"Acute cardiovascular responses to different types of exercise and in different populations"

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Background

An integrated view of the physiological responses to physical exercise is seldom offered by the available literature, since hemodynamic, metabolic and muscle variables are generally studied in different subjects, by a variety of methods and tools. The first aim of the present project, therefore, is to gather such information by studying all variables on a subject at a time. Subjects will perform different types of exercise, as outlined below, and will belong to different categories: healthy young, healthy aged, chronic heart failure (CHF) and diabetic (type II) patients; for each category: males and females.

The acute cardiovascular response to exercise consists in an increase in cardiac output (CO) that is accomplished by raising both heart rate (HR) and stroke volume (SV): the combination of these variables is expected to be affected by the exercise type as well as by age, gender and health status. The central hemodynamic adjustments match the metabolic response: pulmonary ventilation increases linearly with the increase in oxygen consumption (VO\textsubscript{2}) to achieve a stationary sub-maximal state, or up to the maximal oxygen consumption (VO\textsubscript{2max}). The relationship between ventilation (VE) and oxygen consumption allows identifying the intensity of work beyond which lactate accumulates and CO\textsubscript{2} outflow increases: thus the ventilatory threshold can be determined (Wasserman, 1964) that gives information about the metabolic system - the type of energy production during exercise. The muscle response (peripheral adjustments), is evaluated by measuring peripheral oxygen extraction and blood flow to the muscles involved in the exercise. Thus, complete information about central and peripheral mechanisms during exercise will be gathered.

In old humans, the progressive decrease in muscle mass (atrophy) and the reduction in daily physical activity, cause different physiological responses to exercise: the maximum oxygen consumption in a 70 year old man is 3.0 l min\textsuperscript{-1}(2.0 l min\textsuperscript{-1} women) while in a young male it is 4.5 l min\textsuperscript{-1} (3.3 l min\textsuperscript{-1} female) and the total muscle area at 70 years is around 50 ± 48 mm\textsuperscript{2}, while at 28 years it is about 80 ± 48 mm\textsuperscript{2}.

Another example of altered response to exercise is chronic heart failure (CHF). This disease is characterized by an inability of the heart to pump enough blood into the body, which leads to an alteration of the physiological parameters. In CHF patients, for example, VO\textsubscript{2max} is about 20.2 ± 4.7 ml kg\textsuperscript{-1} min\textsuperscript{-1}, peak work (workload) is 123 ± 30 watts, while in a young man it is 255 ± 87 watts, the VO\textsubscript{2} threshold (VT) is respectively 13.9 ± 1.8 and 25.9 ± 1.0 ml kg\textsuperscript{-1} min\textsuperscript{-1}. Finally, the ejection fraction (FE), an index used to estimate the
effectiveness of the pump function of the heart, in healthy subjects is over 55%, while in these patients it can be less than 30% (fisiologia applicata allo sport, Katch).

In female patients, with type II diabetes mellitus, the VO2 is far lower than in healthy elderly ladies: 17.7 ± 4.0 ml kg\(^{-1}\) min\(^{-1}\) versus 25.1 ± 4.7 ml kg\(^{-1}\) min\(^{-1}\).

In the literature, the physiological adjustments to exercise in males and females, different ages and types of disease, have been well documented. Few studies, however, reported comprehensive comparisons (metabolic, hemodynamic and muscular parameters) between the acute response to aerobic activity and force activity. Especially lacking is the comparison among different populations.

**AIM(S)**

The aim of this project is to study acute responses to three different types of exercise, in different populations, on the assumption that the integrated physiological response depends on the type of activity, gender, age, physical training and disease states. Cardiovascular changes (with special attention to: heart rate, stroke volume and cardiac output) will be matched to metabolic and muscle-related adjustments, during and after each exercise performance.

**COMPARISON**

1. **male VS female** for all categories
   - to study the gender differences
   - Young people are considered the control group. The comparison of the elderly with the young is a starting point for evaluation of pathological groups

2. **healthy elderly VS young subjects**
   - To characterize the disease and the influence it has on the physiological response to different types of exercise compared with non-pathological subjects of the same age
   - to study the physiological adjustments to exercise in people with diabetes, especially in view of possible alteration of the autonomic nervous system function, and to compare with healthy elderly.

