3].

In this paper, the first development stage of such a system for BP monitoring based on the PTT method is presented. Section II of this paper describes the theory behind the PTT measurement method. Section III describes the evaluation of components integrated into the system hardware platform and the design of a custom hardware and new sensors. Section IV concludes the work with some preliminary test results and a description of future work to be undertaken.

II. PULSE TRANSIT TIME

A method that seems to have a good potential to enable non-invasive continuous BP measurement is the Pulse Transit Time method. PTT is defined as the time needed for the blood wave that goes out of the heart with each beat to arrive at a peripheral body site, in our case the wrist or fingertip. The delay (PTT) is calculated as the time difference between the peak of electrocardiograph (ECG) and the peak of photoplethysmogram (PPG) signals.

The main factors that determine the speed of propagation of the pulse wave, and which thus affect the PTT value, are the elasticity coefficient, the thickness of the arterial wall, the end-diastolic diameter of the vessel lumen and blood density [4]. In 1878, Moens and Korteweg developed a formula that relates the velocity of the pulse with the factors as described in (1):

$$PWV = \frac{D}{PTT} = \sqrt{\frac{tE}{\rho d}} \qquad (1)$$

The Pulse Wave Velocity (PWV) is dependent on a number of arterial properties, namely the elasticity of the artery wall E, the arterial wall thickness t, the arterial diameter d and the density of the blood ρ [5]. So, as the density of blood is close to that of the density of the water, the main factors that influence the velocity of the pulse wave are the properties of the arterial vessels, stiffness and

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thickness. These factors vary from person to person on an individual basis [4]. In the calculation of BP parameters from PTT readings for an individual, this would be solved through a calibration activity as part of the measurement protocol, but this is insufficient, as vessel properties keep changing in a dynamic fashion due to a variety of factors [6]. Factors that can change vessel properties include ambient temperature [7, 8] barometric pressure [9], sleep-wakefulness status of the person [10], time of the day [11], sport activities [12] and sometimes it can even change by the control of the brain or sympathetic system [13].

III. TYNDALL PTT EVALUATION SYSTEM

In order to evaluate the impact of the variability inducing factors described above in the evaluation of BP and blood vessel properties, the WSN group at Tyndall has developed novel multi modal sensing system with the required hardware, sensors and algorithms, to be able to carry out the necessary measurements. The design flow utilised to build this system is shown in Figure 2 and the first prototype of the measurement system is shown in Figure 1.

A. *Microcontroller Hardware System Design*

The focus of this system development is the implementation of a smart sensing device in the form factor of a wrist watch, which would include the processor, battery, data visualisation interface, communications and all sensors.

To achieve this, our design methodology had to focus on three main parameters. First, the size of the components should be small enough to fit in our miniaturised target device. Second, the microcontroller (MCU) should be powerful in its operations, as it will be a real time data acquisition system and it will run all the algorithms inside the embedded microprocessor. And third, it should be a system that spends as little energy as possible as it is battery operated.

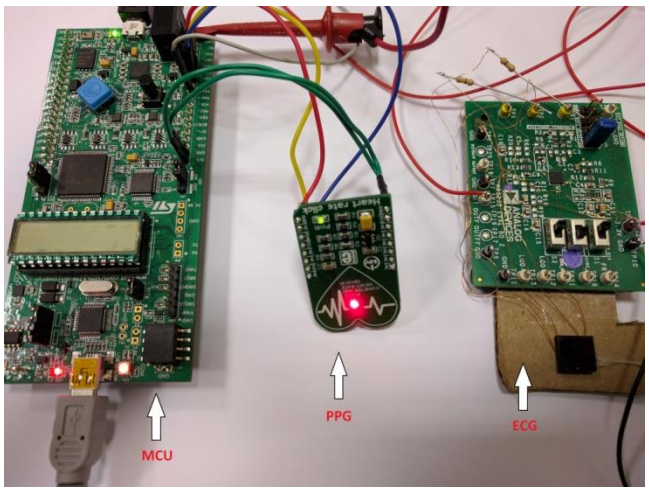

Figure 1. Setup of the evaluation board prototype data acquisition system.

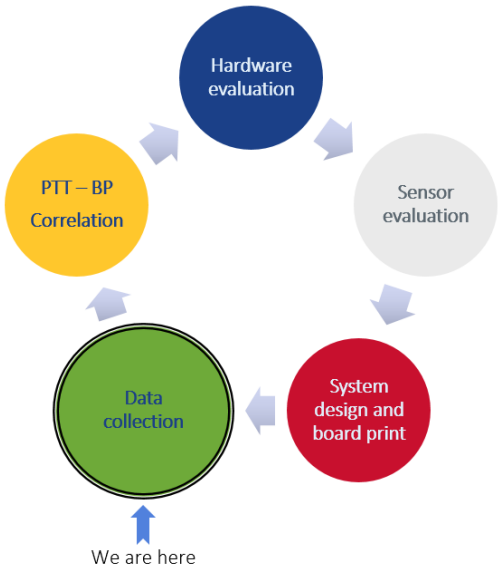

Figure 2. Design and test flow for the PTT system and current status.

Considering all these parameters, we have chosen the STM L series microcontrollers [17] to use as a computing unit.

As this device is a 32-bit microprocessor that can run at clock speeds of up to 100 MHz, it will satisfy our computing needs from an algorithmic perspective. At the same time, size-wise the STM component is small enough to fit inside a smart watch form factor system and is one of the lowest energy consuming microcontrollers on the market, if embedded code is managed appropriately. In addition to the before mentioned performance characteristics of the STM component, the MCU is also required to have a powerful Analog to Digital converter (ADC) and other digital interfaces to read data from the chosen sensors. Figure 1 shows a picture of evaluation boards that we are using as a first data acquisition prototype. The board on the left is the evaluation board with the STM microcontroller MCU.

B. *ECG and PPG sensors*

To develop the necessary algorithms to calculate PTT, it is anticipated that we will need to have datasets associated with two signals associated with the cardiovascular system. Heart, during work activities, generates a bio-signal that is well known and characterised as ECG, this is one of the wave forms we need to establish our BP measurement algorithm. Generally, these signals are recorded by placing electrodes on the skin, on the chest area, where the signals are stronger. Reading ECG by placing electrodes on the chest, gives the strongest and most easily read signal, but this is not comfortable and convenient for the user. For the Tyndall ECG measurement system, we will use two active electrodes, which will be placed in the watch in a wrist mounted implementation.

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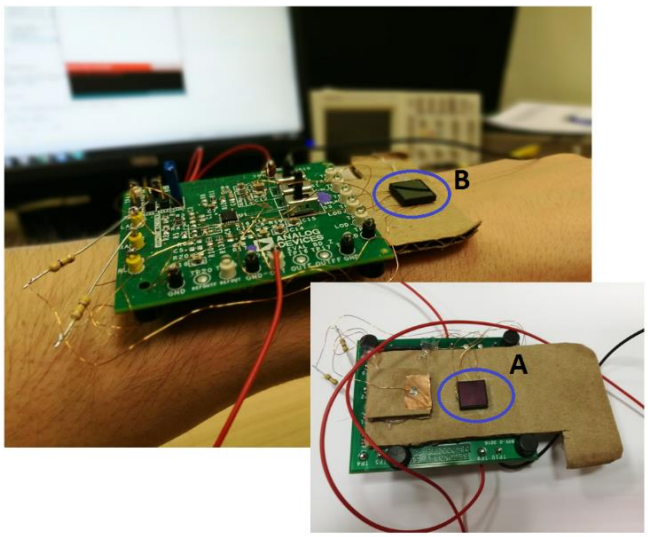

Figure 3. Evaluation board of ECG sensor.

The sensor used for this application is named the Electric Potential Integrated Circuit (EPIC) from Plessey Semiconductors [16]. The EPIC sensor can be used, as a replacement technology for traditional wet-electrode ECG pads, because it requires neither gels nor other contact-enhancing substances. When the EPIC sensor is placed on (or in close proximity to) the patient, an ECG signal can be recovered.

To illustrate the placement of the electrodes to enable ECG measurements, consider Figure 3, where we show the development board of ECG sensor placed on a subject's wrist (electrodes in contact with the skin on the underside of the board as shown in the smaller picture). To enable ECG measurement in the wrist mounted scenario, there are two electrodes, electrode A and B. Electrode A will be under the watch and will touch the skin. Electrode B will be placed over the watch, so every time the user wants to measure BP, the user should touch electrode B with a finger of the opposite hand to read the differential signal. Figure 4 shows the differential amplifier which enables generation of the differential bio-signal. Input1 is the electrode touching the skin on the wrist and Input2 is the electrode touched by the finger of the opposite arm.

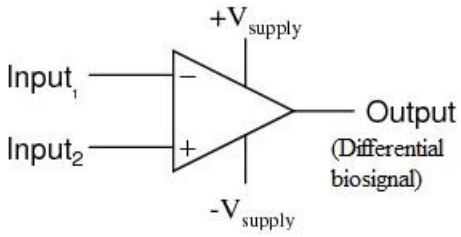

Figure 4. Generating differential biosignal from two inputs

Figure 5. Targeted final device (future work).

Figure 5 shows the layout how the final device would look like. Now, the electrode B from the previous picture would be the brown square on the side of the watch and this is where the user makes the electrical connection and completes the circuit to enable an ECG reading to take place.

The second waveform that is needed to develop the BP measurement algorithm is the signal generated from a photoplethysmogram (PPG) sensor, which shows the level of the volume of blood circulating near the sensor. The system used in the Tyndall implementation is a Maxim PPG sensor, MAX30100, which contains two light-emitting diodes (LED), one red and the other one is infrared together with a photodiode.

The change in volume caused by the pressure pulse is detected by illuminating the skin with the light from a LED and then measuring the amount of light either transmitted or reflected to a photodiode. Each cardiac cycle appears as a peak, as seen in Figure 9.

We are using this sensor to read PPG data from the fingertip, which is optimal as at the fingertip the PPG signal tends to be clear and not very noisy. Care needs to be taken however to ensure the sensor does not move when it is touching the fingertip. For initial data set acquisition and algorithm development, the fingertip implementation will be used for this reason until the wrist PPG sensor development is finished.

The same sensor has been tested acquiring real time data from the wrist mounted implementation. On the wrist the waveforms tend to be noisier and will require further filtering and signal processing to develop a signal of sufficient quality for use in real scenarios.

C. Prototype wrist mounted PPG data acquisition system

Based on the PPG measurement system described in the previous section, the WSN group at Tyndall have developed an application specific, new, PPG sensor system, which will enable data sets from the wrist to be taken directly and is of a form factor appropriate to that envisaged for the final product. A picture of the board is shown in Figure 6, where one can see the main components on a 5cm by 3cm sized PCB microsystem. The board contains a USB connection module, the microcontroller, the ECG sensor and the new PPG sensor circuit, which will be described in the next few paragraphs. A 3D printed enclosure will be printed for the board, which

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will make it able to be used as a wrist mounted system and facilitate collection of data from participants in a reliable, repeatable and accurate fashion.

Experiments have shown that variation in the position of the LEDs, as well as the particular power and wavelengths of different LEDs impact significantly on the quality of the PPG signal obtained.

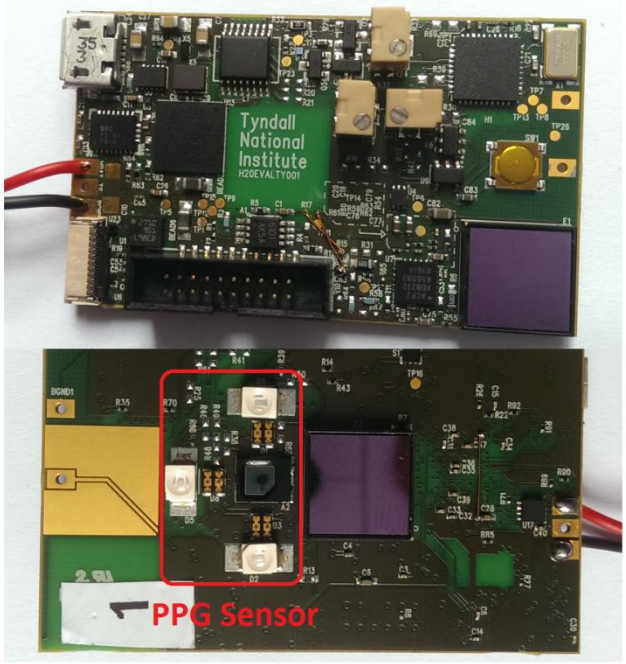

Figure 6. Wrist mounted PPG data acquisition system.

To test different scenarios, we have designed an integrated circuit with nine LEDs mounted in a circular manner around a photo diode, three green LEDs, three red and three infrared are used for this experimental setup. Diodes are arranged around the photodiode, as shown in Figure 6. This series of experiments is currently underway and will enable the design team to find the optimal configuration of diodes from the perspective of position, colour (wavelength) and intensity.

The new PPG sensor circuit is designed with the intention to test different configurations and positions of LEDs and photodiode within the same board. There are three different options to control LEDs in the same board. A block diagram of this circuit is shown in Figure 7, which describes the flow, how the MCU can control LEDs through the three LED controlling plans.

There are three experimental setups developed for this system to optimise PPG acquisition parameters. In option A (Plan A), an additional integrated circuit (IC) to MCU will control which LEDs will be on and the limit of current intensity. This IC has an analog output so that we can vary very precisely the intensity of the light output from the LEDs to achieve the optimum level for wrist monitoring of PPG signals.

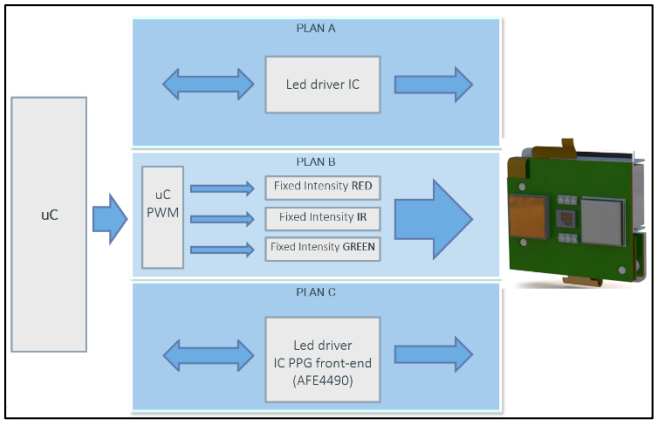

Figure 7. Three different test configurations of LEDs from PPG sensor.

In the option B (Plan B), every colour group (green, red and infrared) is connected to a potentiometer and Pulse Width Modulation (PWM) unit of the MCU. This will enable variation of the intensity of the LEDs very precisely. Also in this case, the output will be analog and the ADC can be used to read data.

The option C (Plan C) requires the integration of an additional IC also. This chip (Analog Front End - Texas Instruments AFE4490 [18]) controls the state of LEDs in a similar way to option A, except that LEDs here can be controlled only in groups, so there is the same intensity for all the red LEDs for example. In this case, digital output is the advantage, so data can be read the same way that is done with the fingertip PPG sensor. If accuracy is the same with other plans, this plan can be selected as it is more convenient because the chip samples data and the output is given through a digital protocol.

D. Sensor Data Acquisition System evaluation

To calculate PTT, we use the peak of the ECG wave form and the peak of the PPG wave. Other features of waves can be used, like the beginning of QRS complex in ECG or the segment with the highest slope in PPG signal, but peaks are easier to detect and so we go faster to an initial prototype for clinical tests. Additional tests may carry on to determine if other features of the waves may give better accuracy. To identify the required peaks in the signals an initial sampling frequency of 100Hz was used. Sampling rate can be increased in future experiments if additional features need to be detected which will require higher precision [14]. The Maxim PPG sensor has a digital output using an SPI protocol and it generates an interrupt after each sample is taken. The USB virtual COM port is enabled in the microcontroller, so we use this interface to send data to and from a PC to develop the data analytics. The PPG and ECG data sets are sent in real time to the PC, and plotted to check the quality of the waves. As we mentioned earlier, the waveforms from the sensors when located on a fingertip are of superior quality and are what we are using for the initial algorithm development in the calculation of PTT.

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We tested the same sensor on the wrist, and the results were not good enough. Firstly, the sensor needs much more time to get stable. Even after we start to see the standard shape of the wave, it is very noisy and hardly readable, and also we lose the wave with small movements of the sensor or hand. In Figure 8, we can see the best wave we could get from the Maxim sensor on the wrist. For the final wrist mounted system, additional filtering and signal processing will be required on the wave forms for this reason.

The ECG sensor is combined with a circuit created using an Analog Devices (AD8232 [19]), which was designed to record ECG signals using classic electrodes, but is modified and used with EPIC ECG electrodes in our case. This chip has an analog output and is sampled at the same rate, 100Hz, as the PPG wave. The MCU's ADC unit is used, and the data from ADC registers are read every time an interrupt is triggered by the PPG sensor. The same sampling rate for both waves is used in the literature [15], and we have also implemented this. It means that we will only use one interrupt service routine in the microcontroller, and less instructions will be used to implement the algorithms and measure time difference between peaks of two waves.

As seen in Figure 9, the red colour wave is the real time ECG signal from the sensors. The signal is good enough to be able to detect the peaks as this will be the main feature we will extract from ECG at this stage.

This signal is plotted from raw data, so no post processing done. In the future, software noise filtering can be applied on the signal, which would result with a clearer graph, and other features of the signal can be detected.

In Figure 9 again, we can see the plotted waveforms and datasets needed to determine PTT. The blue, lower graph is the PPG wave form from the fingertip. This wave from fingertip is clear and consistent, which means peaks can be easily located. Both waves are shown on the same plotting area to visualize PTT. Time difference between two vertical segments is the value of PTT.

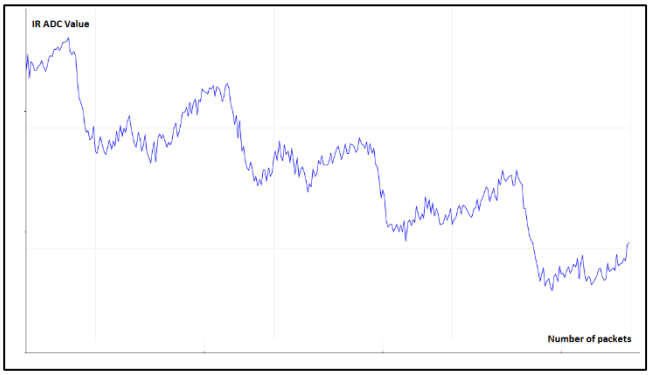

Figure 8. Real time data from Maxim sensor on wrist.

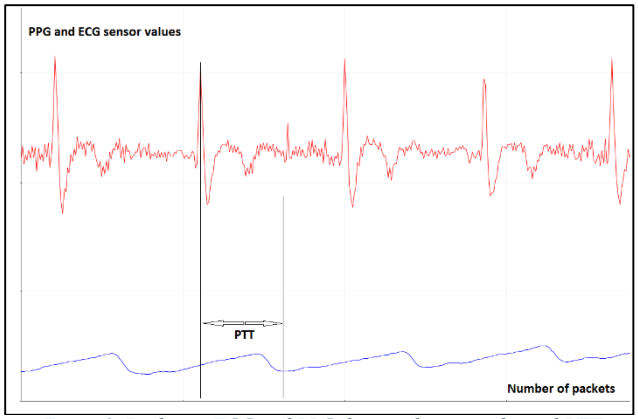

Figure 9. Real time ECG and PPG data on the same plot and PTT.

