1 Plan

Hypothesis

The aim of the experiment is to explore the effect of fatigue, whether emotional (giving up) or muscular (unable to lift), on blood oxygenation and heart rate during anaerobic exercise.

During aerobic exercise we expect blood oxygenation to reduce as oxygen is moved to the muscles. We infer that anaerobic exercises have a much higher oxygen requirement, as fatigue is reached considerably quicker. Thus, the hypothesis is that blood oxygenation should be higher during early work-out and lower as fatigue is reached.

Given that higher heart rates are associated with aerobic exercising, we explore whether we reach similar numbers during an anaerobic exercise – especially close to fatigue. Despite the aforementioned higher oxygen requirement, a lower pulse rate is expected.

Experimental design

The study has been developed by only one student and to be performed by only one student, and this is taken into consideration in the design. The task, consequently, consists of performing deadlifts to "exhaustion" within 5 to 8 repetitions, such as to remain in what is usually considered anaerobic. The exercise is repeated for 6 sets with a 1 minute interval between them. We are using a finger-attached pulse oximeter, therefore a whole-body exercise is chosen so as to both push the individual harder and avoid blood pooling away from the fingers.

Since anaerobic exercises are done in short bursts, blood oxygenation and heart rate are measured while resting, upon completion of each set, and before initiating the subsequent set. These are performed using a pulse oximeter, and we compare the heart rate with a manually measured one against the carotid artery.

Determining the appropriate weight to use and whether fatigue has been reached are very individual, hence it is preferable to have a subject who is familiar with the exercise and the gym generally, so as to reach muscular, not emotional, fatigue.

Finally, in warming up with aerobic exercises, we establish a control against which we may compare anaerobic fatigue heart rates.

2 Results

Manually measured heart rate is the count of beats felt against the carotid artery (MPR) in the period of 10 seconds, therefore the following calculation is performed:

$$\mathrm{PR}\ (\mathrm{BPM}) = \frac{\mathrm{MPR}}{10\,\mathrm{s}} \cdot 60\,\mathrm{s}\,\mathrm{min}^{-1} \tag{1}$$

Considerations regarding the two subjects

	Subject 1	Subject 2
Gender	Male	Female
Age	26	19
Description	Out of shape/Experienced	Avid gym goer
Barbell mass	130 kg	80 kg

Table 1: Subjects summary

The variation of machine measured pulse rates seen in Figures 1 and 2 is within expectation. On the other hand, using the chronometer to measure 10 seconds in which beats would be counted, it was decided that the trailing milliseconds would simply be disregarded. Not only did the long measurement period exacerbate the variation in the values, but, in reflection, it may have been beneficial to record the times as well, allowing for heart rates which are not multiples of 6.

Focusing on the muscular fatigue of Subject 1, we see a mean (μ) pulse rate of 176 and a standard deviation (σ) of 4. This is generally much higher than those achieved during lighter loads and aerobic exercise, which lumped together have $\mu = 160$ – ultimately falsifying our hypothesis.

