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Protocol for Cardiac Assessment of Recreational Athletes

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Abstract— **In this work, the development of a database on physical fitness is presented. As initial population to fill this database, people who practice recreational sports at the Universidad Simon Bolivar (USB) were chosen. The goal was studying individual physical fitness in order to structure exercise routines that gives certain benefits without risking the individual health, promoting a less sedentary way of life. Before the study, a low-cost noninvasive protocol was designed to determine the level of physical fitness. The methodology consisted of four steps: a) A review of existing protocols to propose a set of physical fitness (International Physical Activity Questionnaire (IPAQ)), cardiovascular (heart rate variability, heart rate recovery time and arterial blood pressure), anthropomorphic, aerobic (maximum oxygen consumption) and mood state (Profile of Mood State (POMS)) measurements, which allow sketching a complete profile on the sportsman physical fitness. b) Instrumental data collection. c) Electrocardiographic signal processing. d) Data post-processing using multivariate analysis. The database was composed of 26 subject from USB. Ten subjects were soccer players, ten were mountain climbers and six were sedentary people. Results showed that the heart rate recover time after 2-3 min, IPAQ and maximum oxygen consumption have higher weights for classifying individuals according to their habitual physical activity. Heart rate variability, as well as, POMS did not contribute greatly for discriminating recreational sport from sedentary persons.**

I. INTRODUCTION

Modern life offers numerous advantages to the human being, as an example: transportation, pre-processing of food, worldwide interconnection, etc. Modernity offers longevity to the population. However, it is also the one that causes problems like sedentarism, which is nowadays a global pandemic. There are a number of investigations focused on proving that no matter the discipline that is practiced, it is essential to be physically active; this and a proper nutrition are the bases of good health and longevity. The benefits of physical activity are multiple. Nevertheless in elite athletes, there are cases of sudden death, which is a paradox since they are the standard of good health. The causes of sudden death tend to be cardiovascular, that might or might not be associated with over-training. A health assessment prior to participation in sports is necessary to prevent accidental injuries. This is important not only for elite athletes, but it should also be emphasized in all those people who practice sports on a regular basis, especially after age 30 [1]. The American Heart Association recommends: review of family and personal history, physical examination (murmur, femoral pulses, features of Marfan syndrome and arterial pressure measurement). It also recommends an annual review of the individual, through an electrocardiogram (ECG) and a stress test [2]. By developing a database from multivariate fitness assessment, some insight might be drawn about relations between variables linked to physical activity and physiological adaptation in sports. This study aimed at the development and analysis of a multi-parametric database having a population of recreational sports practitioners, focused on two disciplines: football and hiking (climbing and cross-country). The population consisted of members of the university (students, faculty, etc.) since the long term goal is to offer our community a simple way to evaluate their condition and improve their fitness. For this purpose, a multivariable protocol was develop in order to characterize the population in terms of physical conditioning.

II. METHODS

A. Sample

The database consisted in 26 subjects: ten football player, ten climbers and cross country runners and six sedentary subjects. All sports were practiced in a recreational way. Individuals were all men aged between 18 and 32 years old, non-smokers and without a medical precondition (arrhythmia, diabetes, asthma, heart condition). The protocol was explained to the subjects emphasizing that due to the stress test they might experience discomfort and they were entitled to stop the test at any moment. After the subject had accepted the terms and understood the protocol to follow, each subject was asked to sign consent. This consent is an ethical and legal requirement. Additionally, a consent from the Sports Division of USB was obtained.

B. Designed protocol

The designed protocol can be seen in Fig.1 and it is explained as follow:

- **Preliminary conditions:** The requirements previous to the test were: avoid the practice of strong exercise two days before the test, avoid alcohol or caffeine the day of the test, a three-hours fasting before the test. Through a series of questions it was described the health condition of the subjects. If the subject had had a muscle-skeletal injury, cold, or viral infection, two weeks previous the evaluation, the test was discarded.
- **Anthropometric measurements:** For the measurements, it was used a stadiometer, a scale, a skinfold

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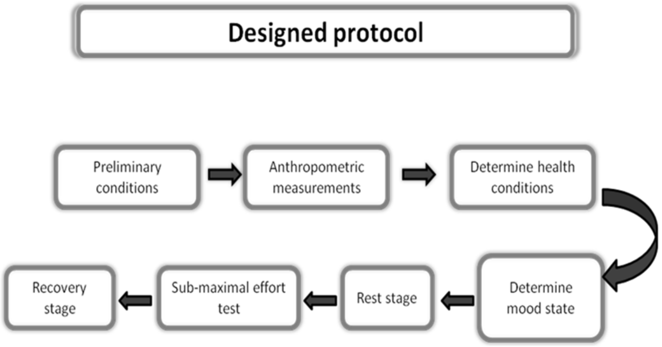

