Hogeschool van Amsterdam
Amsterdam Institute of Allied Health Education
European School of Physiotherapy

Professional Assignment Project

SkillsLab
In support of digital tools and self-directed learning

6 minute submaximal exercise tests:

- Harvard Step Test
- Åstrand Bike Test

(including: 2 videos and 2 manuals)

Members:
Alison Cheevers
Cathrine Pettersen

Client:
Bob van den Berg
HvA

Coach:
Bert Loozen, Movement Scientist, HvA

Hva, 26th January 2007
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Foreword

This document is designed for Physiotherapy students at the Hogeschool van Amsterdam who are learning to perform exercise testing as part of their bachelors degree in physiotherapy. This document presents two manuals for two submaximal exercise tests. They should be used in conjunction with and support the two complementary digital videos.

The digital videos and manuals give a step-by-step guide in how to carry out the exercise tests for the Åstrand Bike Test and the Harvard Step Test. They should become an intrinsic part of the ESP programme for international students.

The authors of this Professional Assignment Project could have completed the project without the help of other. We would like to thank a number of people. Firstly, our client Bob van den Berg from the Hogeschool van Amsterdam; he was always there to help us, his comments were valuable and despite sickness he always replied to our ‘urgent’ requests! To our coach we say thank you for your comments and your flexibility with making appointments. We also thank Bas Moed for offering suggestions and lending us his brand new book on exercise testing. A big thanks must go to Technical Support, we could never have produced such high quality videos without their help and patience. We thank Grace Smith for saying yes to helping us make the videos; she did not realize that yes meant such hard work – she was great. We also thank the students that participated in our questionnaire especially at a difficult time with exams and presentations. Of course, a special thanks goes towards our partners who spent weeks putting up with us. Lastly, we thank ourselves because at times it was stressful but we always managed to support each other with a smile.

Alison Cheevers
Cathrine Pettersen
January 2007
1. Introduction
The Hogeschool van Amsterdam (HvA), like all higher education institutions across the developing world, is active in the international market for education. This parallels the increasing use of technology in education and the move towards self-directed learning, where the student becomes an “active” learner, setting their own educational goals and where knowledge is the necessary competency in the job market.

To keep up with the trends HvA, in an on-going process, is looking to improve its digital services, integrating them into the learning experience through the intranet, Internet and a comprehensive Mediatheek.

This thesis brings to the Mediatheek two new digital videos, both of which are supported by two digital manuals. In particular, they have been produced in English to enter the English language Digital Library at the school. They are specifically for the ESP Programme but can be used by any discipline that is interested in exercise testing. The two digital videos are designed to support the learning of physiotherapy students, especially Module 2.2. Both digital videos demonstrate where, when and how to do a submaximal exercise test:

Video 1: Åstrand Bike Test
Video 2: Harvard Step Test

A questionnaire was sent to 10 students as a quality control for the two videos and supporting manuals. The questionnaire can be found in appendix 3.

This outlines the trends in higher education and why digital learning has become an essential aspect to education. This is then followed in appendices 1 and 2 with a paper-version of the two manuals supporting the two digital videos for the Åstrand Bike Test and the Harvard Step Test. Each manual has it’s own contents page, appendices and references.
2. Background

2.1 Trends in higher education
In all areas of higher education profound changes are taking place. This is due to increasing pressure in the school systems, changing societies whereby knowledge-work becomes ever more important, and because information and communication technologies are transforming our economies (Roes H., 2001).

Twigg and Miloff (1998: taken from Roes 2001) looked at the changing learning situation in the United States and highlighted trends that they saw as fuelling the changes affecting higher education. According to Roes (2001) these trends are also applicable to the European situation:

- The number of students entering higher education is continuing to rise;
- Students are increasingly heterogeneous and bring different experiences with them. There is a need to accommodate different learning styles, customisation and alternative learning routes;
- Increasingly, work and study are combined leading to more flexible arrangements between schools and students;
- There is a general trend towards lifelong learning;
- Education is under constant budgetary pressure, thus there is a need for more efficient and effective education;
- Increasingly, students behave more and more like consumers, they want to make informed choices about how and where they want to be educated;
- Teachers exhibit more job-hopping behaviour than in the past;
- There are too many drop-outs in the current educational system.

Due to these trends Twigg and Miloff envisaged a future learning environment that would be:

- Student-centred
- Interactive and dynamic
- Enabling group work on real world problems
- Enabling students to determine their own learning routes
- Emphasising competencies like information literacy in support of lifelong learning.

In a knowledge society emphasis on information and communication technologies becomes paramount with the Internet and web search engines providing a platform of learning that meets the trends in education. A common
theme is the adoption of more active learning styles in which students take more responsibility for their own learning goals and for the ways in which to realise these objectives (Roes H., 2001). Here, active learning implies that students do not just stick to what their teachers tell them but use technology to seek out information in order to solve problems at hand and to develop their competencies in order to achieve their goals.

2.2 Digital Libraries
Libraries are a key support in higher education and research. They are the traditional conduit for information and learning. They have reacted to the trends in higher education and understand the need to embrace new technologies and student self-directed learning. This has been realised through the growth of:

- Digital libraries and digital learning environments;
- Digital portfolios;
- Information literacy;
- Collaborative course design;
- The relationship between physical and virtual learning environments.

Digital libraries go hand in hand with the digital learning environment; they are able to integrate traditional media with new digital and Internet sources, offering their services to support active learning in the new knowledge driven society; and they hold a key role in an educational institute as the guardians of knowledge working with the various departments to link courses and student portfolios.

New technologies are not just add-ons to existing learning practices, they fundamentally alter the way education shall be delivered in the future. For the reasons outlined above, higher education is changing towards a self-directed, lifelong learning paradigm; if students are moving towards an active learning style, embracing self-responsibility the educational institution will, in the future, need to be flexible, and in order to remain competitive, they must build on their digital library services and intranet platforms for the delivery and teaching of knowledge (Fischer G. & Scharff E., 1998).
3. Two digital videos and manuals

This Professional Assignment Project primarily aims to deliver two high quality digital videos and manuals which are found below. These have been made as a resource for the digital library found in the Mediatheek at the Hogeschool van Amsterdam. They can be found below in appendices 1 and 2. To ensure quality control of the videos and manuals a questionnaire was sent to ten students before completion of the finished products. The results of this exercise were very positive and additions to the videos and manuals were not necessary. The questionnaire and results can be seen in appendix 3 at the back of this project document.
4. References (see also above references at the end of each manual)


Appendix 1: Submaximal testing: Åstrand Bike Test

Hogeschool van Amsterdam
Amsterdam Institute of Allied Health Education
European School of Physiotherapy

Åstrand Bike Test

SkillsLab
6 minute submaximal exercise test
(Video and Manual)

Group members: Alison Cheevers
Cathrine Pettersen

January 2007
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1. Introduction
Submaximal testing is an important tool in physiotherapy. It is commonly used in practical settings and across different subject groups. This manual is designed to be used in conjunction with the digital video found in the HvA Mediatheek, Digital Library Service. Both the video and this manual was produced by third year ESP students for their Professional Assignment Project.

2. What is submaximal testing, when and how is it used?
The ability to do aerobic exercise is very important for activities of daily living and maintaining a healthy lifestyle. Aerobic capacity can be tested to measure the ability to do exercise specifically by measuring the amount of oxygen required (VO₂). Unlike anaerobic power, which is related to local muscular strength and to the amount and rate of ATP produced by the anaerobic metabolic pathways (ATP-PC system and anaerobic glycolysis), aerobic power reflects the ability of the lungs, blood, heart, muscles, and other organs and organ systems to transport and utilise O₂ via the aerobic metabolic pathways; determining a person’s level of cardiorespiratory fitness has therefore both general and clinical applications (Foss M.L. & Keteyian S.J., 1998).

The measurement of maxVO₂ can be used in a variety of different settings: elite athlete, healthy individuals in the fitness setting, and persons with known diseases or classified as high risk (for example, heart disease and obesity). In the latter group, persons with chronic disease or disability, it is vital to know their maxVO₂ as many of these people have a very low ability to consume and utilise oxygen. Maximal steady-state oxygen consumption (VO₂MSS) is in the usual range of 40% to 70% of maxVO₂. Many people with a chronic disease or disability have a maxVO₂ that is below the 40% maxVO₂ that is required for

3. Direct measurement of maxVO₂
Determining an individual’s aerobic power (cardiorespiratory fitness) can be best achieved through the direct measure of maxVO₂ while the individual is exercising. MaxVO₂ reflects the body’s ability to transport and utilise O₂, with changes in ventilation, perfusion, heart rate and stroke volume, and/or peripheral utilisation of O₂, all having an influence on maxVO₂. Therefore, the measurement of maxVO₂ is considered to be the best measure of cardiorespiratory fitness (Foss M.L. & Keteyian S.J., 1998).

Measuring maxVO₂ directly is usually done through graded exercise tests and selecting a test protocol that best fits the fitness level of the person being tested. Usually the test requires that the individual reaches voluntary fatigue within 6 to 12 minutes. The maxVO₂ is reached when one or more of the following criteria have been achieved:

1. A further increase in work rate results in no further increase in VO₂ (a plateau);
2. The Respiratory Exchange Ratio (R) exceeds 1.10 to 1.15;
3. If measured, post-exercise blood lactate exceeds 8 to 10mM (Foss M.L. & Keteyian S.J., 1998).

