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Use of Heart Rate Monitors for the Harvard Step Test

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Abstract

Background: Physical inactivity or sedentary lifestyle is one of the four major health risks associated with the four more lethal types of chronic non-communicable diseases considered as the global major killers at present time. Physical activity/inactivity is reflected on physical fitness/unfitness. One way of getting insight into an individual's physical condition is by applying a cardiac stress test, like the Harvard Step Test. When using Heart Rate Monitors (HRMs) in this test, if the readings are not made at the proper time, they give either higher or lower readings as compared to those obtained by the conventional way.

Methods: Both methods (manual counting and using heart rate monitors) were compared and the level of agreement examined.

Results: Effectively, readings at minutes 1:00, 2:00 and 3:00 give higher frequencies and underestimate the level of physical fitness.

Conclusion: A better approach when using HRMs would be to take three readings during the first half of each minute (i.e., 01:00, 01:15, 01:30, 02:00, 02:15, 02:30, 03:00, 03:15 and 03:30), average them, and then sum these 3 values or, alternatively, to use the readings midway between second :00 and second :30 (i.e., values obtained at minute 01:15, 02:15 and 3:15).

Keywords: Physical activity; Heart rate monitors; Harvard Step Test

Background

Since the year 2008, the World Health Organization [1] has considered Non-Communicable Diseases (NCDs) as the world's largest killers. For 2012 it was estimated that they accounted for 52% of global deaths for people under the age of 70 years, with four types of them being responsible for 76% of these NCDs deaths: cardiovascular diseases 37%, cancers 27%, chronic respiratory diseases 8% and diabetes 4% [2]. At the same time, it is considered that they are associated with four major risk factors related to lifestyle: Tobacco use, physical inactivity, unhealthy diet, and the harmful use of alcohol [3].

There are three main physical aspects that are influenced and, therefore, reflect lifestyle: Intestinal microbiota composition, body composition and physical fitness [4] the present time, the estimation of physical fitness as well as that of nutritional condition should be a must for everybody. The Harvard Step Test is a simple, easy to carry out and inexpensive way for indoor assessment of cardiovascular fitness and has been used especially by researchers working in emerging economies [5]. While there is not yet an easy way to perform and low-cost method to assess the first of those three aspects, there are some to assess the last two. For body composition, for instance, we have, among others: Body Mass Index (BMI), skin folds measurements, Bioelectrical Impedance Analysis (BIA) and waist to height ratio [6]. For physical fitness there are also a variety of methods: Cardiovascular endurance tests such as step tests, muscular strength tests such as the hand grip test, and flexibility tests like the "sit and reach" test [7].

Although the benefits of regular physical activity are well documented [8], the World Health Organization [9] estimated that "Globally, around 23% of adults aged 18 and over were not active enough in 2010 (men 20% and women 27%)…". Physical fitness is considered as an outcome of regular physical activity or exercise [10]. Inversely, physical inactivity is reflected in a bad physical fitness, and this is one of the main health risk factors for NCDs [10]. Due to the global costs posed by these diseases worldwide [11], the WHO has launched the "Global action plan on physical activity 2018-2030" [9].

For all reasons mentioned above, the availability of methods or techniques to assess physical fitness that are low cost, reliable and easy to perform is desirable. In this paper, we focus on the

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Harvard Step Test (HST), developed by Lucien Brouha et al. in 1942 at Harvard University-USA [12]. It is a simple, relatively reliable, easy to carry out and inexpensive way for indoor assessment of cardiovascular fitness. Despite some disadvantages (for instance, variations in the mechanical characteristics between individuals), the increasing necessity of improving public health makes of this test a good tool for the evaluation of physical fitness for individuals and communities. The original test consists in stepping up and down into a bench 50 cm high for five minutes or until exhaustion [5]. Once the exercise is stopped, the Heart Rate (HR) is measured by palpating the arterial radial or carotid pulse between minutes 1:00 and 1:30 (pulse 1), 2:00 and 2:30 (pulse 2), and 3:00 and 3:30 (pulse 3). The Brouha Index (BI) is then calculated, by multiplying the duration of the test in seconds by 100 and dividing this result by two times the sum of the three pulses. A qualitative scale can then be used with the categories of cardiovascular endurance status or physical fitness as: Excellent, good, average, low average or poor [13].

