Energy Consumption and Work Load

Don Pugh

Ergonomics Lab

Table of Contents

Introduction

This laboratory examines the relationship of energy consumption to work load. The theoretical basis for the experiment is as follows. The human metabolic process utilises glycogen to produce physical energy. Initially, in the anaerobic stage, energy and lactic acid are produced without the direct need for oxygen. In the later aerobic stage, to alleviate fatigue, lactic acid needs to be broken down with oxygen to form water and carbon dioxide. If inadequate oxygen is available, oxygen debt occurs. The body increases its breathing rate and heart rate to increase the oxygen rich blood flow and this demand continues after the cessation of activity. As the available oxygen gradually meets bodily needs, breathing and the heart rate slow to the basal metabolic rate. The basal metabolic rate is the heart rate required to maintain the body in a resting state.

Oxygen consumption is the best measure of body energy requirements. However, measurement of oxygen consumption requires sophisticated equipment. Because increased oxygen consumption speeds up the stroke rate of the heart, this measure of heart beat per minute may be used as an indirect measure of energy consumption. The relationship is linear with energy consumption. An index of physical fitness may be obtained by measuring the heart rate recovery curve by taking heart stroke measurements at regular intervals following physical activity.

Increased workload requires increased energy consumption. Various types of physical work vary workload. Static work, caused by holding a weight away from the body, exceeds dynamic work in energy consumption. The minimal workload involves maintaining good posture with the weight close to the body's centre of gravity.

Goals

This study examines two issues. Firstly, it compares the differences between static and dynamic workloads on energy consumption and the recovery period. Secondly, it examines the effects of increasing workload on energy consumption as represented by heart rate.

Hypotheses

Static weights of equal weight to dynamic weights will increase the workload and the consumption of energy and will lengthen the recovery period.

Increased workload will increase energy consumption and result in a gradual recovery of the oxygen debt.

Method

Apparatus

Two devices were used to create workload. Firstly, a wooden six cm step was available. A pack sack with nine kilograms of bricks was used as a load. Secondly, a peddle exercise cycle was available with an ergometer indicating three, six and twelve kiloponds.

Subjects

Subjects were twenty third year Murdoch University students in their early twenties, divided equally between males and females.

Procedures

Students were grouped in pairs. To measure static versus dynamic workload, students recorded their basal heart rate while standing quietly for five minutes. In Condition 1, wearing a pack sack with nine kilograms of bricks, students stepped on, then off a step at a rate of 1 step per second for one minute. After one minute heart rates were measured. Readings were again taken after two and three minutes.

The activity was repeated. In condition 2, the weight was held out vertically in a static position rather than being placed on the back. Measurements were repeated as described above.

In the second activity subjects recorded basal heart rate after resting in a sitting position for five minutes. Subjects then peddled for two minutes each at three, six and twelve kiloponds, while measuring their heart rates after each two minute interval. The subjects then rested and recorded their heart rates every two minutes for ten minutes.

Results

Insert Figs: 1 to 3 Here

Class means for condition 1 are shown in Figure 1. The graph indicates that the mean heart rate for carrying the static weight was six heart beats faster at the finish of the exercise period and for each of the three recovery periods. Individual results shown in Figure 2 follow a similar trend with peak heart rate in condition 2 being above that of condition 1 by 8 beats per minute.

A correlated two tail t-test was conducted to ascertain whether the difference in mean heart rates at the conclusion of testing was a significant difference or an artifact of sampling error. Results are in Table 1.

Table 1

t-Value,	Degrees of Freedom,	t critical value
-1.172	9	2.228 at .05

In the bicycle test, the heart rate increased considerably, as shown in Figure 3 from 72 at rest to 92, 122 and 154 heart beats per minute as workload increased from 3 to 6 and 12 kiloponds. The heart rate decreased slowly to 110, 99 95 92 and 87 heart beats per minute during each two minute rest interval. The personal data also graphed in Figure 3 indicated a similar trend.

Discussion

Results indicate firstly that there was no statistical support for the theory that static loads consume more energy than dynamic loads. There is support for the hypothesis that increased workload increases oxygen consumption.