Fig. 1. Designed protocol

calliper and anthropometric tape. The weight and height were determined, as well as several measurements were taken, in order to obtain the somatotype of each subject and the percentage of fat, muscle, bone and water. This was based on the International Society for the Advancement of Kinanthropometry (ISAK) protocol. Furthermore it was implemented a digital scale (Tanita UM600) that implements the bio-impedance method to determine the percentage of fat and water in the subject.

- **Physical activity level:** The level of training and physical activity was determined using the International Physical Activity Questionnaire (IPAQ), which is a simple and economic tool [3].
- **Mood state:** The Profile of Mood State questionnaire (POMS) was applied to determine the mood state of each subject before the effort test, in order to analyze the relationship between mood state and performance, and also to quantify the motivation [4].
- **Rest stage:** A 12- lead configuration was implemented to obtain all ECG records using a CardioSoft equipment. In this stage each subject was in supine position for ten minutes, which allows making an ECG spectral analysis. After this stage, blood pressure was taken in supine and sitting position. Additionally, Heart Rate Variability (HRV), and rest Heart Rate (HR) were calculated.
- **Sub-maximal effort test:** A sub-maximal effort test was chosen since during the development of this project, the presence of a medical staff was not guaranteed. A sub-maximal test has the advantage that as long as all the requirements and previsions are taken into account, there is not a legal commitment to have the presence of a doctor during the protocol. A one minute warm-up was in order to allow the subject to be familiarized with the cycle ergometer and a ten-electrode ECG configuration. For the stress test it was implemented the protocol YMCA for cycle ergometer, which is oriented to sub-maximal tests (85 percent of the theoretical maximum HR) [5]. The theoretical maximum HR ($HR_{max_{age}}$) was determined using the equation [5]:

$$HR_{max_{age}} = 206,9 - 0.67 * age$$

  It was also applied the Borg scale during the sub-maximal test to determine the subjective perception of effort [6]. The sub-maximal test was stopped if any of the following conditions were reached [7].
  - The subject cannot continue with a new increment in power, due to dizziness, cough or breathing problems.
  - If muscle-skeletal pain is too severe.
  - If HR starts dropping progressively during the test.
  - Paleness and cold sweats (vasoconstriction).
  - The subject is exhausted according to Borg scale.
  - If subject presents a HR 10bpm over the theoretical HR according to subject's age.
  - If subject has reached the targeted HR according to the protocol YMCA.

  From this 12-lead ECG register it was taken the maximal HR during effort, which allows the estimation of the maximal oxygen consumption. This was done according to YMCA protocol.
- **Recovery stage:** Once the sub-maximal effort test was finished, a one-minute cool-down in the cycle ergometer was in order. This was done at 50Watts and 50rpm. Besides, the blood pressure was taken for monitoring purposes. Afterwards, the subject remained in supine position for ten minutes while an ECG register was taken. Finally the blood pressure after this stage was taken in supine and sitting position. From this register, Heart Rate Recovery (HRR) was measured and HRV parameters were calculated at 2, 3 and 10 minutes.

C. Data Analysis

A Principal Component Analysis (PCA) was done for each variable groups $i)$ IPAQ $ii)$ POMS $iii)$ Rest Stage $iv)$ Sub-maximal effort $v)$ Recovery stage $vi)$ Anthropometric measurement. Multiple Factorial Analysis (MFA) was performerd in three different ways:

- **MFA1** all variables groups
- **MFA2** cardiovascular variables corresponding to rest stage sub-maximal effort and recovery stage groups
- **MFA3** variables related to POMS, IPAQ and anthropometric measurement.

These variables are described in Chinea, 2010 [8].