Authors have begun to use HRMs to measure HR during the HST, what could mean an improvement both in accuracy and easiness to perform the test. One way of doing it is to measure HR at minutes 1:00, 2:00 and 3:00, [14,15]. Given the fact that HR recovery after submaximal exercise has the shape of an exponential decay [16], we hypothesize that this could give higher values when compared to the traditional method of counting the HR during intervals of 30 sec, as recommended in the original version of the HST. The aim of this work was to test a protocol designed to establish more appropriate moments to read the HR when using electronic HRMs for the HST, so that the results are comparable between the two methods, avoiding a possible underestimation of physical fitness.

Materials and Methods

Experimental approach to the problem

The strategy used for our work was as follows:

a) We selected a convenience sample of 45 students at our university, who performed a modified HST, and the measurements of pulse rates were taken by four observers: observers 1, 2 and 3 manually took the HR at the right radial artery, left carotid artery, and left radial artery, while observer 4 read it at different intervals using a HRM with the band placed in the thorax (Figure 1).

b) The idea was to compare the results obtained by observer 4 at 3 different time intervals (minutes 1:00, 2:00 and 3:00; minutes 1:15, 2:15 and 3:15, and minutes 1:30, 2:30 and 3:30 after the test had finished), and also the average of them, against the average of those obtained by observers 1, 2 and 3. The average of three observers for the manual (traditional) way of measuring the HR was chosen in order to have more reliable data as reference.

This approach gave us eight data sets, with which we made six comparisons, as follows (Figure 2):

Data set [1]: Observer 1:

Data set [2]: Observer 2:

Data set [3]: Observer 3:

Data set [4]: Observers 1-3 average of data sets 1-3.

Data set [5]: Observer 4, minutes 1:00, 2:00 and 3:00.

Data set [6]: Observer 4, minutes 1:15, 2:15 and 3:15.

Data set [7]: Observer 4, minutes 1:30, 2:30 and 3:30.

Data set [8]: Observer 4, average of data sets 4, 5 and 6. (5,6 and 7)

Comparison (1): Between data sets 1, 2 and 3.

Comparison (2): Between data sets 5, 6 and 7.

Comparison (3): Data set 8 versus data sets 5-7.

Comparison (4): Data set 4 versus data set 8.

Comparison (5):

Comparison (6):

Protocol to obtain six comparisons from eight data set from the average of three observers for the manual (traditional) way and the average of one observer using HRM the measurement of the HR.

Subjects

A convenient sample of 45 healthy volunteers with normal BMI (median age 18.9 years old, minimum 16.4 years and maximum 28.6 years, 36 women, 9 men) were recruited at the University of Caldas, Colombia, South America. The study procedures were approved by the Bioethical Committee of Sciences for Health faculty at the University of Caldas with approval number 073 and it was classified as "low risk" according to resolution 8430 of 1993 of the Colombian Ministry of Health. It was also conducted according to the rules of the declaration of Helsinki. The protocol was fully explained to the volunteers and informed consent was obtained from all subjects participating in the study.

Furthermore, this work fulfilled with the ethical standards contained in the publication "Ethical Issues Relating to Scientific Discovery in Exercise Science" [17].

Testing procedures

The original HST [5], was modified in that we used 40 and 35 cm high steps for men and women, respectively, according to the average body height for the Colombian population, which is estimated to be 170.64 cm for men, and 158.65 for women [18] tapping frequencies were 30 steps/min for men and 24 steps/min for women.

Volunteers were instructed as how to perform the test, and, after finishing the exercise, right and left radial, as well as the left carotid pulse were measured simultaneously by observers 1, 2 & 3, respectively. Observer 4 read the frequency values form a Polar® HRM (Polar® Vantage NV) at the following times after finishing the test (minute: second): 01:00, 01:15, 01:30, 02:00, 02:15, 02:30, 03:00, 03:15 and 03:30. A Yamaha multi metronome YM-2000 was used to keep the rhythm and four Casio HS3 stopwatches were available to measure the time (one for each observer, see Figure 1).

Statistical analyses

Following tests were used for this purpose: Grubbs and Dixon for the presence and exclusion of outliers, Shapiro-Wilks for normality, Student's t for comparison of two means and ANOVA for the comparison of more than two means. Statistical significance was accepted when $p<0.05$.

