FITNESS FOR MINE RESCUE PERSONNEL

GUIDELINE

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CONTENTS

Page

FOREWORD

This Department of Industry and Resources guideline offers a practical approach for mine managers and supervisors to assist in ensuring that mine rescue personnel are appropriately medically and physically fit, so reducing the risk of injury, or sudden incapacity during a mine rescue event or training.

The procedures included in this guideline are not regulations and compliance is not mandatory. However adherence to these recommended minimum requirements should improve personnel preparedness for the arduous and physically demanding emergency events when they occur.

Comments on, and suggestions for improvements to the guideline are encouraged. This guideline will be revised as appropriate.

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LEGISLATIVE REQUIREMENTS

Provision in the Regulations for dealing with emergencies in a mine are covered in the Mines Safety and Inspection Regulations, 1995 as follows:

Preparation of emergency plan

4.30 (1) The principal employer at, and the manager of, a mine must ensure that a plan dealing with emergencies at the mine is prepared -

(a) in the case of an existing mine, as soon as is practicable after the commencement day; or
(b) in any other case, before mining operations commence at the mine.

Penalty: see regulation 17.1.

(2) The plan referred to in subregulation (1) must -

(a) identify hazards that might cause an emergency at the mine;

(b) assess the risk of such an emergency occurring; and

(c) specify what measures have been or are to be taken to prevent or deal with any such emergency, including -

(i) The provision of appropriate facilities and equipment;
(ii) The provision of effective alarm systems;
(iii) The testing of alarm systems;
(iv) The development of procedures to deal with emergencies;
(v) The training of employees in emergency procedures;
(vi) The training of employees in fire fighting, mine rescue and other relevant emergency response functions; and

4.31 The review of facilities, equipment and procedures.

4.32 The principal employer at, and the manager of, a mine must ensure that the plan is updated and revised whenever it is necessary to do so due to any change in mining operations, equipment, systems or procedures at the mine.

Penalty: see regulation 17.1.

Mine rescue equipment for underground mines

4.33. (1) The principal employer at, and the manager of, an underground mine must ensure that –

(a) Adequate rescue equipment and breathing apparatus are provided at the mine; and
(b) Persons trained in the use of that equipment and apparatus are available or on call at the mine at all times while persons are working in the mine.

Penalty: See regulation 17.1.

(2) In subregulation (1) (a) -

"adequate" means adequate having regard to the nature and extent of mining operations conducted at the mine the degree of risk to persons working at the mine and the availability of other rescue equipment and personnel outside the mine.

1. INTRODUCTION

Under the Regulations there is a requirement to train employees in emergency procedures, in fire fighting, mine rescue and other relevant emergency response functions.

The work of mine rescue is unpredictable, occurring at extremely short notice, usually physically and psychologically demanding, and therefore requires individuals who are in good health and have an adequate level of fitness.

In selecting members for a mine rescue team each individual should, amongst other requirements, be:

- In good health and physically fit
- Have good vision and hearing
- Capable of performing long and arduous physical labour.

It is important that each member in medically examined by a physician prior to commencing mine rescue training and annually thereafter.

2. HEALTH ASSESSMENT

The health assessment of prospective mine rescue personnel should be done before the commencement of the physical training programme.

The health assessment should include:

- A questionnaire on:
  - Current health status
  - Past medical problems
  - Current medications.
- Clinical assessment for:
  - Status of current medical problems
  - Identification of risk for sudden medical problems during arduous physical activity

- Capacity to perform mine rescue work and wearing of gear (particularly SCBA).

Examples of a health profile questionnaire and clinical assessment form are included as Appendix A and B, respectively.

Guidelines for medical practitioners when conducting the medical examination of mine rescue personnel are included as Appendix C.

3. PHYSICAL FITNESS ASSESSMENT

Once the medical fitness is ascertained then there should be a physical fitness assessment for:

- Cardio-respiratory fitness, also known as aerobic fitness;
- Musculoskeletal fitness.

Aerobic fitness can be assessed using an exercise protocol and determining the pulse response of the individual. (See Appendix D for suggested exercise protocols).

