POLITECNICO DI TORINO

Project report
"Smart measurements in sports and physical activity"

Impact of Aerobic Training Frequency and Rest on Aerobic and Anaerobic Performance: A Comparative Study of Active vs. Sedentary Individuals

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1. QUESTION

How will a 10-days aerobic training program affect aerobic and anaerobic performances in active versus sedentary individuals, and what is the impact of rest days on these improvements?

This project aims to assess the effects of a 10-days aerobic training program on aerobic and anaerobic performances among active and sedentary subjects, with a specific focus on the impact of rest days. Utilizing a smartphone to monitor changes in running efficiency and jump height, the study hypothesizes that aerobic training will yield greater improvements in aerobic capacity for sedentary subjects compared to the active one, due to their lower initial fitness levels. It also posits that anaerobic performance such as jump height, will show some improvements, particularly in sedentary participants. Furthermore, the study will explore whether continuous training without rest days leads to greater enhancements compared to intermittent training, highlighting the role of recovery in physical adaptations.

This hypothesis stems from a need to understand how different intensities and frequencies of exercise can affect the rapid improvement of physical fitness, particularly in less active individuals.

2. THE RELEVANCE OF THE QUESTION

Addressing this question is crucial because it demonstrates how visible improvements from a short-term training program can motivate sedentary individuals to initiate and maintain physical activity. By showcasing the rapid benefits achievable within just 10 days, the project should encourage increased participation in regular exercise. This is not only important for physical health but also for mental well-being, as regular physical activity is known to significantly reduce symptoms of depression and anxiety, encouraging individuals to adopt more active and organized lifestyles. Additionally, exploring the impact of rest days sheds light on how incorporating recovery into training regimens helps to maintain a healthy balance between exercise demands and everyday life, which not only enhances performance but also supports long-term adherence to physical activity. This balanced approach prevents burnout and contributes to overall well-being, providing a structured and sustainable way to enhance both physical and mental health.

Theoretical basis motivating the hypothesis

The theoretical basis motivating the hypothesis is rooted in established principles of exercise physiology, particularly the principles of overload and specificity. According to the overload principle, enhancements in physiological functions occur when the body experiences increased demand, which in the context of our study, involves introducing regular running exercise to both active and sedentary individuals. It is hypothesized that this increased demand will lead to cardiovascular and respiratory efficiency improvements, particularly in sedentary individuals who start at a lower baseline, thus showing more noticeable gains. Moreover, the specificity principle suggests that training adaptations are specific to the activities undertaken; however, aerobic training can indirectly enhance anaerobic capacities. In fact, with aerobic training there is not only a significant increase in the amount of glycogen and the number of mitochondria inside the muscle cells, enhancing the muscle's ability to use oxygen to transfer energy, but also a slight increase in the ATP and PCR, which are anaerobic components. Additionally, aerobic training promotes metabolic adaptations by shifting energy substrate utilization from carbohydrates towards fats, thereby preserving carbohydrates for anaerobic efforts. This adaptation potentially improves the performance in activities requiring quick, explosive power, such as vertical jumping.

These principles guide the hypothesis that both sedentary and active subjects will demonstrate measurable improvements, albeit potentially at different rates, with an a more pronounced impact in sedentary individuals. Furthermore, the examination of the role of rest days will provide insights into how recovery influences these adaptations, applying the overload principle by balancing stress and recovery to optimize physiological improvements.

3. METHODS

Instruments

Three smartphones with built-in accelerometers and GPS capabilities were employed to capture detailed data on energy expenditure, distance, and movement patterns:

- Smartphone Devices:
    - Device 1: Samsung SM-A415F
    - Device 2: Realme GT Master Edition
    - Device 3: iPhone 14
- Accelerometer 1:
    - Name: LSM6DSL Accelerometer
    - Maximum Range: 78.4532 m/s^2
    - Resolution: 0.0023942017 m/s^2
    - Minimum Delay: 5000 µs
    - Version: 15932
    - Vendor: STMicro
- Accelerometer 2:
    - Name: LSM6DS3C Accelerometer Non-wakeup
    - Maximum range: 78,4532 m/s^2
    - Resolution: 0,0023928226 m/s^2
    - Minimum Delay: 10 ms
    - Version: 142606
    - Vendor: STMicro
- Accelerometer 3:
    - No information available
- GPS:
    - Horizontal Accuracy: 9 m

The devices, worn on the arm using a bracelet, were employed to track and analyse data related to users' positions and movements during outdoor physical activities. They integrated both GPS for position measurement and a triaxial accelerometer for movement analysis.