Results

The Grubbs & Dixon test identified two outliers that were excluded from further analysis, ending with 43 subjects (34 female, nine male). All sets of data had a normal distribution with p-values equal or greater than 0.076. There was no statistically significant

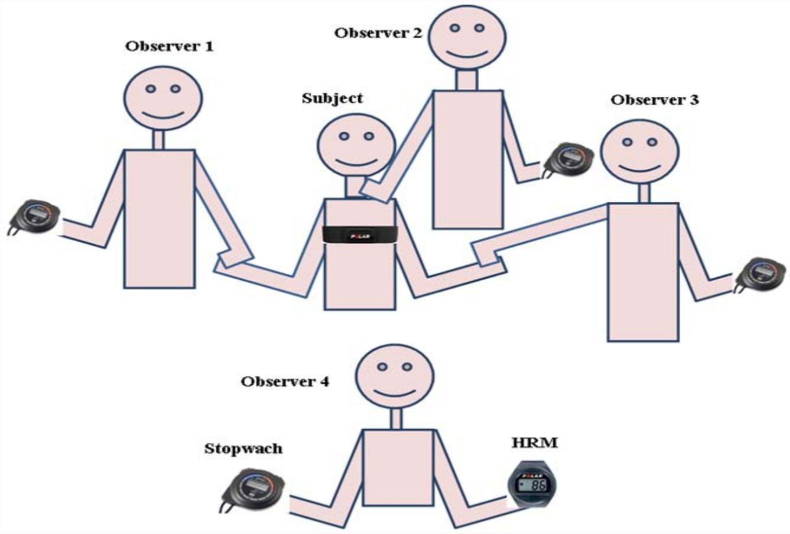

Figure 1: Setting for the measurement of the HR after finishing the HST.

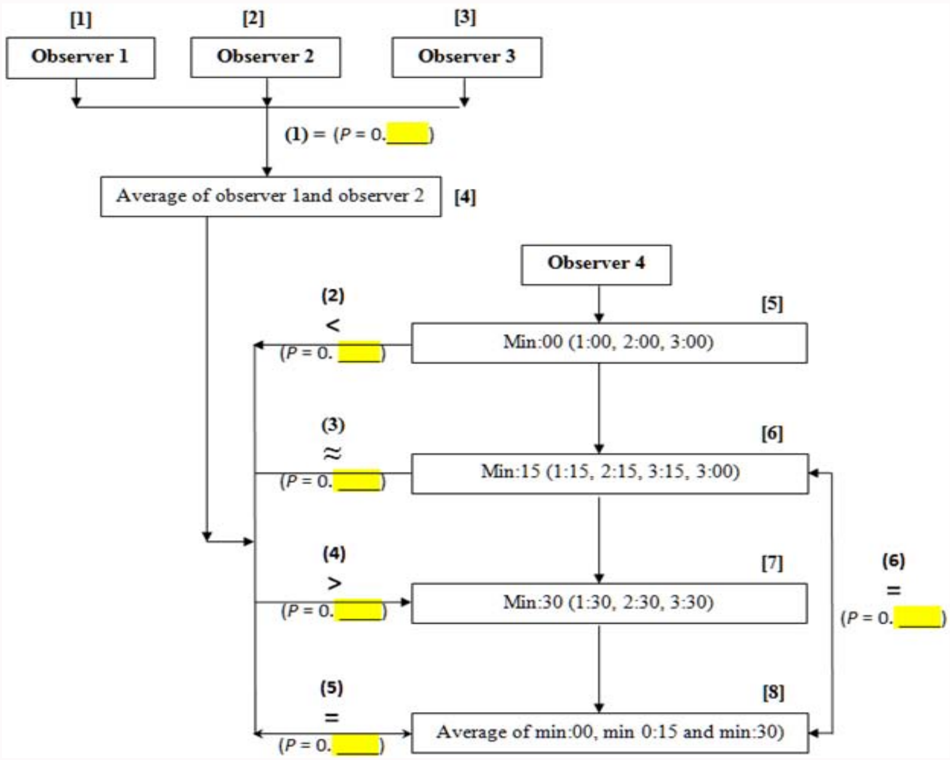

Figure 2: Protocol to obtain six comparisons from eight data set from the average of three observers for the manual (traditional) way of measuring the HR.

differences between the measurements taken by observers one, two and three (p-value =0.682), while there were differences (p value <0.0001) between the three sets of measurements taken by observer four (at seconds :00, :15 and :30, with a p-value <0.0001), being the mean at seconds :00 (data set 5) > the mean at seconds :15 (data set 6) and this, in turn, being > the mean at seconds :30 (data set 7). The comparison between data set 8 against data sets 5, 6 and 7 showed that set 8 was different from sets 5 and 7 but equal to set 6 (p value >0.116). Finally, the comparison between data set 4 and data set 8 gave no statistically significant differences (p value =0.132). Figure 2 gives a clear idea of both strategies used for the analysis of the data, as well as the results.

