

CHAPTER 3

PROCEDURES AND METHODS

3.1 INTRODUCTION

Laboratory tests are widely used by athletes of many different endurance sports in an effort to guide training, optimise race performance and to monitor recovery. The science of sport is particularly exciting and challenging. Measuring anaerobic and aerobic fitness helps not only to characterise an individual's ability to perform a certain task but it can also be used to quantify the effect of a change in training regimen on performance. Testing helps to describe the characteristics of the athlete but can also help to assess the effects of exposure to altitude and pollution and the effect of ergogenic aids. Determining one's cardiovascular fitness also has both general health and clinical applications. The extent to which these and other factors are "trainable" as opposed to genetically determined is a topic of considerable debate (Bouchard et al., 1992).

3.2 TESTING PROCEDURES

3.2.1 Subjects

Five male marathon athletes volunteered to take part in the different tests and were informed in detail about the nature of the experiment and about possible risks. All the subjects were training for the 1998 Comrades Marathon and all of them had run the Comrades before. They had been following a training programme for a minimum of 4 years and were experienced treadmill runners. All the subjects were non-smokers and were free of any disease. The day before each test, no intensive training was allowed. Their regular training regimens included running of at least 80 km weekly, with workouts of moderate to high intensity.

3.2.2 Experimental environment

Laboratory tests were administered in an air-conditioned laboratory at a temperature of 20°C, and a relative humidity of 45%-55%. Analysers were calibrated before each subject's test by

using gases of known concentration. The same biokineticist was employed in subsequent testing.

3.3 TESTING

3.3.1 Anthropometrical measurements

The evaluation of body composition permits quantification of the major structural components of the body – muscle, bone and fat (McArdle et al., 1996).

3.3.1.1 Anthropometry equipment

Anthropometry tape: A flexible steel tape calibrated in centimetres with millimetre gradations.

Weighing scales: A medical balance scale calibrated to the nearest 100 g. Detecto standing scale was used to measure body weight.

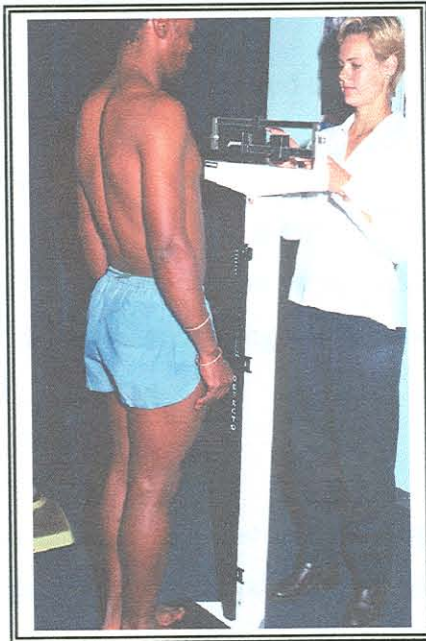


Figure 10: Detecto standing scale to determine body mass

Anthropometer: Anthropometer with foot plate, calibrated in centimetres with millimetre gradations.

Skinfold caliper: Harpenden caliper calibrated to 50mm in 0,2mm divisions, accurately interpolated to the nearest 0,1 mm.

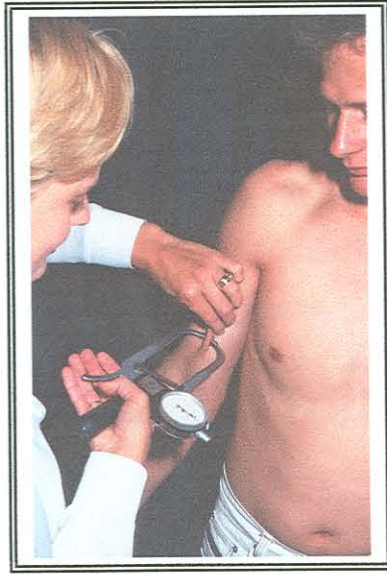


Figure 9: Measuring body composition using a Harpenden skinfold caliper

Wide-spread calipers: Widespread calliper calibrated to the nearest 0,2 mm.

3.3.1.2 Anatomical landmarks

Landmarks are identifiable skeletal points, which generally lie close to the body's surface and are the "markers" which identify the exact location of the measurement site. All the variables unless stated otherwise, were measured according to the procedures of the anthropometric manual of Lohman et al. (1988).

a. Skinfolts

1. *Triceps:* The fold is vertical and parallel to the line of the upper arm, on the posterior-mid-acromiale–radiale line. Taken on the most posterior surface of the triceps muscle. Arm relaxed with the shoulder joint slightly externally rotated and elbow extended by the side of the body.
2. *Subscapular:* Inferior angle of the scapula along a line running laterally and obliquely downwards from the subscapular landmark at an angle (approximately 45°) as determined by the natural fold lines of the skin.
3. *Biceps:* Mid-acromiale-radiale line with the fold running vertically parallel to the axis of the upper arm. Arm relaxed with the shoulder joint slightly externally rotated and elbow extended. Located on the most anterior aspect of the biceps.