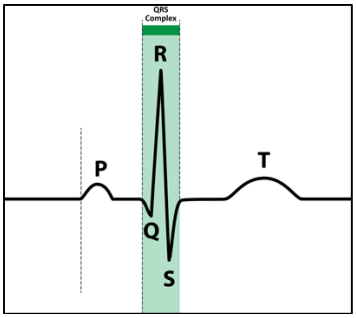

Figure 10. ECG QRS complex.

Figure 10 shows a close up representation of the ECG peaks QRS complex. The R peak will be considered a starting point to measure PTT for the purposes of our algorithm development. The PPG wave is inverted, as the wave shows the level of absorption, so it means at the lowest peak the light is absorbed the most and this is because of the amount of the blood in vessels at that moment.

So, the distance between two black vertical lines on Figure 9 is the value of PTT used in our evaluation and future calculations.

IV. CONCLUSIONS AND FUTURE WORK

There is no doubt that a BP monitor that would be accurate, reliable, cuffless, and comfortable with easy to carry out frequent or even continuous measurements would be priceless for clinical diagnosis of cardiovascular illness diagnosis. For decades, research has been carried out to achieve this goal. Pulse transit time (PTT) seems to be the most promising method to achieve it, based on literature. But until now, one of the challenges to be addressed is in the development of an appropriate data acquisition system to provide the necessary data sets for such a system. The main challenges are: vessel's properties changing from person to person, vessel's properties can be changed by factors within body or ambient conditions and clear data acquisition from comfortable wearable sensors.

The WSN group at Tyndall has started a recent research program in the development of such a system. In this paper,

 ISBN: 978-1-61208-604-0

we are showing practical results of the first phase of the work in progress. The main focus at this early stage is in the design development and evaluation of the computing hardware, sensors, custom board design and data acquisition. Initial results of evaluating the integrated ECG sensor and PPG sensor are shown during the study, also with a new PPG sensor design for the wrist.

For future work, we will use the new PPG sensor designed and the intermediate board to do measurements on people in clinical validation trials with clinical partners and continue the development of the required processing and algorithms to provide BP measurements from PTT measurements.

A list of biggest factors that affects blood pressure has been created, and measurements will be carried out to try to quantify the influence they have. These measurements will enable the development of the required algorithms that would relate BP and PTT, which will be the main part of the complete study to be reported in subsequent publications.

ACKNOWLEDGMENT

These research is a part of the H2O (Human to Objects) project funded by the European Union under the CATRENE program. This publication has emanated from research supported in part by a research grant from Science Foundation Ireland (SFI) and is co-funded under the European Regional Development Fund under Grant Number 13/RC/2077.

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 ISBN: 978-1-61208-604-0

Assessing the Microbial Quality of Tahini (Sesame Paste) in Lebanon

Zeinab Alaouie, Nancy Hallal, Ali AlKhatib, Hassan M. Khachfe
Lebanese International University
Beirut, Lebanon
Email: zeinab.h.alaouie@gmail.com, nancy.hallal@liu.edu.lb, ali.alkhatib@liu.edu.lb, hassan.khachfe@liu.edu.lb

***Abstract*-The microbiological quality of tahini produced by several manufacturers in Lebanon was evaluated. Forty two tahini samples were collected randomly from retail markets throughout the country with production dates ranging from October 2015 to August 2017. The majority of the samples were from companies that are international exporters of the product. Six of the obtained samples were from a traditional tahini manufacturer. All samples were assessed for the total aerobic plate count, the presence and enumeration of *Staphylococcus aureus*, yeasts and molds, *Salmonella*, coliforms and *Escherichia coli*. Spread plate methods were used for detection and enumeration. The following results were obtained: the aerobic plate count of the samples ranged between $1x10^2$ CFU/g and $6.2x10^5$ CFU/g with an average of $6.9x10^4$ CFU/g. *S. aureus* count ranged between <20 CFU/g and $9.2x10^3$ CFU/g with an average of $4.7x10^2$ CFU/g. Yeasts and molds were present at counts ranging from <10 CFU/g to $1.5x10^5$ with an average of $2.3x10^4$ CFU/g. Total coliform counts ranged between <30 CFU/g and $3.4x10^5$ CFU/g with an average of $3.4x10^4$ CFU/g. *E. coli* was present in 43% of the samples (18 out of 42), while *Salmonella* was confirmed present in 17% of the samples (7 out of 42). When compared with Lebanese standards, many of the samples showed unacceptable quantities of microbial contamination and this was not impacted by the storage time, nor the processing method.**

Keywords-Tahini; Sesame Paste; Microbiology; Lebanon.

I. INTRODUCTION

Tahini is a well-known Middle Eastern condiment made from toasted ground hulled sesame seeds. The paste has gained popularity all over the globe as a result of its health and culinary benefits [1]. In 2014, the Middle East and Mediterranean tahini market was estimated to be at a value of US$783.9 Million, with forecasts of a further escalation by 2020. Lebanon has been an important exporter of tahini, and is home to many key players in the market [2].

The importance of tahini comes from the fact that it is used commercially and at a household level as an ingredient in many cultural delicacies. These include products that have gained international popularity, such as Hummus, and mtabal betejen (roasted eggplant and tahini) [3]. The paste is also used as a sauce for meats like shawarma, and as a sauce for fish, also known as tarator. Tahini also makes up about 50% of halawa, a sweet made up of tahini, sugar, citric acid and *Saponaria officinalis* root extract [4].

Tahini is of high nutritive value. It is rich in lipids, proteins, carbohydrates, niacin, thiamin, and some minerals like calcium, and phosphorous [5].

The traditional way of tahini processing in Lebanon includes: sorting the seeds to remove dark or imperfect seeds, followed by soaking the seeds in salt water. This helps settle impurities and dirt at the bottom and ease the peeling process. The seeds that are floating on the surface of the water are then collected, peeled and washed. The next step involves roasting the seeds, followed by the stone-grinding phase, which brings out the oil in the sesame and turns it into a paste.

Many tahini manufacturers, however, rely on a fully automated process. Instead of soaking the seeds in salt water, they are passed into a centrifuge that separates any impurities. The sesame then enters a washing machine, followed by a drying machine and then a roaster. The roasted sesame is cleaned once again and sorted by color. The accepted seeds then undergo grinding, are homogenized and then finally pasteurized at a high temperature for several hours to get rid of any potential bacteria [6][7].

After production tahini is stored at room temperature and has a shelf life up to 2 years [8]. It is typically consumed directly and does not require any further processing. Therefore, it should be free from any pathogenic bacteria upon packaging. The raw sesame itself should also be free from microbes, so as not to increase the risk of contamination. [9] However, despite the development of a hazard analysis critical control point (HACCP) plan for the manufacturing of tahini [10], in recent years, sesame paste has emerged as a product of concern, with many of the end products containing *Salmonella*, *Staphylococcus aureus* , *Escherichia coli*, and a number of other hazardous microbes. In addition tahini has a low water activity (~0.16) as well as low pH (~5.9) [10], conditions that permit the growth of many foodborne microorganisms [11].

The presence of microbes has been attributed to a number of reasons including, the microbial quality of sesame seeds, poor hygiene and sanitation, and improper processing and storage conditions [12]. Outbreaks of *Salmonella* infections have been traced back to tahini, some particularly correlated with Lebanese products [13]. Though some studies have dealt with the microbiological quality of sesame seed products, a collective investigation into tahini products in Lebanon using conventional plating methods has yet to be established. Therefore, the objective of this study will be to detect and enumerate microbial contamination of tahini in Lebanon, while also checking the impact of storage time and processing method on the microbial quality. This paper includes four sections. Aside from the introduction, Section 2

 ISBN: 978-1-61208-604-0

will include a detailed description of the materials and methods used in the study. In Section 3 we mention the microbial results obtained and whether sample age and the method of processing may have had an impact on the obtained results, which we discuss in accordance to similar studies. In the final section, Section 4, we wrap up our research in a concluding statement and mention some limitations, as well as possible future work in the related area.

II. MATERIALS AND METHODS

A. Sampling

Forty two tahini samples with production dates varying from October 2015 to August 2017 were collected from retailers and producers throughout Lebanon. Six of the samples were obtained from a company that produces tahini via the traditional method (no automated machinery). Sample weights varied between 200g and 900g. All samples were held at room temperature (25^{o}C) and collected in their original packages, which were wiped with ethanol before testing. Using a sterilized rod, the samples were thoroughly mixed. 25 g of each sample were then transferred aseptically into separate sterile plastic bags containing 225 ml of buffered peptone water for homogenization. Homogenization was carried out using a stomacher (Model, 1605 BL Smart) for 2 minutes. Following homogenization ten-fold serial dilutions up to 10^3 were prepared and inoculated on appropriate media.

B. Microbial Analysis

Aerobic plate counts (APC), *Staphylococcus aureus,* coliforms, and yeasts/molds counts were determined for each sample, as well as the presence or absence of *Escherichia coli,* and *Salmonella.*

C. Aerobic Plate Count

APCwas determined according to the procedure specified by Morton R.D [14]. 0.1 ml of each dilution was inoculated and spread onto plate count agar (PCA) (Himedia) and left to dry. The plates were then incubated at 35±1^{0}C for 48 ±2 hours.

D. Staphylococcus aureus

S. aureus was detected and enumerated via surface plating 0.5 ml on Mannitol Salt agar (MSA) (Himedia) and incubating plates at 35±1^{0}C for 48 ±2 hours. Colonies with typical and atypical *S. aureus* morphology were confirmed by catalase and coagulase test. This method is in accordance with that specified by the British standards institution, with a modification of the agar [15].

E. Yeast and Mold

Yeast and mold counts were determined following spread plate inoculation onto Saubaurad dextrose agar (SDA) (Himedia). Plates were incubated at 25 ±1^{0}C for 5 days. This procedure was taken from the United States Food and Drug administration (USFDA) [16] however the proposed agar was substituted with SDA.

F. Total coliforms and Escherichia coli

Total coliforms were enumerated on Eosin methylene blue agar (EMB) (Himedia) [17]. An addition to the procedure determined by Gehm & Heukelekian included pre-enrichment of 1 ml of the samples with 10 ml lactose broth (Himedia) for 48 hours, at an incubation temp of 35 ±1^{0}C. Following the pre-enrichment step, 1 ml of each dilution was surface plated onto EMB agar plates and incubated at 35±1^{0}C for 48 ±2 hours. Plates with typical *E.coli* colonies were confirmed for presence of the bacteria via biochemical IMViC tests (Himedia).

G. Salmonella

For detecting *Salmonella*, the FDA Bacteriological analytical Manual (BAM) procedure was implemented, with some modifications [18]. Pre-enrichment was carried out by suspending 25g of each sample in 225ml of lactose broth (Himedia), followed by incubation at 35±1^{0}C for 24 ±2 hours. 1 ml of each sample was then transferred to 10 ml tubes of selenite F broth (SFB) (Himedia) and incubated at 35±1^{0}C for 24±2 hours. After incubation, 3 mm loopfuls were streaked onto Salmonella Shigella agar (SS) (Himedia) and incubated for another 24 ±2 hours. Typical and atypical colonies for presumptive *Salmonella* were then transferred to Triple Sugar Iron Agar (TSI) (Himedia). Confirmation was carried out via IMViC biochemical tests (Himedia), urease broth (Himedia), and Phenol D broth (Himedia).

H. Statistical analysis

The data was analyzed using analysis of variance (ANOVA) complete randomized design, and computed via the java software SPSS. Differences among means of the treatments were analyzed using Duncan. Significant differences are determined when $p \leq 0.05$.

III. RESULTS AND DISCUSSION

APC, *S. aureus*, total coliform, and yeast and mold counts, as well as the presence or absence of *Salmonella* and *E.coli* are shown in Table 1. The aerobic plate count of the samples ranged between $1x10^2$ CFU/g and $6.2x10^5$ CFU/g with an average of $6.9x10^4$ CFU/g. *S. aureus* count ranged between <20 CFU/g and $9.2x10^3$ CFU/g with an average of $4.7x10^2$ CFU/g. Yeast and mold was present at counts ranging from <10 CFU/g to $1.5x10^5$ with an average of $2.3x10^4$ CFU/g. Total coliform counts ranged between <30 CFU/g and $3.4x10^5$ CFU/g with an average of $3.4x10^4$ CFU/g. *E.coli* was confirmed present in 43% of the samples (18 out of 42), (presence of *E.coli* was noted when confirmed counts exceeded 10 CFU/g), while *Salmonella* was confirmed present in 17% of the samples (7 out of 42).

Lebanese standards (LIBNOR NL 71 :2012) set the unacceptable limit for APC, yeast and molds, E.coli and Salmonella at 1x104 CFU/g, 1x103 CFU/g, 10 CFU/g, and

 ISBN: 978-1-61208-604-0

0 CFU/g respectively [19], beyond which microbial content could prove hazardous upon consumption. Standards available from the gulf countries (GSO) set the limit for *S. aureus* in tahini at $1x10^2$ CFU/g [20]. As seen in Table 2, a considerable amount of the samples analyzed contained unacceptable microbial content. 43% of the samples contained unacceptable quantities of APC and *E. coli.*

TABLE 2. MICROBIAL ANALYSIS OF FORTY TWO TAHINI SAMPLES IN LEBANON

	Microbial Analysis CFU/g					
Sample by Manu-facturer	*APC*	*S. aureus*	*Yeast and Mold*	*Total coliforms*	*E. coli*	*Salmo-nella*
A	$3x10^{2a}$	60	$4x10^2$	$1.4x10^4$	+	-
B	$5x10^2$	60	$1x10^2$	$2.2x10^2$	-	-
C	$4x10^2$	60	$1x10^2$	$3.7x10^3$	+	+
D	$6.8x10^2$	<20	<10	$7.30x10^3$	+	-
E	$2.3x10^3$	$2.2x10^2$	<10	$2.1x10^3$	-	+
F	$7x10^2$	60	$6x10^2$	>300	-	+
G	$8.8x10^4$	$3.8x10^2$	$3x10^3$	$3x10^4$	+	-
A	$1x10^2$	$2x10^2$	<10	<30	-	+
B	$1.2x10^4$	$1.8x10^2$	$6.2x10^3$	$2.5x10^4$	+	-
C	$4.5x10^4$	$9.2x10^3$	$4.4x10^4$	$4.8x10^3$	+	-
D	$3x10^2$	60	$4x10^4$	$6.6x10^3$	-	-
E	$6x10^2$	<20	$7x10^2$	$7x10^4$	+	-
F	$1x10^3$	$3.2x10^2$	$1x10^2$	<30	-	-
G	$3x10^2$	40	$4x10^2$	$2x10^3$	+	-
A	$7.5x10^3$	$2.8x10^2$	$1.5x10^3$	$2.5x10^3$	-	-
B	$1.4x10^3$	$1.3x10^2$	$1.9x10^3$	$4x10^3$	-	-
C	$3.2x10^3$	$2x10^2$	$8.3x10^3$	$2.3x10^4$	-	+
D	$6.3x10^3$	50	$3x10^2$	<30	-	-
E	$2.5x10^3$	$1.1x10^2$	<10	$5x10^2$	-	-
F	$2x10^2$	<20	<10	$2.6x10^3$	+	-
G	$1.2x10^4$	60	$1.2x10^4$	$1.2x10^4$	-	-
A	$7x10^2$	60	$2.3x10^3$	$1.3x10^4$	+	-
B	$1x10^2$	<20	$1.5x10^4$	$1x10^2$	-	-
C	$4x10^4$	$1.2x10^2$	$1.5x10^5$	$4x10^2$	+	-
D	$3.1x10^5$	$1.2x10^2$	$7x10^2$	$2.9x10^4$	-	-
E	$2.5x10^5$	<20	$1x10^3$	$1.6x10^4$	+	+
F	$6.5x10^4$	$5.6x10^3$	$1.2x10^5$	$4.3x10^3$	+	-
G	$2.3x10^4$	<20	$5.2x10^4$	$4.1x10^3$	+	-
A	$5x10^4$	40	$1.8x10^4$	$1x10^2$	-	-
B	$1.5x10^4$	$2.2x10^2$	$7.8x10^4$	$2x10^4$	-	+
C	$2.3x10^5$	$1.6x10^2$	$3.8x10^4$	$4x10^4$	+	-
D	$5x10^2$	<20	$6.2x10^3$	$2.2x10^3$	-	-
E	$6x10^3$	80	$3x10^3$	$3.5x10^4$	-	-
F	$2.2x10^3$	$3x10^2$	$1.2x10^4$	$2.2x10^4$	-	-
G	$2x10^2$	<20	$1.9x10^4$	$1.5x10^3$	+	-
A	$5.5x10^4$	$3.2x10^2$	$3.4x10^4$	$3.2x10^5$	-	-
B	$6.2x10^5$	$1x10^2$	$1.2x10^5$	$2.2x10^5$	-	-
C	$3.3x10^5$	$5.4x10^2$	$1.1x10^5$	$3.4x10^5$	-	-
D	$3.3x10^5$	80	$6.4x10^3$	$1.2x10^5$	+	-
E	$1.5x10^3$	40	$1.1x10^5$	$9.3x10^4$	-	-
F	$1.1x10^5$	$2.2x10^2$	$8.4x10^3$	$5.2x10^3$	+	-
G	$1.3x10^4$	<20	$3.2x10^2$	$1x10^2$	-	-
Average counts	$6.9x10^4$	$4.7x10^2$	$2.3x10^4$	$3.4x10^4$	18/42	7/42

[a] Calculations were based on average of duplicate replications
+, presence of microbe in unacceptable amounts
-, absence of microbe, or present but in acceptable amounts

Almost half of the samples (48%) showed unacceptable quantities of S. aureus, while more than half of the samples were unacceptable for yeast and mold quantities (64%). Meanwhile coliform counts were intolerably high in 98% of the tested samples. Even minute amounts of *Salmonella* are detrimental to one's health and therefore 17% of the samples were found to be hazardous. These results were also consistent with standards set by the FDA for ready to eat foods [21].

TABLE 1. COMPARISION OF SAMPLE RESULTS WITH MICROBIAL STANDARDS

Micro-organism	Unacceptable limits	Unacceptable samples *N*	% unacceptable
APC[a]	$1x10^4$ CFU/g	18	43%
S.aureus[b]	$1x10^2$ CFU/g	20	48%
Yeast and molds[a]	$1x10^3$ CFU/g	27	64%
Total coliforms[a]	$1x10^2$ CFU/g	39	93%
E.coli[a]	10 CFU/g	18	43%
Salmonella[a]	0 CFU/g	7	17%

[a] obtained from LIBNOR standards
[b] obtained from GSO standards

Furthermore, when the microbial content of the samples were determined in accordance with sample age, there seemed to be no significant differences. Therefore the amount of time the product spends on the shelf seemed to have no significant impact ($p>0.05$) on the microbial quality. In a similar study however, the microbial counts of tahini were seen to have decreased after four months [10].