Whilst the direct measure of maxVO₂ is considered the best and most accurate, there are a number of disadvantages:
• The test is difficult and stressful. Many persons, especially with chronic disease or disability, do not achieve a ‘true’ maxVO\(_2\). Instead, they reach a point at which they cannot continue not because of limitations in the supply of oxygen but through some other limiting factor such as mental fatigue, fear, lack of motivation or symptoms such as chest pain and light-headedness. If this is the case, the individuals are said to reach symptom-limited exhaustion and this is referred to as peak VO\(_2\) (Durstine J.L. & Moore G.E., 2003);
• Direct testing requires the use of expensive equipment and trained staff and is therefore prohibitive in many settings;
• The presence of a cardiologist or physician is required;
• Due to above reasons it is not a practical test for general health screening and testing of large groups (Maud P.J., & Foster C., 1995).

4. **Indirect estimation of maxVO\(_2\)**

4.1 *Estimation of maxVO\(_2\)*

To overcome the difficulties in performing a direct test indirect measures of maxVO\(_2\) have been devised. Two of the most well-known tests are the Åstrand Bike Test and the Harvard Step Test. These are called submaximal tests and are based on the linear relationship between heart rate (HR) and VO\(_2\): the greater exercise intensity or VO\(_2\) the higher the heart rate. In other words, if you plot the results of a submaximal test on a graph (graph 1, heart rate against workload) a linear line, representing VO\(_2\) used, emerges because physiological theory tells us that as workload increases so does the heart rate and therefore
VO₂. Indirect estimates work by extrapolating information from this graph to predict maxVO₂ (Maud P.J., & Foster C., 1995). It does this by continuing the linear relationship line towards the maximum.

Graph 1 Sample graph for the extrapolation method of estimating maxVO₂ (Maud P.J., & Foster C., 1995).

Using this linear relationship, the Åstrand Ryhming Nomogram (appendix 1) was designed to estimate maxVO₂ from the results of a submaximal test. It simply estimates how the heart rate would continue increasing, in line with the workload, as a direct maxVO₂ test would do. This is how the indirect measure of maxVO₂ is calculated and for example, the use of the Åstrand Ryhming Nomogram gives a ± 15% standard deviation from a directly measured maxVO₂ (Foss M.L. & Keteyian S.J., 1998).

4.2 Calculating the intensity of exercise
With indirect estimates of maxVO₂ the individual exercises submaximally (as opposed to bringing the individual to their maximal aerobic output) and to ensure that the test is being performed at the correct level of intensity and avoiding the expense of direct VO₂ measurement, various indirect techniques
that correlate well with measured VO$_2$ can be used to guide exercise intensity. These are heart rate measurement, the blood lactate threshold or rating of perceived exertion (Foss M.L. & Keteyian S.J., 1998). The heart rate techniques are practical and easy to use and can be used for elite athletes, the general population and for persons with chronic disease or disability; training intensity is judged mainly by the degree of stress placed on the cardiorespiratory system. The blood lactate threshold method is more difficult to perform and is mainly used with elite athletes and the study of training intensity, and the degree of stress placed on the metabolic systems within skeletal muscle. The third technique, a rating of perceived exhaustion (Borg scale), is highly applicable to persons with chronic disease or disability where teaching the heart rate methods becomes difficult and where medication, such as beta blockers, render pulse taking less accurate (Foss M.L. & Keteyian S.J., 1998).

4.3 *Karvonen method*

In this manual we use one of the heart rate methods for calculating exercise intensity for a submaximal exercise test. This is known as the *Karvonen method* (or heart rate reserve method). The other method, the *straight percentage method* is not discussed here.$^1$ In the Karvonen method the increase in heart rate that occurs above the resting heart rate is taken into consideration.

---

$^1$ The straight percentage method is calculated using the formula 220 minus age and multiplied by a percentage of maximal heart rate that is usually between 60 to 90% of maximum. A target heart rate of 60 to 90% of maximum corresponds to a VO$_2$ that is between 50 and 85% of maximum. One of the problems with this method is that exercising at the lower end of exercise intensity the heart rate is very low in comparison to the Karvonen method and falls outside of the parameters of the Åstrand Ryhming Nomogram when calculating maxVO$_2$. 
The formula is as follows:

\[
\text{Target heart rate (THR)} = (\text{heart rate reserve}) \times \text{percentage of HRR} + \text{restHR} \\
= (\text{max HR} \ (220-\text{age}) - \text{restHR}) \times \text{intensity} + \text{restHR}
\]

So, a 60 year old exercising with a 60% rate of heart rate reserve (intensity) and with a resting heart rate of 70\(^2\) b.p.m would have a THR of 124 b.p.m:

\[(160 - 70) \times 60\% + 70 = 124 \text{ b.p.m.}\]

For an initial submaximal baseline test, level of intensity should be set between 40 and 60%. Using the above example, a 60 year old male would need to exercise with a target heart rate of between 106 b.p.m and 124 b.p.m.

Physiological theory says that in training for endurance type sports a training effect will be enjoyed if intensity is set between 50 and 85% of maxVO\(_2\). This is because of the *progressive load principle* where improvements in fitness are seen when intensity is progressively raised during the training programme. However, in untrained persons a training effect may be as low as 40 to 50% of maxVO\(_2\). With well-trained or elite athletes the intensity could be as high as 90% of maxVO\(_2\) for an effect to be seen (Foss M.L. & Keteyian S.J., 1998).

Although it is more accurate to measure maxVO\(_2\) directly the prohibitive nature of maximal testing means that submaximal testing is an attractive alternative; it is cheap and easy to use, patients are comfortable with it as it is

\(^2\) It is best to take the resting heart rate first thing in the morning just after waking-up. Otherwise, take it after a 30 minute sleep or rest.
less stressful, and it can be used in many different setting to carry-out baseline, intermittent and end results of a training programme.

5. When not to use submaximal testing

Although stated above that submaximal testing can be used in a variety of settings, including elite athletes and persons with chronic disease or disability, it is most probable, with these groups, that direct baseline measurement of max$VO_2$ is more appropriate. For the elite athlete working to improve their performance at the margins means that accurate information of max$VO_2$ is required to set and finely tune training programmes. For persons with chronic disease and disability it is equally important to have a correct measure of max$VO_2$ so as to set a safe training programme. For example, a heart patient on beta blockers will have a lower heart rate than normal and indirect estimates of max$VO_2$, using the heart rate measures, will lead to false test parameters. Therefore, the physiotherapist has to judge whether submaximal testing for baseline measurement of max$VO_2$ is appropriate for the patient and may wish to refer the patient for a direct test to measure max$VO_2$. Once accurate max$VO_2$ is known submaximal testing can always be used to follow-up with intermittent and end measurements, if considered safe.

6. The Åstrand Bike Test

The Åstrand Bike Test (also known as the Åstrand-Ryhming test) was first developed by P.O. Åstrand in 1956. It is a 6 minute test that uses a cycle ergometer (a fixed exercise bike), can be used in both men and women of various ages and relies on the linear relationship between heart rate and VO2.

---

3 This level of information is hard to reference. The authors have been taught this on the ESP Programme at the HvA.
as described above to predict maxVO2. The test enjoys a ± 15% standard deviation from a directly measured maxVO2 (Foss M.L. & Keteyian S.J., 1998).

6.1 Subject
Before starting the test the subject must give informed consent and therefore must understand the procedure, potential risks and benefits of the test.

6.2 Health history
It is necessary to determine the current health status and lifestyle of the subject before the test. An example of a health history questionnaire can be found in appendix 2.

6.3 Contraindications to exercise testing
When exercise testing there are a number of conditions that could render the test dangerous and these are therefore contraindicated. Some are more serious than others and a distinction is made between absolute and relative contraindications. You will find a list of contraindications in appendix 3. Where a subject has a condition that is considered a relative contraindication, and where it is possible to test, it is more likely that this person will be advised to take a direct measure of maxVO2 and this will be done in the presence of specially trained staff and a cardiologist.

6.4 Indications when to stop a test
As with contraindications, indications to stop a test can be split between absolute and relative indications. You will find a comprehensive list in appendix 4. However, below is a list of indications for stopping a test for “low-risk” persons:
- Dizziness and/or nausea (headache);
- Heart problems (angina-like symptoms);
- Irregular heart beat;
- Subject requests to stop;
- Physical or verbal manifestations of severe fatigue;
- Breathlessness or a feeling of a lack of air;
- Fainting;
- Orthosympathetic responses (sweating or pallor);
- Leg cramps or claudication;
- Failure of the test equipment.

6.5 Pre-test preparation

On the morning of the test the subject must take their resting pulse on awakening. The procedure for taking a pulse should be explained and practiced with the subject, for example taking a wrist pulse for 15 seconds and multiplying it by 4 to reach a per minute resting heart rate. Failing this, the subject must rest (lying down) for 30 minutes before the test and then take their resting pulse.

A primary concern about submaximal testing is the lack of standardisation of the procedures. It is therefore important that the subject understands the instructions and follows them each time that they are tested. They must be told to avoid any strenuous activity for 24 hours prior to testing and to avoid a heavy meal, caffeine, or nicotine within 2 to 3 hours of testing. Any medications taken before testing should be noted and if possible there use should be consistent from one test to another. It is also important that the subject becomes familiar with the testing equipment and test procedures, before the test is done for real. Also, it makes sense that there must be enough
of a rest period between practice of the test and the real test (Noonan V. & Dean E., 2000).