III. RESULTS

In Table I can be seen the results of the questionnaire IPAQ. As shown, the highest statistically significant difference between athletes and sedentary people is in the item of vigorous activity. In Table II can be seen the results of the anthropometric measurements. There are not statistically significant differences between athletes and sedentary subjects. In Table III are shown the results of the sub-maximal effort test statistically significant differences ($p < 0.001$) are found between athletes and sedentary subjects in the entry VO_{2max},

TABLE I

RESULTS OF IPAQ QUESTIONNAIRE PER DISCIPLINE

	Hiking Climbing	Football	Sedentary
Vigorous activity $*2, *3$	2632±1451	2616±1494	280±384
Low activity $*2, *3$	1071±833	969±1062	255±225
Total IPAQ $*2, *3$	3743±1867	3777±2114	535±480
Total sedentarism	**1821±756**	**1899±828**	**2000±590**

Statistically significant difference($p < 0.05$) *1 (hicking vs. football) *2 (hicking vs. sedentary) *3 (football vs. sedentary)

TABLE II

RESULTS OF ANTHROPOMETRIC MEASUREMENTS

	Hiking Climbing	Football	Sedentary
Waist/hip index	0.89±0,09	0.83±0.05	0.94± 0.06
% Muscle	25.86±3.97	25.58±5.05	28.54±3.97
% Adipose issue	43.64±3.15	42.51±3.11	40.86±2.28
% Bones	12.74±0.81	12.28±1.05	13.39±1.45
% Residua l	12.09±1.16	11.21±1.52	11.91±1.11
% Skin	5.67±0.41	5.42±0.51	5.30±0.95

as well as between football players and sedentary people in the entry maximal power ($p < 0.001$). In Table IV are shown the results of HRR by discipline.

- After 2 minutes of recovery, between cross country athletes and football players ($p < 0.001$) and between football players and sedentary subjects ($p < 0.001$).
- After 10 minutes of recovery, between cross country athletes and sedentary subjects ($p < 0.001$) and between football players and sedentary subjects ($p < 0.001$).
- After 2 minutes of recovery with one minute of cooling, between football players and sedentary subjects ($p < 0.001$).
- After 3 minutes of recovery with one minute of cooling, between football players and sedentary subjects ($p < 0.001$).

In TableV are shown the results corresponding to the HRV related to the rest stage. Principal finding from PCAs described in next section. Results from MFAs could be sumarized as follow:

- **MFA1** The first factor (inertia 18.71%) is related to IPAQ variables , second factor inertia (14.16%) is related to rest stage.
- **MFA2** The first factor (inertia 27.67%) is related to heart rate variables and second factor inertia (20.43%) is related to HRR variables.
- **MFA3** The first factor (inertia 25.81%) is related to IPAQ variables , second factor inertia (16.76%) is related to POMS, IPAQ and anthropometric measurement.

TABLE III

RESULTS OF SUB-MAXIMAL EFFORT TEST

	Hiking Climbing	Football	Sedentary
$VO_{2max.}$ $(mL/kg.min)$ $*2, *3$	43.85±5.42	45.24±4.96	37.84±4.44
Max. Power (W) $*3$	222.77±31.82	245.85±37.85	204.00±34.50

Statistically significant difference($p < 0.05$) *1 (hicking vs. football) *2 (hicking vs. sedentary) *3 (football vs. sedentary)

TABLE IV

RESULTS OF HRR (bpm)

recovery time	Hiking Climbing	Football	Sedentary
2 min $*1, *3$	70.14±10.36	83.85±10.95	68.84±14.53
3 min $*3$	71.02±9.80	83.06±12.06	70.31±12.79
10 min $*2, *3$	78.39±9.05	87.87±11.98	74.51±11.83
1 $min_{rec2min}$ $*3$	77.14±9.80	83.06±12.06	70.31±12.79
1 $min_{rec3min}$ $*3$	78.43±8.81	83.13±10.73	71.71±13.57
1 $min_{rec10min}$ $*2, *3$	86.77±9.10	88.41±12.90	72.77±13.45

Statistically significant difference($p < 0.05$) *1 (hicking vs. football) *2 (hicking vs. sedentary) *3 (football vs. sedentary)

TABLE V

RESULTS OF HRV REST STAGE

	Hiking Climbing	Football	Sedentary
RR (ms) $*1, *3$	964.1±140.3	1059.4±111.9	942.3±160.0
SD RR (ms)	70.93±18.30	68.92±19.47	61.15±16.41
rMSSD (ms) $*1$	61.25±16.84	47.39±21.23	47.67±23.07
LF (ms^2) $*1, *2$	1171.8±752.0	1011.0±233.1	820.83±432.8
HF (ms^2) $*1$	1079.4±1043.0	960.8±852.3	1238.2±1197.6
LF/(LF+HF) $*1, *3$	0.41±0.17	0.59±0.23	0.46±0.19

Statistically significant difference($p < 0.05$) *1 (hicking vs. football) *2 (hicking vs. sedentary) *3 (football vs. sedentary)

