



Research articles

An observational study on the accuracy of heart rate readings between smart watches and a hand held vital sign monitor in static and dynamic motions on a healthy young adult population

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ABSTRACT

There are various devices and applications available in the market that can be used to measure heart rates. These are becoming increasingly popular. Amongst these include the Apple watch, the Xiaomi MI Band and using the Thermal Application (T.A.P.) software (used through a Smartphone). In clinical practice and research, usually the E.C.G. Is used to measure the heart rates, (apart from manually counting the beats by palpation). The study will determine the accuracy of using the available devices in the market (previously mentioned), and also determine if they can be used on patients or subjects while sitting and walking, in clinical practice and researches. Method: It will be a comparative observational study. 50 students, selected as per the inclusion and exclusion criteria from Datta Meghe Institute of Medical Sciences will be the subjects of this study. Their heart rates will be monitored with the three devices, and compared with the readings from an E.C.G. It will be done as per Bruce protocol during walking, and in static sitting. The accuracy of the devices will be determined by analyzing the results acquired. The devices are: Apple watch, Xiaomi MI band, and a smart Phone with Thermal Application (T.A.P.) software installed. The successful completion of the study will determine which of the devices show the most accurate heart rate readings, in what positions of a patient (sitting or walking) it would be acceptable to use these devices (in terms of accuracy) in the case where an E.C.G. is not available, or at a time of urgency. The study will also show if it would be appropriate to use these devices in clinical practice and research studies.

Keywords: HR Measurement, Smart Watch, Apple Watch, Exercise Intensity, Wearable Devices.

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INTRODUCTION

People in this day and age, are paying more and more attention to their physical well-being. In order to keep up with their health status, having software applications on their smart phones and using devices such as smart watches are increasing in popularity amongst users [1,2] and is practically becoming a norm. [3,4]. There have been multiple cases where these devices have been used to self-monitoring, which then led to subsequent seeking of medical attention, despite knowing the fact that the devices were not specifically medical graded devices. [5]. A popular feature of these devices includes the ability to display the heart rates of the individual on screen. The Electrocardiogram method undoubtedly still remains the Gold Standard means of measuring the heart rate, but is not always practically feasible to be used in everyday practices, in research settings as well as clinically. [6].

The smart watches of interest in this study include the Xiaomi MI band and Apple smart watches. These work on the basis

of photoplethysmography (PPG), which has been found to be an accurate heart rate form of measurement, compared to a standard ECG, and some of the devices and applications that use this means of heart rate measurement are most reliable at rest. [4,7]. However, PPG technology has been proven to not be accurate for higher intensity forms of exercises [6]. Apple Watch uses infra-red light-emitting diodes (LED) and two green lights paired with light-sensitive photodiodes. These detect the volume of blood flow through the wrist. Xiaomi MI band uses the same principle as well to calculate the heart rate. [8,9].

The other focus of interest in this study, apart from the smart watches, is the smart phone Thermal Application (T.A.P.) software, that is used along with a thermal camera, to detect the heart rate of a person without actually coming into physical contact with the person (or in other words, a handheld vital sign monitor); rather it is carried out by simply taking a 30 second video of the person's face

selecting the region of interest, and the heart rate is automatically calculated. ^[10]. Tiny color changes are noticed in the Red Green and Blue (RGB) facial images due to the pulse of the blood volume, which is detected by the RGB thermal camera to measure the heart rate of the subject. ^[11,12].

This particular study will aim at comparing the accuracy of these 3 devices in measuring the heart rate: The Apple watch, the Xiaomi MI band, and the T.A.P. smart phone application, by comparing them with the Gold Standard means of measuring the heart rate by using an Electrocardiogram (E.C.G.) monitor. It will be carried out in 2 parts, the first being with the subject in a static sitting position, and the second with the subject in motion where he/she will be walking on the treadmill, whilst gradually increasing the speed as per the Bruce Protocol ^[13].