### 6.6 Tools needed to perform the test

1. Cycle ergometer (fitness bike)  
2. Heart Rate Monitor  
3. Weight Scale  
4. Pen and paper  
5. Nomogram (appendix 1)

### 6.7 The Test

Step 1: As described above take the subject’s health history and determine if there any contraindications;  

Step 2: Ask the subject for their self-measured resting pulse as described above;
Step 3: Using the Karvonen formula calculate the heart rate, at a given intensity (set usually between 40 and 60% for the baseline test), that you want the subject to reach in the test (the target heart rate). The subject (in the video) is a 49 year old female working at an intensity of 60%, and with a resting heart rate of 70 b.p.m, her target heart rate is:

\[
\text{(maxHR (220-age) – RHR) x 60% + 70 = THR}
\]
\[
(171 – 70) \times 60\% + 70 = \text{THR 131 b.p.m}
\]

Step 4: Take the weight of the subject. This is necessary later when calculating ml per kg;

Step 5: Place the heart rate monitor on to the skin of the subject using the contact gel. It must be placed around the chest and over the heart, as shown in the video (please note that it must be on the skin; in the video it is placed over clothing but this was due to the subject’s wishes for privacy). Fix the watch to the subject’s wrist and set the watch on to heart pulse mode – check that the pulse signal from the monitor is being picked up by the watch. One of the reasons that it might not work is that the strap may not be tight enough (please note that the subject needs to be a few metres away from another person using a heart monitor otherwise incorrect signals can be picked up);

In this test, the heart rate can be taken both from the watch and the cycle ergometer. The bike has an in-built heart monitor that takes the pulse from the subject’s monitor around their chest.
Step 6: Adjust the seat of the bike to the subject. This is usually at hip height. When the subject begins to cycle the knee should not be fully stretched but a little bent. Ask if the subject feels comfortable;

Step 7: Have ready a piece of paper and pen to take note of the subject’s heart rate during the test;

Step 8: Ask the subject to begin cycling. Enter into the bike the workload (watts) that you want the subjects to begin with. The standard protocol is 150 watts for males and 100 watts for females, although this is based on young, healthy subjects. If the subject is older, very unfit, has a chronic disease or disability then you can start at a lower level. Tell the subject to cycle with an rpm (rotation per minute) of 60 and set the bike to 6 minutes.

Below are pictures of the bike settings found in the gym at the HvA:

Choose “oefening”:

4 Elsewhere, workloads are set at 150, 100, or 75 watts for well-trained, moderately trained and untrained subjects respectively (Maud P.J. & Foster C., 1995)
Choose “vermogen”:

Adjust “tijd” to 6 minutes:

Adjust “vermogen” watts:
THE TEST HAS BEGUN!!!

Step 9: At the end of each minute take note of the subject’s heart rate;

Step 10: In the first two minutes the idea is that the subject should reach a steady-state of exercising (it is not an all out maximal test don’t forget!). To reach a steady state you may need to adjust the watts so that the subject is working at a level that keeps their heart rate steady. Do this in small steps so as their heart rate does not fluctuate too much. By the end of minute 2 you want the subject to be working close the target heart rate;

Step 11: You must watch the subject throughout the test for any indications to stop the test as discussed above and in appendix 4. Signs of sweating and red cheeks are normal of course.

Subject is biking after 3 mins with 60 rpm and 65 watts:
Step 12: Throughout the test make sure that the subject does not talk as this has an upward effect on the heart rate. On the other hand, you the physiotherapist must help motivate the subject so that they reach the end of the test safely. For standardisation it is important from one test to another (within the same subject and group testing) that your verbal encouragement is the same, otherwise the tests cannot be compared honestly.

Step 13: After minute 6 the subject must cool-down so ask them to continue to cycle, at a lower intensity (drop the watts) for 1 minute.

Step 14: At the end of the test you should have a list of the subject’s heart rate for 6 minutes, for example:

<table>
<thead>
<tr>
<th>Minute</th>
<th>HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>138</td>
</tr>
<tr>
<td>2</td>
<td>123</td>
</tr>
<tr>
<td>3</td>
<td>125</td>
</tr>
<tr>
<td>4</td>
<td>128</td>
</tr>
<tr>
<td>5</td>
<td>130</td>
</tr>
<tr>
<td>6</td>
<td>130</td>
</tr>
</tbody>
</table>

Now, take an average of minutes 5 & 6. Using the above example the average is:

\[
130 + 130 / 2 = \text{avg. 130 b.p.m}
\]
Step 15: Using the Nomogram (next page and appendix 1), mark the average heart rate and mark the rate of watts that the subject trained at. Draw a line between the two marks and where this line dissects the VO2 line in the middle, take the reading. If the subject is above 35 years you will have to apply a correction factor, which is written in the bottom left corner of the Nomogram.

Below, you can see the results, using the Nomogram, for the 49 year old female in the video, training at 60% intensity with a target heart rate of 130 b.p.m:

Age = 49
Weight = 61kg
THR = 130 b.p.m (intensity 60%)
Average heart rate = 130 b.p.m
Workload (watts) = 65 approx
MaxVO2 = 2.5 l/min
Age correction = 2.5 x 0.78 = 1.95 l/min
MaxVO2 per kg = 1.95 x 1000 = 1950

1950 ml / 61kg = 31.97 ml/kg/min
<table>
<thead>
<tr>
<th>age (yrs)</th>
<th>factor (x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1.2</td>
</tr>
<tr>
<td>16</td>
<td>1.1</td>
</tr>
<tr>
<td>17-35</td>
<td>1.0</td>
</tr>
<tr>
<td>35</td>
<td>0.87</td>
</tr>
<tr>
<td>40</td>
<td>0.83</td>
</tr>
<tr>
<td>45</td>
<td>0.78</td>
</tr>
<tr>
<td>50</td>
<td>0.75</td>
</tr>
<tr>
<td>55</td>
<td>0.71</td>
</tr>
</tbody>
</table>
6.8 Interpreting results

Norms

There are established normative values for maxVO2. A general overviews of normal values can be found in Maud P.J. & Foster C. (1995). A more comprehensive list can be found in appendix 5 from the Western Australian Department of Industry and Resources (Dec 1997).

Taking the above results from the test of the 49 year old, female subject, the values are considered average when compared to normative data.

Confounding factors

It is also important when looking at the results of a test to take into consideration any confounding factors that may have had an impact on the results of a test or a series of tests (test reliability). As explained earlier there is a need for standardisation when testing and many of these confounding factors relate to this problem in submaximal testing. Here is a list of possible confounding factors that might be experienced:

- The room temperature, noise level and humidity between tests;
- The amount of sleep the subject had prior to testing;
- The subject’s emotional state;
- Medication the subject may be taking;
- The time of day;
- The subject’s caffeine intake;
- The time since the subject’s last meal;
- The test environment;
- The subject’s prior test knowledge/experience;
• Accuracy of measurements;
• Inappropriate warm-up;
• Talking of subject during test;
• The personality, knowledge and skill of the tester is the same for each test that the subject undertake.

7. Conclusion
Submaximal testing is an integral part of physiotherapy. It is relatively easy to perform, it is cheap, safe and the reliability is good in comparison to direct testing of maxVO2. Therefore, submaximal testing is a practical way in which health experts can carry-out an exercise test to determine maximal aerobic power.

This manual is a step-by-step guide in how to perform the Åstrand Bike Test. It supports the digital video and provides a reference list for further reading.
8. References


Åstrand, PO "Human Physical Fitness with Special Reference to Sex and Age," *Physiological Review.*, 36: 307-335 (1956).


Gov’t of Western Australia, Dept. of Industry & Resources, *Fitness for Mine Rescue Personnel Guideline*, Issue December 1997


**Websites:**
www.americanheart.org
www.acc.org
www.kngf.nl
9. Appendices

1. Åstrand Ryhming Nomogram

2. Health history questionnaire

3. Contraindications to exercise testing

4. Indications when to stop an exercise test

5. Normative data for submaximal exercise testing
Appendix 1  The Åstrand Ryhming Nomogram

ÅSTRAND-ÅSTRAND NOMOGRAM

<table>
<thead>
<tr>
<th>age (yrs)</th>
<th>factor (x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1.2</td>
</tr>
<tr>
<td>16</td>
<td>1.1</td>
</tr>
<tr>
<td>17-35</td>
<td>1.0</td>
</tr>
<tr>
<td>35</td>
<td>0.87</td>
</tr>
<tr>
<td>40</td>
<td>0.83</td>
</tr>
<tr>
<td>45</td>
<td>0.78</td>
</tr>
<tr>
<td>50</td>
<td>0.75</td>
</tr>
<tr>
<td>55</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Appendix 2   Health history questionnaire

Below is an example of a typical health questionnaire from a sports clinic:

---

Health Status Questionnaire

Instructions
Complete each question accurately. All information provided is confidential if you choose to submit this form to your fitness instructor.