Another factor studied was the processing method, whether by traditional methods or solely automated machinery (modern). Statistical analysis of the data showed

TABLE 3. COMPARISION OF MICROBIAL CONTENT OF TAHINI SAMPLES DEPENDING ON SAMPLE AGE

	Sample age (Months)				
Micro-organism CFU/g	Fresh[a]	x≤ 3	3<x≤6	6<x<12	≥12
N[b]	6	15	15	4	2
APC	$2.3x10^4$	$8.9x10^4$	$7.3x10^4$	$7.3x10^4$	$6.7x10^3$
S. aureus	90	$7.9x10^2$	$4.6x10^2$	58	$1.6x10^2$
Yeast & molds	$1.4x10^4$	$2.8x10^4$	$3x10^4$	$8.3x10^3$	$4.1x10^4$
Total coliforms	$8.3x10^4$	$6.6x10^4$	$2.5x10^4$	$4.7x10^2$	$1.5x10^4$
E. coli	4^c	4^c	9^c	0^c	1^c
Salmonella	0^c	5^c	2^c	0^c	0^c

[a] Fresh samples include samples tested directly after production
[b] number of samples within each sample age group
[c] number of samples positive for presence of microbe

TABLE 4. COMPARISION OF MICROBIAL CONTENT OF TAHINI SAMPLES DEPENDING ON PROCESSING METHOD

	Tahini Processing Method	
Microorganism CFU/g	Traditional[a]	Modern[b]
N[c]	6	36
APC	$2.3x10^4$	$7.6x10^4$
S. aureus	90	$5.4x10^2$
Yeast & molds	$1.4x10^4$	$2.5x10^4$
Total coliforms	$8.3x10^4$	$3.8x10^4$
E.coli	4	14
Salmonella	0	7

[a] No automated machinery
[b] Solely automated machinery
[c] number of samples within each processing method group

in Table 4 also showed no significant differences ($p>0.05$) between the samples. Therefore the processing method does not appear to be an influencing factor in regards to microbial counts.

The obtained results indicate that some tahini produced in Lebanon is hazardous and could pose life threatening consequences. In addition, about 35 percent of tahini produced in the country is exported, specifically to the USA, EU, Australia and the GCC. The products tested in this study include some of the country's major producers and exporters. The fact that Lebanese tahini has had incidents where *Salmonella* was detected, has reduced the quantities for export, especially to the USA [22]. Therefore the results indicate that Lebanese tahini could also have threatening consequences to health on a global scale, or to the country's profits from tahini exports. Similar studies on the microbial quality of sesame seed products have been carried out and similar results were obtained. Tahini samples taken immediately after production from 14 plants located in Amman, Jordan were found to contain significant results of APC, coliforms, *S. aureus*, and yeasts and molds [8]. This is not the first time *Salmonella* has been identified in tahini. In a comparable study in Saudi Arabia, *Salmonella* was apparent in 20% of the samples studied [23]. *Salmonella* was also identified in other sesame seed products [24]. In Turkey, a study done on the microbial quality of halva (halawa), also showed that *Salmonella* dominated in many of the samples [8].Tahini has a low water activity and is therefore considered to be a low risk food. However it is a ready to eat product and there are many critical points during production that can expose the product to contamination if good manufacturing processes are not implemented. Contamination may occur from the use of contaminated water during washing or soaking, cross contamination during processes that are open to air, for example, grinding or filling, or bad hygiene conditions within the factory [7]. Therefore it is strongly recommended that tahini manufacturing companies strictly adhere to the implementation of good manufacturing processes to ensure safe microbial counts. Other studies have even shown that contamination could come from the soil or sesame seeds themselves [25], and so thorough investigation of the microbial quality of sesame seeds used for tahini production in Lebanon could also be assessed in the near future.

This is the first collective study in Lebanon that determines the quality of tahini produced in the country by studying the microbial quality of the products via conventional plating methods, while also considering the sample age as well as the processing methods as possible impact factors.

Although the paper does only consider Lebanese products, it is worth noting that all the studied samples are from companies that export tahini worldwide, making the problem a global concern. Also, other major worldwide exporters (e.g., Turkish, Jordanian, and Saudi Arabian companies) also carried out similar studies on the tahini quality in their respective countries [10][23][8], and hence, this study is to complement the others. Furthermore the discovery of contaminated tahini products in other countries, (Jordon, Turkey, and Saudi Arabia) [10][23][8] motivated us to test the quality of tahini in Lebanon.

IV. CONCLUSION

The results of this study provided an evaluation into the microbial quality of forty two tahini products manufactured in Lebanon and showed that some products are unacceptable in accordance to local and international standards. The results were also determined to be irrespective of the sample age, or processing method. Limitations include unequal sample sizes for the different factors studied (sample age, processing method) due to limited resources, and the randomization procedure. Currently, more samples are being assessed for microbial contamination in order to provide more accurate results. Further testing will be required to determine the source of contamination in order to contain it. Furthermore, the study could be a basis for further research (19) aimed at eradicating high microbial counts in tahini without impacting the overall physiochemical quality.

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 ISBN: 978-1-61208-604-0

A Cost-efficient, Camera-based Electronic Nose

Noor Alrabeeah[1], Omar Osman[1], Ali Hage-Diab[1,3], Houssein Hajj-Hassan[2,3], Hassan M. Khachfe[1,2,3, ✉]
[1] Department of Biomedical Engineering
[2] Department of Biological & Chemical Sciences
[3] Lebanese Institute for Biomedical Research & Applications (*LIBRA*)
Lebanese International University
Beirut - Lebanon
{31230440, 11310051}@students.liu.edu.lb, {ali.hagediab, houssein.hajjhassan, hassan.khachfe}@liu.edu.lb

***Abstract* - Human's olfactory system has a large number of receptor types that respond only to a limited number of molecules. Since human noses are subject to fatigue and inconsistency and lack the sensitivity to low-concentration molecules, scientists have developed the Electronic noses. E-nose is a device that identifies the specific components of volatiles and analyzes the chemical makeup to identify it. Current applications include detection of odors specific to diseases for medical diagnosis, and detection of gas leaks for environmental protection. An E-nose consists of both, a mechanism for chemical detection through an array of electronic sensors and mechanism for pattern recognition similar to that of the neural network. Relating to the previous work of our fellow colleagues and major development of the E-nose by scientists at Tufts University, our E-nose developed here consists of a Biosensor, which is a protein extracted from animals and a labeling component that is a chemical dye that is suitable to the protein used. As for the electronic part of the prototype that is responsible for the detection of color change of the dye during the interaction with the odors, it is made up of an application programmed for this specific purpose that ensures proper detection of RGB (red, green and blue) value color change.**

Keywords - E-nose; Volatiles; Biosensors; Chemical dye; RGB values

I. INTRODUCTION

The olfactory system is one of the most intelligent sensory systems to be developed in the mother's womb. The primary pathway consists of two components, the olfactory epithelium and the olfactory bulb. Olfaction means the sense of smell. The main organ involved in olfaction is the nose, which has millions of receptors for smelling that are present within olfactory epithelium. This epithelium has three kinds of cells: basal, supporting, and olfactory receptor cells [1]. Olfactory receptors are bipolar neurons that are made up of dendrites and an axon that ends at the olfactory bulb. The most important part of this receptor is the olfactory hairs that respond to chemicals that are breathed in. When odorants enter the nose, the olfactory hairs that are present inside the nose become activated, generating the potential that then initiates the response [2]. Signals move from the olfactory cells to the olfactory bulb and move on to different parts of the brain, depending on what kind of signals. Figure 1 illustrates the process by which olfactory information is transmitted to the brain.

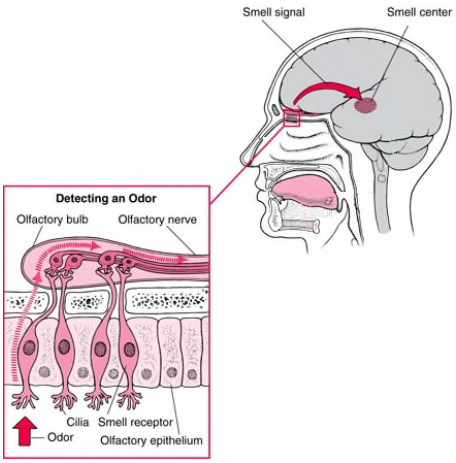

Figure 1. Olfaction procedure where signals move from the olfactory cells to the olfactory bulb and move on to different parts of the brain [3]

Human sniffers are costly when compared to electronic noses. Electronic noses are quick and use reliable new technology of gas sensors. One major point is detection of hazardous or poisonous gas that is not possible with human sniffers that could be overcome by electronic devices.

Scientists thought of coming up with a device to overcome these complications. The solution to these difficulties would also advance the relationship between biology and technology. An electronic nose (e-nose) is a device that identifies the specific components of an odor and analyzes its chemical makeup to identify it. Electronic noses have been around for several years, but have typically been large and expensive. Current research is focused on making the devices smaller, less expensive, and more sensitive. [4]

A next-generation artificial nose developed by Tufts neuroscientists [4] uses DNA (Deoxyribonucleic Acid) to detect odors, and possible applications range from medical to commercial to defense. Researchers at Tufts have pioneered the use of DNA molecules to detect millions of odors. In early versions of the electronic nose, airborne odors passed over a square of silk screen treated with a mixture of a reactive polymer (a large molecule comprising

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a chain of smaller ones) and a fluorescent dye. If some property of the odor, its molecular shape, polarity or charge—interacted with the polymer, the fluorescent dye would glow in response. The trouble was, for each odor they wanted to detect, the researchers had to find, mainly through trial and error, the specific polymer that could serve as a sensor. Over 15 years, the Tufts team and researchers elsewhere discovered 20 to 30 polymers capable of detecting a handful of odors. Figure 2 shows Tuft's University device and it could be tailored to be used in the food and beverage industry, ensuring high quality products and detecting possible contaminants [5].

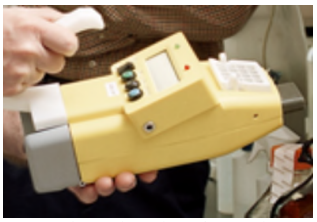

Figure 2. Tufts University Electronic Nose [6]

As for the medical field, other researchers have come up with a device later called Nano Artificial Nose as shown in figure 3 [6]. In the absence of clear surrogate clinical markers that could discriminate between various sources of respiratory infections, over-treatments with antibiotic prescriptions are evidenced in a large portion of the treated cases. There has been an increasing interest in recent years in improved methods for diagnosis of many metabolic and infectious diseases. These new methods are expected to be non-invasive and inexpensive, while allowing: (1) screening of high-risk populations for emerging diseases; (2) early detection and prediction of diseases; and (3) evaluation and monitoring of therapy efficacy.

Figure 3. Nano Artificial Nose

A prototype of cross-sensitive nanowire-based sensors to be integrated in the 'Nano Artificial Nose' were trained to detect target disease related mixtures of biomarkers. Advanced development of the Nano Artificial Nose disease detection capabilities are present for the detection of the following indications from exhaled breath: Streptococcus; Methicillin resistant (MRSA); Staphylococcus; etc. Nano Artificial Nose technology detects specific disease biomarkers based on a change in the blood chemistry or metabolic activity (which is reflected in the chemical composition of the exhaled breath and cell/tissue headspace) rather than by other forms of imaging or invasive blood analysis [7].

Relating to the previous work of our fellow colleagues and major development of the E-nose by scientists at Tuft's University, our E-nose consists of a Biosensor, which is a protein extracted from animals and a labeling component that is a chemical dye that is suitable to the protein used. To detect color change, an application is programmed and used to validate the interaction occurring between odors and proteins.

The rest of the paper is structured as follows. In section 2, represent the materials used, the requirements and device design, the project working process and the methods used. Afterwards, in section 3, experiments, results and data analysis are described. Then, section 4, results are discussed and explained. Finally, in section 5, a conclusion summarizes the requirements of this project and enhancements that meet the market requirements.

II. MATERIALS AND METHODS

E-Nose technology joins several analysis techniques that make way to understanding the structures and composition of odors. Figure 4 illustrates the diagram of the device that consists of a chamber containing the fan and battery, biopolymer sensor, and odor receiving duct that is analyzed using a programmed application that recognizes the color change.

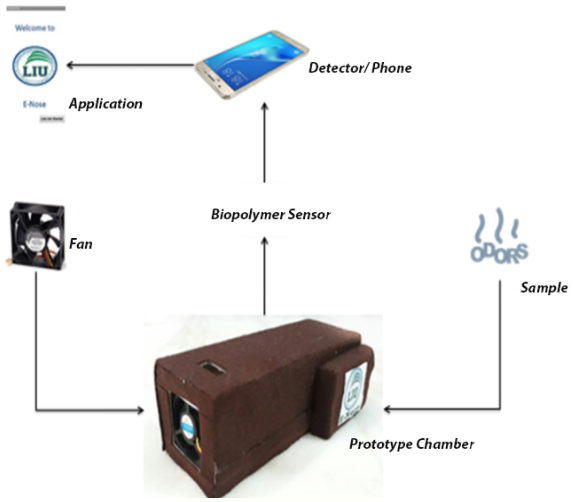

Figure 4. LIU (Lebanese International University) E-Nose Block Diagram

Materials and Preparation Steps:

1) Use an Analytical Balance to weigh 3.5mg of ALP (alkaline phosphatase) protein
2) Dilute with 0.67ml distilled water at 33ºC to obtain 5.2g/l concentration
3) Take 10ul prepared ALP and add to it 5ul coomassie dye and 5ul tea tree oil and pour in 1.5ml eppendorf tubes
4) Prepare reference tubes containing:
   a) 10ul ALP protein with 5ul coomassie dye (control tube)
   b) 5ul coomassie dye with 5ul tea tree oil
   c) 5ul coomassie dye
5) Mix the combinations for 2 min using a vortex mixer

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6) Place the sampled tubes in a water bath at 33ºC for 30 min
7) Record the change in color at the end of the experiment, each tube with respect to the reference tube containing the protein-dye mixture, using the phone camera
8) Analyze and compare the results using the LIU E-Nose application

III. RESULTS

LIU E-nose application serves as the image processing software programmed using MIT (Massachusetts Institute of Technology) App inventor [8]. The software makes use of a typical phone with 13-megapixel rear autofocus, a wide aperture for extra light reaching image sensor, and an LED (light emitting diodes) flash. Software attains RGB values at fixed distance from the samples as well as exact focused point in all the tubes to minimize light differences and have more precise results.

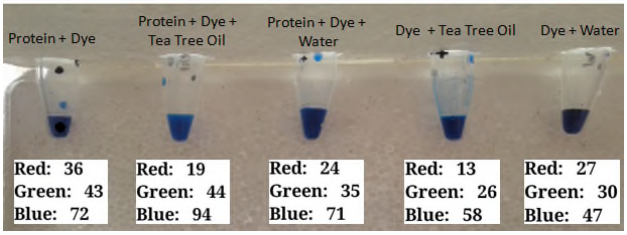

Figure 5. RGB Values of the Prepared Samples in Liquid Phase

Figure 5 shows the different results obtained from the experiment at the same time. The figure shows the prepared samples with a label with its content above each tube, while the RGB values are listed below the tubes. Detailed explanation of the results is further mentioned in the discussion.

We keep the following conditions of the samples constant:

- Temperature using water bath
- pH levels using ALP; stable pH
- Volume and concentrations using pipettes, balance, and dilution factor

We used alkaline phosphatase as the protein due to its key features:

- 4 hydrophobic pockets are necessary to interact with the acquired odors
- Stable pH levels reduce odors' pH influence
- Temperature stability (up to 80 degrees) [9].

We choose tube 1 to the left as the reference and control to compare the color change of the rest of the tubes to it. Following is the protein and dye interacting with tea tree oil, transparent and low viscosity organic oil with a specific chemical structure.

To eliminate the effect of dilution that might be the reason of the lighter blue color of the sample, we add in the 3rd tube with the same volume of the tea tree oil than that of tube 2 and notice that there is difference in color as compared to the mixture with the organic oil. Thus, another factor is studied, and this showed positive results.

In the following tubes, 4 and 5, we tested for the interaction between the organic oils and dye. It is required to validate that the interaction is with the protein and not the dye. Comparing the results of the tube 4 to tube 2, and tube 5 to tube 3, the dye did not quite change its color, which made us conclude that there is minimal interaction between the oils and dye.

IV. DISCUSSION

Electronic noses were originally used for quality control applications in the food, beverage and cosmetic industries. Current applications include detection of odors specific to diseases for medical diagnosis, and detection of gas leaks for environmental protection [10].

The advancement of e-noses may be coupled with different sensor technologies, such as optical sensors, conductive polymers, and in our case biopolymers.

Initiating our analysis, a color sensor is used, combined with an arduino that controls and acquires data received by the sensor. First experiments showed detection of color change of the RGB values while stabilizing surrounding conditions to prevent artifacts from influencing our results. Yet, after maintaining constant light, temperature, and sample settings, inadequate results were obtained. Any little light disruptions, as well as inappropriate distance of sensor from samples caused false results. In addition, reflections off of objects placed in the surroundings, either sample or sensor, did have a wrong impact on the results. Thus, another detection method is used after several trials performed earlier. CCD (charge-coupled device) camera is considered more convenient than the color sensor due to the high efficiency of this camera, as well as the broad availability of this sensor. Combined with a microcontroller or analyzing unit, this arrangement makes way to detecting the RGB value changes more accurately than that of the color sensor, as well as proper analysis of the results.

It is validated that DNA interacts with odors as mentioned in Tuft's University experiments. The experiments conducted here are through using proteins as biopolymers instead of DNA. It is known that protein normally binds lipids. Most odors are hydrophobic, which makes them candidates to bind to the hydrophobic pockets available in the protein structures used here [11].

The specific influences of conditions that might affect the interaction of the protein with the samples are avoided. Temperature is maintained constant at 37 degrees, using a water bath. The first experiments included the use of LDH (lactate dehydrogenase) and BSA (bovine serum albumin) proteins. Several trials were conducted on these proteins. In addition, to prevent any pH fluctuations, ALP is used

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instead of the previous proteins for its high affinity to bind lipids without changing pH levels. Setting pH at a specific value is required, for we are not probing the change in pH, but we shall see odor sensitivity.

In order to visualize color change, a labeling substance is used. The marker used here is the coomassie blue dye. To detect the color change after an interaction between the biopolymer and certain odors, the dye fluoresces and changes its degree that facilitates the visualization of the interaction occurring between the protein and volatiles. The coomassie blue dye associates with basic and aromatic amino acids, thereby causing shift in absorbance during protein determination [12].

The volatiles used in this experiment are coconut oil, rose water oil, cloves oil and tea tree oil. Coconut oil has high viscosity that prevented proper mixing with proteins. Rose water and cloves oils already have a non-transparent color, thus they will affect the RGB values analysis. We used the tea tree oil, a transparent, low viscosity, and essential organic oil with a specific chemical structure is then used.

Binding of hydrophobic entities like odors may induce structural changes to protein due to the presence of hydrophobic pockets that may change their optical characteristics. Such interaction with lipids will induce structural changes down to the helical structure of proteins (Angstroms measurement unit) that affect their color nature, e.g.: globin proteins that change color from dark red to light violet based on structural change; cytochromes, hemoglobin, etc.

Optical activity of substance changes based on its modification in structure impacts transparency vs. opacity as well as color vs. color change.

The detected difference of the RGB values can be visualized both using the naked eye, as well as by using the application. The application uses the camera that is set to measure RGB values so there is no need for any pre-processing.