IV. DISCUSSION

It is noteworthy that the gathering of the database implied some difficulties associated with the selection of individuals and the amount thereof. The requirements consisted of age (18-32 years), sex (male), a minimum of ten people per discipline, and athletes belonging to the same sportive

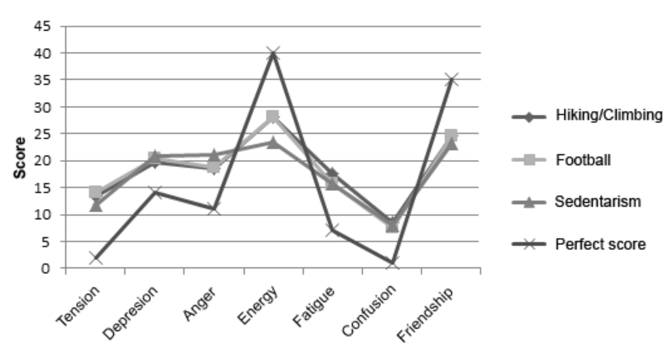

Fig. 2. Expected results - POMS

discipline, hence sharing the same training. While the USB athlete population is quite large, many do not belong to a particular discipline, or have a population that meets the requirement of ten individuals per discipline. In the case of the sedentary people, the difficulties encountered were related to poor motivation and fear of having a low performance by the subjects. Below are the most significant findings for the measures studied:

- According to the results of PCA, blood pressure did not play a decisive role in the characterization of individuals, however, we recommend its measurement in different stages of the protocol should be maintained, in order to monitor and ensure the physical integrity of the individual during the test.
- As for POMS questionnaire, by performing the PCA, 69 items were reduced to 30, Nevertheless, we still not consider proper to use a shorter version of the questionnaire, because this database is not large enough to validate it. The POMS variables had no considerable weight in the MFA3 made, or at least, it did not shown a difference between the groups evaluated. However, this is not considered to invalidate the tool. It is believed that the usefulness of this questionnaire is to determine the influence of mood on sports performance.Therefore, so its value can be observed if the protocol is repeated in individuals several times, and if there is a change in their performance, POMS will identify if the reason for the change is an alteration to the training or is related to the mood of the individual (Fig. 2).
- Due to logistical problems the anthropometric measurements could not be obtained for the entire database. There were no major discrepancies between the percentage of fat and water between athletes and sedentary subjects. Since all subjects were young students, there might be significant differences for an older population.
- MFA1 results suggest to separates analysis in two groups variables: MFA2 and MFA3. According to the obtained results in the MFA2, the HRV is not an important pattern value to differentiate an athlete from a sedentary subject, which was also observed in the individual results of the HRV where statistical difference was present between the disciplines assessed. Perhaps this type of adaptation is evident in high-performance athletes and not in recreational sports.
- MFA3 emphasizes that IPAQ proved to be a valid tool for classifying individuals according to their physical activity. Levels of sedentarism and light activity did not provide differences between athletes and sedentary subjects, it is the amount of vigorous activity that carried out the differences and thus allow the classification of individuals.
- The results of the estimation of VO_{2max} permitted to differentiate between sedentary subjects and recreational athletes. Nevertheless, this method placed both athletes and sedentary thresholds below what is expected for their age. This might be due to the fact that a cycle ergometer was used despite in the evaluated disciplines, cycling was not included. To replicate the conditions under which athletes train is very important to obtain a correct measurement of oxygen consumption, which is why today's researchers seek testing outside medical facilities, and instead take the test into the training field. While this situation causes to lose control in a number of variables, such as ventilation, temperature, humidity, etc, in the market there are mobile systems to obtain an accurate measure of control even without the above aspects.
- HRR played an important role in the characterization of subjects from the cardiovascular point of view, including the stages of two and three minutes, hence it is recommended to decrease the recovery phase of the protocol to five minutes in order to: i) Have a register long enough to do a frequency analysis of the cardiac activity. ii) Taking the variables of interest to characterize individuals (HRR after 2 minutes, HRR after 3 minutes, and HRR after 3 minutes with 1 minute of cooling).

V. CONCLUSIONS

It is considered that the results of the protocol provide a holistic approach to fitness of the individual, which is highly recommended before engaging in training. This will ensure that an individual's health is not adversely affected by exercise. On the other hand, the results allow individuals to design a conditioning exercise program to their needs, seeking to improve their profile and obtain the necessary sense of well being to get away from inactivity. Our future work will consist in increasing the number of subjects in the database as well as diversify the disciplines involved.

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