Part 1. Information about the Individual

1. Social Security number ________________ Date ________________
2. Legal name ___________________________ Nickname ________________
3. Mailing address ____________________________
   Home phone ________________ Business phone ________________
4. EI ____________________________
   Personal physician ________________ Phone ________________
   Address ____________________________
5. EI ____________________________
   Person to contact in emergency ________________ Phone ________________
6. Sex (circle one): Female Male (RF)
7. RF Date of birth: ________________
   Month Day Year
8. Number of hours worked per week: Less than 20 20-40 41-60 Over 60
9. SLA More than 25% of time spent on job (circle all that apply)
   Sitting at desk Lifting or carrying loads Standing Walking Driving

Part 2. Medical history

10-A. RF Circle any who died of heart attack before age 55:
   Father   Brother   Son
10-B. RF Circle any who died of heart attack before age 65:
   Mother   Sister   Daughter
11. Date of
   Last medical physical exam ____________________________ Year
   Last physical fitness test ____________________________ Year

12. Circle operations you have had:

<table>
<thead>
<tr>
<th>Back SLA</th>
<th>Heart MC</th>
<th>Kidney SLA</th>
<th>Eyes SLA</th>
<th>Joint SLA</th>
<th>Neck SLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ears SLA</td>
<td>Hernia SLA</td>
<td>Lung SLA</td>
<td>Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13. Please circle any of the following for which you have been diagnosed or treated by a physician or health professional:

<table>
<thead>
<tr>
<th>Alcoholism SEP</th>
<th>Diabetes SEP</th>
<th>Kidney problem MC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anemia, sickle cell SEP</td>
<td>Emphysema SEP</td>
<td>Mental illness SEP</td>
</tr>
<tr>
<td>Anemia, other SEP</td>
<td>Epilepsy SEP</td>
<td>Neck strain SLA</td>
</tr>
<tr>
<td>Asthma SEP</td>
<td>Eye problems SLA</td>
<td>Obesity RF</td>
</tr>
<tr>
<td>Back strain SLA</td>
<td>Gout SLA</td>
<td>Phlebitis MC</td>
</tr>
<tr>
<td>Bleeding trait SEP</td>
<td>Hearing loss SLA</td>
<td>Rheumatoid arthritis SLA</td>
</tr>
<tr>
<td>Bronchitis, chronic SEP</td>
<td>Heart problem MC</td>
<td>Stroke MC</td>
</tr>
<tr>
<td>Cancer SEP</td>
<td>High blood pressure RF</td>
<td>Thyroid problem SEP</td>
</tr>
<tr>
<td>Cirrhosis, liver MC</td>
<td>Hypoglycemia SEP</td>
<td>Ulcer SEP</td>
</tr>
<tr>
<td>Concussion MC</td>
<td>Hyperlipidemia RF</td>
<td>Other</td>
</tr>
<tr>
<td>Congenital defect SEP</td>
<td>Infectious mononucleosis MC</td>
<td></td>
</tr>
</tbody>
</table>

14. Circle all medicine taken in last 6 months:

<table>
<thead>
<tr>
<th>Blood thinner MC</th>
<th>Epilepsy medication SEP</th>
<th>Nitroglycerin MC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetic SEP</td>
<td>Heart rhythm medication MC</td>
<td>Other</td>
</tr>
<tr>
<td>Digitalis MC</td>
<td>High blood pressure medication MC</td>
<td></td>
</tr>
<tr>
<td>Diuretic MC</td>
<td>Insulin MC</td>
<td></td>
</tr>
</tbody>
</table>
15. Any of these health symptoms that occurs frequently is the basis for medical attention. Circle the number indicating how often you have each of the following:

5 = Very often
4 = Fairly often
3 = Sometimes
2 = Infrequently
1 = Practically never

a. Cough up blood MC
   1 2 3 4 5
b. Abdominal pain MC
   1 2 3 4 5
c. Low-back pain MC
   1 2 3 4 5
d. Leg pain MC
   1 2 3 4 5
e. Arm or shoulder pain MC
   1 2 3 4 5
f. Chest pain RF MC
   1 2 3 4 5
g. Swollen joints MC
   1 2 3 4 5
h. Feel faint MC
   1 2 3 4 5
i. Dizziness MC
   1 2 3 4 5
j. Breathless with slight exertion MC
   1 2 3 4 5
k. Palpitation or fast heart beat MC
   1 2 3 4 5
l. Unusual fatigue with normal activity MC
   1 2 3 4 5

Part 3. Health-related behavior

16. RF Do you now smoke (or have smoked in last 6 months)? Yes No

17. RF If you are a smoker, indicate number smoked per day:
   Cigarettes: 40 or more 20-39 10-19 1-9
   Cigars or pipes only: 5 or more or any inhaled Less than 5, none inhaled

18. RF Do you exercise regularly (i.e., accumulate at least 30 min per day, at least five days/week)? Yes No

19. How many days per week do you accumulate 30 minutes of moderate activity?
   0 1 2 3 4 5 6 7 days per week

20. How many days per week do you normally spend at least 20 minutes in vigorous exercise?
   0 1 2 3 4 5 6 7 days per week

21. Can you walk 4 miles briskly without fatigue? Yes No

22. Can you jog 3 miles continuously at a moderate pace without discomfort? Yes No


Part 4. Health-related attitudes

24. *RFT*These are traits that have been associated with coronary-prone behavior. Circle the number that corresponds to how you feel:
   
   6 = Strongly agree
   5 = Moderately agree
   4 = Slightly agree
   3 = Slightly disagree
   2 = Moderately disagree
   1 = Strongly disagree

   I am an impatient, time-conscious, hard-driving individual.

   1   2   3   4   5   6

25. List everything not already included on this questionnaire that might cause you problems in a fitness test or fitness program:

   
   
   
   
   
   
   
   

Code for Health Status Questionnaire
The following code will help you evaluate the information in the Health Status Questionnaire.
EI = Emergency Information — must be readily available.
MC = Medical Clearance needed — do not allow exercise without physician’s permission.
SEP = Special Emergency Procedures needed — do not let participant exercise alone; make sure the person’s exercise partner knows what to do in case of an emergency.
RF = Risk Factor for CHD (educational materials and workshops needed).
SLA = Special or Limited Activities may be needed — you may need to include or exclude specific exercises.
OTHER (not marked) = Personal information that may be helpful for files or research.

Appendix 3  Contraindications to exercise testing

Below is a list of absolute and relative contraindications for exercise testing:

**Absolute**
- Acute myocardial infarction (within 2 days)
- High-risk unstable angina
- Uncontrolled cardiac arrhythmias causing symptoms or hemodynamic compromise
- Symptomatic severe aortic stenosis
- Uncontrolled symptomatic heart failure
- Acute pulmonary embolus or pulmonary infarction
- Acute myocarditis or pericarditis
- Acute aortic dissection

**Relative**
- Left main coronary stenosis
- Moderate stenotic valvular heart disease
- Electrolyte abnormalities
- Severe arterial hypertension
- Tachyarrhythmias or bradyarrhythmias
- Hypertrophic cardiomyopathy and other forms of outflow tract obstruction
- Mental or physical impairment leading to inability to exercise adequately
- High-degree atrioventricular block

American College of Cardiology Foundation
American Heart Association
Appendix 4  Indications when to stop an exercise test

Below is a list of absolute and relative indications to stop a test. Some indications are relevant to direct testing of \text{maxVO}_2 and not submaximal testing:

**Absolute indications**
- Drop in systolic blood pressure of .10mm Hg from baseline blood pressure despite an increase in workload, when accompanied by other evidence of ischemia
- Moderate to severe angina
- Increasing nervous system symptoms (e.g. ataxia, dizziness, near-syncope)
- Signs of poor perfusion (cyanosis or pallor)
- Technical difficulties in monitoring ECG or systolic blood pressure
- Subject’s desire to stop
- Sustained ventricular tachycardia
  ST elevation ($\geq$ 1.0mm) in leads without diagnostic Q-waves (other than V1 or a VR).

**Relative indications**
- Drop in systolic blood pressure of .10mm Hg from baseline blood pressure despite an increase in workload, in the absence of other evidence of ischemia
- ST or QRS changes such as excessive ST depression (.2 mm of horizontal or downsloping ST-segment depression) or marked axis shift
- Arrhythmias other than sustained ventricular tachycardia, including multifocal PVCs, triplets of PVCs, supraventricular tachycardia, heart block or bradyarrhythmias
- Fatigue, shortness of breath, wheezing, leg cramps, or claudication
- Development of bundle-branch block or IVCD that cannot be distinguished from ventricular tachycardia
- Increasing chest pain
- Hypertensive response

American College of Cardiology Foundation
American Heart Association
## Appendix 5  Normative data for submaximal exercise tests

### Astrand Bicycle Ergometer Test VO\(_2\) max Normative Data – Females

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Below Average</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 - 29 years (l/min)</td>
<td>&lt;1.69</td>
<td>1.70-1.99</td>
<td>2.00-2.49</td>
<td>2.50-2.79</td>
<td>&gt;2.8</td>
</tr>
<tr>
<td>(ml.kg/min)</td>
<td>&lt;26</td>
<td>29-34</td>
<td>35-43</td>
<td>44-48</td>
<td>&gt;49</td>
</tr>
<tr>
<td>30 - 39 years (l/min)</td>
<td>&lt;1.59</td>
<td>1.60-1.89</td>
<td>1.90-2.39</td>
<td>2.40-2.69</td>
<td>&gt;2.70</td>
</tr>
<tr>
<td>(ml.kg/min)</td>
<td>&lt;27</td>
<td>28-33</td>
<td>34-41</td>
<td>42-47</td>
<td>&gt;48</td>
</tr>
<tr>
<td>40 - 49 years (l/min)</td>
<td>&lt;1.49</td>
<td>1.50-1.79</td>
<td>1.80-2.29</td>
<td>2.30-2.59</td>
<td>&gt;2.60</td>
</tr>
<tr>
<td>(ml.kg/min)</td>
<td>&lt;25</td>
<td>26-31</td>
<td>32-40</td>
<td>41-45</td>
<td>&gt;45</td>
</tr>
<tr>
<td>50 - 65 years (l/min)</td>
<td>&lt;1.29</td>
<td>1.30-1.59</td>
<td>1.60-2.09</td>
<td>2.10-2.39</td>
<td>&gt;2.40</td>
</tr>
<tr>
<td>(ml.kg/min)</td>
<td>&lt;21</td>
<td>22-28</td>
<td>29-36</td>
<td>37-41</td>
<td>&gt;42</td>
</tr>
</tbody>
</table>

