dx.doi.org/10.24254/CNIB.18.49

Evaluation of Astroskin Bio-monitor during high intensity physical activities

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Abstract— **As humans go deeper into space, the need for a compact and accurate health monitoring system is imperative for the Exploration Medical Capability (ExMC) Element of Human Research Program (HRP). Thus, it is necessary to develop new technologies and advances in support of long duration space missions. In the study conducted, the goal was to validate the second prototype of the Astroskin bio-monitor system performance, developed by Carré Technologies in collaboration with the Canadian Space Agency (CSA), during high intensity physical activities. The Astroskin system is designed as a garment with built-in sensors, a headband with an optical sensor and a module that connects to the garment; allowing monitoring, recording and analyzing physiological parameters such as the electrocardiogram (ECG), heart rate, blood pressure, pulse oximetry, respiratory rate, and body temperature in a non-obtrusive way. The results provided feedback for improvements both in hardware and software. A previous prototype was tested in an analog space environment HERA in 2016, monitoring a crew's physiological parameters for 24-hour sessions.**

Keywords—**Bio-monitor, physiological parameters, space exploration.**

I. Introduction

At the International Space Station (ISS), crew participates in experiments that require the acquisition of their vital signs. Currently, the process is done by connecting several devices to the crewmember for the different measurements which results in a sometimes uncomfortable and inefficient way to measure several physiological parameters. For medical management, the ISS also relies in an electrocardiogram (ECG) and blood pressure (BP) device minimally integrated with on-board systems. This translates in time consumption to manually store and transmit data from the device to the ground [1].

Fig. 1 Astroskin version 2 electronic module developed by Carré Technologies.

For this reason, NASA and the Canadian Space work in collaboration to advance the development of the Astroskin, a prototype developed by Canadian company Carré Technologies that aims to integrate key physiological signal measurements into a compact device [2].

The Astroskin is bio-monitor system that includes measurements of ECG, systolic BP, heart rate (HR), breathing rate (BR), skin temperature, activity levels (provided by 3-axis accelerometer) and oxygen saturation in blood (SpO2). The design consists on a garment with built-in sensors and a headband with an optical sensor; they both connect to a small electronic module, Astroskin version 2 (Fig. 1) for analysis, storing and streaming of data to a mobile device. The garments used for this study were designed to interface with the earlier version of the Astroskin module. Improved garments were not available.

II. Method

The study consisted of approximately 120 minutes, high intensity activity test, in which 4 subjects (2 male, 2 female) were tested on a treadmill (Sole, model TT8), a bicycle ergometer (Lode, model 91105), and an aerobic rower (Sunny Health and Fitness, SF-RW5622) as shown on Fig. 2**.** For each type of exercise there was a warm-up, and then 4 increasing levels of difficulty followed by a cool-down stage. All subjects had also a 5 minute recovery before going into the next exercise.

Halfway through each stage (1.5 min. for running and cycling stages, 1 min. for rowing) subjects were asked to rate their perceived exertion heart rate according to Borg's CR10 Scale. These scale ratings go from 0 to 10 with 15 different levels that represent the perception of exertion from "Nothing at all" to "Extremely strong" [3]. As safety measure, each subject's submaximal level for heart rate [4] was computed according to their age with (1) and then heart rate was monitored with the Polar H7 device and continuous systolic BP with the Astroskin. Exceeding submaximal heart rate level, rating a high exertion or requesting to stop were the criteria for stopping the study.

$$85\%\ \textit{Age Predicted Maximum HR} = (220\text{-}\textit{age})*.85 \qquad (1)$$

In addition to monitoring submaximal heart rate levels, Polar H7 was also used to standardize measurements and then compare with the device being tested; data was visualized with the Polar Beat App on a mobile device.

Fig. 2. Exercise protocol. Left: 23 minutes on treadmill. Center: 23 minutes on bicycle ergometer. Right: 20 minutes on rower machine.

While the subject was wearing the Astroskin System, the module connected to a mobile app via Bluetooth. The app runs on iOS and streams all the parameters continuously, showing the sensors data and the computed metrics (Fig. 3).

After completing the study, data was retrieved from the module by downloading it to the computer with the Astroskin Application for MacOS and a USB cable. Raw data analysis was later done with DADiSP software.

Fig. 3 App display of Astroskin parameters and sensors.

III. RESULTS AND DISCUSSION

Raw and processed data of the parameters being monitored was obtained from the Astroskin module. Analysis with the module's algorithms was accurate when compared to raw data process with DADiSP software.