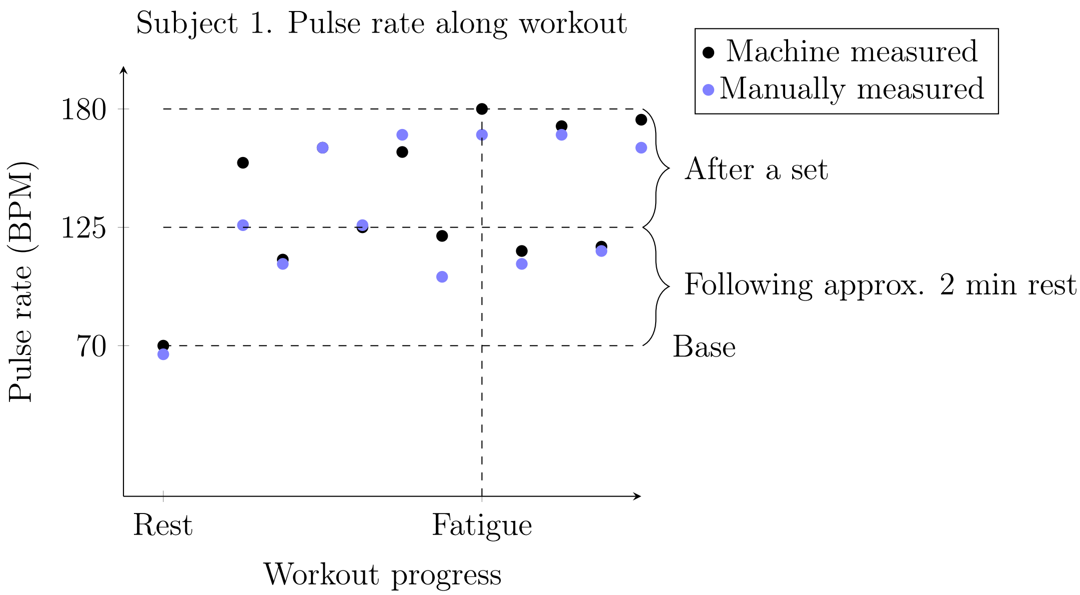

Figure 1: Note that each dot represents a set and its subsequent rest period. Furthermore, fatigue is determined after the set completion, as reported by the subject.

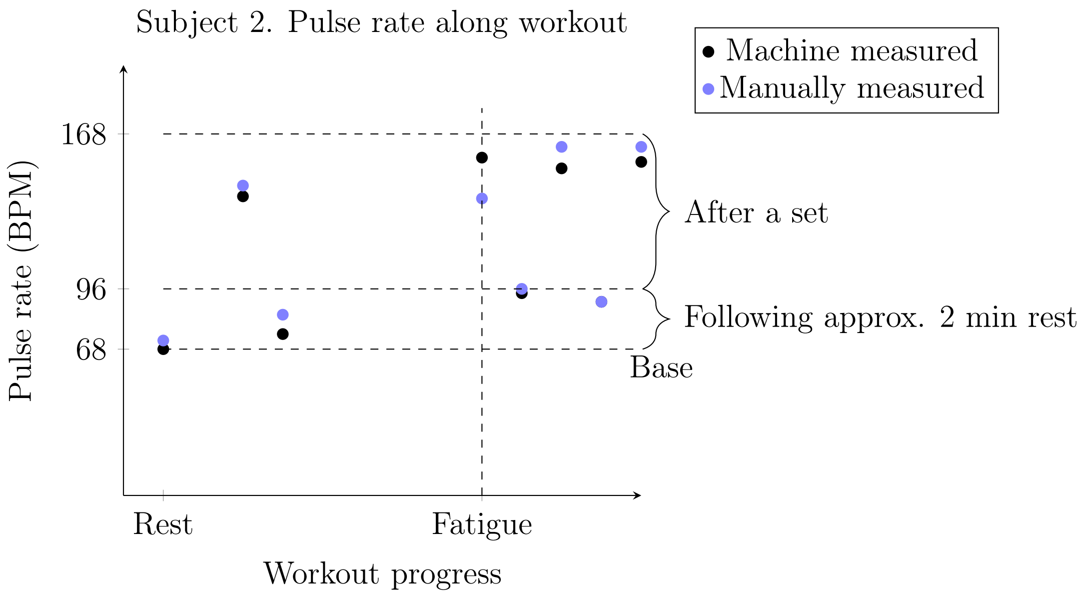

Figure 2: Note that subject 2 reported fatigue on the second set. This was determined to be emotional fatigue based on the subject's (subjective) lack of strain during the exercise.

Surprisingly, oxygen saturation was kept largely constant across all sets as can be seen in Figure 3. Indeed, the graph clearly shows the central tendency for each subject. There is, however, one interesting exception, when subject 1 felt light-headed after a set, the lowest oxygen saturation was measured – 93%. This was accompanied by the highest pulse rate, 180 BPM (machine)/168 BPM (manual). Approximately 5 seconds later, the light-headedness was gone, blood oxygenation shot to 97% and pulse rate 166 BPM (machine). This is not represented in the graph, as it is somewhat qualitative.