Men using over 40 mL O_2/kg/min and women exceeding 35 mL O_2/kg/min are acceptably fit.

The recovery pulse rate at 5 minutes can also indicate fitness, 100-110 beats per minute is satisfactory.

Muscular fitness (endurance and strength) is best assessed by using a task specific series of activities under self contained breathing apparatus SCBA set up as an assault type course. Assessment is then done by measuring the elapsed time to perform all the tasks (shovelling, carrying blocks, walking up slopes) and recording the mean time taken for all the group members. A mine rescue member is assessed at fit if they are better than minus two standard deviations from this mean. (See Appendix D for suggested exercise protocols).

4. REFERENCES

1. Williams, M. Fitness Testing for adolescents and young adults. Australian Family Physician March 1979:8p279-288.

2. Stoboy, H. Physical Fitness Testing Methods and Criteria. Transactions New York Academy of Sciences 1968:30p483-496.

3. Quigley, B. Task Specific Fitness Testing: An Application for Rescue Workers. January 1986. Department of Human Movement Studies, University of Queensland, St Lucia.

4. Astrand, P.O. Worktest with Bicycle Ergometer. Varberg, Sweden. Monarch Crescent. AB p29.

5. Handbook of Training in Mine Rescue and Recovery Operations 1992. Ministry of Labour Ontario, Canada.

6. Mine Rescue Medical Guidelines. Occupational Health Service, Joint Coal Board of New South Wales 2 June 1993.

APPENDIX A

Health Questionnaire - Mine Rescue Personnel. (To be completed by Applicant.)

Name: .....

Date of birth:.....

Occupation: .....

	Yes	No	Comment
1. Have you seen a doctor in the last 12 months?			
2. Have you got any medical problems at the moment?			
3. Are you taking any medication at present?			
4. Chest			
- Do you suffer from asthma			
- Do you have chronic bronchitis			
- Do you have emphysema			
- Have you ever had a collapsed lung			
- Have you had tuberculosis			
5. Heart			
- Have you ever had heart problems.			
- Do you get angina or chest pain.			
- Do you have high blood pressure.			
- Do you get dizzy spells or fainting attacks.			
6. Stomach and bowel			
- Do you have a stomach or duodenal ulcer.			
- Do you have an irritable bowel or colitis.			
- Do you have a hernia.			
7. Nervous system			
- Do you have epilepsy or seizure.			

- Do you have problems in any nerves.		
- Do you have any ear disease.		
- Do you have any hearing loss.		
- Have you any vision loss or double vision.		
- Do you wear glasses or contact lenses.		

	Yes	No	Comment
8. Musculoskeletal system			
- Do you have any neck or back pain			
- Have you had back problems in the past.			
- Do you have any joint problems.			
- Do you have normal strength in both arms and legs.			
- Can you wear a face mask/respirator.			
9. Skin			
- Do you suffer from eczema or allergic skin conditions.			
10. Kidney			
- Do you suffer any kidney problems.			
11. Other			
- Do you have diabetes.			
- Do you have thyroid problems.			
- Do you have any allergies.			
- Have you had anaemia.			

APPENDIX B

Clinical Assessment - Mines Rescue Personnel. (To be completed by Examiner.)

Name: .....

Date of birth: .....

Male ☐ Female ☐

Section I

Height **Weight** **BMI**

Build Slight ☐ Average ☐ Muscular ☐ Obese ☐

Urine analysis Normal Yes/No

Protein ☐ Sugar ☐ Other ☐

Vision	**Right**	**Left**
Near		
Far		

Visual fields Normal/abnormal

Audiometry kHz	**0.5**	**1.0**	**1.5**	**2.0**	**3.0**	**4.0**	**6.0**	**8.0**
Left ear								
Right ear								

	Delete as applicable.	**Comment.**
ENT		
Ear canals	Normal/abnormal	.....
Tympanic membrane	Normal/abnormal	.....
Cardiovascular	Normal/abnormal	.....
Pulse:	...../min	Regular/irregular .....
Blood pressure:	.....	.....
Peripheral pulses:	present/absent	.....
Respiratory	Normal/abnormal	.....