### Astrand Bicycle Ergometer Test VO\(_2\) max Normative Data – Males

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Below Average</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 - 29 years (l/min)</td>
<td>&lt;2.79</td>
<td>2.80-3.09</td>
<td>3.10-3.69</td>
<td>3.70-3.99</td>
<td>&gt;4.00</td>
</tr>
<tr>
<td>(ml.kg/min)</td>
<td>&lt;38</td>
<td>39-43</td>
<td>44-51</td>
<td>52-56</td>
<td>&gt;57</td>
</tr>
<tr>
<td>30 - 39 years (l/min)</td>
<td>&lt;2.49</td>
<td>2.50-2.79</td>
<td>2.80-3.39</td>
<td>3.40-3.69</td>
<td>&gt;3.70</td>
</tr>
<tr>
<td>(ml.kg/min)</td>
<td>&lt;34</td>
<td>35-39</td>
<td>40-47</td>
<td>46-51</td>
<td>&gt;52</td>
</tr>
<tr>
<td>40 - 49 years (l/min)</td>
<td>&lt;2.19</td>
<td>2.20-2.49</td>
<td>2.50-3.09</td>
<td>3.10-3.39</td>
<td>&gt;3.40</td>
</tr>
<tr>
<td>(ml.kg/min)</td>
<td>&lt;30</td>
<td>31-35</td>
<td>36-43</td>
<td>44-47</td>
<td>&gt;48</td>
</tr>
<tr>
<td>50 - 59 years (l/min)</td>
<td>&lt;1.89</td>
<td>1.90-2.19</td>
<td>2.20-2.79</td>
<td>2.80-3.09</td>
<td>&gt;3.10</td>
</tr>
<tr>
<td>(ml.kg/min)</td>
<td>&lt;25</td>
<td>26-31</td>
<td>32-39</td>
<td>40-43</td>
<td>&gt;44</td>
</tr>
<tr>
<td>60 - 69 years (l/min)</td>
<td>&lt;1.59</td>
<td>1.60-1.89</td>
<td>1.90-2.49</td>
<td>2.50-2.79</td>
<td>&gt;2.80</td>
</tr>
<tr>
<td>(ml.kg/min)</td>
<td>&lt;21</td>
<td>22-26</td>
<td>27-35</td>
<td>36-39</td>
<td>&gt;40</td>
</tr>
</tbody>
</table>

Government of Western Australia  
Department of Industry and Resources  
Appendix 2: Submaximal testing: Harvard Step Test

Hogeschool van Amsterdam
Amsterdam Institute of Allied Health Education
European School of Physiotherapy

Harvard Step Test

SkillsLab
6 minute submaximal exercise test
(Video and Manual)

Group members: Alison Cheevers Cathrine Pettersen

January 2007
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1. Introduction

Submaximal testing is an important tool for physiotherapy. It is commonly used in practical settings and across different subject groups. This manual is designed to be used in conjunction with the digital video found in the HvA Mediatheek, Digital Library Service.

2. What is submaximal testing, when and how is it used?

The ability to do aerobic exercise is very important for activities of daily living and maintaining a healthy lifestyle. Aerobic capacity can be tested to measure the ability to do exercise specifically by measuring the amount of oxygen required (VO2). Unlike anaerobic power, which is related to local muscular strength and to the amount and rate of ATP produced by the anaerobic metabolic pathways (ATP-PC system and anaerobic glycolysis), aerobic power reflects the ability of the lungs, blood, heart, muscles, and other organs and organ systems to transport and utilise O2 via the aerobic metabolic pathways; determining a person’s level of cardiorespiratory fitness has therefore both general and clinical applications (Foss M.L. & Keteyian S.J., 1998).

The measurement of maxVO2 can be used in a variety of different settings: elite athlete, healthy individuals in the fitness setting, and persons with known diseases or classified as high risk (for example, heart disease and obesity). In the latter group, persons with chronic disease or disability, it is vital to know their maxVO2 as many of these people have a very low ability to consume and utilise oxygen. Maximal steady-state oxygen consumption (VO2MSS) is in the usual range of 40% to 70% of maxVO2. Many people with a chronic disease or disability have a maxVO2 that is below the 40% maxVO2 that is required for activities of daily living, employment, and maintenance of

3. Direct measurement of maxVO2

Determining an individual’s aerobic power (cardiorespiratory fitness) can be best achieved through the direct measure of maxVO2 while the individual is exercising. MaxVO2 reflects the body’s ability to transport and utilise O2, with changes in ventilation, perfusion, heart rate and stroke volume, and/or peripheral utilisation of O2, all having an influence on maxVO2. Therefore, the measurement of maxVO2 is considered to be the best measure of cardiorespiratory fitness (Foss M.L. & Keteyian S.J., 1998).

Measuring maxVO2 directly is usually done through graded exercise tests and selecting a test protocol that best fits the fitness level of the person being tested. Usually the test requires that the individual reaches voluntary fatigue within 6 to 12 minutes. The maxVO2 is reached when one or more of the following criteria have been achieved:

1. A further increase in work rate results in no further increase in VO2 (a plateau);
2. The Respiratory Exchange Ratio (R) exceeds 1.10 to 1.15;
3. If measured, post-exercise blood lactate exceeds 8 to 10mM (Foss M.L. & Keteyian, 1998).

Whilst the direct measure of maxVO2 is considered the best and most accurate, there are a number of disadvantages:
• The test is difficult and stressful. Many persons, especially with chronic disease or disability, do not achieve a ‘true’ maxVO2. Instead, they reach a point at which they cannot continue not because of limitations in the supply of oxygen but through some other limiting factor such as mental fatigue, fear, lack of motivation or symptoms such as chest pain and light-headedness. If this is the case, the individuals are said to reach symptom-limited exhaustion and this is referred to as peak VO2 (Durstine J.L. & Moore G.E., 2003);

• Direct testing requires the use of expensive equipment and trained staff and is therefore prohibitive in many settings;

• The presence of a cardiologist or physician is required;

• Due to above reasons it is not a practical test for general health screening and testing of large groups (Maud P.J., & Foster C., 1995).

4. Indirect estimation of maxVO2
4.1 Estimation of maxVO2
To overcome the difficulties in performing a direct test indirect measures of maxVO2 have been devised. Two of the most well-known tests are the Åstrand Bike Test and the Harvard Step Test. These are called submaximal tests and are based on the linear relationship between heart rate (HR) and VO2: the greater exercise intensity or VO2 the higher the heart rate. In other words, if you plot the results of a submaximal test on a graph (graph 1, heart rate against workload) a linear line, representing VO2 used, emerges because physiological theory tells us that as workload increases so does the heart rate and therefore VO2. Indirect estimates work by extrapolating information from
this graph to predict maxVO2 (Maud P.J., & Foster C., 1995). It does this by continuing the linear relationship line towards the maximum.

![Graph 1](image1.png)

**Graph 1** Sample graph for the extrapolation method of estimating maxVO2 (Maud P.J., & Foster C., 1995).

Using this linear relationship, the Åstrand Ryhming Nomogram (appendix 1) was designed to estimate maxVO2 from the results of a submaximal test. It simply estimates how the heart rate would continue increasing, in line with the workload, as a direct maxVO2 test would do. This is how the indirect measure of maxVO2 is calculated and for example, the use of the Astrand Ryhming Nomogram gives a ± 15% standard deviation from a directly measured maxVO2 (Foss M.L. & Keteyian S.J., 1998).

### 4.2 Calculating the intensity of exercise

With indirect estimates of maxVO2 the individual exercises submaximally (as opposed to bringing the individual to their maximal aerobic output) and to ensure that the test is being performed at the correct level of intensity and
avoiding the expense of direct VO2 measurement, various indirect techniques that correlate well with measured VO2 can be used to guide exercise intensity. These are heart rate measurement, the blood lactate threshold or rating of perceived exertion (Foss M.L. & Keteyian S.J., 1998). The heart rate techniques are practical and easy to use and can be used for elite athletes, the general population and for persons with chronic disease or disability; training intensity is judged mainly by the degree of stress placed on the cardiorespiratory system. The blood lactate threshold method is more difficult to perform and is mainly used with elite athletes and the study of training intensity, and the degree of stress placed on the metabolic systems within skeletal muscle. The third technique, a rating of perceived exhaustion (Borg scale), is highly applicable to persons with chronic disease or disability where teaching the heart rate methods becomes difficult and where medication, such as beta blockers, render pulse taking less accurate (Foss M.L. & Keteyian S.J., 1998).