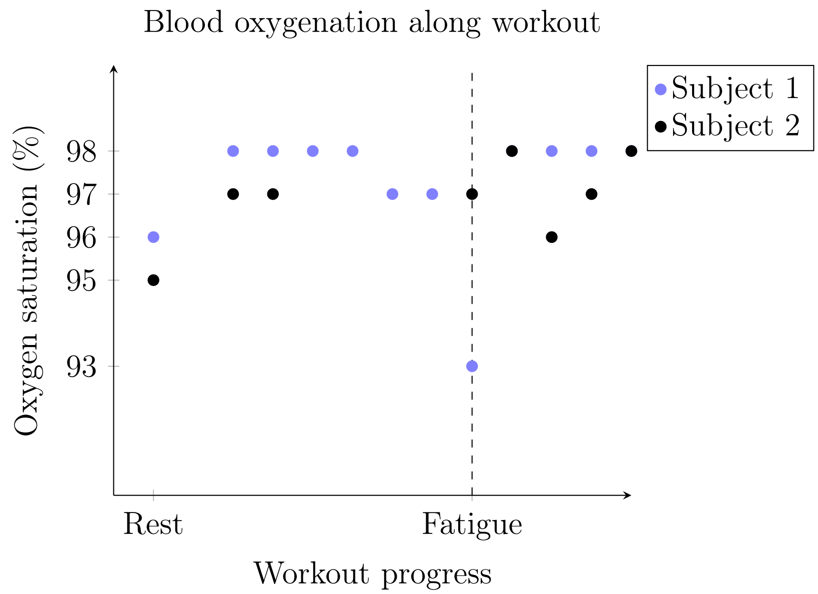

Figure 3: The first point shows base oxygenation, and every pair of subsequent points is a set and its break.

3 Discussion and future

We expected to see medium-strain aerobic exercises leading to a much higher pulse rate than the one achieved those of anaerobic. Seeing as this was not the case, the comparison was abandoned.

Rest heart rates were measured the moment before each new set. Nevertheless, while measuring heart rate, sitting down or squatting meant a drop of around 20 BPM, and we are unsure whether Subject 2's measurements were taken sitting down – or their increased level of fitness, as expected, accounts for the faster recovery rate. Note that subject 1 is out of shape, and expectedly has a higher heart rate during the 2 or so minute rest period, however it is imperative that this is controlled for in further experiments.

Despite the expectation that vasoconstriction on fingers would show a reduction in oxygen saturation, the largely stable blood oxygenation suggests otherwise. Given that the weights are held in one's hand, this may explain the high oxygenation when we would otherwise expect blood flow and oxygen to be largely focused on the larger muscles performing the exercise.

For subject 1 muscular fatigue was accompanied by a considerably raise in the barbell's mass due to time constraints. An increase in the exercise's strain would lead to higher pulse rate, and therefore this study is unable to differentiate between increased strain and pure fatigue. A further study would be required forcing fatigue at "medium" weights with more sets, for an appropriate comparison.

The attempt at having one female and one male subject was appropriate, and a larger sample size for a future experiment would be ideal. This means having access to a larger group of fit and unfit individuals who are well versed with this particular exercise in order to push for muscular fatigue; the latter of which is likely to be a problem. Ultimately, each subject's physiological responses are only measurable against themselves, and therefore information on variability can only be drawn from a much larger number of samples from each subject – something perhaps impractical given the setup.

Conclusively, all the hypotheses were incorrect. Given our understanding of improved heart recovery post exercise and the results, this is perhaps the best conclusion that can be drawn from this experiment.

Future experiment This experiment could not have been conducted with the equipment available at our lab, however utilising a static bike with high resistance may be analogous. In addition to all the described considerations, and given a similar setup to this one, it would be beneficial to perform another exercise such that heart rate and oxygen saturation can be monitored continuously.

Despite falsifying all of the hypotheses, continuing the study with similar parameters would be very interesting – especially if it could be extended long-term, and it reflects a subject's fitness improvements over weeks or months.