Spirometry FEV_1 ..... FVC ..... FEV_1/FVC ratio .....

(predicted FEV_1 ..... FVC .....)

Abdomen	Normal/abnormal	.....
Hernia	Yes/No	.....
Nervous system	Normal/abnormal	.....
Coordination	Normal/abnormal	.....
Balance	Normal/abnormal	.....
Reflexes	Normal/abnormal	.....
Cranial nerves	Normal/abnormal	.....
Musculoskeletal	Normal/abnormal	.....
Cervical spine	Normal/abnormal	.....
Thoracic spine	Normal/abnormal	.....
Lumber spine	Normal/abnormal	.....
Upper limbs	Normal/abnormal	.....
Lower limbs	Normal/abnormal	.....
Dermatological	Normal/abnormal	.....

Section II

Fitness assessment (submaximal test)
(See Appendix D)

Pass/Fail

Oxygen uptake VO_2 max
(Male > 40 ml O_2/kg/min)
(Female > 35 ml O_2/kg/min)

Additional tests (if indicated)

Section III

Recommendations by examiner:

1. Is there any condition that makes this individual unfit to be a Mines Rescue Officer?
   Yes/No. Comment:.....
   .....
   .....

2. Is there any condition that makes this individual unfit to do strenuous physical activities?
   Yes/No. Comment:.....
   .....
   .....

3. Is there any condition that makes this individual incapable of using self contained breathing apparatus (SCBA)?
   Yes/No. Comment:.....
   .....
   .....

In my opinion this individual is:

- Fit/unfit to be a Mines Rescue Officer
- Fit/unfit to commence training.
- Fit/unfit to wear self contained breathing apparatus.

Signed:.....

Doctors Name (Print): .....Date:.....

Address:.....
.....
.....

APPENDIX C

GUIDELINES FOR THE MEDICAL EXAMINATION OF MINE RESCUE PERSONNEL

Mine Rescue Personnel should be reliable individuals who work safely, be experienced mineworkers, be reasonably fit and exercise regularly, and capable of performing physical activities in adverse conditions.

Mine rescue and training can be very demanding both physically and mentally. Personnel therefore must be physically fit to perform arduous tasks in adverse conditions, wearing heavy apparel, use breathing apparatus and be free of medical problems.

The conditions likely to be encountered include:

- Adverse hot, humid and smokey atmospheres;
- Working over rough and broken terrain in awkward positions;
- Carrying heavy unpredictable loads and people wearing cumbersome equipment with reduced visibility;
- Poor conditions, confined spaces and falling objects; and
- High psychological stress conditions.

Because of these demands performing the tasks of a mine rescue officer certain medical problems require critical review.

Cardiovascular variables

Absolute contraindications

- Known ischaemic heart disease
- Valvular heart disease
- Cardiomyopathies
- Resting blood pressure systolic > 160 diastolic > 100
- Heart block or pacemakers

Relative contraindications

- Surgically corrected IHD with normal work capacity

- Body mass index > 32
- Evidence of severe raised serum cholesterol > 6.5
- Excessive smoker > 40/day
- Age > 45 years

Should there be relative contraindications in a mine rescue officer then an exercise stress test should be arranged.

Respiratory variables

Self-contained breathing apparatus (SCBA) significantly increases the respiratory effort. Failure to cope with SCBA may endanger the mine rescue officer, their colleagues and those being rescued.

Absolute contraindications
- Active respiratory disease
- Chronic airways obstruction
- Asthma, exercise induced asthma
- Emphysema
- Mouth or nasal deformities

Relative contraindications
- FEV_1 or FVC less than 70% of predicted value
- FEV_1/FVC ratio < 75%

Gastrointestinal variables

Absolute contraindications
- Abdominal hernia
- Active GI or hepatobiliary disorder

Relative contraindications
- Peptic ulcer on treatment
- Ulcerative colitis
- Active diverticular disease
- Pancreatitis