4.3 Karvonen method

In this manual we use one of the heart rate methods for calculating exercise intensity for a submaximal exercise test. This is known as the Karvonen method (or heart rate reserve method). The other method, the straight percentage method is not discussed here. In the Karvonen method the increase in heart rate that occurs above the resting heart rate is taken into consideration.

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5 The straight percentage method is calculated using the formula 220 minus age and multiplied by a percentage of maximal heart rate that is usually between 60 to 90% of maximum. A target heart rate of 60 to 90% of maximum corresponds to a VO2 that is between 50 and 85% of maximum. One of the problems with this method is that exercising at the lower end of exercise intensity the heart rate is very low in comparison to the Karvonen method and falls outside of the parameters of the Astrand Ryhming Nomogram when calculating maxVO2.
The formula is as follows:

Target heart rate (THR) = (heart rate reserve) x percentage of HRR + restHR

= (max HR (220-age) – restHR) x intensity + restHR

So, a 60 year old exercising with a 60% rate of heart rate reserve (intensity) and with a resting heart rate of 70 b.p.m\(^6\) would have a THR of 124 b.p.m:

\[(160 – 70) \times 60\% + 70 = 124 \text{ b.p.m}.\]

For an initial submaximal baseline test, level of intensity should be set between 40 and 60%. Using the above example, a 60 year old male would need to exercise with a target heart rate of between 106 b.p.m and 124 b.p.m.

Physiological theory says that in training for endurance type sports a training effect will be enjoyed if intensity is set between 50 and 85% of maxVO2. This is because of the *progressive load principle* where improvements in fitness are seen when intensity is progressively raised during the training programme. However, in untrained persons a training effect may be as low as 40 to 50% of maxVO2. With well-trained or elite athletes the intensity could be as high as 90% of maxVO2 for an effect to be seen (Foss M.L. & Keteyian S.J., 1998).

Although it is more accurate to measure maxVO2 directly the prohibitive nature of maximal testing means that submaximal testing is an attractive alternative; it is cheap and easy to use, patients are comfortable with it as it is

\(^6\) It is best to take the resting heart rate first thing in the morning just after waking-up. Otherwise, take it after a 30 minute sleep or rest
less stressful, and it can be used in many different setting to carry-out baseline, intermittent and end results of a training programme.

5. When not to use submaximal testing

Although stated above that submaximal testing can be used in a variety of settings, including elite athletes and persons with chronic disease or disability, it is most probable, with these groups, that direct baseline measurement of maxVO2 is more appropriate. For the elite athlete working to improve their performance at the margins means that accurate information of maxVO2 is required to set and finely tune training programmes. For persons with chronic disease and disability it is equally important to have a correct measure of maxVO2 so as to set a safe training programme. For example, a heart patient on beta blockers will have a lower heart rate than normal and indirect estimates of maxVO2, using the heart rate measures, will lead to false test parameters. Therefore, the physiotherapist has to judge whether submaximal testing for baseline measurement of maxVO2 is appropriate for the patient and may wish to refer the patient for a direct test to measure maxVO2. Once accurate maxVO2 is known submaximal testing can always be used to follow-up with intermittent and end measurements, if considered safe.

The Harvard Step Test is a simple 6 minute test that does not require the techniques outlined above for calculating maxVO2, namely heart rate measurement, blood lactate threshold and rating of perceived exertion. Instead, the submaximal aspect of the test is inherent to the step apparatus itself; for example, it is not necessary to calculate target heart rates in order for

---

7 This level of information is hard to reference. The authors have been taught this on the ESP Programme at the HvA.
the subject to exercise at a certain intensity because the height of the steps (40 cm males, 33 cm females) and the step frequency (22.5 steps/minute) have been designed so that the subject exercises submaximally. Calculating the level of intensity that the subject worked at, can be calculated using the Karvonen heart rate formula, but this will be discussed later (see the interpreting the results” section).

6. The Harvard Step Test (Åstrand -Ryhming method) – a manual

The Harvard Step Test was first developed by Brouha, Graybriel and Heath in 1943 (Brouha, Graybiel & Heath, 1943, found in Maud & Foster, 1995). In its original form, the recovery heart rate is used when estimating aerobic power. In this version the test makes use of the Åstrand-Ryhming Nomogram. It is a simple 6 minute step test that uses a step bench that is 40cm high for males and 33cm high for females. Subjects exercise with a step frequency of 22.5 steps per minute. It can be used for both men and women of various ages and relies on the linear relationship between heart rate and VO2 to predict maxVO2. The test has been used as part of exercise testing for more than 50 years.

There are limitations in the Harvard Step Test. The workload cannot be adjusted and depending on the subject the test can be easier or harder (intensity too low or too high). For example, a very unfit subject may be exercising closer to their maximum aerobic capacity whilst a very fit subject or elite athlete will probably be exercising at a level that is below the intensity that a submaximal test requires.
6.1 Subject

Before starting the test the subject must give informed consent and therefore must understand the procedure, potential risks and benefits of the test.

6.2 Health history

It is necessary to determine the current health status and lifestyle of the subject. In appendix 2 you will find one example of a health history questionnaire.

6.3 Contraindications to exercise testing

When exercise testing there are a number of conditions that could render the test dangerous and these are therefore contraindicated. Some are more serious than others and a distinction is made between absolute and relative contraindications. You will find a list in appendix 3. Where a subject has a condition that is considered a relative contraindication, it is more likely that this person will be advised to take a direct measure of maxVO2, and this will be done in the presence of specially trained staff and a cardiologist.

6.4 Indications when to stop the test

As with contraindications, indications to stop a test can be split between absolute and relative indications. You will find a comprehensive list of indications in appendix 4, however, below is a list of indications for stopping a test for “low-risk” persons:

- Dizziness and/or nausea (headache);
- Heart problems (angina-like symptoms);
- Irregular heart beat;
- Subject requests to stop;
- Physical or verbal manifestations of severe fatigue;
- Breathlessness of a feeling of a lack of air;
- Fainting;
- Orthosympathetic responses (sweating or pallor);
- Leg cramps or claudication;
- Failure of the testing equipment.

6.5 Pre-test preparation

On the morning of the test, the subject must take their resting pulse on awakening. The procedure for taking pulse should be explained and practiced with the subject, for example taking a wrist pulse for 15 seconds and multiplying it by 4 to reach a per minute resting heart rate. Failing this the subject must rest (lying down) for 30 minutes before the test, and then take their resting pulse. The resting pulse can be used when interpreting the results of the test, in particular calculating the level of intensity that the subject exercised at.

A primary concern about submaximal testing is the lack of standardisation of the procedures. It is therefore important that the subject understands the instructions and follow them each time that they are tested. They must be told to avoid any strenuous activity for 24 hours prior to testing and to avoid a heavy meal, caffeine or nicotine within 2 to 3 hours of testing. Any medications taken before testing should be noted and if possible there use should be consistent from one test to another. It is also important that the subject becomes familiar with the testing equipment and test procedures before the test is done for real. Also, it makes sense that there must be enough of a rest period between practice of the test and the real test (Noonan & Dean, 2000).
6.6 Tools you will need to perform the test

1. Step bench

Female 33cm  Male 40cm

2. Heart Rate Monitor

3. Tape recorder

4. Step Frequency cassette

22.5 steps/minute

5. Weight scale

6. Pen and paper

7. Nomogram (appendix 1)
6.7 The test

Step 1: As described above, take the subject’s health history and determine if there are any contraindications;

Step 2: Ask the subject for their self-measured resting pulse as described above;

Step 3: Take the weight of the subject. This is necessary later when calculating ml per kg;

Step 4: Place the heart rate monitor on to the skin of the subject using the contact gel. It must be placed around the chest and over the heart, as shown in the video (please note that it must be placed on the skin, in the video it is placed over clothing due to the subject’s wishes for privacy). Fix the watch to the subject’s wrist and set the watch on to heart pulse mode – check that the pulse signal from the monitor is being picked up by the watch. One of the reasons that it might nor work is that the strap may not be tight enough (please note that the subject needs to be a few metres away from another person using a heart monitor, otherwise incorrect signals can be picked up);

Step 5: Make sure that the tape recorder and cassette both work!

Step 6: Make sure that you have chosen the correct bench depending on whether the subject is male or female;
Step 7: Have ready a piece of paper and pen to take note of the subject’s heart rate during the test;

Step 8: Start the cassette on the tape recorder. Demonstrate, together with the subject, the stepping cycle in rhythm with the step frequency heard on the cassette. On count 1 the subject places one foot on the bench followed by the other foot; on count 2 the first foot is brought back down to the floor followed by the other foot. Right leg, left leg leading preference is left to the subject to choose.

Step 9: Once the subject is comfortable with the stepping cycle the test can begin. Use the stop watch or your own watch to start the test.

Step 10: At the end of each minute take note of the subject’s heart rate. You will have to ask the subject to give you the pulse reading from their heart rate monitor watch.