The accuracy of these devices are important to study because in the case of the smart watches, exercise intensities directly depend on the heart rate displayed on the screen. ^[14]. If the heart rate readings are incorrect, this could lead to complex health complications and hence poorly affect the performance of exercise ^[11]. The accuracy of the T.A.P. application in measuring the heart rate is important due to the intention of it being use in future research and clinical practices. With the increasing options of devices available in the market that can be used to measure the heart rate of an individual, the question arises as to which ones can actually provide readings accurate enough to be used in practice.

The study will determine and compare the accuracy of the Apple watch, the Xiaomi MI band, and the Thermal Application software in measuring the heart rates of individuals, by comparing their results with an E.C.G readings results. This will provide researchers and doctors with knowledge about the accuracy of the usage of the particular devices/ software focused in the study, to be used on various different subjects/ patients in different scenarios (for example: in an E.C.G. monitor is not available at a time of need, whether the subject is seated or walking), and whether a certain device or software is better than the others.

METHODOLOGY

The study will be conducted in the Cardio-respiratory department of the Physiotherapy sector at Acharya Vinoba Bhave Rural Hospital (AVBRH), Sawangi Meghe, Wardha, after approval from Institutional Ethics Committee of Datta Meghe Institute of Medical Sciences, deemed to be University.

20 subjects will be used in this study. The aims and method will be previously clarified to them beforehand. The subjects will be screened to ensure they fit into the eligibility criteria. A written consent form will be filled. The procedure of the study is shown in Figure 1.

20 subjects will be selected for the study, who fall into the

eligibility criteria. The inclusion criteria will be as follows: subjects of either gender between the ages of eighteen to thirty-five; healthy and does regular exercise; they should willingly volunteer to be subjects of the study. The exclusion criteria will be as follows: subjects who have had a history of hospitalization in the last five years due to cardiac complications, respiratory complications, hypertension, lower limb fractures; who show signs and symptoms of acute or chronic respiratory or cardiac conditions. The discontinuation criteria of the study will be if the subject feels like fainting or becomes too fatigued or breathless to carry out the activity.

Participant timeline

The study duration will be for 6 months. The subject must be willing to be screened for eligibility and to be part of the study on the whole. After this, a timetable will be made, assigning particular days to each subject. They will come on that day and the devices to measure the heart rates will be used when the subject is positioned in sitting, and while walking.

Information about the study will be given to the students of the institute and all those who are interested will be called together to be given a brief introductory talk about the study. Once this is over, they will be given the consent forms to sign and will have to undergo screening for the eligibility in order to take part in the study. A finalized list will be made of the subjects that will be used, and a timetable will be made, assigning each subject a day to come to the college in order for the investigator to carry out the study and obtain the heart rate readings. Each subject requires only one visitation. In each visitation, clear instructions will be given to the subjects as to how to adjust the settings on the treadmill as per the Bruce Protocol that will be used for the second part of the study. Any questions about the study and the procedure will be answered by the investigator. The heart rate readings will be noted down from all four devices (Apple watch, Xiaomi MI band, the smart phone, and the ECG monitor) in the first part of the study with the subject seated, and the second part with the subject on a treadmill at every three-minute interval. The subjects should fall into the eligibility criteria of the study and should willingly volunteer as subjects for the study. The whole process and procedure will be supervised by the research coordinator and principal investigator.

Overview

The study will be conducted in the cardio-respiratory department of Ravi Nair Physiotherapy College, Sawangi (Meghe), Wardha. It will take a total of six months to complete the study. The devices involved in the study include the Apple watch, first announced in 2014 by Tim Cook, the latest version being the Apple Watch series 5 ^[13,14]; the Xiaomi band manufactured by Foxconn was first released in 2014, its latest version is the Xiaomi MI Band 4

^[12]. One of their most popular features is the ability to display the heart rate, which is what the study is focused on. The Thermal Application software used in the handheld vital sign monitor is still not available in the market yet and is currently still being researched on. The college is a good study setting because there will be many students available, which fit into the eligibility criteria.

This will be an observational comparative type of study, to observe the accuracy of heart rate readings between smart watches and a handheld vital sign monitor in static and dynamic motions. Ethical clearance will have to be obtained before conducting the study. There will be two parts involved in acquiring the data required for the study. The heart rate readings will be taken when the subject is static (sitting on a chair), and when the subject is moving (walking on a treadmill).