- Hepatitis

Renal variables

Absolute contraindications

- Renal failure
- Multiple renal stones

Neurological variables

Absolute contraindications

- History of epilepsy or seizure
- Fainting, loss of consciousness, TIA's
- Disorders of coordination or muscle control
- Peripheral neuropathies
- Parkinson’s disease
- Vestibular disorders

Relative contraindications

- Frequent and severe headaches, migraines
- History of severe head injury

Hearing

Absolute contraindications

- Audiometry loss in either ear 500 - 4500 Hz > 60 dB
- Perforated tympanic membrane
- Suppurating ear disease

Relative contraindications

- Current middle ear disease
- Hearing loss 500 - 6000 Hz > 40 dB

Vision

Absolute contraindications

- Loss of vision in one eye
- Tunnel vision
- Diplopia

Relative contraindications

- Contact lenses
- Nystagmus
- Failure of ishihara > 6 plates
- Distant vision worse than $^{6}/_{12}$ best eye unaided
- Near vision N10 or better
- Reduced peripheral vision

Haematological indicators

Absolute contraindications

- Active leukaemia, lymphoma
- Severe anaemia Hb < 10 gm
- Polycythaemia

Endocrine indicators

Absolute contraindications

- Insulin dependent diabetes
- Systemic steroid therapy
- Cushings syndrome
- Pituitary disease

Relative contraindications

- Thyroid disease
- Non insulin dependent diabetes

Musculoskeletal indicators

Absolute contraindications

- Any condition limiting full range of motion, strength or coordination in the four limbs

Relative contraindications

- Acute or chronic spinal pain
- Minor strength deficiencies
- Facial characteristics preventing good seal with SCBA face piece

Behavioural indicators

Absolute contraindications

- Evidence of agoraphobia, claustrophobia, pyromania
- History of panic disorders
- Alcohol or drug dependence

Thank you for reviewing this mine rescue officer and assessing their fitness to perform the full group of tasks expected. It is important that this group remain physically and medically fit.

APPENDIX D

GUIDELINES FOR ASSESSING PHYSICAL FITNESS

Fitness can be assessed in several ways. It is possible to do this in a consulting room, the gymnasium or in the workplace using modest equipment.

Cardio - respiratory fitness: The most widely used index is the maximal oxygen intake (VO_2 max), this is aerobic fitness. The VO_2 maximum can be assessed directly via a maximal exercise test or it can be predicted from a submaximal test. The use of a treadmill or a cycle ergometer is recommended. The treadmill is preferred as it involves the largest muscle mass requiring the person to support their own body weight. However a well controlled cycle ergometer protocol is perfectly acceptable (see suggested protocol below).

Minimum acceptable standards for aerobic fitness:

Males ~ 40 ml O_2/kg/minute

Females ~ 35 ml O_2/kg/minute

Passing at these levels of aerobic fitness allows an individual to form the mine rescue group.

Squad assessment for musculoskeletal fitness: It is recommended that a sequence of physical tasks be setup as a course (to be done under SCBA for those mines requiring this):

- Brisk walk under SCBA - 500 metres
- Walk up incline/steps carrying gear (15 kg) - 200 metres
- Shovel material (e.g. fines) into 44 gallon drum and fill
- Move cement blocks through 1 metre high tunnel, 15 metres long - 10 blocks
- Move stacked 20 kg items 10 metres and restack 5 - 10 units
- Sawing type task using wall pulleys - 5 minutes
- Return to base under SCBA - 500 metres.

The whole sequence should take 25-30 minutes as part of a circuit and be performed by each individual. The mean time taken to perform the seven tasks can be calculated for each squad. Anybody whose personal time is slower than 2 standard deviations from the mean should be classed as unfit.

APPENDIX E

BICYCLE ERGOMETER TEST PROTOCOLS

i ASTRAND BICYCLE ERGOMETER TEST

Introduction

The Astrand Bicycle Ergometer Test predicts maximal oxygen consumption from a submaximal heart rate exercise and power output values.