Each device was configured to collect GPS data at a 1 Hz frequency and accelerometer data at 50 Hz, facilitating a thorough analysis of each subject's physical activities.

Data collected from both the GPS and accelerometer were combined to provide a comprehensive analysis of physical activity. The GPS tracked position, while the accelerometer detected accelerations to analyse movement patterns and assess activity intensity. This integration allowed for precise calculation of users' speed and pace, providing a detailed insight into physical performance and effort level.

Experimental Protocol

In our study, three volunteer subjects were tested. Anthropometric data collected includes weight, age, and height for each participant. The anthropometric details of the subjects are as follows:

- Subject 1: Weight: 55 Kg, Age: 23 years, Height: 1,71 m, Gender: Male, Smoker
- Subject 2: Weight: 61 Kg, Age: 23 years, Height: 1,72 m, Gender: Male, Smoker
- Subject 3: Weight: 55 Kg, Age: 23 years, Height: 1,65 m, Gender: Female

Prior to the first training session, all the subjects performed 10 vertical jumps. Over the following 10 days, subjects 2 and 3 ran for 20 minutes each day, while subject 1 ran for 20 minutes every other day, to assess the effect of rest. During running sessions, participants were instructed to maintain a steady and comfortable pace.

At the end of the two weeks, all subjects again performed 10 vertical jumps to assess the anaerobic response to the training program. An external observer visually monitored jump execution to ensure proper performance.

Data Analysis

Data from each session were processed using MATLAB 2023b ®.

To compute energy expenditure (EE) during aerobic activities, accelerometer data from the smartphone's built-in accelerometer were processed. By using MATLAB Mobile, the device recorded three-dimensional acceleration data at a sampling frequency of 50 Hz, capturing the nuanced movements of subjects during the running activities. The raw data were initially processed using a Butterworth bandpass filter (8th order, 0.1 Hz to 20 Hz passband), chosen for its efficacy in isolating relevant frequency components by removing gravitational effects and high-frequency noise, so ensuring motion analysis accuracy. The filtered data were then integrated using the trapezoidal rule to calculate Integrated Absolute Acceleration (IAA), providing a measure directly proportional to energy expenditure. The total integrated absolute acceleration (IAA_{tot}) was subsequently calculated as the sum of IAA values divided by the sampling frequency. This integrated value was then fed into a regression model (Bouten model) that converts acceleration data into estimates of energy expenditure based on established metabolic rates, calculated as:

$$\mathrm{EE_{act}} = \alpha + \beta \times \mathrm{IAA_{tot}}$$

where α and β are empirical constants. The metabolic rate was converted from watts per kilogram to kilocalories, factoring in activity duration and subject body mass to provide a cumulative energy utilization measure.

Parallel to the EE computation, the distance travelled during exercise sessions was calculated using the Euclidean formula to determine distances between GPS coordinates. This method accounts for the Earth’s oblate spheroidal shape, enhancing measurement precision over simpler flat-earth models. The spheroid model has implications for defining geographic coordinates, particularly latitude.

The Earth radius R is calculated using the formula:

$$\mathrm{R} = \frac{a}{\sqrt{1 - (e * sin(\phi))^2}}$$

Where “a” is the semi-major axis of the Earth's ellipsoid, “e” is the eccentricity of the ellipsoid and ϕ is the geodetic latitude.

To convert from geodetic to geocentric coordinates, neglecting the altitude, the formulas are:

$$x_p = (R)\cos(\phi)\cos(\lambda)$$

$$y_p = (R)\cos(\phi)\sin(\lambda)$$

$$z_p = R(1 - e^2)\sin(\phi)$$

Then the Euclidean distance formula was used to assess the travelled distance:

$$D = \sqrt{(x_{p1} - x_{p2})^2 + (y_{p1} - y_{p2})^2 + (z_{p1} - z_{p2})^2}$$

This approach is vital for ensuring the accuracy of distance measurements, as it directly impacts the assessment of exercise intensity and the overall analysis of physical activity outcomes.