Step 11: You must watch the subject throughout the test for any indications to stop the test as discussed above and in appendix 4. Signs of sweating and red cheeks are normal of course;

Step 12: Throughout the test, make sure that the subject does not talk as this has an upward effect on the heart rate. On the other hand, you the physiotherapist must help motivate the subject so that they reach the end of the test safely. For standardisation, it is important from one test to another (with the same subject) that
your verbal encouragement is the same, otherwise the two tests cannot be honestly compared;

Step 13: When the test has ended you can ask the subject to walk around the gym/room for a minute cool-down;

Step 14: At the end of the test you should have a list of the subject’s heart rate for 6 minutes, for example:

<table>
<thead>
<tr>
<th>Minute</th>
<th>HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>145</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>153</td>
</tr>
<tr>
<td>4</td>
<td>154</td>
</tr>
<tr>
<td>5</td>
<td>156</td>
</tr>
<tr>
<td>6</td>
<td>156</td>
</tr>
</tbody>
</table>

Now take the average of the last two minutes. Using the above sample the average is:

156 + 156/2 = avg 156

Step 15: Using the Nomogram, mark the average heart rate and mark the weight of the subject. Draw a line between the two marks and where this line dissect the VO2 line in the middle, take the reading. If the subject is below 17 years old or above 35 years old, you will have to apply a correction factor, which is written in the bottom left hand corner of the Nomogram.
Below you can see the results, using the Nomogram (following page), for the above example of our 49 year old female weighing 61 kg:

<table>
<thead>
<tr>
<th>Age</th>
<th>= 49</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>= 61 kg</td>
</tr>
<tr>
<td>Average heart rate</td>
<td>= 156 b.p.m.</td>
</tr>
<tr>
<td>MaxVO2</td>
<td>= 2.4 l/min</td>
</tr>
<tr>
<td>Age correction</td>
<td>= 2.4 x 0.78 = 1.87 l/min</td>
</tr>
<tr>
<td>MaxVO2 per kg</td>
<td>= 1.87 x 1000 = 1870 ml</td>
</tr>
<tr>
<td></td>
<td>1870 ml / 61 kg = 30.66 ml/kg/min</td>
</tr>
<tr>
<td>age(yrs)</td>
<td>factor(x)</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>15</td>
<td>1.2</td>
</tr>
<tr>
<td>16</td>
<td>1.1</td>
</tr>
<tr>
<td>17-35</td>
<td>1.0</td>
</tr>
<tr>
<td>35</td>
<td>0.87</td>
</tr>
<tr>
<td>40</td>
<td>0.83</td>
</tr>
<tr>
<td>45</td>
<td>0.78</td>
</tr>
<tr>
<td>50</td>
<td>0.75</td>
</tr>
<tr>
<td>55</td>
<td>0.71</td>
</tr>
</tbody>
</table>
6.8 Interpreting results

**Norms**

There are established normative values for maxVO2. A general overview of norms can be found in Maud & Foster (1995). A more comprehensive list can be found in Appendix 5, from the Western Australian Department of Industry and Resources (Dec. 1997). Taking the above results from the test of the 49 year old female, the values are considered average when compared to normative data.

**Confounding factors**

It is also important when looking at the results of a test to take into consideration any confounding factors that may have an impact on the result of a test, or a series of tests (test reliability). As explained earlier, there is a need for standardisation when testing and many of these confounding factors relate to this problem in submaximal testing. Here is a list of possible confounding factors that might be experienced:

- The room temperature, noise level and humidity between tests
- The amount of sleep the subject had prior to testing
- The subject’s emotional state
- Medication the subject may be taking
- The time of day
- The subject’s caffeine intake
- The time since the subject’s last meal
- The test environment
- The subject’s prior test knowledge/experience
- Accuracy of measurements
• Inappropriate warm up
• Talking of the subject during test
• The personality, knowledge and skill of the tester is the same for each test that the subject undertakes.

Intensity

With the Harvard Step Test it is not known at which level of intensity the subject exercised at. However, this can be calculated using the Karvonen heart rate formula. The Karvonen formula (also known as the heart rate reserve method) is a heart rate method that calculates a target heart rate for submaximal exercise testing and is, for example, used in the Åstrand Bike Test. The formula is as follows:

\[
\text{Target Heart Rate (THR)} = (\text{heart rate reserve}) \times \text{percentage of HRR} + \text{rest HR};
\]

\[
= \left( \text{maxHR}(220-\text{age}) - \text{rest HR} \right) \times \text{intensity} + \text{rest HR}
\]

So, for example, the 49 year old female exercising with a 60% rate of heart rate reserve (intensity) and with a resting heart rate of 70 b.p.m\(^8\) would have a THR of 131 b.p.m:

\[
(171 - 70) \times 60\% + 70 = \text{THR} 131\text{b.p.m.}
\]

With the Harvard test that was carried out in the video we know that the average heart rate of minute 5 & 6 of the test was actually 156 b.p.m; we know

\(^8\) It is best to take resting heart rate first thing in the morning, just after waking-up. Otherwise, take it after a 30 minute sleep or rest.
that the resting heart rate was 70 b.p.m, so in order to calculate intensity we have to use the Karvonen formula by working backwards:

\[
(171 - 70) \times X + 70 = 156 \text{ b.p.m;}
\]

\[
(171 - 70) \times X = 156 - 70
\]

\[
X = \frac{156 - 70}{171 - 70}
\]

\[
= 0.91 \times 100 = 91\%
\]

Therefore, we can now say that the subject worked at 91% of maximum. This is closer to a maximum test than submaximal. This highlights one of the criticisms of the Harvard Step Test, that it can be too difficult for persons that are unfit, older and short in height.

7. Conclusion
Submaximal testing is an integral part of physiotherapy. It is relatively easy to perform, it is cheap, safe and the reliability is good in comparison to direct testing of maxVO2. Therefore, submaximal testing is a practical way in which health experts can carry-out an exercise test to determine maximal aerobic power.

This manual is a step-by-step guide in how to perform the Harvard Step Test. It supports the digital video and provides a reference list for further reading.
8. References


Åstrand, PO "Human Physical Fitness with Special Reference to Sex and Age," *Physiological Review.*, 36: 307-335 (1956).


Gov’t of Western Australia, Dept. of Industry & Resources, *Fitness for Mine Rescue Personnel Guideline*, Issue December 1997


**Websites:**
www.americanheart.org
www.acc.org
www.kngf.nl
9. Appendices

1. Astrand Ryhming Nomogram

2. Health history questionnaire

3. Contraindications to exercise testing

4. Indications when to stop an exercise test

5. Normative data for submaximal exercise testing
Appendix 1  The Åstrand Ryhming Nomogram

<table>
<thead>
<tr>
<th>age (yrs)</th>
<th>factor (x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1.2</td>
</tr>
<tr>
<td>16</td>
<td>1.1</td>
</tr>
<tr>
<td>17-35</td>
<td>1.0</td>
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<tr>
<td>35</td>
<td>0.87</td>
</tr>
<tr>
<td>40</td>
<td>0.83</td>
</tr>
<tr>
<td>45</td>
<td>0.78</td>
</tr>
<tr>
<td>50</td>
<td>0.75</td>
</tr>
<tr>
<td>55</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Appendix 2  Health history questionnaire

Below is an example of a typical health questionnaire from a sports clinic:

Health Status Questionnaire

**Instructions**
Complete each question accurately. All information provided is confidential if you choose to submit this form to your fitness instructor.

**Part 1. Information about the individual**

1. Social Security number __________________________ Date ______________
2. Legal name __________________________ Nickname ______________
3. Mailing address __________________________
   Home phone __________________________ Business phone __________________________
4. EI
   Personal physician __________________________ Phone __________________________
   Address __________________________
5. EI
   Person to contact in emergency __________________________ Phone __________________________
6. Sex (circle one): Female Male (RF)
7. RF Date of birth: __________________________
   Month Day Year
8. Number of hours worked per week: Less than 20 20-40 41-60 Over 60
9. SLA More than 25% of time spent on job (circle all that apply)
   Sitting at desk Lifting or carrying loads Standing Walking Driving

**Part 2. Medical history**

10-A. RF Circle any who died of heart attack before age 55:
   Father Brother Son
10-B. RF Circle any who died of heart attack before age 65:
   Mother Sister Daughter
11. Date of
   Last medical physical exam __________________________
   Year
   Last physical fitness test __________________________
   Year

12. Circle operations you have had:

- Back SLA
- Heart MC
- Kidney SLA
- Eyes SLA
- Joint SLA
- Neck SLA
- Ears SLA
- Hernia SLA
- Lung SLA
- Other

13. Please circle any of the following for which you have been diagnosed or treated by a physician or health professional:

- Alcoholism SEP
- Diabetes SEP
- Kidney problem MC
- Anemia, sickle cell SEP
- Emphysema SEP
- Mental illness SEP
- Anemia, other SEP
- Epilepsy SEP
- Neck strain SLA
- Asthma SEP
- Eye problems SLA
- Obesity RF
- Back strain SLA
- Gout SLA
- Phlebitis MC
- Bleeding trait SEP
- Hearing loss SLA
- Rheumatoid arthritis SLA
- Bronchitis, chronic SEP
- Heart problem MC
- Stroke MC
- Cancer SEP
- High blood pressure RF
- Thyroid problem SEP
- Cirrhosis, liver MC
- Hypoglycemia SEP
- Ulcer SEP
- Concussion MC
- Hyperlipidemia RF
- Other
- Congenital defect SEP
- Infectious mononucleosis MC

14. Circle all medicine taken in last 6 months:

- Blood thinner MC
- Epilepsy medication SEP
- Nitroglycerin MC
- Diabetic SEP
- Heart rhythm medication MC
- Other
- Digitalis MC
- High blood pressure medication MC
- Diuretic MC
- Insulin MC
15. Any of these health symptoms that occurs frequently is the basis for medical attention. Circle the number indicating how often you have each of the following:

5 = Very often
4 = Fairly often
3 = Sometimes
2 = Infrequently
1 = Practically never

a. Cough up blood
   1 2 3 4 5
b. Abdominal pain
   1 2 3 4 5
c. Low-back pain
   1 2 3 4 5
d. Leg pain
   1 2 3 4 5
e. Arm or shoulder pain
   1 2 3 4 5
f. Chest pain
   1 2 3 4 5
g. Swollen joints
   1 2 3 4 5
h. Feel faint
   1 2 3 4 5
i. Dizziness
   1 2 3 4 5
j. Breathless with slight exertion
   1 2 3 4 5
k. Palpitation or fast heart beat
   1 2 3 4 5
l. Unusual fatigue with normal activity
   1 2 3 4 5

Part 3. Health-related behavior

16. RF Do you now smoke (or have smoked in last 6 months)? Yes No

17. RF If you are a smoker, indicate number smoked per day:

Cigarettes: 40 or more  20-39  10-19  1-9
Cigars or pipes only: 5 or more or any inhaled  Less than 5, none inhaled

18. RF Do you exercise regularly (i.e., accumulate at least 30 min per day, at least five days/week)? Yes No

19. How many days per week do you accumulate 30 minutes of moderate activity?
   0 1 2 3 4 5 6 7 days per week

20. How many days per week do you normally spend at least 20 minutes in vigorous exercise?
   0 1 2 3 4 5 6 7 days per week

21. Can you walk 4 miles briskly without fatigue? Yes No

22. Can you jog 3 miles continuously at a moderate pace without discomfort? Yes No


Part 4. Health-related attitudes

24. These are traits that have been associated with coronary-prone behavior. Circle the number that corresponds to how you feel:
   6 = Strongly agree
   5 = Moderately agree
   4 = Slightly agree
   3 = Slightly disagree
   2 = Moderately disagree
   1 = Strongly disagree

   I am an impatient, time-conscious, hard-driving individual.
   1 2 3 4 5 6

25. List everything not already included on this questionnaire that might cause you problems in a fitness test or fitness program:

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Code for Health Status Questionnaire
The following code will help you evaluate the information in the Health Status Questionnaire.
EI = Emergency Information—must be readily available.
MC = Medical Clearance needed—do not allow exercise without physician’s permission.
SEP = Special Emergency Procedures needed—do not let participant exercise alone; make sure the person’s exercise partner knows what to do in case of an emergency.
RF = Risk Factor for CHD (educational materials and workshops needed).
SLA = Special or Limited Activities may be needed—you may need to include or exclude specific exercises.
OTHER (not marked) = Personal information that may be helpful for files or research.

Appendix 3  Contraindications to exercise testing

Below is a list of absolute and relative contraindications for exercise testing:

**Absolute**
- Acute myocardial infarction (within 2 days)
- High-risk unstable angina
- Uncontrolled cardiac arrhythmias causing symptoms or hemodynamic compromise
- Symptomatic severe aortic stenosis
- Uncontrolled symptomatic heart failure
- Acute pulmonary embolus or pulmonary infarction
- Acute myocarditis or pericarditis
- Acute aortic dissection

**Relative**
- Left main coronary stenosis
- Moderate stenotic valvular heart disease
- Electrolyte abnormalities
- Severe arterial hypertension
- Tachyarrhythmias or bradyarrhythmias
- Hypertrophic cardiomyopathy and other forms of outflow tract obstruction
- Mental or physical impairment leading to inability to exercise adequately
- High-degree atrioventricular block

American College of Cardiology Foundation
American Heart Association
Appendix 4  Indications when to stop an exercise test

Below is a list of absolute and relative indications to stop a test. Some indications are relevant to direct testing of maxVO2 and not submaximal testing:

**Absolute indications**
- Drop in systolic blood pressure of .10mm Hg from baseline blood pressure despite an increase in workload, when accompanied by other evidence of ischemia
- Moderate to severe angina
- Increasing nervous system symptoms (e.g. ataxia, dizziness, near-syncope)
- Signs of poor perfusion (cyanosis or pallor)
- Technical difficulties in monitoring ECG or systolic blood pressure
- Subject’s desire to stop
- Sustained ventricular tachycardia
  ST elevation (≥ 1.0mm) in leads without diagnostic Q-waves (other than V1 or a VR).

**Relative indications**
- Drop in systolic blood pressure of .10mm Hg from baseline blood pressure despite an increase in workload, in the absence of other evidence of ischemia
- ST or QRS changes such as excessive ST depression (.2 mm of horizontal or downsloping ST-segment depression) or marked axis shift
- Arrhythmias other than sustained ventricular tachycardia, including multifocal PVCs, triplets of PVCs, supraventricular tachycardia, heart block or bradyarrhythmias
- Fatigue, shortness of breath, wheezing, leg cramps, or claudication
- Development of bundle-branch block or IVCD that cannot be distinguished from ventricular tachycardia
- Increasing chest pain
- Hypertensive response

American College of Cardiology Foundation
American Heart Association
## Appendix 5  Normative data for submaximal exercise test

### Astrand Bicycle Ergometer Test VO₂ max Normative Data – Females

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Below Average</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(l/min)</td>
<td>(ml.kg/min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 - 29 years</td>
<td>&lt;1.69</td>
<td>29-34</td>
<td>35-43</td>
<td>44-48</td>
<td>&gt;2.8</td>
</tr>
<tr>
<td></td>
<td>&lt;28</td>
<td></td>
<td></td>
<td></td>
<td>&gt;49</td>
</tr>
<tr>
<td>30 - 39 years</td>
<td>&lt;1.59</td>
<td>28-33</td>
<td>34-41</td>
<td>42-47</td>
<td>&gt;2.70</td>
</tr>
<tr>
<td></td>
<td>&lt;27</td>
<td></td>
<td></td>
<td></td>
<td>&gt;48</td>
</tr>
<tr>
<td>40 - 49 years</td>
<td>&lt;1.49</td>
<td>26-31</td>
<td>32-40</td>
<td>41-45</td>
<td>&gt;2.60</td>
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<td>&lt;25</td>
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<td>&gt;46</td>
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<tr>
<td>50 - 65 years</td>
<td>&lt;1.29</td>
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<tr>
<td></td>
<td>&lt;21</td>
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<td></td>
<td></td>
<td>&gt;42</td>
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</table>

### Astrand Bicycle Ergometer Test VO₂ max Normative Data – Males

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Below Average</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
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<tbody>
<tr>
<td></td>
<td>(l/min)</td>
<td>(ml.kg/min)</td>
<td></td>
<td></td>
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<tr>
<td>20 - 29 years</td>
<td>&lt;2.79</td>
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<td>44-51</td>
<td>52-56</td>
<td>&gt;4.00</td>
</tr>
<tr>
<td></td>
<td>&lt;38</td>
<td></td>
<td></td>
<td></td>
<td>&gt;57</td>
</tr>
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<td>30 - 39 years</td>
<td>&lt;2.49</td>
<td>35-39</td>
<td>40-47</td>
<td>48-51</td>
<td>&gt;3.70</td>
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<td>&lt;34</td>
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<td>&gt;52</td>
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<td>40 - 49 years</td>
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<td>&gt;40</td>
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</tbody>
</table>

Government of Western Australia  
Department of Industry and Resources  
Appendix 3: Quality Control Questionnaire

Below is a copy of the questionnaire that we sent to 10 students, 5 for the Harvard Step Test and 5 for the Åstrand Bike Test. It consisted of 10 questions each worth a maximum of 10 points giving a potential total score of 100. The videos were divided between 2nd and 3rd year students. We ideally would have like all students to have come from the 2nd year but due to exams this was not possible. We wanted 2nd year students because they had only just completed module 2.2 where exercise testing, in particular the Harvard Step Test and the Astrand Bike Test, were taught. The results, when computed, for the Harvard Step Test gave a mean score of 8.7 across each question.

<table>
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Table 1 Mean results of questionnaire per question
The results for the Astrand Step gave a mean score of 8.8. One student commented that the text on the video was too high on their screen but we think it was their television as we found this was not a problem with the other students. One student voiced concern that the video was a little too fast when discussing the results of the test. All other comments were complementary only.

Overall, the questionnaire was positive towards the videos both for the Harvard Step Test and the Astrand Bike Test. It was pleasing to note that question 10 when students were asked if these videos would have been useful in Module 2.2, they gave a high score (a mean of 9.3 Harvard and 9.0 Astrand). As this is the main reason for developing these products the authors are happy with this results and the answers to the other nine questions.

Please see over page for a copy of the questionnaire:
1. do you think that interactive learning tools support the learning process?
   ![Rating Scale]

2. do images in the video support the text?
   ![Rating Scale]

3. is the video interesting?
   ![Rating Scale]

4. is the video visually stimulating?
   ![Rating Scale]

5. is the video of good length?
   ![Rating Scale]

6. is the information logical?
   ![Rating Scale]

7. can you now carry out the test after watching the video?
   ![Rating Scale]

8. what is your general impression of the quality of the video?
   ![Rating Scale]

9. does the manual support the video?
   ![Rating Scale]

10. would Physiology 2.2 have been easier with this supportive video and manual?
    ![Rating Scale]

How could this video be improved?