Equipment

Calibrated Monark bicycle ergometer
ECG or technique for heart rate measurement
Digital timer/clock
Metronome

Procedures

1. Zero the bicycle ergometer power output for frictionless pedalling.

2. Adjust the seat height for the individual to be tested (slight knee flexion on the extreme downstroke of the pedal).

3. Determine the power output to be set.

    a. The pedal speed is 50 revolutions per minute (18km/hr on the speedo, or 100 beats/min on the menotrome).
    b. The distance covered by a point on the (specially machined) wheel is 6 metres for each pedal revolution.
    c. The frictional resistance in kiloponds (kp) is determined after the following considerations:
        (i) The aim of the test is to produce a heart rate above 130 beat/min after a period of 6 minutes. (If the heart rate is less than 130 bpm than a second higher load must be set for the next 6 minutes). Several loads may be incorporated in the test if the time permits. No further workload is necessary if the steady state heart rate is greater than 150 bpm.

(ii) Power output is determined by multiplying three factors: pedal speed, distance and frictional resistance.
e.g. 50 pedal revolutions/min
x 6 meters/revolution
x 1kp resistance = 300 kpm/min

(iii) A power output of 600 kpm/min is probably suitable for a healthy female. A power output of 900 kpm/min is probably suitable for a healthy male. For persons expected to have a low physical work capacity, e.g. small muscled, completely untrained, or older individuals, power outputs a s low as 300 kpm/min may be chosen.

(iv) One of the following power outputs must be chosen.
Females: 300,450,600,750 and 900 Kp/min
Males: 300, 600, 900, 1200 and 1500 Kp/min

4. The test may be commenced. A pre-exercise heart rate may be taken.

5. Heart rates should then be taken in the last 10 to 15 seconds of each minute for 5 minutes or until the test is completed.

A steady-state heart rate is said to be obtained when the heart rates at the end of the 5th and 6th minutes do not differ by more than 5 beats/min. An average of these two values is used in the calculation of the predicted VO_2 max.

If a steady-state heart rate is not achieved (is still rising) and the heart rate is greater than 150 bpm, then the test should be discontinued. If a steady-state heart rate is not attained but is less than 150 bpm than the test may be continued for another minute and the 6th and 7th minute heart rates averaged and used in the calculation of predicted VO_2 max.

Result Sheet

NAME			Weight	Age	Date
Minute	**Work Rate**	**Heart Rate - HR(bpm)**	**RPE**		
1.					
2.					
3.					
4.					
5.					
6.					
***7.**					

Calculation of predicted maximal oxygen consumption

1. Average of the steady state heart rates measured during the final two minutes.	
2. Initial estimate of VO_2 max. in l/min	
3. Age correlation factor	
4. Final estimate of VO_2 max in l/min	
5. Estimated VO_2 max in ml/kg/min	
6. Fitness Category in: l/min ml/kg/min	

1. Average the steady state HR's of the final two minutes.

2. Using the test power output and steady-state HR, and the appropriate table for females or males (see next page), determine the initial estimate of predicted VO_2 max in l/min.