V. CONCLUSION

As a conclusion, the focus of this project is to mimic the functionality of the olfactory system using materials available in every lab. This makes way to producing a cost-effective and easy to use device to perform the necessary function. The experiments were performed on similar materials as that of Tuft's University then deviated the attention onto using proteins instead of DNA as the sensors for odor identification. It was validated that each gaseous and liquid phased molecules and odors interact differently when in contact with different proteins. This variance is used to check for better repeatability, sensitivity, and stability. This is analyzed by using a developed LIU E-nose application that records and displays the values of change in color post protein-odor interaction. Further practice shall lead to a better understanding of the specific interaction with given odors that can lead to notable discoveries in the field of diseases' testing and identification as well as in other daily-life fields.

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 ISBN: 978-1-61208-604-0

Smart Military Healthcare Monitoring and Tracking System on Raspberry Pi and Arduino

Ali Bazzi, Moslem Ghamloush, Mostafa Ibrahim, Majd Ghareeb, Samih Abdul-Nabi, Hassan Khachfe
International University of Beirut - Department of Computer and Communication Engineering
Lebanon, Beirut, 146404 Mazraa, LIU Campus, Block F, 2nd Floor
Email: firstname.lastname@b-iu.edu.lb

***Abstract*— Although technology advances cannot help in limiting the dreadfulness of war, they can at least be deployed to reduce war effects and casualties. One way to help in this aim could be by tracking and monitoring the location and health situation of troops in the battle. The main objective of the work presented in this paper is to design and implement a complete tracking system that is composed of a mini portable server as a central unit hosted on a Raspberry Pi to read soldier's location, state, and health information through wireless communication from a small monitoring unit that is attached to the soldier's arm. Moreover, the system provides an emergency button that requests help when pressed if a soldier is facing an urgent problem. A set of test cases has been applied and the results achieved by our prototype have presented a promising accuracy and efficiency when applying such a system.**

Keywords—Healthcare monitoring; tracking system; Raspberry Pi; Raspbian; ESP8266; Arduino; Wifi communication.

I. INTRODUCTION

On September 28 1951, Daniel Hunt, 18, of Columbiaville was a member of Company A, 1st Battalion conducting operations near an area referred to as Heartbreak Ridge [2]. The Chinese launched an attack, which the company repelled. Prior to their attack, the Chinese launched a barrage of mortar fire against the Americans in which survivors withdrew to friendly lines. Hunt was reported missing in action. During an investigation by the U.S. Army Casualty office, three members of Hunt's unit reported that he had been killed during the fight, so the Army declared him deceased. Today, 7780 Americans remain unaccounted for from the Korean War [1]. Thousands of cases like "Hunt" are encountered around the world, showing that the issue of unaccounted soldiers is a common in war zones.

Some people believe that known military communication tools can help to avoid the above mentioned issue. However, natural factors, lack of knowledge about the battlefield, loss of connection between soldiers, power failure of these tools, barrage jamming and so on, constitute other obstacles for soldiers and their leadership.

These and many other problems have led researchers to think about new solutions benefiting from the evolution of technologies. Throughout the years, many technologies have been invented to solve the Missing-In-Action problem, but they remained weak. Most of these systems are based on tracking the soldiers' movements, which is not always an efficient way to detect the real situation on the ground. Navigation and situating are important, but need tiring activities which GPS (Global Positioning System) makes easier. The GPS has turned out to be a significant technology for the U.S. military and other defense forces around the world since the 1980's [2]. With the ability to provide accurate positioning continuously, day or night, in any conditions, GPS has helped ground troops in Iraq and Afghanistan navigate across expansive, barren deserts that have few markers or distinguishable features. Although GPS provides the position of soldiers in battle, it is still considered weak and far away from healthcare when any of health issues are faced during battle.

From all the above-mentioned issues, we arrived at the objective of our paper, which is designing a new "smart military healthcare monitoring and tracking system" that would significantly reduce the effects of problems encountered during the combat. Our system grants the leader the ability to track his troops on the map application and monitor their health statuses continuously in battle, even in advanced lines, by accessing the Web page directly from the small central server or by using a mobile application.

The rest of the paper is organized as follows. In Section II, we talk about some similar applications to our system. Section III gives an overview of the system architecture. Section IV talks about the used components and describes the implementation in detail. Section V summarizes the main contributions of this paper.

II. RELATED WORKS

Medically, health statuses of patients with critical conditions are a great concern for doctors who seek new and innovative healthcare systems. In the past, militarily armies monitored their soldiers with the aid of primitive communication systems, such as walkie-talkie, until the technological development enabled tracking systems using satellites.

A. Movement/traking system

The United States Army invented a Movement Tracking System (MTS) that is a logistics communication platform under the Program Executive Office (PEO) for Enterprise Information Systems (PEO EIS) [3]. It is

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designed for commanders to track assets on the battlefield with encrypted text messaging. It is a satellite-based tracking and communicating system designed to provide command and control between the leader and the soldiers.

This device can continuously monitor the soldier's location during battle, which improves the leader's control of the troops without the need for primitive communication tools which require manual usage. MTS's main disadvantage is that the health statuses of soldiers remain absent from such systems.

B. *Smart systems for healthcare monitoring using communication means*

Health monitoring systems have rapidly evolved recently, and smart different systems have been proposed to monitor patient's current health conditions. In a recent work [4], authors are proposing a "Smart real-time healthcare monitoring and tracking system using GSM/GPS technologies", which concentrates on checking the patient's blood pressure and body temperature. This system was built for social healthcare in light of GSM and GPS innovations and as a compelling application for real time health monitoring and tracking. In case of emergency, a short message service (SMS) will be sent to the doctor's mobile number along with the measured values through the GSM module. Moreover, the GPS gives the location data of the patient who is under observation all the time. While this system covers the issue of healthcare status provision, it cannot continuously track the person's required information. In addition, the usage of GSM to send short messages is more expensive and can face some mistakes, such as when the doctor's phone is out of service or due to man-made confusion (in the military case), etc.

In another work [5], authors proposed "Patient Health Management System". This system is based on smart devices and wireless sensor networks for real time analysis of various parameters of patients. This system is aimed at developing a set of modules which can facilitate the diagnosis for the doctors through tele-monitoring of patients. It also facilitates continuous investigation of the patient for emergencies looked over by attendees and caregivers. A set of medical and environmental sensors is used to monitor the health, as well as the surroundings, of the patient. This sensor data is then relayed to the server using a smart device or a base station.

Each of the systems discussed above provides a feature needed before, during and after a combat. MTS provides continuous tracking of soldiers' movements, but their health statuses are missing, "Smart real-time healthcare monitoring" system provides health statuses tracing, but not continuously, "Patient Health Management System" provides health monitoring using smartphones over The Internet or using servers to extract information.

In our design, we are trying to achieve the goals of existing systems by combining their features in one small wearable device. The importance of our system compared to other products is manifested in its ability to simultaneously keep an eye on soldiers' health status alongside their locations without the need for manual control, which facilitates leader-troops communication, even on the front line. Moreover, the central unit, unlike the systems discussed, is a small portable device to be held by the leader. It hosts the information locally without any need for huge servers or access points between soldiers and their leader.

III. SYSTEM OVERVIEW

As depicted in Figure 1, we have two main components. The first one is the central unit that plays the role of a server and it is usually controlled by the group leader. The second one holds the monitoring units worn by the soldiers in the battle.

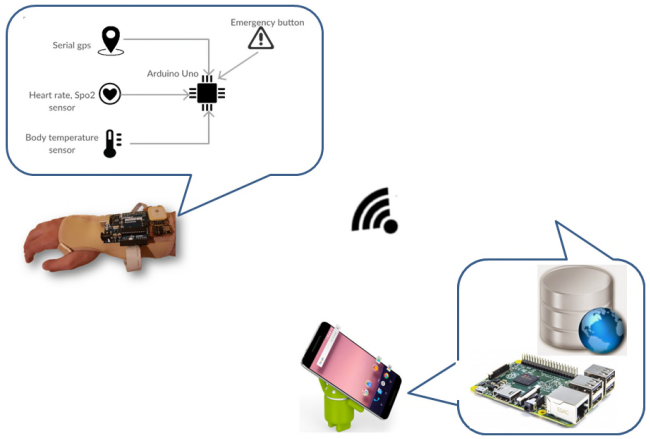

Figure 1. System Architecture diagram

The central unit will be portable with light weight and small size. For simplicity of connection, this unit could provide an access point to the soldiers to make sure no intermediate equipment is needed. This server will host all the needed information, such as the database and the Web pages. Hence, data retrieval will be done locally and no need for any external connection such as GSM or Internet will be needed. This will help in increasing the system security, connection speed and data localization, since the information of a group of soldiers does not need be be published on a large scale. This unit can be controlled via a Web application that could be accessed directly from it or via a mobile application that is designed to do the same objective. The other main component of our system is a small wearable glove that is equipped with all the sensors and detectors to connect soldiers to their operations campaign. This will be done by detecting body temperature, oxygen level in blood, heart beat rate, speed and location of each soldier. All this information will be sent periodically and automatically to the central unit notifying the commander of any issue, injury or maybe death. Additionally, our system provides an emergency button that

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gives the soldier the possibility to request help when facing a non-medical urgent problem.

IV. IMPLEMENTATION TOOLS AND DETAILS

A. Monitoring unit implemetation

In our system, the monitoring unit is composed of a microcontroller connected to a heart pulse sensor, oxygen level and body temperature sensor, serial GPS, emergency button, and ESP8266, as shown in Figure 2.

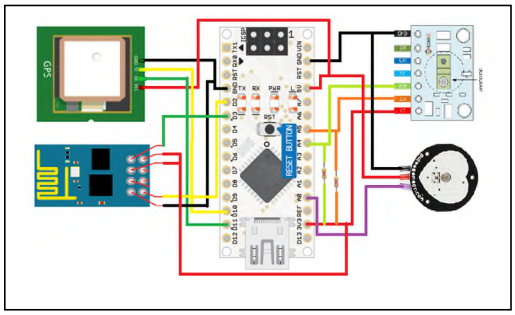

Figure 2. Monitoring unit implementation board.

The Arduino Uno is a small, complete, and breadboard-friendly board. It has 14 digital pins, and each of them can be used as an input or output. It also has 8 analog pins, each of which provides 10 bits of resolution.

We connected the heart pulse sensor to an analog pin of the microcontroller. The pulse sensor reads a waveform and calculates the BPM (Beats Per Minute), as well as the IBI (Inter Beat Interval), which is the time between beats [7].

The oxygen level and body temperature are both measured using the MAX30100 chip. The only required connection to the sensor is the I2C bus (SDA, SCL lines, pulled up). The MAX30100 is an integrated pulse oximetry, body temperature, and heart-rate monitor sensor solution [8]. The accuracy of the pulse sensor was better, so we ignored the heart rate value measured by MAX30100 and we used it as a supporter in case we have any fail in the heart pulse sensor.

In addition, we used NEO-6M GPS Module to measure the speed of each soldier beside his location as latitude and longitude values. The serial GPS communicates serially with the microcontroller. This GPS Module uses the latest technology to give the best possible position information. Also, it comes with ceramic antenna.

Finally, the microcontroller sends all measured values using serial communication to the Wi-Fi module which is connected to digital pins. The Wi-Fi Module (ESP8266) is programmed to get values from the microcontroller following a specific algorithm; then, it sends these values through WIFI to the central unit where the leader monitors. The ESP8266 is a self-contained system on chip with integrated TCP/IP protocol stack that can give any microcontroller access to any WIFI network. The ESP8266 is capable of either hosting an application or offloading all WIFI networking functions from another application processor.

B. Central unit impelementation

Raspberry Pi with Linux operating system is the central unit. The leader can browse the Web page built for the system to track and monitor his soldiers. In addition, we added a 7 Inch LCD touchable screen and a keyboard to allow the leader to access the Web site directly from the server. As shown in Figure 3, the central unit is a portable device with small dimensions (15cm width x 15cm height and less than 10cm depth) so the leader can hold it in the battle even in advanced lines and stay connected to his soldiers.

Figure 3. Portable central unit based on Raspberry Pi.

The original Raspberry Pi is a small computer with a processor, RAM (Random Access Memory) and graphics chip. It has various interfaces and connectors for external devices communication [9]. In our system, we configured it as a server. We used Raspberry Pi V3 Model B which has 512 MB of RAM.

C. Web page and Android Application implementation

Each soldier in the battle held a user-friendly wearable device composed of the microcontroller, sensors required and a WIFI Module. A real prototype of soldier's device is shown in Figure 4. The microcontroller gets all sensors' values and sends them to the central unit directly using WIFI signals without passing through any access point.

Each soldier must turn on his own device, which is programmed only for his unique id, without any need for any manual configuration. This device will send the soldier's id, health status and location information continuously. In addition, any soldier with normal health status can notify his leader by pressing an emergency button if he needs any help. The leader can track and monitor his soldiers directly from the small portable access unit, or any other PC connected locally to this unit, by accessing the Web page built for the system from any browser. After login, the Web page displays a map showing all the soldiers in the battle, as shown in Figure 5. The soldiers are

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represented by markers; the icon of a marker changes depending on the health status, or in case of an emergency. The leader can also use the Web page to add, remove, and view his soldiers and their personal information.

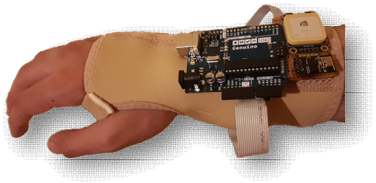

Figure 4. Soldier's wearable device.

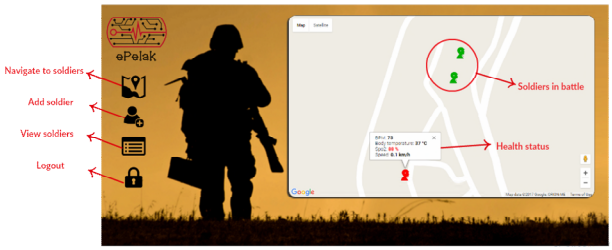

Figure 5. Main Web page shows soldiers on Map.

We developed an Android application to allow the leader to use it instead of the Web page to track and monitor his troops on a map, as shown in Figure 6. This application allows the leader to add and show soldiers health statuses and personal information displaying them in a list, as shown in Figure 7.

V. CONCLUSION

The main objective of this paper was to design and implement a complete system for monitoring and tracking soldiers' health information and location in a battle. Our system provides a wearable device for each soldier and a portable device for the leader. This enhances his ability of caring about the band benefiting from a Web page and an Android application. This system has a humanitarian aim since it can decrease the effects of many issues in battle including soldiers unaccounted for and the difficulty of health status monitoring. The system security can be addressed using encryption technologies, such as AES (Advanced Encryption Standard) for the data exchanged between the central unit and the soldiers. This system could be tested on real soldiers to prove its applicability. Another enhancement on the system could be by providing an agreed upon secret code to be sent with the emergency button in order not to abuse this facility by the enemy. Moreover, the range of the WIFI signals is limited 100 m, and the GSM cannot be used because its signals are weak in the battle area or they do not even exist. Our system can be improved by introducing a new communication system using microwave signals with frequencies lower than WIFI band (around 2.4 GHz).

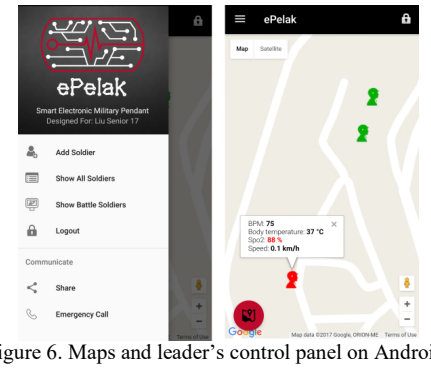

Figure 6. Maps and leader's control panel on Android.

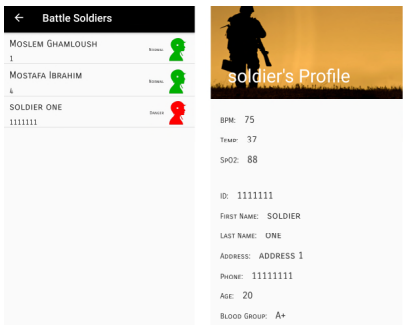

Figure 7: List of battle soldiers and their health.

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 ISBN: 978-1-61208-604-0

Standardization of Blood Pressure Management in Cedro Galán, a Semi-Rural Community in Nicaragua

Holly O'Brien, Elimarys Perez-Colon
Department of Internal Medicine-Pediatrics
University of South Florida
Tampa, FL, USA
e-mail: hobrien1@health.usf.edu, eperezco@health.usf.edu

Elizabeth Nicole Teal
Department of Obstetrics and Gynecology
University of California San Francisco
San Francisco, CA, USA
e-mail: e.nicole.teal@gmail.com

Aly Strauss
Department of Gastroenterology and Hepatology
Johns Hopkins University
Baltimore, MD, USA
e-mail: aly.t.strauss@gmail.com

Taylor Martin
Department of Emergency Medicine
University of Texas
Houston, TX, USA
e-mail: taykmar11@gmail.com

Wendy Sanchez
Department of Family Medicine
Universidad Americana
Managua, Nicaragua
e-mail: wendy.sanchez33@yahoo.com

***Abstract*—Research supports the use of evidence-based guidelines in the management of hypertension. However, there is limited literature regarding translation of these initiatives to resource-poor settings. Specifically, Nicaragua has no evidence of appropriate treatment or management of hypertension. A team from the University of South Florida Morsani College of Medicine created a community-specific, algorithm-based educational program to standardize management of hypertension in the semi-rural community of Cedro Galán. Patients enrolled had monthly monitoring of systolic and diastolic blood pressures. The launch of the pilot program was followed by evaluation and intervention six months later. Results were analyzed using retrospective chart review, and separated into pre-pilot, post-pilot, and post-intervention data. Primary and secondary outcomes included blood pressure, community adherence, and provider confidence. Mean systolic and diastolic pressures for all patients prior to the pilot (n=10) were 146/78 mmHg, between pilot and intervention (n=16) were 153/83 mmHg, and after intervention (n=17) were 145/81 mmHg. Patient adherence to medications and provider confidence increased, and patient clinic appointment attendance increased from a median of 47% at baseline to a median of 100% post-intervention. Our study suggests that community-specific, evidence-based education programs that include algorithm development can increase community adherence, provider confidence, and also blood pressure. Limitations include lack of similar research to be used for comparison, and we stress the need for continued study in this subject.**

Keywords- Quality improvement; Patient outcomes; Equity in health care; Primary care; Cardiovascular diseases; Developing countries; Patient education; Guidelines

I. INTRODUCTION

Nicaragua is the poorest country in Central America, and the second poorest in the Western Hemisphere, and much of the country lacks access to basic resources [1][2]. Almost 50% of the population lives below the poverty line [3], and individuals face a unique set of risk factors related to barriers in access to care [4]-[6]. As of yet, there has been limited clinical research in Nicaragua, but it is well known that cardiovascular disease (CVD) is a leading cause of death [4][5][7][8], with hypertension being the primary risk factor for development of CVD [7][8]. There have been studies evaluating the prevalence of hypertension in Nicaragua [10], but there is little evidence to suggest appropriate management and treatment of hypertension [4]. Contributing to this is the fact that the majority of clinics in Nicaraguan communities tend to focus on acute conditions, rather than non-communicable disease [11]. Those caring for chronic disease in Nicaragua often rely on guidelines developed in other countries, cost constraints or their own personal experiences. Available guidelines for medical practitioners include the Joint National Committee (JNC) guidelines [12] and the Latin American Society of Hypertension (LASH) guidelines, but there is no good evidence that such guidelines fit the local context of rural communities in Nicaragua [13]. Research in Honduras has shown a positive impact from the formation of a community-based hypertension treatment program, with improved blood pressures, adherence to medications, and political support [14]. The aim of our study is to incorporate a personalized algorithm-based educational program for

 ISBN: 978-1-61208-604-0

practitioners in a rural Nicaraguan clinic. We sought to assess whether such a program would effectively result in reduced blood pressures and improved adherence to medications. To our knowledge, this is the only study evaluating the incorporation of cost-effective and evidence-based hypertension management into a rural setting in Nicaragua.