Discussion and Conclusion

The HST is an indoor and easy to perform way of establishing the cardiovascular endurance of individual and populations. The use of HRM can further improve and facilitate its use, but the readings of the HR ought to be taken at an appropriate time. The results of this study show that if they are taken just at the beginning of minutes one, two and three (i.e., at 1:00, 2:00 and 3:00 min after finishing the test), the readings would be much higher than those manually obtained as in the original version of the test (pulse count between minutes 1:00-

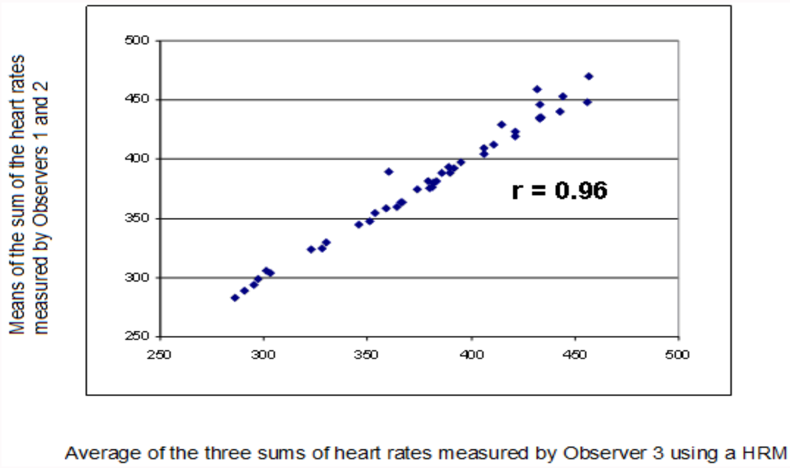

Figure 3: Averages of results obtained for the eight different data sets analyzed in this study.

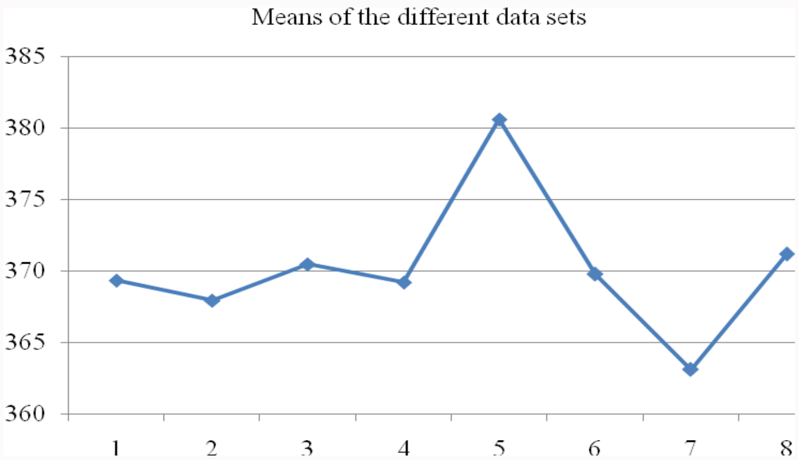

Figure 4: Average of three sums of heart rates measured by Observer 4 using an HRM.

Table 1: Mean and Standard Deviation (SD) of the manual readings of the observers 1-3 and readings with the HRM of the observer 4 and the average between these.

	A) Manual readings taken by observers 1 & 2	B) Readings with HRM at minutes 1:00, 2:00 & 3:00	C) Readings with HRM at Minutes 1:15, 2:15 & 3:15	D) Readings with HRM at Minutes 1:30, 2:30 & 3:30	E) Average of B), C) and D) compared to A)
Mean	-1.3	-14.2	-2.5	4.6	-2.0
SD	8.2	16.0	15.2	14.8	7.5

1:30, 2:00-2:30 and 3:00-3:30). Therefore, it would be appropriate to read the pulses either at three different times in each interval and average then or, still easier, to take a single reading in the middle of each interval: As, for instance, at minutes 1:15, 2:15 and 3:15 (Figure 3, 4).

We think that the main practical application of these results is that the use of HRMs can simplify the use of the HST taking HR readings at just three specific moments. If HRMs are available, the test could be performed with many subjects at the same time, each wearing his/her own monitor and writing down the values. Even if an accompanying person is present for each subject, the reading of the HR and its notation would be easier. The fact that measures obtained electronically agree with those that would be obtained manually is of importance because it makes the two methods comparable (Table 1).

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