Predicted VO_2 max - Female						Predicted VO_2 max - Male					
	Power Output						Power Output				
HR	**300**	**450**	**600**	**750**	**900**	**HR**	**300**	**600**	**900**	**1200**	**1500**
120	2.6	3.4	4.1	4.8		**120**	2.2	3.5	4.8		
121	2.5	3.3	4.0	4.8		**121**	2.2	3.4	4.7		
122	2.5	3.2	3.9	4.7		**122**	2.2	3.4	4.6		
123	2.4	3.1	3.9	4.6		**123**	2.1	3.4	4.6		
124	2.4	3.1	3.8	4.4		**124**	2.1	3.3	4.5	6.0	
125	2.3	3.0	3.7	4.4		**125**	2.0	3.2	4.4	5.9	
126	2.3	3.0	3.6	4.3		**126**	2.0	3.2	4.4	5.8	
127	2.2	2.9	3.5	4.2		**127**	2.0	3.1	4.3	5.7	
128	2.2	2.8	3.5	4.2	4.8	**128**	2.0	3.1	4.2	5.6	
129	2.2	2.8	3.4	4.1	4.8	**129**	1.9	3.0	4.2	5.6	
130	2.1	2.7	3.4	4.0	4.7	**130**	1.9	3.0	4.1	5.5	
131	2.1	2.7	3.3	4.0	4.6	**131**	1.9	2.9	4.0	5.4	
132	2.0	2.7	3.2	3.9	4.5	**132**	1.8	2.9	4.0	5.3	
133	2.0	2.6	3.2	3.8	4.4	**133**	1.8	2.8	3.9	5.3	
134	2.0	2.6	3.1	3.8	4.4	**134**	1.8	2.8	3.9	5.2	
135	2.0	2.6	3.1	3.7	4.3	**135**	1.7	2.8	3.8	5.1	
136	1.9	2.5	3.1	3.6	4.2	**136**	1.7	2.7	3.8	5.0	
137	1.9	2.5	3.0	3.6	4.2	**137**	1.7	2.7	3.7	5.0	
138	1.8	2.4	3.0	3.5	4.1	**138**	1.6	2.7	3.7	4.9	
139	1.8	2.4	2.9	3.5	4.0	**139**	1.6	2.6	3.6	4.8	
140	1.8	2.4	2.8	3.4	4.0	**140**	1.6	2.6	3.6	4.8	6.0
141	1.8	2.3	2.8	3.4	3.9	**141**		2.6	3.5	4.7	5.9
142	1.7	2.3	2.8	3.4	3.9	**142**		2.5	3.5	4.6	5.8
143	1.7	2.2	2.7	3.3	3.8	**143**		2.5	3.4	4.6	5.7
144	1.7	2.2	2.7	3.2	3.8	**144**		2.5	3.4	4.5	5.7
145	1.6	2.2	2.7	3.2	3.7	**145**		2.4	3.4	4.5	5.6
146	1.6	2.2	2.6	3.2	3.7	**146**		2.4	3.3	4.4	5.6
147	1.6	2.0	2.6	3.1	3.6	**147**		2.4	3.3	4.4	5.5
148	1.6	2.1	2.6	3.1	3.6	**148**		2.4	3.2	4.3	5.4
149		2.1	2.6	3.0	3.5	**149**		2.3	3.2	4.3	5.4
150		2.0	2.5	3.0	3.5	**150**		2.3	3.2	4.2	5.3
151		2.0	2.5	3.0	3.4	**151**		2.3	3.1	4.2	5.2
152		2.0	2.5	2.9	3.4	**152**		2.3	3.1	4.1	5.2
153		2.0	2.4	2.9	3.3	**153**		2.2	3.0	4.1	5.1
154		2.0	2.4	2.8	3.3	**154**		2.2	3.0	4.0	5.1
155		1.9	2.4	2.8	3.2	**155**		2.2	3.0	4.0	5.0
156		1.9	2.3	2.8	3.2	**156**		2.2	2.9	4.0	5.0

Predicted VO_2 max - Female						Predicted VO_2 max - Male					
	Power Output						Power Output				
HR	**300**	**450**	**600**	**750**	**900**	**HR**	**300**	**600**	**900**	**1200**	**1500**
157		1.9	2.3	2.7	3.2	**157**		2.1	2.9	3.9	4.9
158		1.8	2.3	2.7	3.1	**158**		2.1	2.9	3.9	4.9
159		1.8	2.2	2.7	3.1	**159**		2.1	2.8	3.8	4.8
160		1.8	2.2	2.6	3.0	**160**		2.1	2.8	3.8	4.8
161		1.8	2.2	2.6	3.0	**161**		2.0	2.8	3.7	4.7
162		1.8	2.2	2.6	3.0	**162**		2.0	2.8	3.7	4.6
163		1.7	2.2	2.6	2.9	**163**		2.0	2.8	3.7	4.6
164		1.7	2.1	2.5	2.9	**164**		2.0	2.7	3.6	4.5
165		1.7	2.1	2.5	2.9	**165**		2.0	2.7	3.6	4.5
166		1.7	2.1	2.5	2.8	**166**		1.9	2.7	3.6	4.5
167		1.6	2.1	2.4	2.8	**167**		1.9	2.6	3.5	4.4
168		1.6	2.0	2.4	2.8	**168**		1.9	2.6	3.5	4.4

3. Multiply the age correction factor or the correction factor for the true maximum heart rate. The age correction factor is based on a maximum HR of 195 bpm. Interpolation from the age. HR max and other factors may occur where necessary. Multiplying the initial estimate of predicted VO_2 max by the age (or true HR max) correction factor gives the final estimate of predicted VO_2 max in litres/min.