In this paper, we will outline our methods, results, and conclusions. Section 2 starts by detailing our patient population, and then discusses the launch of the pilot program, intervention and adjustment, hypotheses, and outcomes measured. Section 3 provides results, divided into primary and secondary outcomes. Finally, Section 3 is a discussion of our findings, conclusions, and recommendations for future projects.

II. PATIENTS AND METHODS

A. Study Design and Setting

We used an observational research design to incorporate an evidence-based and cost-sensitive algorithm into a rural Nicaraguan clinic. We visited the community on multiple trips over a 1 year period to provide education and receive feedback about the program. Institutional Review Board approval was given for this study by the University of South Florida (USF). (Institutional Review Board number: Pro00026167)

This study was completed in Cedro Galán, a semi-rural resource-poor community located on the outskirts of Managua, Nicaragua. This community is home to an estimated 3,500 individuals whose incomes are, on average, $1.32 per person per day. Only 25% of adults in Cedro Galán have completed secondary school [15]. Up until October 2013, this community had extremely limited access to even basic health services and health education. This history of disconnection from the healthcare system combined with low socioeconomic status and low educational levels put this population at extremely high risk for many adverse health outcomes including but not limited to cardiovascular disease [15].

Research was conducted in the primary care clinic that opened in Cedro Galán in 2013. This clinic was created by and is managed though a collaboration USF and Manna Project International (MPI) [16], a non-profit organization that offers holistic community development. A Nicaraguan general practitioner physician and nurse staff the clinic three times weekly. Since the clinic has opened, it has provided two to three thousand consultations annually. USF Internal medicine physicians visit bi-annually to provide continuing medical education as well as patient consults.

B. Pilot: Algorithm Development and Provider Education

The USF Health team offered chronic disease management education to our partner Nicaraguan health care providers in two steps. The first occurred during an initial capacity building trip in March 2015. Internal Medicine physicians from USF Health started by presenting the JNC 8 guidelines (including changes from JNC 7) to the Nicaraguan providers. Next, they held individual meetings with the Nicaraguan providers to discuss their thoughts on the guidelines and perceived limitations with respect to implementation. Table I illustrates the questions that were asked during these individual meetings. Using the JNC guidelines as a foundation, with local practitioner input, a one-page algorithm was developed for practitioners to follow when managing hypertension. USF physicians also discussed potential side effects and recommended monitoring for each drug. All meetings were held and education provided in the local providers' native language.

TABLE I. QUESTIONS NECESSARY FOR COMMUNITY-SPECIFIC ALGORITHM DEVELOPMENT

How are the current prescribing practices of providers in the area determined? Are there any guidelines already followed?	What is the currently recommendation by the appropriate governing body for the management of the disease targeted?
What are the major comorbidities of the targeted population?	What medications in those recommendations are not accessible in the targeted population?
What is the level of control currently of the disease targeted? What medications is the population currently taking for management of the targeted disease?	What is the data for medications that can be utilized as a substitute for those medications that are not readily accessible? Has that data been shown to apply to the targeted population?
What medications are readily accessible in the region?	Is there repeated education established for providers, with adequate follow up in between education sessions?
What are the limitations in accessing those medications that are available?	Is there a method for providers to ask questions should the algorithm become difficult to follow?
What is the cost of available medications?	

C. Intervention: Algorithm Adjustment & Further Provider Education

Analysis of treatment patterns and overall blood pressure control following the first capacity building trip indicated that the proposed guidelines were not being consistently followed. We completed a root cause analysis in collaboration with the health providers and our partner MPI to determine why this was the case and came up with

 ISBN: 978-1-61208-604-0

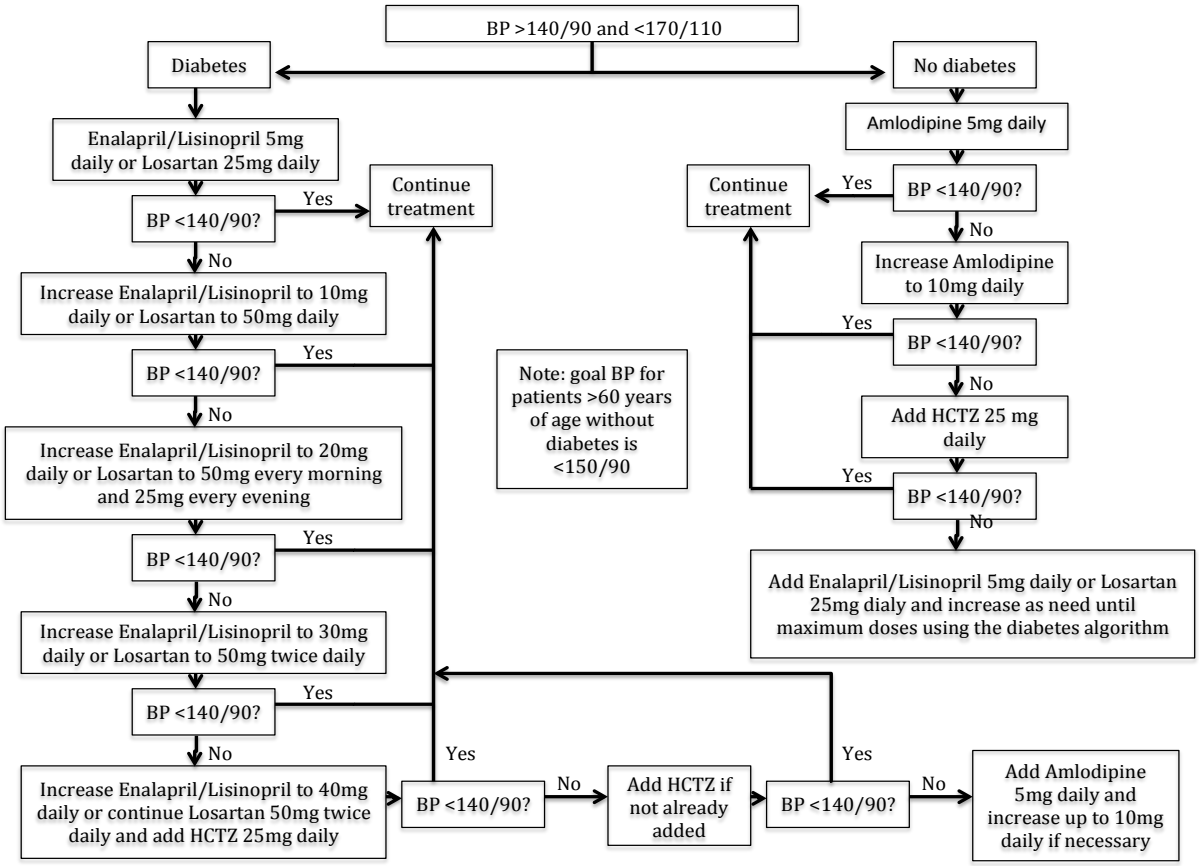

Figure 1. Community-specific evidence-based treatment algorithm

the following issues:

1. Insufficient funding to pay for complete supply of medications
2. Insufficient funding to pay for monitoring labs (ie creatinine, potassium)
3. Minimal clinic time to practice putting guidelines in place with real patients
4. Confusion regarding quantities of medications to be distributed to patients

Between March and October of 2015, we worked in collaboration with the Nicaraguan providers and MPI to combat these issues. First, we reviewed the JNC guidelines taking into close consideration the cost of each medication at the local pharmacy and costs of monitoring labs. Using that information, we adjusted the one-page algorithm for the most cost effective treatment of hypertension in that specific community (Figure 1). Some of these substitutions included specifying with medication within a category to use. Making simple substitutions such as Enalapril instead of Lisinopril dramatically decreased the cost of treatment for many patients simply due to local pricing. In the customized algorithm, we included conservative but safe laboratory monitoring schedule. Clinic scheduling was changed to having a dedicated day for patients with hypertension to visit, as their appointments often required more time. Discussion with local practitioners revealed concerns regarding dispensing greater than a one month supply to patients, related to issues with theft, and it was decided that patients would visit once monthly to receive their blood pressure checks and to receive their medications. Lastly, during the October 2015 capacity building trip, USF Health attending physicians saw each chronic patient with the local physician and worked with her to create six-month plans based on the algorithm for every patient. Patients continued to come to clinic monthly, and those six-month plans required minimal adjustment by the Nicaraguan providers. Nicaraguan providers were also informed that they could make remote consults to USF providers as needed via the electronic community health records system. These changes were intended to encourage more consistent implementation

 ISBN: 978-1-61208-604-0

of the guidelines in the Cedro Galán Clinic and of the improve blood pressure control.

D. Outcomes and Hypothesis

The primary outcome was blood pressure management, which was evaluated using the electronic community health record. Secondary outcomes included medication and treatment adherence, evaluated by adherence to clinic appointments and reported adherence to medications, as well as provider confidence. Provider confidence was evaluated subjectively, in discussions with local practitioners, as well as in use of the guidelines independently to adjust patient treatment plans. We hypothesized that patient blood pressure, patient adherence, and provider confidence would all improve with our community-specific algorithm-based educational program.

E. Data Analysis

Although this is an observational study based on sharing our experience to help others undergoing similar endeavors, we also collected some basic data about our patients with hypertension impacted by the program. All data was obtained from retrospective chart review. The data was examined in three different time intervals, outlined below.

1. Prior to Pilot
2. Between Pilot and Intervention
3. After Intervention

Charts reviewed were determined by inclusion criteria of diagnosis of hypertension, defined as blood pressure greater than 140/90, age greater than 18 years, and enrollment in "USF Health Nicaragua Chronic Patient Program." Baseline characteristics of all patients were obtained. For each of the patients, monthly systolic and diastolic blood pressures (mmHg) were collected by chart review to obtain data from October 2014 to April 2016. Averages of systolic and diastolic pressures were calculated separately, and displayed in a run chart for each month. Finally, trends in blood pressure were evaluated by obtaining averages in systolic and diastolic pressures for all patients in each of the three time intervals outlined above.

III. RESULTS

Among those meeting inclusion criteria (N = 17) patient baseline characteristics showed a mean age of 58 years (SD 14) and mean weight of 70 kg (SD 11). Four of the patients were male, while 13 were female. Eight of the patients had coexisting Type 2 Diabetes Mellitus (Table II).

A. Primary Outcome: Blood pressure

Figure 2 shows the run chart of blood pressure averages. Table III illustrates overall mean blood pressures prior to the pilot, between the pilot and intervention, and after the intervention. The mean systolic and diastolic

TABLE II. BASELINE PATIENT CHARACTERISTICS (N=17)

	Mean (SD) or N (%)
Age (years)	58 (14)
Sex	
Male	4
Female	13
Weight (kg)	70 (11)
Diabetic	8

pressure for all patients was 146/78 mm Hg at baseline, compared to 153/83 mm Hg (systolic SD 30.8, diastolic SD 12.7) between the pilot and the intervention, and145/81 mm Hg after the intervention. Both systolic and diastolic pressure averages showed an increase in between the pilot and the intervention, but then a decline, more prominently in systolic pressures, after the intervention. It must be taken into account that, prior to the pilot, there were only ten patients that were identified as meeting inclusion criteria. All additional patients were added in between the pilot and intervention. Of note, there were more than double the number of diabetics in the post-pilot compared to before the pilot, which could explain the absence of large decline in blood pressures. All patients appeared to be more stable following the intervention.

TABLE III. MEAN BLOOD PRESSURE VALUES

	Mean Blood Pressure (mm Hg)
Prior to Pilot	146/78
Between Pilot & Intervention	153/83
After Intervention	145/81

Pilot date started 3/7/15. Intervention date started 10/10/15. Blood pressures before Pilot, between Pilot and Intervention, and 6 months following Intervention.

B. Secondary Outcomes: Community and Local Provider Effects

Local providers self-reported increased confidence in prescribing practices, and followed the algorithms more consistently, making changes when needed, after the intervention. Community members also self-reported increased medication adherence and understanding of management of their hypertension. Median and average number of kept appointments for medication refills and blood pressure checks increased, most prominently after the intervention, and is shown in Figure 3 below. The

 ISBN: 978-1-61208-604-0

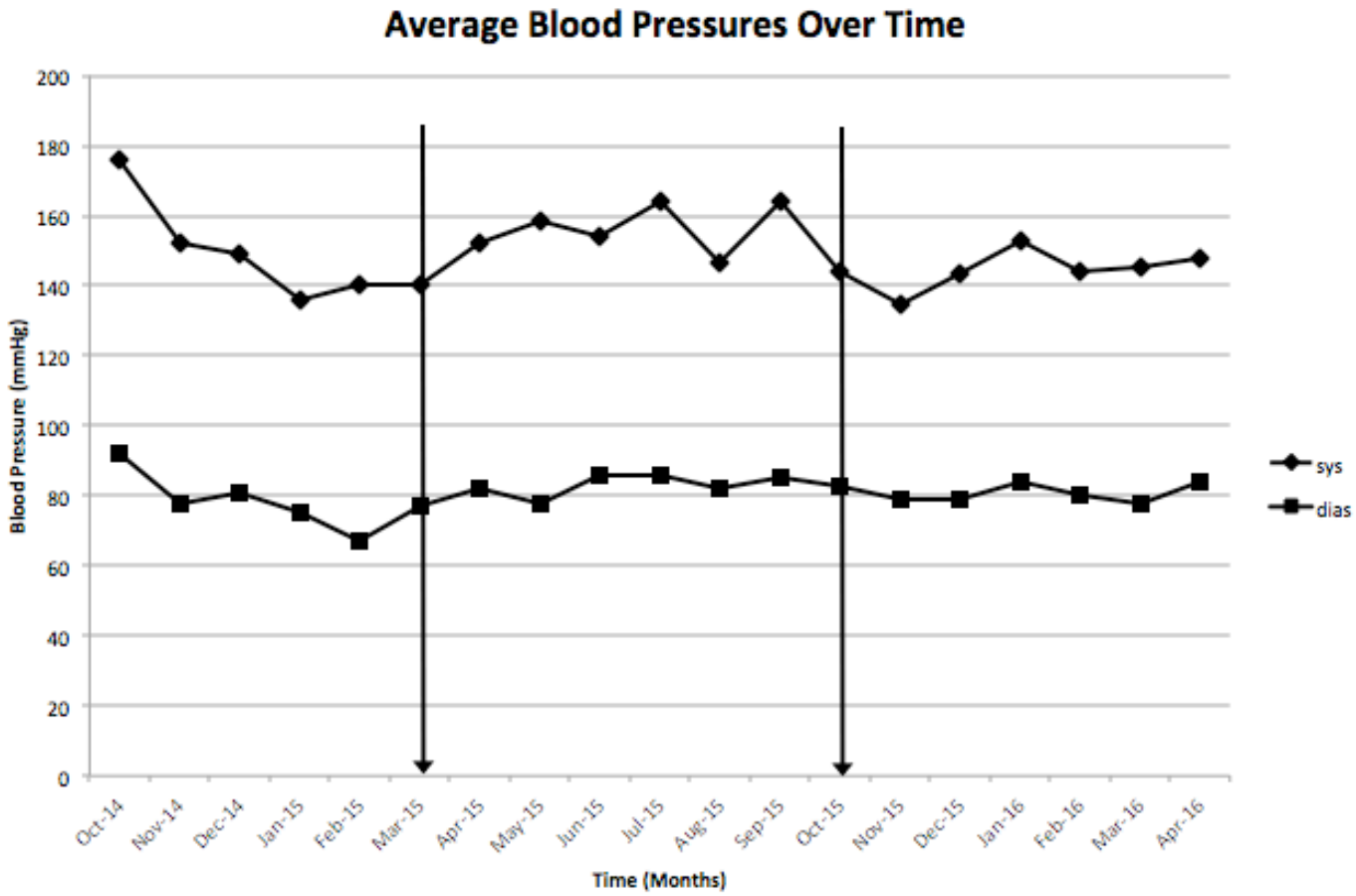

Figure 2. Average blood pressures over time, with arrows indicating pilot and intervention

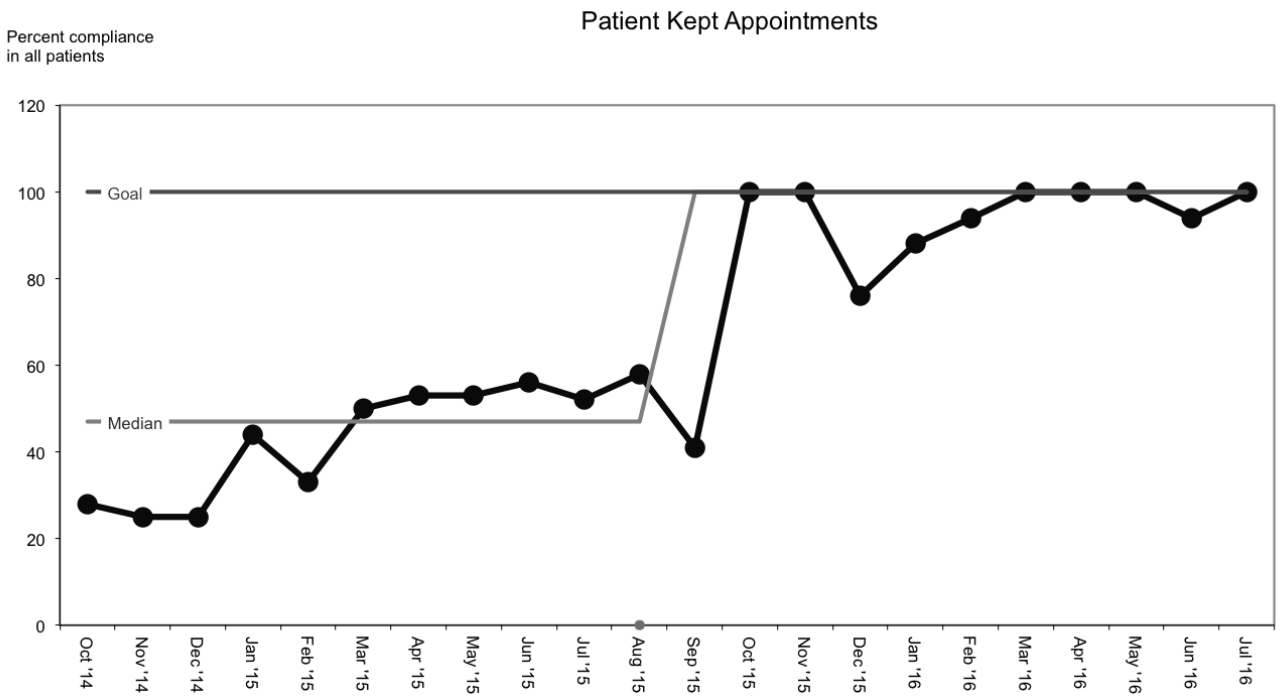

Figure 3. Percent of patients presenting to clinic for monthly blood pressure checks and medication refills

 ISBN: 978-1-61208-604-0

appointment compliance median was 47% at baseline, compared to 100% after the intervention.