The first part of the study (with the static subject) will require the following materials: a chair (for the subject to sit on), an adjustable tripod stand (to hold the smart phone) positioned one meter ^[11] in front of the chair, a smart phone with the Thermal Application (T.A.P.) software installed (handheld vital sign monitor) in it placed in position on the tripod stand, a thermal detector (to be attached onto the phone), an Electrocardiogram (E.C.G.) machine with adhesive electrodes (for ease of placement on the subjects chest), and an Apple smart watch and the Xiaomi MI band.

The second part of the study (with the subject in motion) will be conducted after taking a short break of 5 minutes after conducting the first part of the study. It will require the following materials: a treadmill (for the subject to walk on), an adjustable tripod stand (to hold the smart phone) positioned one meter in front of the treadmill, a smart phone with the Thermal Application (T.A.P.) software installed in it placed in position on the tripod stand, a thermal detector (to be attached onto the phone), an Electrocardiogram (E.C.G.) machine with adhesive electrodes (for ease of placement on the subjects chest), and an Apple smart watch and the Xiaomi MI band.

For the first part of the study, the subject will be made to sit for five minutes on a chair in order to allow the heart rate to come back to its normal resting rate; while an E.C.G. monitor will be set up and its adhesive electrodes secured in place on the appropriate positions on the chest of the subject. A tripod stand will be adjusted to the height of the face of the subject will be placed 1 meter ^[11] away from him/her, to which the smart phone (which contains the T.A.P. software) and the thermal detector (attached to the smart phone) are securely stabilized. The subject will be instructed to wear the Apple smart watch on the right wrist, and the Xiaomi smart watch on the left wrist. Once all the devices are

turned on, the heart rate readings will then be recorded. The heart rate will be noted down in a notebook from all four devices (Apple watch, Xiaomi watch, the smart phone, and the ECG monitor).

For the second part of the study, the heart rate readings will be recorded when the subject is in motion (walking on a treadmill). In a similar fashion to the first part, the E.C.G. monitor will be set up and the electrodes attached, the tripod height will be readjusted to the height of the subject when standing on the treadmill, and the watches worn. The subject will be allowed to stand on the treadmill (without walking) for 5 minutes, after which he will start walking, with gradual increasing speed as per the Bruce Protocol. Every three minutes, the inclination of the treadmill will be increased (from 0% gradually up to 20 %), as well as the speed (from 1.7mph gradually up to 5.5 mph). The heart rates will be noted down from all 4 devices at each 3-minute interval.

The volunteer will be informed beforehand as to how to stop the treadmill in case he feels that he cannot cope up with the exercise, feels like fainting, is too breathless, etc.