AGE CORRECTION FACTORS		MAXIMUM HEART RATE CORRECTION FACTORS	
Years	**Multiply by**	**HR max**	**Multiply by**
15	1.10	210	1.12
25	1.00	200	1.00
35	0.87	190	0.93
40	0.83	180	0.83
45	0.78	175	
50	0.75	170	0.75
55	0.71	165	
60	0.68	160	0.69
65	0.65	155	
		150	0.64

4. Take the final estimate of predicted VO_2 max in litres/min and multiply by 1000 to get ml/kg/min and then divide the body weight to get a final estimate of predicted VO_2 max in ml/kg/min.

5. Compare the final estimates of predicted VO_2 max in litres/min and ml.kg/min with the normative data below.

TEST RELIABILITY AND VALIDITY

1. A number of authors have found this test both reliable and valid when correlated with VO_2 max.
2. The limitations of all submaximal tests means that the predicted VO_2 max is within 10 to 20% of the persons VO_2 max.
3. Other authors have found that there is a tendency for VO_2 max to be under-estimated in the untrained and over-estimated in the well trained(Wyndham, 1967).

Astrand Bicycle Ergometer Test VO_2 max Normative Data – Females					
	Low	**Below Average**	**Average**	**High**	**Very High**
20 - 29 years					
(l/min)	<1.69	1.70-1.99	2.00-2.49	2.50-2.79	>2.8
(ml.kg/min)	<28	29-34	35-43	44-48	>49
30 - 39 years					
(l/min)	<1.59	1.60-1.89	1.90-2.39	2.40-2.69	>2.70
(ml.kg/min)	<27	28-33	34-41	42-47	>48
40 - 49 years					
(l/min)	<1.49	1.50-1.79	1.80-2.29	2.30-2.59	>2.60
(ml.kg/min)	<25	26-31	32-40	41-45	>46
50 - 65 years					
(l/min)	<1.29	1.30-1.59	1.60-2.09	2.10-2.39	>2.40
(ml.kg/min)	<21	22-28	29-36	37-41	>42

Astrand Bicycle Ergometer Test VO_2 max Normative Data – Males					
	Low	**Below Average**	**Average**	**High**	**Very High**
20 - 29 years					
(l/min)	<2.79	2.80-3.09	3.10-3.69	3.70-3.99	>4.00
(ml.kg/min)	<38	39-43	44-51	52-56	>57
30 - 39 years					
(l/min)	<2.49	2.50-2.79	2.80-3.39	3.40-3.69	>3.70
(ml.kg/min)	<34	35-39	40-47	48-51	>52
40 - 49 years					
(l/min)	<2.19	2.20-2.49	2.50-3.09	3.10-3.39	>3.40
(ml.kg/min)	<30	31-35	36-43	44-47	>48
50 - 59 years					
(l/min)	<1.89	1.90-2.19	2.20-2.79	2.80-3.09	>3.10
(ml.kg/min)	<25	26-31	32-39	40-43	>44
60 - 69 years					
(l/min)	<1.59	1.60-1.89	1.90-2.49	2.50-2.79	>2.80
(ml.kg/min)	<21	22-26	27-35	36-39	>40

BICYCLE ERGOMETER TEST PROTOCOLS

ii PWC 170 BICYCLE ERGOMETER TEST

Introduction

The PWC170 test is a submaximal test progressing in intensity on three occasions, each of three minutes, and requiring that a heart rate of 170 beats/min not to be exceeded.