In the Step Test the increased heart rate for condition 2 has indicated the possibility of an increased energy consumption of the body caused by the increased workload of carrying a nine kilogramme static weight located outside the body's centre of gravity. The oxygen debt created by the increased workload extended the recovery time until the basal heart rate was resumed. However, the t-test result ($p > .05$) was insignificant indicating that this difference may be attributed to sampling error rather than a significant difference between the means.

The experiment was confounded by the fact that all subjects completed the static weight carry after carrying the weight on their back. Consequently, recovery from condition 1 had not yet been fully achieved. The initial heart rate in condition 2 was 3 heart beats faster than condition 1. Half the subjects should have commenced condition 2 as their initial exercise to avoid this confounding influence.

In the Bicycle Test, the heart beat increased dramatically as energy consumption increased with the progressive increase in workload. The graph indicates a linear increase in heart beat. There is also a progressive recovery rate which is curvilinear, with the greatest recovery being in the first two minutes. The drop in heart rate in subsequent two minute intervals is substantially reduced because of the removal of lactic acid by the blood stream.

Use of heart rate lacks precision. The experiment may be improved by increasing the precision in measurement of energy consumption. There is no one adequate measurement of energy consumption. Sanders and McCormick (198) recommend a composite method employing heart rate, mean blood pressure and stroke volume. Other methods include a cardiorespiratory variance score which includes direct measurements of oxygen consumption. Such measures use myograms constructed by an electromyographic (EEG) machines. Calorie consumption is another frequently used measure of energy consumption.

Bibliography

Sanders, Mark S. & McCormick, Ernest J. (1987). Human factors in engineering and design. London: McGraw Hill.