IV. DISCUSSION

This study revealed an increase in mean systolic and diastolic pressures after the Pilot, and a subsequent decline in both systolic and diastolic pressures after the Intervention.

As discussed earlier, there proved to be confusion after the Pilot and initial presentation of the algorithm. Evaluation of the electronic medical record, coupled with discussion with local providers, indicated a number of issues. These issues were addressed via root cause analysis, detailed in Algorithm Development. Many of the problems identified fell into the categories that have been presented in prior reviews as barriers in guideline applications, those being knowledge, attitude, and behavior [17]. The addition of the Intervention to our strategy allowed us to address and correct upon the limitations in each of those categories. Improvement of blood pressure values post-Intervention suggests that those techniques improved upon the organization, understanding, and cost efficiency of the algorithms, and ultimately created a successful algorithm-based educational program. Considering the difficulty in implanting clinical guidelines, we recommend a similar approach for future studies, with regular follow-up intervals and planned Intervention.

It would be necessary to follow-up current pressures to determine whether the decline in blood pressures can be definitively attributed to our methods. We would hypothesize that blood pressures have continued to improve since our retrospective data review.

Effect on the community and local providers was noted to correlate with the improvement in blood pressure post-Intervention. The collaborative process of adjusting the algorithm with local providers built trust with the Nicaraguan health care providers. This phenomenon aligns with recommendations from experts in global health that have emphasized the need for partnership with host countries [18]. The addition of the option for remote consults with physicians in Tampa, Florida, also seemed in to increase prescriber confidence. Treatment plans were more consistently followed.

Community adherence and dedication to self-improvement also seemed to increase over the course of our study. Community members became more active participants in their health care, traveling to clinic monthly to check their blood pressures and refill their medications. This is compatible with models of hypertension management that have been recognized by the American Heart Association, American College of Cardiology, and the CDC, which describes improved clinical outcomes with active involvement and monitoring by both the patient and his/her medical professionals [19]. We highlight a strong need for an educational foundation.

Limitations include the addition of many participants after the Pilot. Our study is limited by small sample size. Finally, we are limited in comparison of our findings with similar initiatives, as there is not current outcomes-based literature regarding the standardization of management of non-communicable disease in resource-poor areas of Nicaragua. However, similar projects in rural areas of Honduras and China have also demonstrated success in creation of community-specific programs [14][20].

V. CONCLUSION

Our evaluation suggests that there could be a benefit to the establishment of community-specific algorithms for the management of hypertension. We stress the need for continued study in this subject, given the significant morbidity and mortality associated with uncontrolled hypertension. However, we suggest that taking the time to develop a community-specific algorithm-based educational program using methods similar to those we have prescribed above can result in improved provider confidence, improved community

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 ISBN: 978-1-61208-604-0

Bibliometric Analysis of Breastfeeding Research in the Middle Eastern Arab Countries

Nancy Hallal[1], Mohamad-Mustafa Hariri[2], Ali Al-Khatib[1], Hassan M. Khachfe[2]
[1] Department of Nutrition and Food Sciences
[2] Lebanese Institute for Biomedical Research and Application (LIBRA)
Lebanese International University
Beirut, Lebanon
nancy.hallal@liu.edu.lb; 41620011@students.liu.edu.lb; ali.alkhatib@liu.edu.lb; hassan.khachfe@liu.edu.lb

Abstract— **The Middle East is a place where breastfeeding is both culturally recommended and socioeconomically needed. The objective of this article was to quantify the research activity about breastfeeding (BF) in the Middle East over the last 10 years. A PubMed search was conducted using medical subject headings and author affiliation to retrieve research articles published from the Middle East between 2007 and 2017 (inclusive). Middle Eastern countries produced only 5% of the total number of BF research articles in the world, with Turkey and Iran ranking at the top of the list. Among the 15 Arab countries probed, Qatar ranked first in the number of BF publications per million people (PMP) averaging 6.61 PMP, while Yemen ranked 15th with the least number of 0.10 PMP. On the other hand, Iran ranked first with 39.93 BF publications per USD$1000 Gross Domestic Product (GDP) per capita, Turkey ranked second with 24.19 publications per USD$1000 GDP per capita, while Bahrain ranked 15th with only 0.44 publications per USD$1000 per GDP per capita. Although the topic poses as both a religious – cultural – recommendation and a socioeconomic necessity, research activity about BF in the Middle East still lags behind developed countries. Greater productivity levels are expected to emerge to accompany the recent significant investment in research in the Arab world in general, and the Gulf countries in particular.**

Keywords-bibliometric analysis; breastfeeding; Middle East.

I. INTRODUCTION

Natural mother's milk has been shown to be a basic and important primary nutritional source for a baby [1, 2]. All while meeting the physiological needs of the baby, breastfeeding is thought to support the psychological development of the neonate through the mother-infant tie [3]. Breastfeeding is a phenomenon that has cultural, social, and spiritual dimensions, very much related to religious doctrines [4].

The recommendations put forth by the World Health Organization (WHO) state that babies should be fed with breast milk for at least two years, with breast milk being the only nutritional supply for the first six months of neonatal age, then additional supplements thereafter [5]. Although the aforementioned recommendations resonate well with the cultural and religious paradigms, only 49% of babies born in 2011 were found to have been breastfed to the age of 6 months, and a fractional 27% to the age of one year [6]. It has also been noticed that the average span of breastfeeding is shorter in richer countries, compared to longer durations in societies with lower incomes [7]. In a study on breastfeeding in United Arab Emirates, a total of 98% of 593 Emirati mothers included in the study initiated breastfeeding and the mean duration of breastfeeding was 8.6 months [8] while it was 52.3% in Hafr Al Batin city in Saudi Arabia [9].

Globally, a lot of research has been done on breastfeeding, from protein interactions and biomedical effects [10]-[12], to maintenance and weaning strategies [13]-[16], to the psychological underpinning of pre- and post-natal phases [17], to the behavioral development of the neonate [18]. This is particularly related to the variety of interests different researchers have on the topic.

Bibliometric studies have been used to analyze and interpret pertinent trends in medical practice, as well as the evolution of research behavior [19]. The purpose of this report is to probe the trends in published breastfeeding research in the Middle Eastern Arab (MEA) countries. In particular, the purpose of this report is to: (1) Describe trends in number of breastfeeding publications produced by the MEA countries, and (2) inspect the abundance of publications produced by different universities within the MEA countries.

The rest of the paper is structured as follows. Section 2 describes the methodology used in the research. Section 3 displays the results obtained. Section 4 discusses the results, and finally, Section 5 gives some conclusions.

II. METHODOLOGY

Papers on "breastfeeding" published between 2007 and 2017 in the Middle East were collected from the data-base website PubMed (available from the National Institutes of Health) during September 2017.

In the following bibliometric analysis, PubMed filters were customized to include the following types of articles: case reports; clinical conference; clinical trial; clinical trial, phase I; clinical trial, phase II; clinical trial, phase III; Clinical study; comparative study; Consensus Development Conference; controlled clinical trial; journal article; letter; meta-analysis; multicenter study; randomized controlled trial; review; Scientific integrity review; systematic reviews; validation studies.

As this research is constricted to the Middle East region, the following 15 countries were investigated: Bahrain; Egypt; Iraq; Jordan; Kuwait; Lebanon; Oman; Palestine; Qatar; Saudi Arabia; Syria; United Arab Emirates; and Yemen. Iran and Turkey were

 ISBN: 978-1-61208-604-0

TABLE I. NUMBER OF PUBLICATIONS, POPULATION SIZE, AND GDP PER CAPITA OF THE 15 MIDDLE EASTERN ARAB COUNTRIES, ALONG WITH IRAN AND TURKEY

Country	number of Publications	Population size	GDP per Capita
Bahrain	1	1.425	2.23
Egypt	62	95.69	3.51
Iran	198	80.28	4.96
Iraq	7	37.2	4.61
Jordan	44	9.456	4.09
Kuwait	13	4.053	28.98
Lebanon	28	6.007	7.91
Oman	13	4.425	14.98
Palestine	6	4.55	2.00
Qatar	17	2.57	59.33
Saudi Arabia	47	32.28	20.03
Syria	4	18.43	2.06
Turkey	261	79.51	10.79
United Arab Emirates	23	9.27	37.62
Yemen	3	27.58	0.99

included for comparison as the closest non-Arab neighboring countries.

To search for the specific publications by topic and country, we applied Medical subject headings (MeSH): the National Library of Medicine (NLM) controlled vocabulary thesaurus used for indexing articles for PubMed. The results were collected by applying the Boolean searching technique (a type of search allowing users to combine keywords with operators (or modifiers) such as AND, NOT and OR to further produce more relevant results. For example, searching for publications on breastfeeding in Lebanon would look like this: “Breastfeeding” AND “Lebanon.”

III. RESULTS

A. Data Filtering

Thirteen thousand nine hundred seventy-five “13975” breastfeeding papers were retrieved from PubMed between 2007 and 2017. Seven hundred twenty-seven “727” (5.2 %) were published from the Middle-Eastern countries. Turkey with 261 publications (35.9 %) ranked first in the Middle East, and along with Iran 198 publications (27.2 %), which ranked second, contributed around two-thirds of publications (Table I).

B. Data Processing

For technical purposes and a more advanced comparison, the number of publications was corrected by means of population size (Table II) and Growth Domestic Product (GDP) (see Table III). This was made possible by dividing the number of publications retrieved by the population size of each country (population size according to the data of the World Bank) and by the USD$1000 GDP per capita, respectively.

IV. DISCUSSION

Although breastfeeding is considered a social and religious mandate [4], as well as – at times – an economic need [7], in most of the developing countries, scientific research to corroborate the benefits of such a natural phenomenon seems to be still lacking in most of these countries.

The results obtained (Figure 1) are hardly considered eligible for fair comparison; this is due to the vast differences in the population size and economic backgrounds of the countries in question.

For the statistical imperfections listed above, and to get rid of the errors associated with population size, we corrected our results by dividing the number of breastfeeding publications by the population size in millions (Figure 2) [20]. For example: United Arab Emirates have 23 breastfeeding publications within the last 10 years, the population size of this country is 9.27 million, dividing 23 by 9.27 will give us (2.48) publications per million. Applying this formula to the 15 Middle Eastern countries yielded the results shown in Table II and Figure 2. Qatar ranked first with 6.61 publications per million, Lebanon ranked second with 4.66 publications per million, while Yemen ranked 15th with the least number of publications 0.10 per million.

TABLE II. RATIO OF PUBLICATIONS TO POPULATION SIZE, IN MILLIONS, IN THE 15 MIDDLE EASTERN ARAB COUNTRIES, ALONG WITH IRAN AND TURKEY

Country	Publications per Million 2007-2017
Bahrain	0.701754386
Egypt	0.647925593
Iran	2.466367713
Iraq	0.188172043
Jordan	4.653130288
Kuwait	3.207500617
Lebanon	4.661228567
Oman	2.937853107
Palestine	1.318681319
Qatar	6.614785992
Saudi Arabia	1.456009913
Syria	0.217037439
Turkey	3.282605962
United Arab Emirates	2.481121899
Yemen	0.108774474

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TABLE III. RATIO OF PUBLICATIONS TO POPULATION SIZE, IN MILLIONS, IN THE 15 MIDDLE EASTERN ARAB COUNTRIES, ALONG WITH IRAN AND TURKEY

Country	Publications per $1000 of GDP 2007-2017
Bahrain	0.448430493
Egypt	17.64125094
Iran	39.93884113
Iraq	1.518569941
Jordan	10.76336737
Kuwait	0.448656447
Lebanon	3.538033864
Oman	0.867687067
Palestine	3.004055475
Qatar	0.286528798
Saudi Arabia	2.34663844
Syria	1.94359682
Turkey	24.19442305
United Arab Emirates	0.611341014
Yemen	3.029293266

To eliminate the economical factor, another correction was introduced; this was made possible by correcting the results with the Gross Domestic Product (GDP) per capita [20]. Dividing the number of breastfeeding publications by the USD$1000 GDP per capita for each Middle Eastern country yielded the results shown in Figure 3. Iran ranked first with 39.93 breastfeeding Publications per USD$1000 GDP per capita, Turkey ranked second with 24.19 publications per USD$1000 GDP per capita, while Bahrain ranked 15th with only 0.44 publications per USD$1000 per GDP per capita. Moreover, the number of universities in the country was taken as another factor that may affect the number of publications, so we calculated the ration of publications to numbers of universities. The results showed that Qatar ranked first followed by Turkey then Jordan while Bahrain was at the end of the list with only 0.067 publications per university (Figure 4). Here, it is worth noting that the various rates obtained are the accumulated averages over the last ten years, and are not presented as per individual years.

V. CONCLUSIONS

At the present time, most of the Middle Eastern Arab countries are lagging behind in terms of research outcomes, in general, and breastfeeding research, in particular. While Jordan and Lebanon show some promises in terms of the publication size with respect to the population size, other high GDP countries – the Gulf States for example – are not investing in this type of research as much as some much poorer countries, like Palestine and Yemen. It also appeared that more effort is needed to encourage universities to be involved in such types of research especially for their significant role in leading research activities in their countries. More probes into the growth rate of this research over the last decade will give insights into the trends taken by researchers in this part of the world.

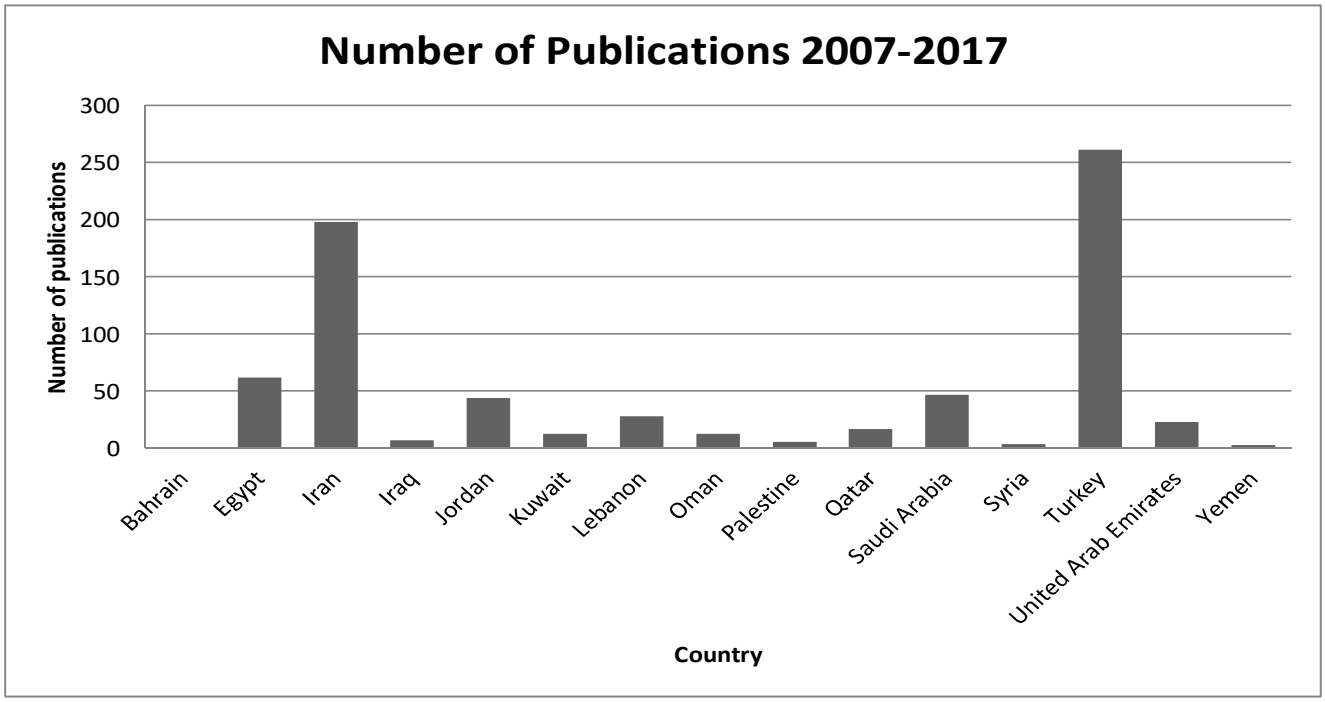

Figure 1. The number of publications per country

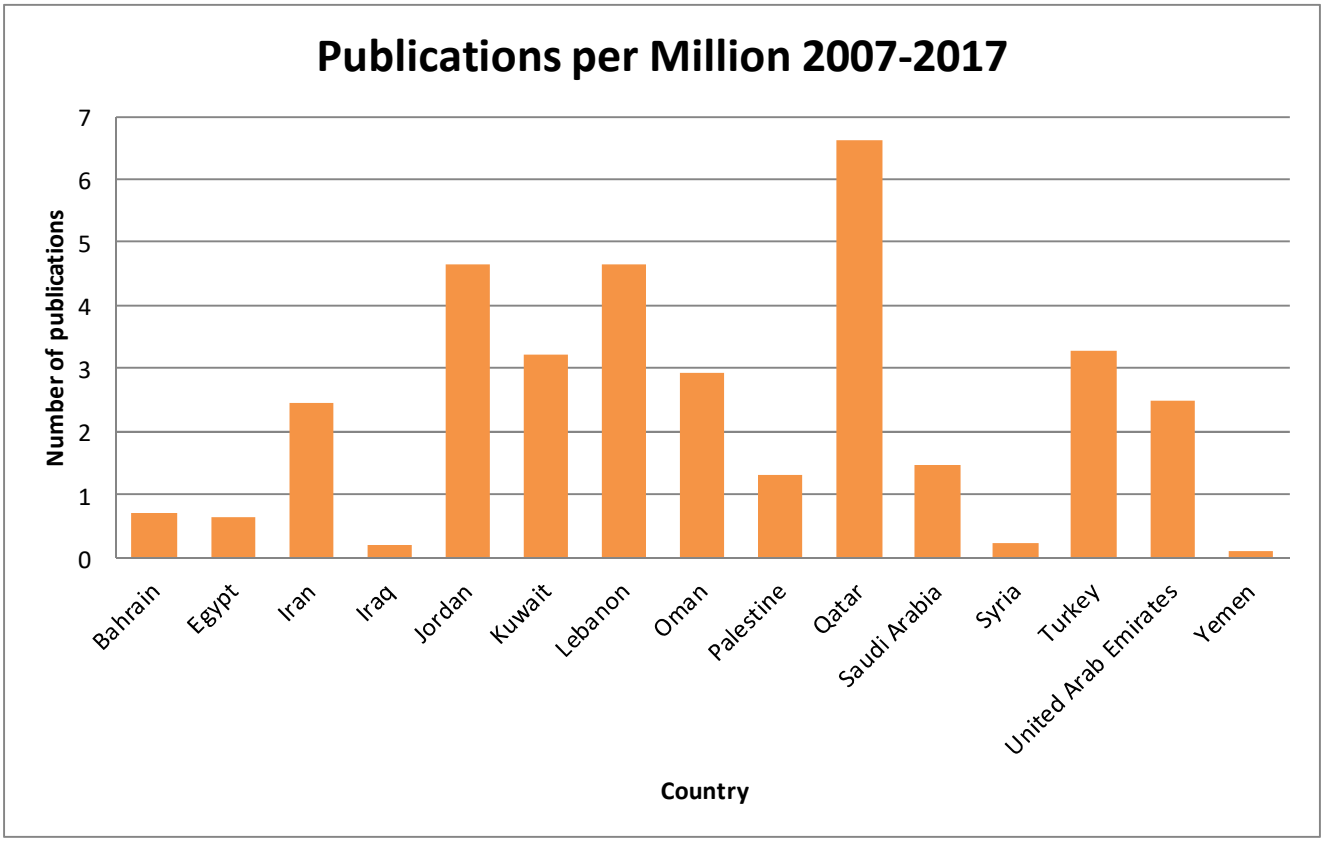

Figure 2. The number of publications with respect to the country's population size