One of the most relevant physiological parameters being measured in the study was HR, which shows in Fig. 4 a high correlation with the Polar device and the processing software. However, in Fig. 4B, it was observed that HR during the treadmill was consistent with heart rate processed with DADiSP but not with heart rate measured by Polar. The results found in this case are due to a garment and sensors issue with F2. For readings to be accurate, sensors have to be well adjusted to the subject's skin, meaning that

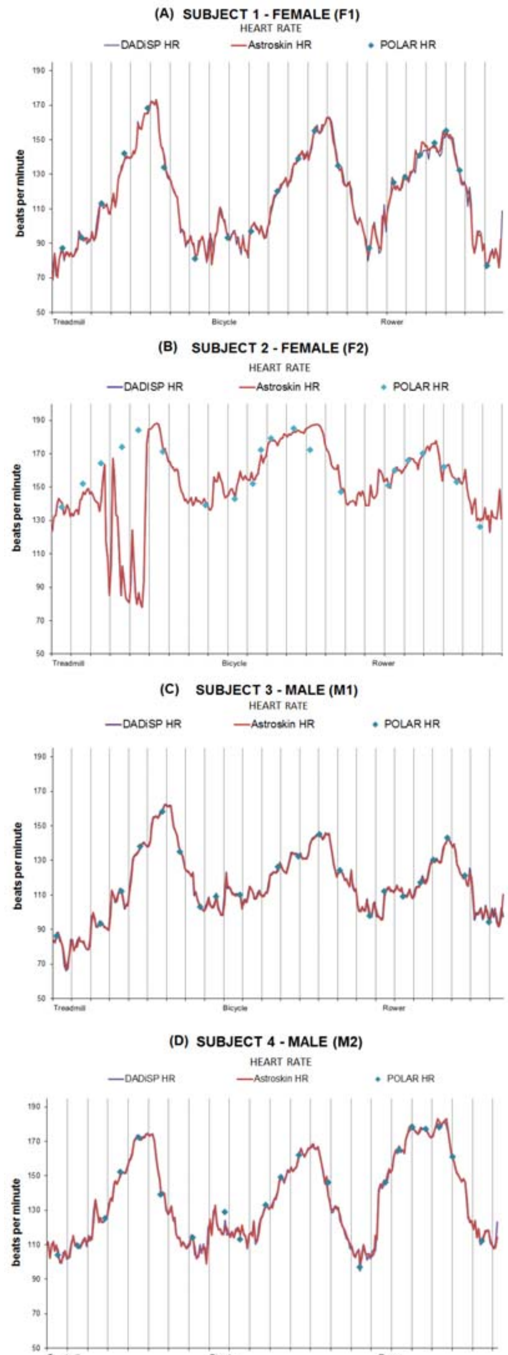

Fig. 4 Heart rate graphs obtained for all subjects.

the garment should be the correct size. For females this task becomes more difficult and in activities that involve more movement the garment tends to shift vertically on the torso as occurred with F2's first exercise. A similar finding occurred with female participants during the HERA study [5]. However, this problem did not occur during bicycle and rowing exercises where the three methods for measuring heart rate were consistent for all subjects.

Recorded exertion levels are shown in Table I. Since this is a subjective rating, it was expected to have big differences between the subjects. Female subjects rated higher exertion than men; subject M2 presented almost no exertion during the whole exercise protocol. Both male participants are regularly physically active which helps them to increase their exertion threshold and feel less than female subjects at same levels of intensity.

While testing subject M2, it was observed that SpO2 levels fell below the normal range (88%) during bicycle and rowing exercise (Fig. 5). The normal range of vital signs at rest is shown in Table II. When the subject is exercising, those parameters serve as reference and it is expected that they increase proportionally to the intensity of the activity. SpO2 levels are the exception; these most often stay between of 95-100% whether exercising or at rest in healthy individuals.

TABLE I
PERCEIVED EXERTION RATES RECORDED FROM SUBJECTS

Exercise		CR10 Rating			
		F1	F2	M1	M2
Treadmill	Warm-Up	0	0	0	0
	1	0.5	0	0.3	0
	2	1	0.3	0.7	0
	3	3	0.5	1.5	0.5
	4	4	2	3	0.7
	Cool Down	5	0.3	1	0.3
	Recovery	0	0	0	0
Bicycle Ergometer	Warm-Up	0.5	0	0.3	0
	1	1	0	0.5	0
	2	2.5	1.5	1.5	0
	3	4	2.5	2.5	0
	4	5	5	4	0
	Cool Down	4	0.7	0.7	0
	Recovery	0	0	0	0
Rower	Warm-Up	0.7	0	0.5	0
	1	1	0	1	0
	2	2.5	1	2	0
	3	4	1	0.5	0
	4	5	0.5	4	0
	Cool Down	3	0	0.5	0
	Recovery	0	0	0	0

It is interesting that M2's breathing rate remained almost constant throughout the study since breathing rate influences oxygenation levels in the blood and the exercise with most individuals is associated with increasing breathing rates. Heart rate and blood pressure changed normally with different intensities of exercise.