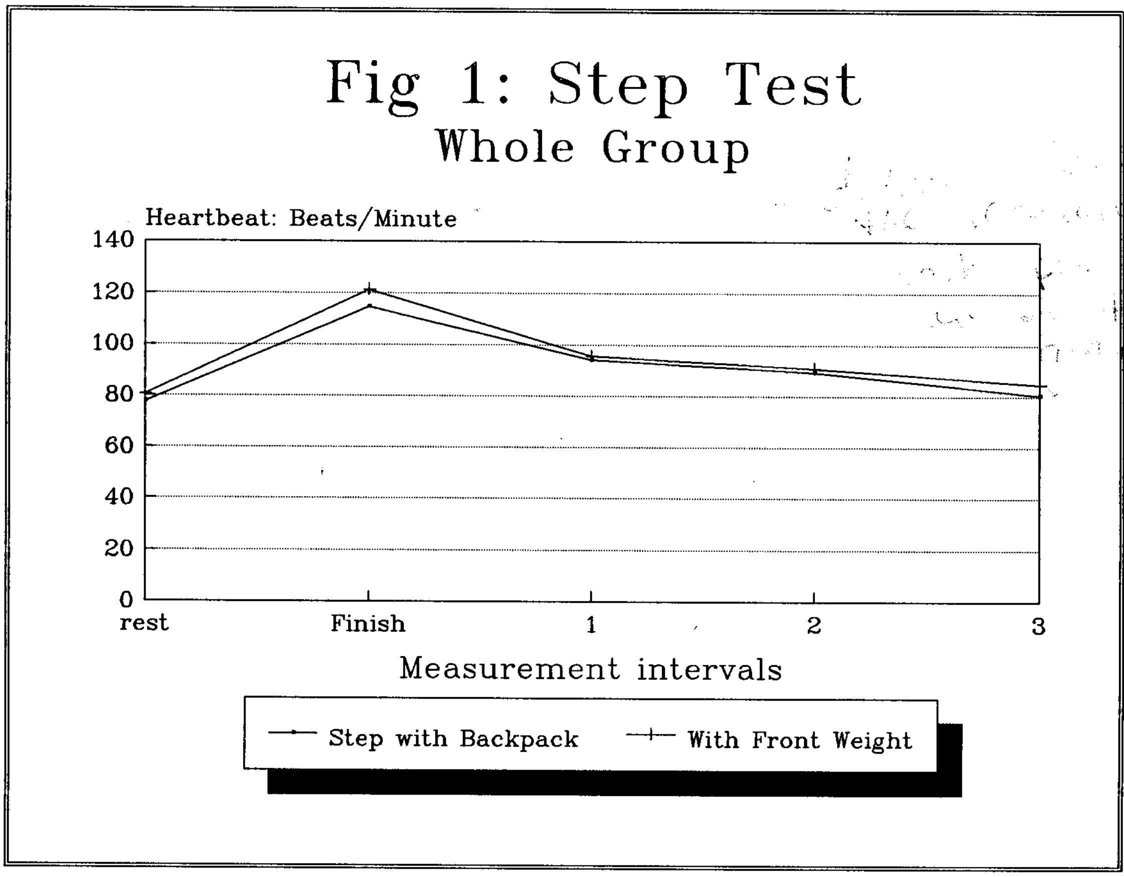

Fig 1: Step Test
Whole Group
Heartbeat: Beats/Minute
140
120
100
80
60
40
20
0
rest
Finish
1
2
3
Measurement intervals
Step with Backpack
With Front Weight

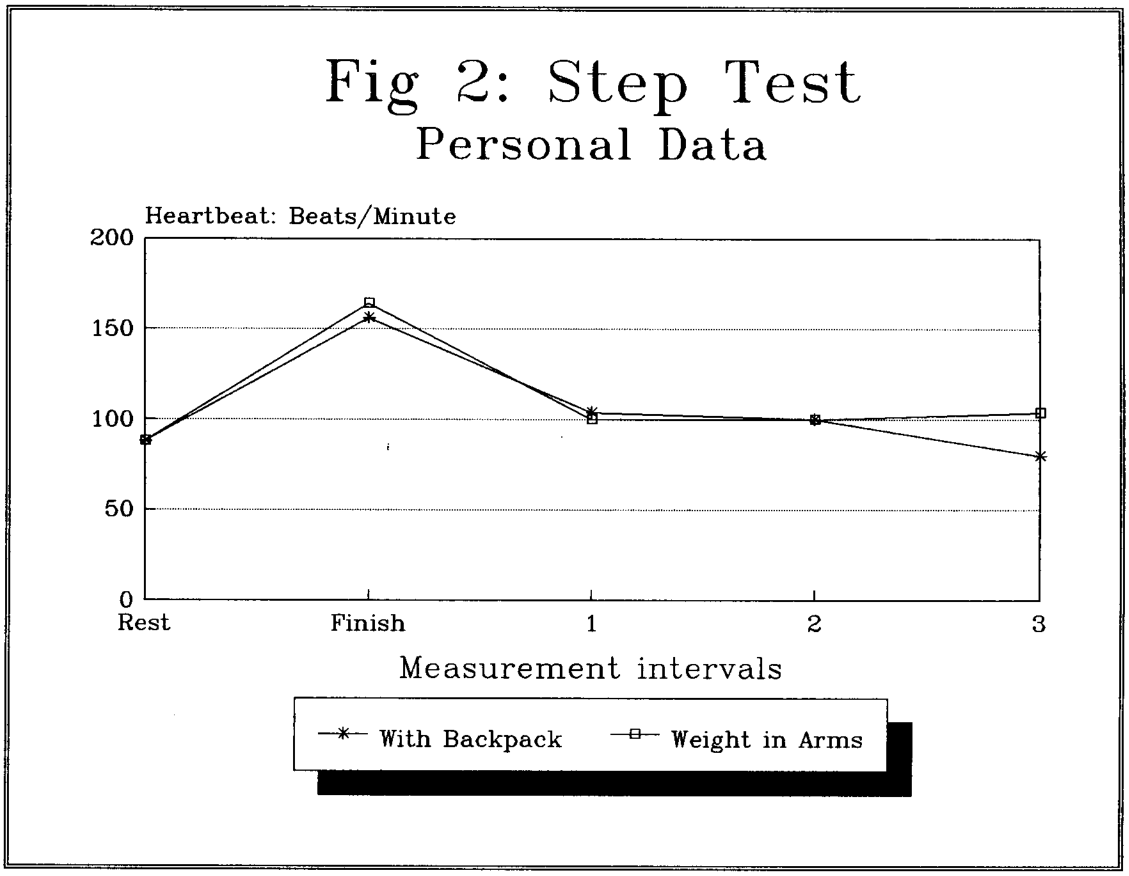
Fig 2: Step Test
Personal Data
Heartbeat: Beats/Minute
200
150
100
50
0
Rest
Finish
1
2
3
Measurement intervals
With Backpack
Weight in Arms