Figure 1. The procedure of the study

Part 1 of the study with the subject seated

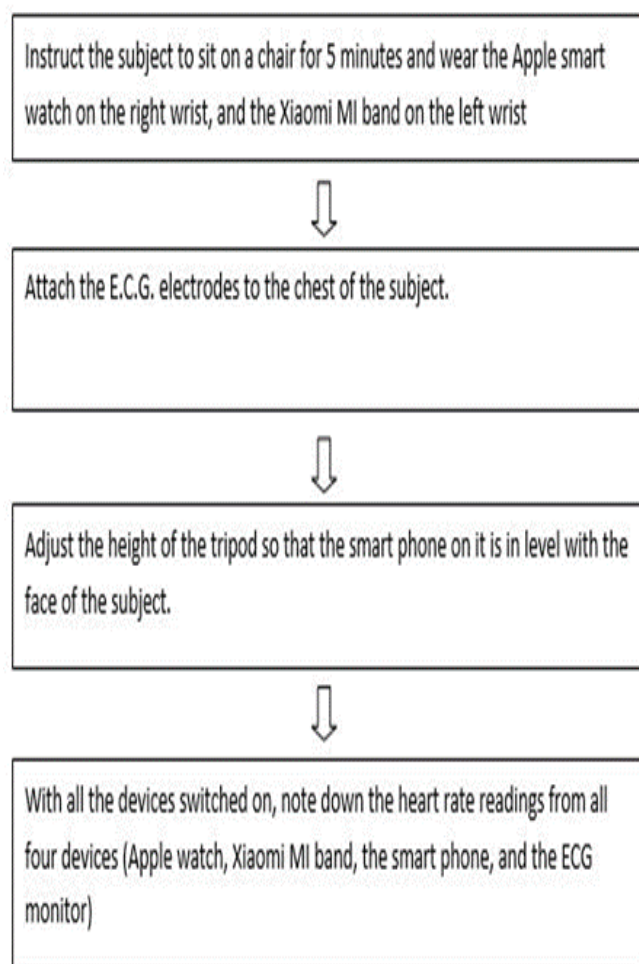
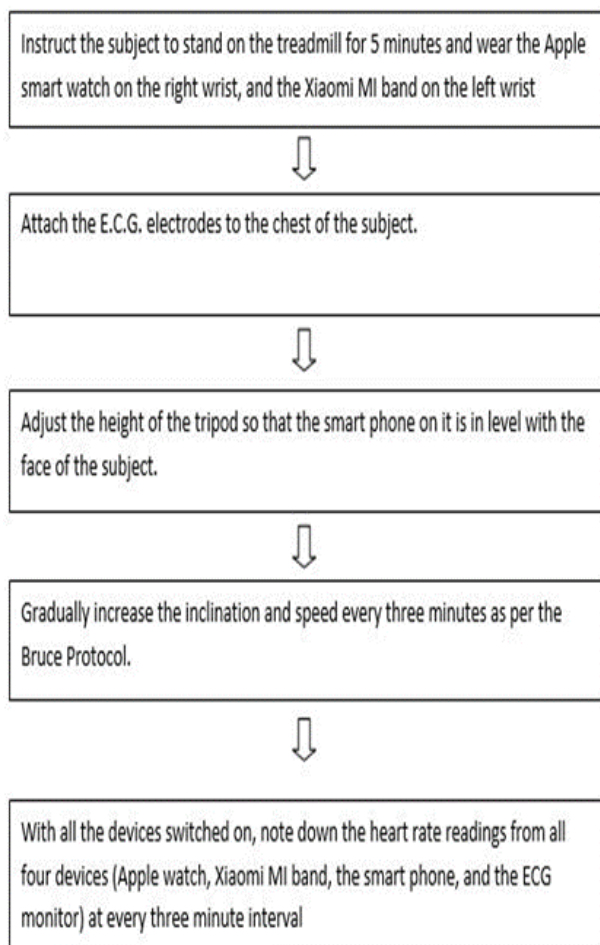


Figure 2. The procedure of the study

Part 2 of the study with the subject on the treadmill**RESULTS**

The data collected from the study will be fed into a computer and the readings that show the results as close to the readings of the E.C.G. results will be termed as the most accurate. These readings will be taken from when the subject is seated, and walking on the treadmill (as per Bruce Protocol).

Data collection

The heart rate readings will be noted down as the subject is sitting and walking by the investigator. It will later be then fed into Microsoft Excel in the computer. The consent forms will be kept in the department itself.

Data management

Data collection and documentation will take place in the context of principal investigators guidance. The data analysis will also be supervised to ensure accurate results

Statistical Analysis Plan

After the heart rate readings have been obtained, the means and standard deviations of them and relative error rate will be found for the subjects in sitting and walking on the treadmill and calculated for each device and the particular corresponding ECG. Paired-Samples Tests of Equivalence will also be performed to examine the equivalence or the lack of differences using two one-

sided tests (TOST) approach between ECG-obtained heart rate results, and Apple Watch and the Xiaomi MI band, and the handheld vital sign monitor measured heart rates in each part of the study.

CONCLUSION

Taking the heart rate of a patient accurately is undoubtedly a thing of importance in clinical setups and researches as well.

Besides the traditional means of taking the heart rate readings, there are now many available devices in the market that make this task quicker. However, the accuracy of using these devices are questionable and hence the question arises as to whether these devices can be used in the clinics and for researches, and also in what physical position the patient is in (sitting, standing, walking, etc.). Determining which devices can be used in particular positions of the patient can be beneficial in the future of medicine, keeping in mind that the results produces are quick to be obtained as well as accurate.

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