A camera set to 60 fps was used to record frontal footage for detailed analysis of vertical jump movements. The jump height was calculated using the flight time technique, which assumes that the take-off and landing velocities are equal and opposite. This technique allows the calculation of jump height using the following equation:

$$y_{jh} = \frac{g}{8} t_{flight}^2$$

For each anaerobic training session, only the last 3 high jumps were considered in the calculation (the other 7 were deemed transitional), and then the average of these three jumps was used to compare the pre- and post-aerobic training data.

4. RESULTS

In this section the results are shown:

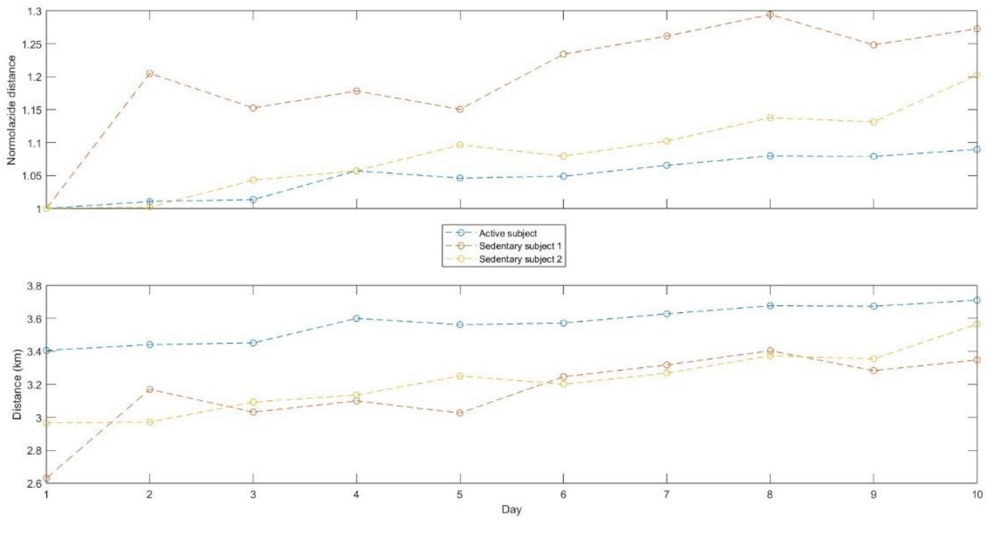

Figure 1*: The figure depicts the daily distance covered by the three subjects over the 20min. The upper subplot illustrates the normalized distance covered by each subject relative to their distance on the first day of measurement. The lower subplot displays the daily distances covered by each subject over the training sessions.*

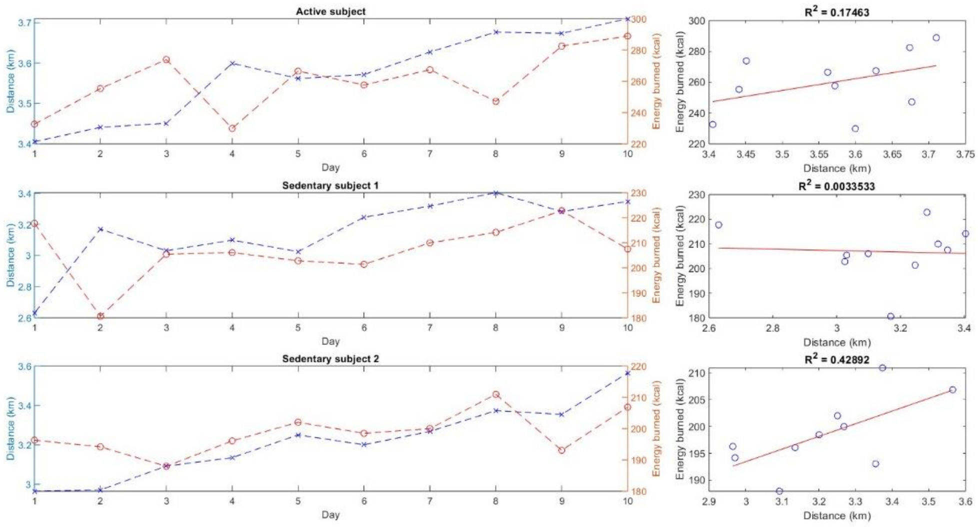

Figure 2*: The figure presents a comparative evaluation of energy burned (kcal) and distance covered (km) metrics for the three different subjects, across the ten days, along with regression analysis. The first column displays the data of energy expenditure (red dashed line with circles) and distance covered (blue dashed line with crosses) for each subject. The second column presents the linear regression analysis between distance covered and energy burned for each subject. The original data points are represented with blue circles, while the regression line is shown as a red line. Each plot title includes the value of the coefficient of determination R^2.*