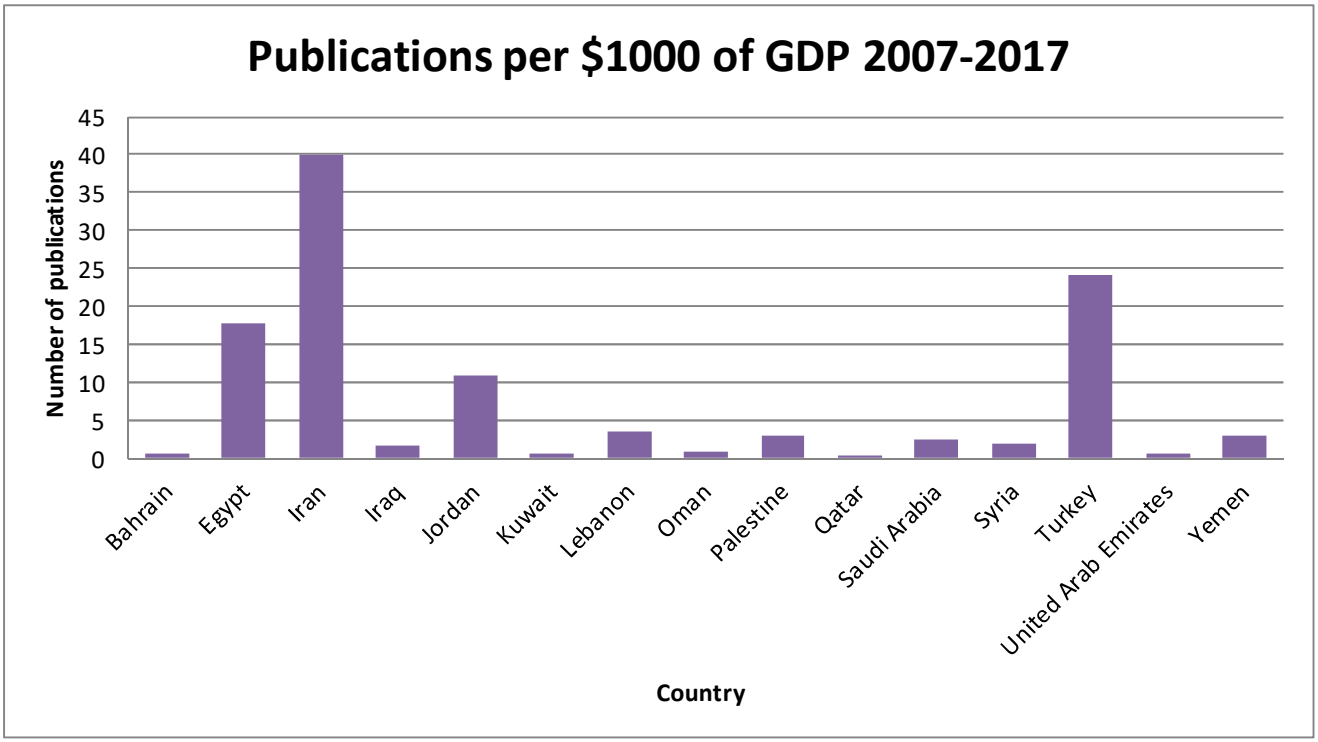

Figure 3. The ratio of publications to the country's GDP

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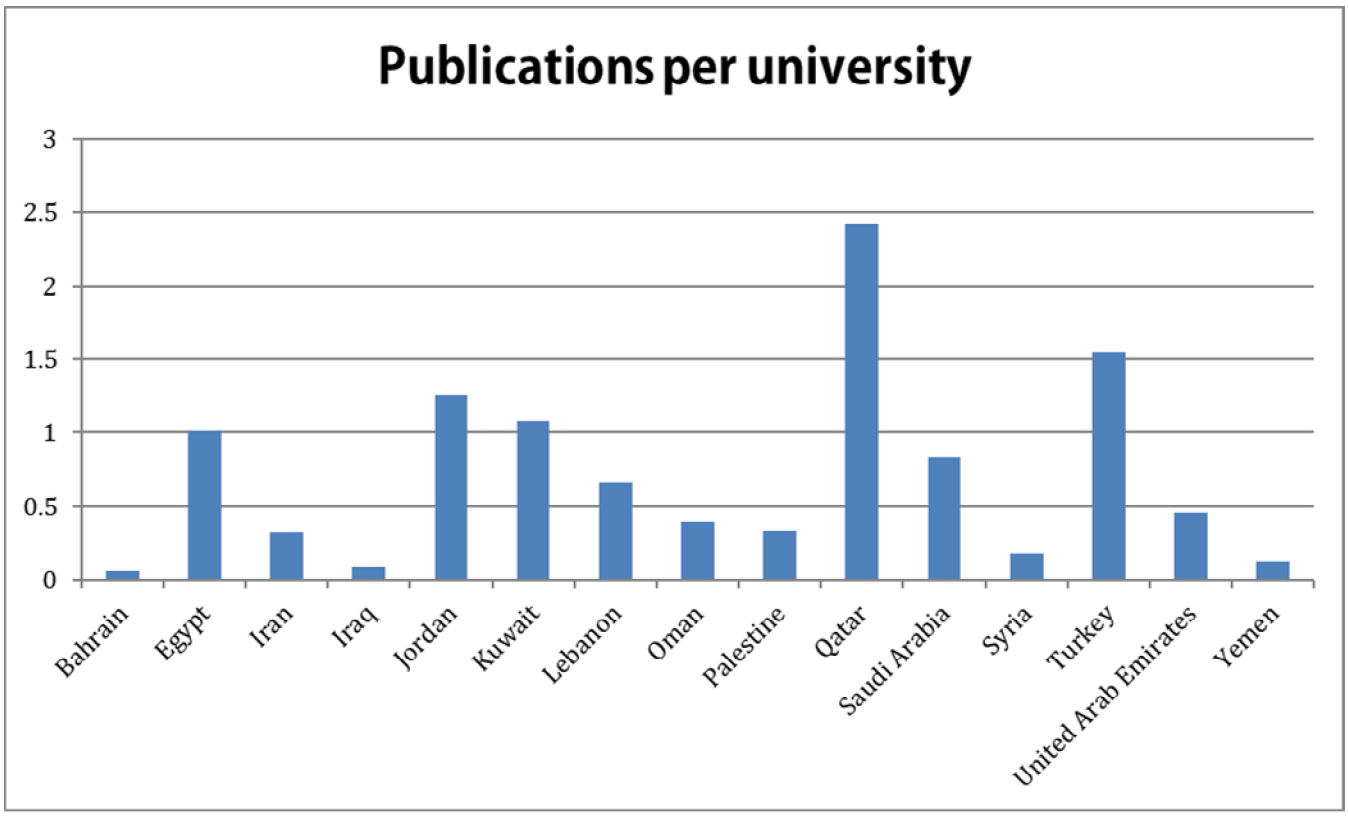

Figure 4. The ratio of the number of publications to the number of universities in each country.

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 ISBN: 978-1-61208-604-0

Big Data & Wearable Sensors Ensuring Safety and Health @Work

Farhad Abtahi, Mikael Forsman
Institute of Environmental Medicine
Karolinska Institutet
Stockholm, Sweden
e-mail: farhad.abtahi@ki.se,
mikael.forsman@ki.se

Fernando Seoane, Heikki Teriö
Department of Biomedical Engineering
Karolinska University Hospital
Stockholm, Sweden
e-mail: fernando.seoane@ki.se, heikki.terio@karolinska.se

Jose A. Diaz-Olivares, Liyun Yang, Ke Lu, Jörgen Eklund, Kaj Lindecrantz
School of Technology and Health
KTH Royal Institute of Technology
Stockholm, Sweden
e-mail: jadiaz@kth.se, liyuny@kth.se, kelu@kth.se,
jorgen.eklund@sth.kth.se, kaj.lindecrantz@sth.kth.se

Cesar Mediavilla Martinez, Santiago Aso
ATOS Spain S.A
Madrid, Spain
cesar.mediavilla@atos.net, santiago.aso@atos.net

Christian Tiemann
Philips Research
Eindhoven, Netherlands
e-mail: christian.tiemann@philips.com

***Abstract*—Work-related injuries and disorders constitute a major burden and cost for employers, society in general and workers in particular. We@Work is a project that aims to develop an integrated solution for promoting and supporting a safe and healthy working life by combining wearable technologies, Big Data analytics, ergonomics, and information and communication technologies. The We@Work solution aims to support the worker and employer to ensure a healthy working life through pervasive monitoring for early warnings, prompt detection of capacity-loss and accurate risk assessments at workplace as well as self-management of a healthy working life. A multiservice platform will allow unobtrusive data collection at workplaces. Big Data analytics will provide real-time information useful to prevent work injuries and support healthy working life.**

Keywords-Preventive Occupational Healthcare; Ergonomics; Wellbeing at Work.

I. INTRODUCTION

Currently, work–related disorders yield a significant cost for society. In Europe, this cost has been estimated to range between 2.6 and 3.8% of gross national product (GNP) [1]. For Sweden, this cost has been calculated to more than 5 billion € annually. The economic impact for occupational stress in the USA exceeds 300 billion USD per year [2]. In addition to quality and productivity losses, a poorly designed workplace can generate a direct cost of over 50000 € for a single company.

Statistics indicate that human error is common in work accidents especially among heavy machinery operators and truck drivers. In 87% of truck accidents caused by the driver, the driver was not fit for driving due to fatigue or use of prescribed drugs [3]. Additionally, it has been shown that implementing health and wellbeing initiatives in companies may not only reduce work absenteeism with average of 25% but also decrease up to 40% workers compensation cost [4, 5]. Thus, there is a great need for solutions enabling prevention of occupational health-risks, preventing accidents in the operation of dangerous machineries, and also improving employee's health and wellbeing at work. The rest of the paper is structured as follows. In Section 2, the main hypothesis of project is described. Project goals are described in section 3 and followed by introducing the consortium in section 4. Use case specification and system architecture are described in section 5 and 6, respectively. Finally concluding with a short summary.

II. WORKING HYPOTHESIS

New technologies provide a basis for practical actions enabling opportunities to ensure a healthy and safe working life. Current rapid developments in sensor technology, mobile data acquisition, improved risk assessment methodologies combined with Big Data analysis allow the development of pervasive and unallocated solutions. We hypothesize that this combination can usually predict the risk at workplaces, the individual's risk of developing work-related disorders and assess the capacity for operating demanding and dangerous machinery (including cranes trucks, buses, trains and airplanes) to a cost that is realistic for the main working environment actors and different stakeholders, *e.g. occupational health services.*

III. PROJECT GOALS

We@Work [6] aims to transform the current implementation of occupational health services achieving the following objectives:

A) To implement a service enabling self-management of health and wellbeing @work for employees.

B) To implement a service enabling screening for psycho-physical capacity to operate demanding equipment.

 ISBN: 978-1-61208-604-0

C) To implement a service for early warning of risks for musculoskeletal disorders caused by adverse work design.

D) To develop such a scalable solution hosting the previous services to a pre-commercial development level.

IV. CONSORTIUM & KEY COMPONENTS

A multidisciplinary consortium involving seven partners from Spain, Netherlands and Sweden has been created:

- *Industry and Occupational Health Enterprise:* Atos Spain S.A. (project leader), Philips Research, Z-Health Technologies AB (Z-HT) and QuironPrevencion.
- *University Hospital and Academia:* Karolinska Institutet, KTH – Royal Institute of Technology, Karolinska University Hospital a part of Stockholm County Council.

Phillip's cloud platform combined with wearable monitoring technologies like garments sensorized with Z-HT's *ECGZ* monitors (see *Figure 2*), [5], inertial motion units and the Phillip's *Health watch*(see *Figure 1*), [7] will boost the potential impact of Atos' *Pocket mHealth* app for self-health assessment and QuironPrevencion's screening tool for predicting loss of psychophysical capabilities: the VAPEL system [8].

V. USE CASE SPECIFICATIONS

In order to validate the different technological solutions developed in this project, two different scenarios have been selected as use cases. The main objective of these is to test the detection of detrimental changes in the workers, produced either by the working or the individual's conditions, by monitoring the variables acquired from the collection of sensor systems. If certain pre-established ranges are surpassed, which could indicate that a loss of the worker's capacity is occurring, immediate actions can be possibly taken to alleviate or avoid this circumstance.

Initially, a risk assessment of the health status of the worker will be carried out, making use of Goldberg's General Health Questionnaire [9]. If the health situation of the worker is especially complex, the platform will communicate it, avoiding sending messages and notifications that may entail a risk. The user could control the maximum amount of notifications to receive per day (except for some priority

Figure 2: Textrode Sensorized Vest;(a) electrode placement in the inner side view (b) front view and monitoring device, (c) back view.

Figure 1: The Philips health watch.

alarms related to health risks).

Some thresholds for heart and respiratory rates could be included to send urgent warnings if these limits are surpassed. Following the acquisition of data from the sensor system, the analytic layer will request the data from Pocket mHealth for the further analysis, making use of stored health and monitoring data to offer recommendations, suggestions and advices being these displayed by Pocket mHealth. On the other hand, the worker could decide if they want to store some of the gathered data in his/her personal health record. The two different scenarios that are included in this use case specification are the following:

A. Sterilizing Unit at a hospital

The setting comprises a real working scenario with 12 employees at the new Karolinska University Hospital environment. These workers are exposed to repetitive movements, awkward postures and strenuous pushing and pulling efforts, in a situation of medium to high activity rate, with manual handling of medical instruments and three different work shifts in a 24-hour time-lapse. It is common to find musculoskeletal disorders in this scenario, especially pain in elbows and shoulders.

In the first stage, data is collected regarding the individual's basic parameters like age, gender, level of daily activity. After, the self-health assessment and VAPEL screening tool are used for monitoring any potential loss of capabilities. The VAPEL tool will be used several times during the day, typically 4 times.

Through the sensor system mentioned before, instant values of biomedical data are acquired. These monitored variables consist of the individual's heart rate, energy expenditure, postures and movements of upper arms, back and wrists, as well as the worker's physical activity (time in sitting / standing / walking / other activities).

Once these variables are stored in the system, algorithms developed by Karolinska Institutet and KTH Royal Institute of Technology (KTH) will be applied, in order to check if the values are inside pre-established ranges. If these ranges are surpassed, an alarm signal will be produced by the system, notifying the worker through the Pocket mHealth, he/she may inform his/her manager, and they may together search for solutions.

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Figure 3: We@Work Architecture Framework

B. *Wellbeing at the office*

The setting is comprised of two different scenarios, located in Stockholm (KTH) and Madrid (Atos), accounting for a total of 24 workers and a time term of project of 2-4 weeks, in an office daily schedule.

In the context of white-collar workers and the office workplace, it is intended to validate the system as a tool to promote and support a healthy and safe working life, reducing the number of work incidences or occupational health problems.

We will make use of real-time data, ergonomic analysis and Pocket mHealth as the user interface, in order to provide notifications, recommendations and warnings to employees. The system will always provide clear and simple messages (feedback, suggestions and advises), avoiding any kind of misunderstanding.

Specifically for the Atos scenario, Premap will support in the identification of risky situations, measuring the variation of response times according to the time of the working day and the day of the week, by means of a mobile device type test. If a risky situation is identified, actions will be done to check if a loss of capability of the worker has been produced, including the realization of the VAPEL test.

VI. System Architecture

In order to structure how the We@Work innovation project will meet the goals defined by use cases, the architecture of the pervasive monitoring solution, see Figure 3, is described.

The We@Work platform consists of a cloud based infrastructure, wearable sensor units and mobile applications. The cloud based backend infrastructure will be developed by Philips and makes use of Amazon Web Services. Android applications by Atos, KTH, Philips and Premap will use the cloud platform for communication, storage, user management, potential big-data analysis and pushing notifications and feedbacks. Each application will have a specific functionality dedicated to data gathering from sensors through Bluetooth or other sources like questionnaires. The communication between sensing layer and cloud system is based on HTTPS protocol through representational state transfer (RESTful) application programming interface (APIs).

According to the use case specifications, the technologies included will be:

- Philips Health watch, a wrist-worn Bluetooth equipped wearable sensor that will allow keeping track of periods of physical activity. This data is synced to a backend system where it can be used for further processing to generate specific outputs for the defined use cases.
- Z-Health ECGZ and garment, which allow the sensing of biopotentials and electrical bioimpedance. Together with a vest or underwear t-shirt equipped with textile electrodes on the chest it is possible to obtain an ECG LEAD II that allows an uncomplicated detection of the R-peak and straightforward extraction of heart rate, enabling heart rate variability analysis.
- Inertial measurement units, in addition to built-in accelerometers Philips Health Watch, with 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer that will be used to measure the exposure of different limbs e.g., arm, shoulder, wrist and/or activity recognition.
- Pocket mHealth, as the main component for the communication with users of We@Work. It will display visualization of relevant data from the user, including reception of the notifications generated by the analysis components based on the data collected from the use, and will serve as a possible source of data collected from the users.
- Analytics algorithms (KTH), to provide workers with feedback, advice and suggestions to health and wellbeing, with the pre-establishment of ranges and decision rules to enable alarms and recommendations. For physical workloads, these will be based on energy expenditure while for repetitive movements and uncomfortable postures this will control relative angles and angular velocity. Physical activities are also evaluated with time sitting / standing / walking. The parameters will be presented on the platform allowing for feedback. Warnings will be triggered when the signals exceed the recommended limits accordingly. The warnings can be shown as notifications on the platform (Pocket mHealth), including both visual and auditory forms.

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- Cloud computing platform, to request/send data from/to the data backend, store data and run analytics. The result of these analyses will be stored in the database by using a custom API. In case of need for a feedback, notifications will be generated through notification system APIs.
- VAPEL, to assess the psychophysical capacity of workers (sufficient or not), through a series of tests that value the basic executive functions. The aim of VAPEL is to get a new system, which is able to assess and measure psychophysical skills of workers in order to ensure a safety workplace.

The system must be secured by providing confidentiality, integrity and availability and must implement basic security behaviors, such as authentication, authorization, confidentiality and data integrity.

CONCLUSION

We@Work project aims to integrate unique and currently available technological systems to obtain a completely integrated information communication technology (ICT) platform for occupational health. The platform will be validated during 2018 in real work scenarios at Karolinska University Hospital as well as within other partners associated with the consortium directly or indirectly.

ACKNOWLEDGMENT

The project has been granted by the Innovation Projects program by the EIT Health with project number 17102.