3. **CHF VS healthy elderly**

4. **diabetics VS healthy elderly**

**Tests**
• a cycle ergometer incremental test to exhaustion
After achieving stable baseline conditions, the test begins with 3 minutes of pedaling with no load (warming up), followed by a starting load of 50 watts (for young and elderly healthy subjects) or 30 watts (for pathological subjects), increased every minute by 20 or 10 watt up to voluntary exhaustion.
(Portapres, NIRS QuarkB2 INNOCOR Lactacidometer Hemoglobinometer)

• A test to determine aerobic exercise variables
The test (square wave SW) is performed on the cycle ergometer with a sub-maximal load; it lasts about 10 min, and is repeated three times: in the first minute baseline values are recorded, in the following 3 minutes pedaling starts without load (effect of movement per se) and the in remaining six minutes the load is raised and kept constant at a value corresponding to 80% of VO$_2$ threshold.
(Portapres, NIRS QuarkB2 INNOCOR Lactacidometer Hemoglobinometer)

• the indirect test 1RM
All subject must raise a given load as many times as they can (with Leg press). If the repetition number exceeds 8 we progressively increase the load, until exhaustion is obtained after max 5 reps (in the elderly we accept 8 reps). This is considered suitable for indirect calculation of 1RM. Each series is separated from the next by at least 2-3 min recovery, in order to avoid the effects of fatigue and the consequent accumulation of lactate. In this way we will find a value in kg that will be used to perform power exercises.

• Test of strength, operating at 80% maximal strength (1RM).
Following the determination of 1RM, subjects must perform an exercise against resistance with the leg press. The session is divided into a warm-up phase in order to maintain the structural integrity of the person (10 minutes: 5 stretching and 5 pedaling with no load or jogging), to prepare the muscles (two series at 50 % of maximum) and a test phase, which lasts about 1 hour and is performed according to the formula of the 3 series (10 minute recovery between series) of 12 repetitions (each repetition should last about 5 sec). Variables are continuously monitored during the tests and for additional 5 min during the recovery period. The instruments used and the variables investigated are the same as
for the aerobic test: HR, VO2, VCO2, VE, R, oxygenated and deoxygenated HB, blood flow, cardiac output, systolic / diastolic blood pressure, total peripheral resistance and blood lactate.

(Portapres, NIRS QuarkB2 INNOCOR Eco Doppler Lactacidometer Hemoglobinometer)

• Test to study the mechanisms involved in the isometric exercise
  the method is the same as in the previous test except that the subject must perform the movement against resistance only once and keep the position as long as possible. This will be repeated three times at 80% 1RM.

(Portapres, NIRS QuarkB2 INNOCOR Eco Doppler Lactacidometer Hemoglobinometer)

• The test to determine the peak power
  the subject will be asked to repeat the exercise three times against resistance at maximum speed.

• The test for maximum isometric contraction
  Subjects will repeat the exercise three times against resistance trying to reach at once and hold for a few seconds the maximum force. Data are collected by load cells.
  At the end of each test all subjects will be asked to assign a value corresponding to his effort, according to the Borg scale. (Strenght gauge, Eco Doppler)

• Anthropometric measurements
  To determine body composition in addition to the usual determination of the BMI index based on height and weight of the subject, we will measure 7 body folds (scapular, mid-thoracic, pectoral, iliac, abdominal, thigh, triceps).

**Instruments**

Tests will execute with the following instruments:

- **Portapres**: beat-to-beat haemodynamic data
- **NIRS**: tissue hemoglobin saturation (deoxygenated, oxygenated, total, saturation)
- **Strenght gauge**: data about MVC
- **K4/quarkB2**: metabolic data (VO2, VCO2, VE, VT and R)
- **INNOCOR**: independent measure of cardiac output
- **Lactacidometer Hemoglobinometer**
- **Eco doppler**: peripheral (muscle) blood flow
DATA ANALYSIS

Means and standard deviations will be calculated for all data collected. Statistical significance will be accepted at P < 0.05 and statistical changes within each group will be estimated by one-way Anova for all variables investigated. Significant differences among different populations and different exercise types will be estimated by 2 (es. age gender/ diabetes health/ chf health) or 3 way Anova.

RESULTS

This study will attempt to provide a complete description of changes in metabolic variables, muscular and cardiovascular values, in three different exercises and in different populations. Particular attention will be given to cardiovascular adjustments during and at the end of the different exercises, with reference to changes in cardiac output, stroke volume and heart rate, blood pressure and total peripheral resistance, and muscle blood flow (Doppler derived data). The study will also analyze the kinetics of transients in the metabolic and cardiovascular variables in the different populations. The information gathered will be used to address gender specific, individually tailored, training programs for aged people with cardiovascular and metabolic chronic conditions. At the end of the project, we will compile a table for each investigated variable collecting the performance characteristics of the different populations in the different types of exercise.