TABLE II
NORMAL VALUES OF PHYSIOLOGICAL PARAMETERS

Normal Values at Rest	Heart Rate	60-80 bpm
	Pressure	120/80 mmHg
	SpO2	95-100%
	Breathing Rate	12-20 bpm

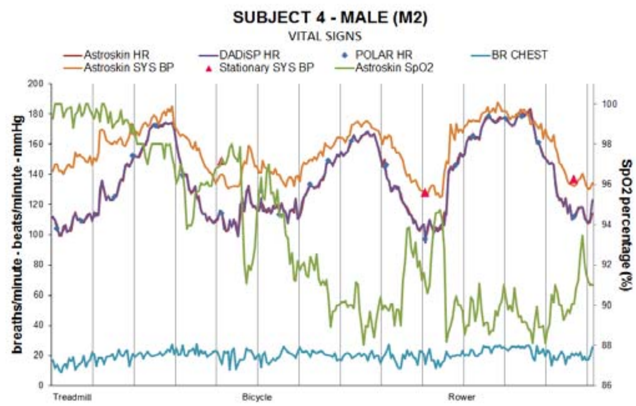

Fig. 5 Subject M2 relevant physiological parameters.

The systolic blood pressure data recorded with the Astroskin system was compared with measurements from a brachial artery cuff device recorded at each recovery period following exercise.

Other Astroskin measured parameters (breathing rate, skin temperature, activity and SpO2) were not considered relevant as a discussion point, since there were no gold standard measurement devices available for comparisons.

IV. CONCLUSIONS

According to the results found in this study, some areas of improvement include:

Sensors - F2 presented issues regarding the fit of the garment which resulted in some inaccurate readings. ECG signal quality was dependent on each subject's skin conductivity. For example, individuals with lower skin impedance showed better signal quality.

Electronic Module - Physical connection between the adapter and headband was not secured due to design issues. It appears that Astroskin algorithm for deriving measures of breathing rate was not scaled correctly.

Standalone Software and App - Initially, software issues caused lack of access and incomplete data acquisition, however this issue was resolved during early stages by the programming engineers at Carré Technologies. There were some iOS App and Bluetooth connectivity issues that are still unresolved.

Issues regarding sensors fit and their connection to the module were solved by Carré Technologies' new version of the garment which includes an improved design for women and no need for an adaptor to connect to the electronic module. However, these issues did not largely affect the device's capability to measure physiological data. After testing the Astroskin system and comparing it to validated devices we can conclude that the device is reliable and provides accurate data of physiological parameters all in one compact device.

Acknowledgements

We would like to thank everyone at the Psychophysiology Lab and the participants who made the study possible. Junuen Villa was supported by CONACYT *Fronteras de la Ciencia* Project FC-2015-2/944. She would like to specially thank Tianna Shaw, Bill Toscano, Patricia Cowings and Sean Winther for their incredible guidance and support during her internship at NASA Ames Research Center, as well as to thank Leonardo Trujillo and Victor López for motivating her to pursue her goals in research.

References

[1] W. Toscano, P. Cowings, M. Krihak, S. Winther and A. Martin, "Human Research Category Protocol HRI-331 An Evaluation of Wearable Biosensor Devices and a Medical Data System during Exercise and Autonomic Function Tests", NASA Ames Research Center, Moffet Field, CA, 2017.

[2] "Bio-Monitor: Keeping an eye on astronauts' vital signs", Canadian Space Agency, 2018. [Online]. Available: http://www.asc-csa.gc.ca/eng/sciences/bio-monitor.asp. [Accessed: 25- Jul- 2018].

[3] G. Borg, *Borg's perceived exertion and pain scales*. Champaign: Human Kinetics, 1998, pp. 13-16, 39-43.

[4] J. Roitman and M. Herridge, *ACSM's resource manual for Guidelines for exercise testing and prescription*, 6th ed. Philadelphia: Lippincott Williams & Wilkins, 2001.

[5] W. Toscano, P. Cowings, P. Sullivan, A. Martin, J. Roy, M. Krihak, S. Winther, A. Hanson and T. Shaw, "Wearable biosensor monitor to support autonomous crew health and readiness to perform", Moffet Field, CA, 2016.