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 ISBN: 978-1-61208-604-0

Implementing Thyroid Ontology for Diagnosis and Care

Özgü Can, Emine Sezer, Murat Osman Ünalır, Okan Bursa, Mine Öz and Tuğçe Dülge
Department of Computer Engineering, Ege University, 35100 Bornova, Izmir, Turkey
e-mail:{ozgu.can, emine.sezer, murat.osman.unalir, okan.bursa }@ege.edu.tr,{mineoz621, dulgeetugce}@gmail.com

***Abstract*— Healthcare systems are changing their information systems with the increased advances in information technologies. With these improvements, patients expectations are also increased. Consequently, patients expect a quick diagnosis process and improvement in the treatment process. Additionally, it is important to share and reuse patients' information between different healthcare organizations and healthcare workers. There are lots of data standards and ontologies developed in the health domain. In this work, we propose a thyroid ontology for the diagnosis and care of the thyroid-related diseases. The proposed thyroid ontology will be a part of the Semantic Web based health information system in order to provide interoperability and reuse of health data. The proposed thyroid ontology can be used for treatment suggestion systems. Therefore, the healthcare decision support system will be improved.**

Keywords-Thyroid Ontology; Healthcare Information Systems; Semantic Web; Ontology Development.

I. INTRODUCTION

The continuous advancements in healthcare information technologies has lead to better opportunities for patients and also for healthcare workers. As healthcare is a consumer-oriented domain, there are various challenges in the healthcare domain. One of these challenges is to provide a better diagnosis and care to patients.

The thyroid gland is one of the most important organs that controls the metabolism of the body. The function of the thyroid gland, which assumes a vital function in the body, may deteriorate due to factors, such as genetics radiation, iodine deficiency and aging. As a result of this, diseases such as goiter, thyroiditis, hyperthyroidism, hypothyroidism, nodule, thyroid cancer can occur. Tests for these diseases are hormone and antibody tests. Hormone tests are based on the T3, T4 and TSH (Thyroid-Stimulating Hormone) values that are secreted by the thyroid. In antibody tests, Anti-TPO (Anti-Thyroidperoxidase) and Anti-TG (Anti-Thyroglobulin) values are more frequently observed.

In this paper, we propose a thyroid ontology. The proposed thyroid ontology in this study has more than one test that refers to these values. Our ontology can identify the disease according to these reference values. In contrast to the ontologies presented in [1] [2] that are based on expert systems, the goal of this ontology is to develop a knowledge base for thyroid disease, to query and to reuse the stored information of patients' test results for diagnosis and care. Therefore, it is possible to integrate the proposed thyroid ontology with other healthcare information systems in order to create an interoperable treatment system [3].

The paper is organized as follows: Section 2 presents the lifecycle of the thyroid ontology and explains the development of the thyroid ontology. Section 3 presents rule examples for the thyroid ontology. Finally, Section 4 concludes and outlines the direction of the future work.

II. THE LIFECYCLE OF THYROID ONTOLOGY

In order to develop the thyroid ontology, we followed the ontology development steps that are presented in [4]. According to this guide, the first step is determining the domain and scope of the ontology. Therefore, we defined the domain and scope of the thyroid ontology by answering some basic questions, such as: "What is the domain of the ontology?", "Where do we use the ontology?", "Who will use the ontology?", etc. The answers to these questions lead us to develop the ontology. In our thyroid ontology, we describe the medical tests that a physician requests in order to diagnose thyroid-related diseases and also to follow her patient's medical situation after the diagnosis. For the diagnosis of thyroid diseases, blood tests, thyroid ultrasound, thyroid scintigraphy and thyroid fine needle aspiration biopsy are used. The scope of the proposed thyroid ontology is only for blood tests. The patient is diagnosed based on the reference values according to the values of the blood test result. In addition to the test results and diagnostics, the laboratories where these tests are performed, the tasks and the patient information are defined in the thyroid ontology.

The second step in the ontology lifecycle is to define the competency questions that the thyroid ontology should be able to answer. While creating these questions, we focused on questions about laboratory results. Some questions are listed below:

- Does the gender and age affect thyroid tests?
- What are thyroid gland diseases?
- Which hormones should be analyzed for the diagnosis of the disease?
- Which hormone tests should be performed to determine disease types?
- How can blood tests be interpreted?
- What is the relationship between TSH, T3 and T4 hormones?
- Are antibodies and hormones the same thing?
- What are the conditions in which the thyroid antibody is used to diagnose the disease?
- Which anti-TPO and anti-thyroglobulin antibodies show hyperthyroidism?
- Is hyperthyroidism the same disease as goiter?
- Is diffuse hyperplasia a goiter disorder or a thyroid disease?

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- Which hormone level should be considered in order to keep track of the primary hyperthyroidism?

After defining the competency questions, we identified the important terms in the thyroid ontology. For this purpose, we created a comprehensive list of terms without considering whether there is a relationship between concepts or not. After completing this list, we performed a distinction between classes and instances that are necessary for the next step. Then, we used the most common methods for developing the class hierarchy, such as "top-down" and "bottom-up". We described the basic class and subclass concepts of the thyroid ontology as seen in Figure 1.

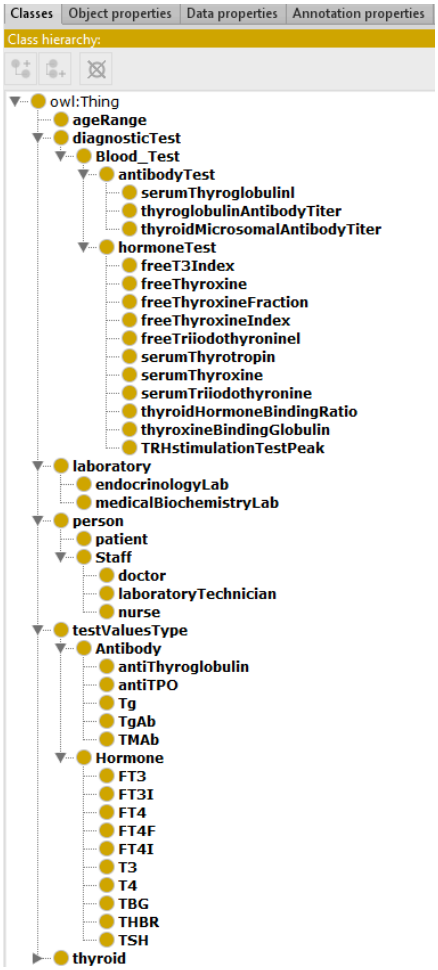

Figure 1. The basic concepts of the thyroid ontology.

The thyroid ontology includes the diagnostic test in order to make diagnoses. For this purpose, we created the `diagnosticTest` class. There are different tests for the diagnosis of each disease, so after establishing the disease hierarchy we created a separate class hierarchy for these tests. Many test methods are used for the diagnosis of the disease. But, in the proposed thyroid ontology we only included blood tests. Blood tests are divided into two subgroups: antibody tests and hormone tests. As seen in Figure 1, antibody and hormone tests are divided into subclasses. Each subclass diagnoses the disease by looking at the values of different hormone or antibody types. A separate class hierarchy has been established for the types of antibodies and hormones that these tests use in diagnostics. The thyroid ontology also includes information on where these tests are performed (`laboratory`), who owns them (`patient`), and who is responsible for the tests (`staff`). Figure 2 shows the subclasses of thyroid disease. Thyroid disease varies according to persons' age. For this reason, we grouped the patients according to their age (`ageRange`) in order to determine at what age range the likelihood of being sick is greater. Patients within the `ageRange` class are kept by age groups. Thus, we can easily reach the age range of the diagnosed patients, and also get a detailed information like the most common disease in the adult age groups.

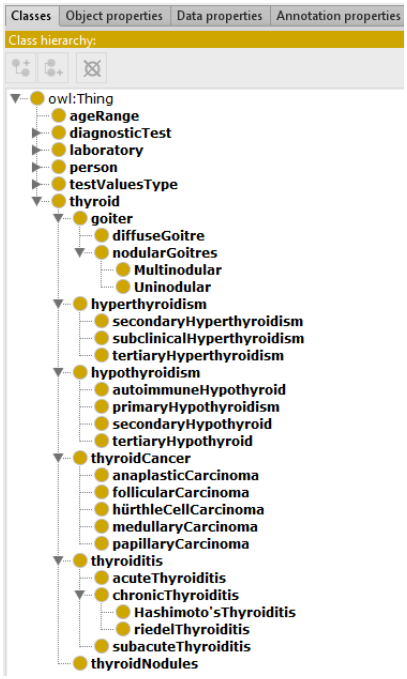

Figure 2. The subclasses of the thyroid class.

After completing the definition of the class hierarchies, we continued to develop the thyroid ontology by specifying object properties in order to represent relationships between classes. The object properties of the thyroid ontology are given in Figure 3. The definition of these properties are listed below:

- `defines`: Represents the relationship between the `diagnosticTest` class and `thyroid` class. So, the diagnosis of the test results will be easily accessed.
- `hasAgeRange`: Represents the relationship between `patient` class and the `ageRange` class. So, it will be possible to determine the age range of diseases that are more common. By using this

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relationship, patients within the ageRange class are kept according to their age groups.

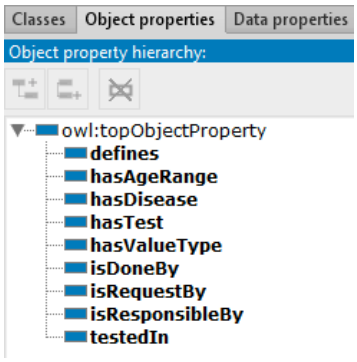

Figure 3. The object properties of the thyroid ontology.

- hasDisease: Represents the relationship between patient class and thyroid class.
- hasTest: Represents the relationship between patient class and diagnosticTest class. So, patients' test information is easily accessed through this relationship.
- hasValueType: Represents the relationship between Blood_Test class and testValuesType class. So, it is easy to learn which hormone value or antibody value are checked in a test.
- isDoneBy: Represents the relationship between Blood_Test class and testValuesType class.
- isDoneBy: Represents the relationship between diagnosticTest class and laboratoryTechnician class. The goal is to easily reach the knowledge of which technician made the test.
- isRequestBy: Represents the relationship between diagnosticTest class and doctor class. By using this relationship, the doctor who requested the patient's tests could be obtained.
- isResponsibleBy: Represents the relationship between diagnosticTest class and nurse class. The aim is to access the information of the nurse in charge of the patient during the testing process.
- testedIn: Represents the relationship between diagnosticTest class and laboratory class. By using this relationship, the information about the laboratory in which the tests are performed could be reached.

After completing the creation of object properties, we continued to develop the thyroid ontology by specifying data properties. Figure 4 shows data properties of the thyroid ontology.

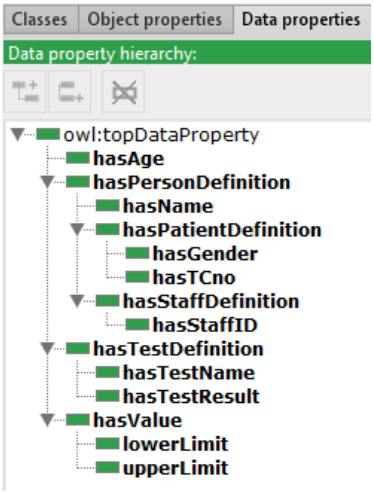

Figure 4. The data properties of the thyroid ontology.

The definition of these properties are listed below:

- hasAge: Represents the age information of the patient.
- hasPersonDefinition: Represents the information about the person.
- hasName: Represents the name information of the person.
- hasPatientDefinition: Represents the information about the patient.
- hasGender: Represents the gender of the person.
- hasTCno: Represents the social security number of the person.
- hasStaffDefinition: Represents the information about the staff.
- hasStaffID: Represents the identity number about the staff.
- hasTestDefinition: Represents the information about the test.
- hasTestName: Represents the name of the test.
- hasTestResult: Represents the result of the test which is used to diagnose the patient by comparing it with the reference values of the patient.
- hasValue: Represents the range values of the hormone and antibody types used in the test.
- lowerLimit: Represents the lower limit of the hormone and antibody types used in the test.
- upperLimit: Represents the upper limit of the hormone and antibody types used in the test.

In Figure 5, all of the relationships between classes of the proposed thyroid ontology are shown.

Finally, we created individuals of the given concepts of the thyroid ontology. The individuals of the thyroid ontology can be seen in Figure 6.

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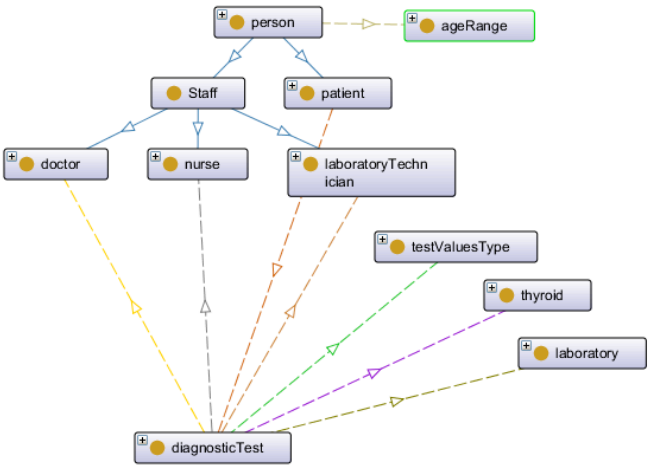

Figure 5. The relationship between the classes of the thyroid ontology.

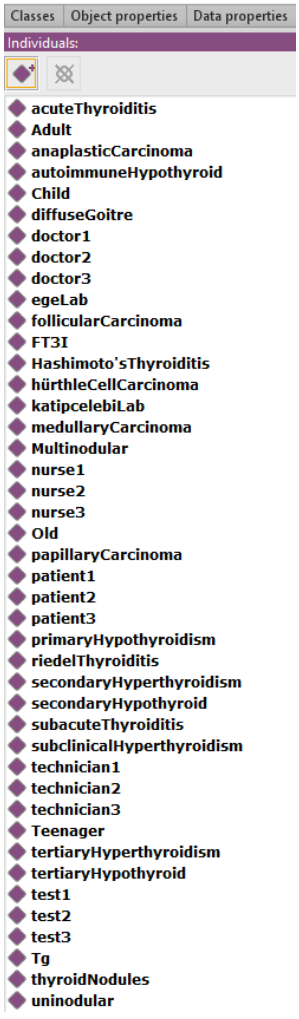

Figure 6. Individuals of the thyroid ontology.

III. IMPLEMENTING RULES

After creating the individuals of the proposed thyroid ontology, we wrote Semantic Web Rule Language (SWRL) [5] rules. Rules allow the ontology to reason about itself [6]. The rules are given in Figure 7.

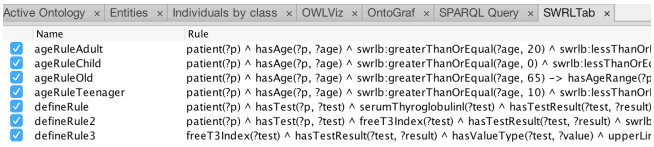

Figure 7. SWRL rules for the thyroid ontology.

The `ageRules` given in Figure 7 automatically set the `hasAgeRange` relationship between the patient and the "child", "teenager", "adult", or "old" instances by comparing the value with the age range when the patient `hasAge` data property value is entered. Therefore, there is no need to enter the age range for the patient.

Figure 8 shows the rule that is written for the diagnosis of the disease. This rule establishes the "defines" relationship between the test and the disease itself, and compares the result of the test with the min. or max. limit of the hormone or antibody that is considered as the reference value. Consequently, according to the result of the test, the disease is diagnosed.

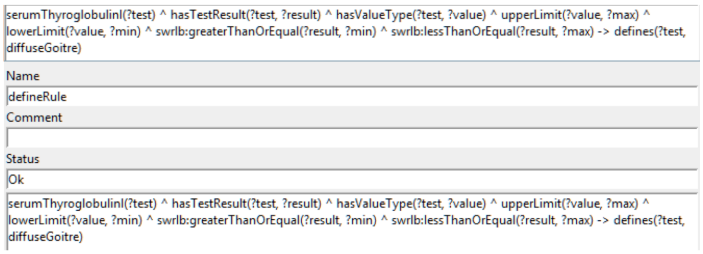

Figure 8. Rule for the diagnosis.

The thyroid ontology has $\mathcal{ALCRF}(\mathcal{D})$ expressivity. Before we run the rules in the proposed thyroid ontology, the axiom number was 472, after we execute rules this number has increased to 661. The related metrics are shown in Figure 9 and Figure 10, respectively. So, this shows the ontology works properly and increases axioms. We also wrote Simple Protocol and RDF Query Language (SPARQL) [7] queries and saw that these rules work correctly. The thyroid ontology is still being developed and extended with new concepts, object and data properties.

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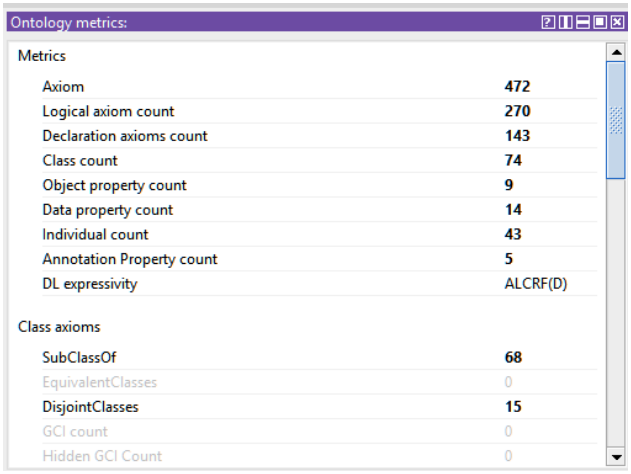

Figure 9. The thyroid ontology metrics before executing rules.

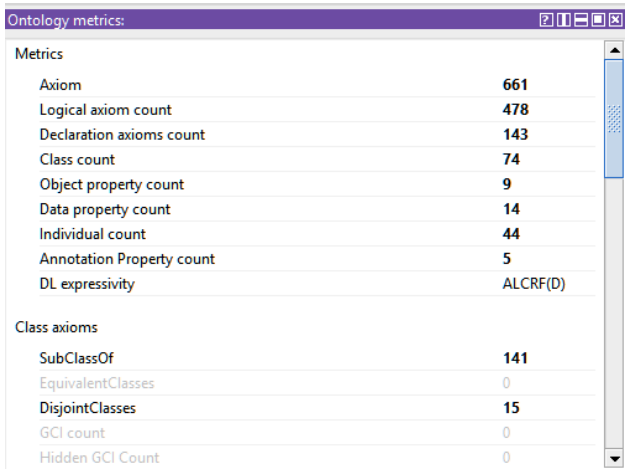

Figure 10. The thyroid ontology metrics after executing rules.

IV. Conclusion And Future Work

In this work, we proposed a thyroid ontology that will be a part of the Semantic Web-based Health Information System. The aim of this work is to provide interoperability and to reuse health data. Therefore, the healthcare decision support system will be improved. The thyroid ontology is still being developed, and will be extended with new concepts. As a future work, we will integrate Friend of a Friend (FOAF) ontology to describe personal information [8]. Also, privacy concepts will be added to the proposed ontology in order to ensure patient privacy.

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