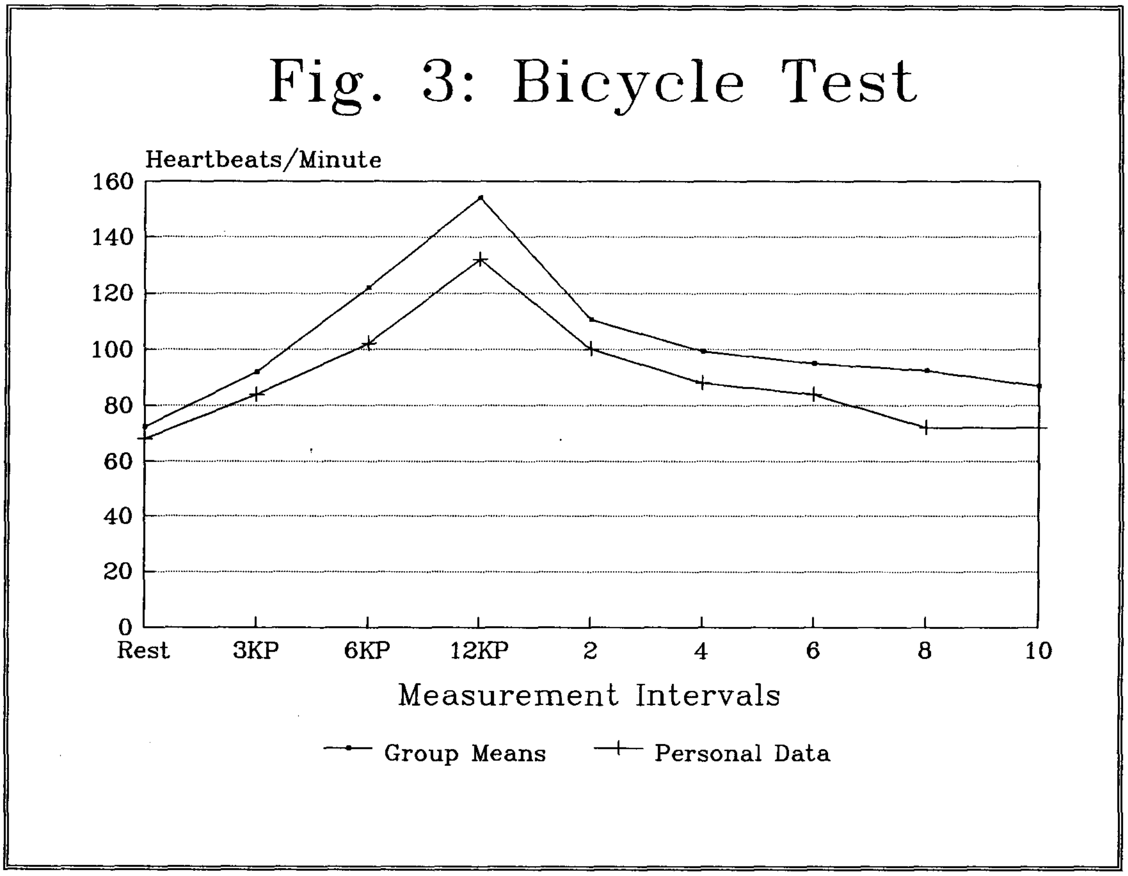
Fig. 3: Bicycle Test
Heartbeats/Minute
160
140
120
100
80
60
40
20
0
Rest
3KP
6KP
12KP
2
4
6
8
10
Measurement Intervals
Group Means
Personal Data