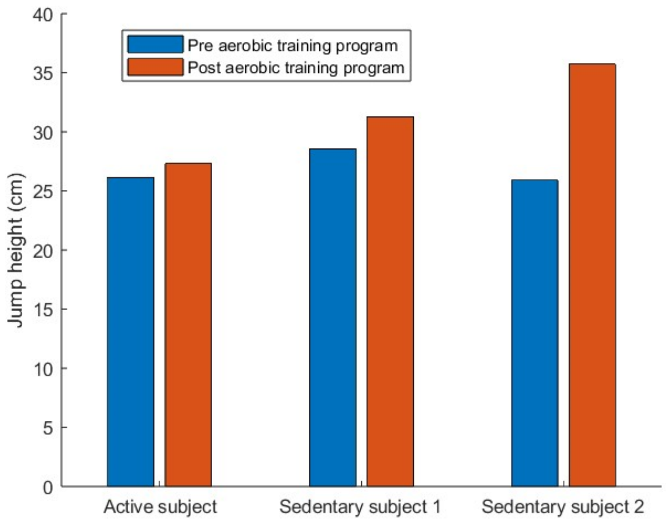

Figure 3*: The bar diagram illustrates the average jump heights from the last three jumps per subject, at the beginning (red) and at the end (blue) of the training program.*

To effectively discuss and interpret the results of this study, it is crucial to focus on several key findings and their implications within the context of aerobic and anaerobic training adaptations.

Figure 1 indicates that the relative improvements in aerobic performance (distance travelled) were more significant in sedentary subjects compared to the active person. This suggests that individuals with lower baseline fitness levels can experience more rapid and noticeable gains when subjected to consistent aerobic exercise.

Environmental conditions, particularly heat, may have varied the results. Elevated temperatures can affect physical performance by increasing fatigue, reducing endurance, and altering cardiovascular strain, which could explain some of the inconsistencies and performance declines observed during the training sessions.

By day 8, the active subject appeared to reach a plateau in the distance travelled, likely due to the adaptive response of her body reaching a temporary limit or the need for varied training stimuli to overcome adaptation resistance.

Conversely, the sedentary subject who engaged in daily running demonstrated consistent improvements, albeit with initial challenges such as muscle pain due to unaccustomed physical activity. In contrast, the sedentary subject who ran every other day reported a less strenuous experience, suggesting that the inclusion of rest days allowed for better recovery and adaptation. This highlights the importance of rest and recovery in training regimens, especially for new exercisers whose bodies may not yet be accustomed to frequent physical stress.

The lack of linear growth in energy expenditure observed in Figure 2 can be largely attributed to the placement of the accelerometer on the arm rather than at the body's centre of mass. Since the arm moves independently during running, this positioning can lead to inaccuracies in the acceleration data, exaggerating or understating actual energy expenditure. To improve accuracy in future measurements, devices should ideally be positioned at the body’s centre of mass, or adjustments should be made to account for the relative motion of the arm.

For what regards anaerobic improvements shown in Figure 3, measured through jump height, there was no significant enhancement observed in the active participant. In contrast, a slight improvement was noted in the sedentary subjects. This outcome may point to the limited cross-training effects of aerobic exercises on anaerobic capacities like jumping, which rely more on fast-twitch muscle fibres and phosphocreatine energy systems. Nevertheless, the modest gains in the sedentary subjects could suggest some degree of muscular adaptation from regular aerobic training.

However, the reliability of jump height measurements may be questioned due to the lack of precision in video analysis compared to advanced tools like force plates, potentially underestimating true anaerobic improvements. For more accurate measures, force plates should have been used.

In conclusion, this study underscores the varying responses to aerobic and anaerobic training based on baseline fitness levels, the significance of recovery periods, and the necessity for precise measurement techniques to accurately assess training adaptations.