Equipment

Calibrated Monark bicycle egometer
ECG or technique for heart rate measurement
Clock
Calculator/Ruler

Procedures

1. Zero the bicycle ergometer power output for frictionless pedalling.

2. Adjust the seat height for the individual to be tested (slight knee flexion on the extreme downstroke of the pedal).

3. Document the clients resting heart rate.

4. Subjectively analyse clients general fitness level. A general guide to appropriate work loads for an average population would be:

Females: 1/1.5/2 Kp Males:2/2.5/3 Kp

5. Set an appropriate workload and ask the client to cycle at a speed of 60RPM. At the end of every minute record the heart rate. At the end of each respective third minute record the heart rate and increase the workload.

6. Repeat this process two more times, making sure the heart rate for the first, second and third work loads fall between 115-130, 130-145 and 145-165 respectively.

7. A warm down period with a light load (0.5 kp-men, 0.25 kp-women), should be done by the client, until the heart rate returns to below 60 % of age predicted maximum (220 - age).

RESULTS
Documenting Results

Name:	**Date:**
Weight:	**Pre-exercise heart rate:**
WR 1 Pedal Speed: _____ revs/min Resistance: _____ kp Work Rate: _____ kp.m/min	Heart Rate 1: _____bpm Heart Rate 2: _____bpm Heart Rate 3: _____bpm **Mean of 2 & 3:** _____ **bpm**
WR 2 Pedal Speed: _____ revs/min Resistance: _____ kp Work Rate: _____ kp.m/min	Heart Rate 1: _____bpm Heart Rate 2: _____bpm Heart Rate 3: _____bpm **Mean of 2 & 3:** _____ **bpm**
WR 3 Pedal Speed: _____ revs/min Resistance: _____ kp Work Rate: _____ kp.m/min	Heart Rate 1: _____bpm Heart Rate 2: _____bpm Heart Rate 3: _____bpm **Mean of 2 & 3:** _____ **bpm**

Bicycle Ergometer Pedalling Speed, Resistance and Work Rate Relationships

RESISTANCE	PEDALING SPEED		
(kp)	50.0 revs/min = 18.0 km/hr	55.5 revs/min = 20.0 km/hr	60.0 revs/min = 21.6 km/hr
0.50	150	167	**180**
0.75	225	250	**270**
1.00	300	333	**360**
1.25	375	416	**450**
1.50	450	500	**540**
1.75	525	583	**630**
2.00	600	666	**720**
2.25	675	750	**810**
2.50	750	833	**900**
2.75	825	916	**990**
3.00	900	999	**1080**
3.25	975	1082	**1170**
3.50	1050	1166	**1260**
3.75	1125	1249	**1350**
4.00	1200	1332	**1440**
4.25	1275	1415	**1530**
4.50	1350	1499	**1620**

Calculating Results

1. The PWC 170 score is best calculated from plotting the mean heart rate against the respective work rate on a graph. Join the points on the graph together using a linear line. Extrapolate the line till it passes through the 170 bpm horizontal line. Drop a plum line down from where the extrapolated line crosses 170 bpm, to the work load axis. Record the predicted maximum VO_2 Uptake result(L/min)

2. VO_2 max $= \dfrac{\text{pred } VO_2 \text{ max(L/min)} \times \text{ACF} \times 1000}{\text{weight(kg)}}$

$= VO_2$ ml/kg/min

Points to remember

1. Should the first rate not produce a heart rate between the range of 115-130 beats/min after 3 minutes, the tester should increase to a work rate which does. The first work rate is essential then treated as a three minute warm-up and the test begun again.

3. Should the first work rate produce a heart rate greater than 130 beats/min after three minutes, this work rate must essentially become the second work rate. Only one work rate may then be set, this work rate should elicit the required steady-state heart

rate between the ranges of 145 -165. While it is easy to fit the line of best fit to these points the error associated with these points may not be determined, and consequently an extrapolation to a heart rate of 170 beats/minute to determine the PWC 170 score may also be in error.

AGE CORRECTION FACTORS		MAXIMUM HEART RATE CORRECTION FACTORS	
Years	**Multiply by**	**HR max**	**Multiply by**
15	1.10	210	1.12
25	1.00	200	1.00
35	0.87	190	0.93
40	0.83	180	0.83
45	0.78	175	
50	0.75	170	0.75
55	0.71	165	
60	0.68	160	0.69
65	0.65	155	
		150	0.64