4. *Iliac crest*: Superior to the iliocristale on the ilio-axilla line. The fold runs slightly downwards toward the medial aspect of the body.
5. *Abdominal*: Vertical fold 5 cm in the midline of the belly of the rectus abdominus from the right-hand side of the omphalion (midpoint of the navel).
6. *Front thigh*: Parallel to the long axis of the femur at the mid-point of the distance between the inguinal fold and the superior border of the patella (when the knee is bent).
7. *Medial calf*: Vertical fold on the medial aspect of the calf at a level where it has maximal circumference. Subject seated and knee 90° flexed and calf relaxed.

b. Girths

1. **Forearm**: Measurement is taken at the maximum girth of the forearm with the subject holding the palm up. Usually occurs just distal to the elbow.
2. *Wrist*: Distal to the styloid processes. It is the minimal girth in this region.
3. *Chest*: Girth is taken at the level of the mesosternal, with the tape around the chest in a near horizontal plane. Measurement is taken at the end of normal expiration.
4. *Waist*: Measurement is taken at the level of the narrowest point between the lower costal border and the iliac crest, at the end of normal expiration with the arms relaxed on the sides.
5. *Hip*: This is taken at the level of the greatest posterior protuberance of the buttocks which usually corresponds anteriorly to about the level of the symphysis pubis.
6. *Thigh*: The girth of the thigh is taken 1 cm below the level of the gluteal fold, perpendicular to the long axis of the thigh.
7. *Calf*: With the weight equally distributed on both feet. The maximal girth of the calf is taken.
8. *Ankle*: The minimum girth of the ankle is taken at the narrowest point superior to the sphyrion tibiale.
9. *Upper arm*: Maximum girth of the biceps muscle.

c. Breadths

1. *Biacromial*: The distance is measured between the most lateral points on the acromion processes.
2. *Bi-iliocrystal*: Distance measured is between the most lateral points on the iliac tubercles.

3. *Transverse chest*: The distance is measured between the most lateral aspect of the thorax when the superior aspect of the calliper scale is positioned at the level of the mesosternal and the blades are positioned at an angle of 30° downward from the horizontal. The measurement is taken at the end of tidal expiration.
4. *Anterior-posterior chest*: The distance is measured between the recurved branches of the wide-spread calliper when it is positioned at the level of the mesosternal. The rear branch of the caliper should be positioned on the spinous process of the vertebra at the level of the mesosternal.
5. *Bi-epicondylar humerus*: Distance is measured between the medial and lateral epicondyles of the humerus when the arm is raised anteriorly to the horizontal and the forearm is flexed at right angles to the upper arm. Because the medial epicondyle is lower than the lateral epicondyle, the *measured distance is oblique*.
6. *Bi-epicondylar femur*: Distance is measured between the medial and the lateral epicondyles of the femur when the subject is seated and the leg flexed at the knee form a right angle with the thigh.

3.3.1.3 Calculations

The Heath Carter method was used to determine the athlete's body composition. There are two available procedures for calculating the anthropometric somatotype. The first is to enter measurements into the Heath-Carter rating form, and the second is to enter the measurements into equations derived from the rating form (Foss & Keteyian, 1998). The following measurements, all taken on the right side of the body, are required to complete the somatotype (Fox et al., 1993). The anthropometry measurements include height, body mass, four skinfold measurement (triceps, subscapular, supra-illiac, medial calf), two bone widths (humerus, femur), two bone girths (upper arm girth, calf) (Pate et al., 1991).

The Drinkwater and Ross method includes the following measurements: height, body mass, seven skinfolds (biceps, triceps, subscapular, supra-illiac, abdominal, frontal thigh, and medial calf), six bone widths (biacromial, bi-iliocrystal, transverse chest, anterior-posterior chest, bi-epicondylar humerus, bi-epicondylar femur) and nine girths (forearm, wrist, chest, waist, hip, thigh, calf, ankle, upper arm). For research purposes, the investigator has had considerable

experience and was consistent in duplication values for the same subject on consecutive days (McDougal et al., 1991).

Data were entered in the labtest's computer program to determined the following:

Absolute fat mass (kg) and fat percentage (%)

$$\frac{(\text{sum of skinfolds}/6 \times 3.25) + 12.13}{(170.18/S)^3} = \text{AFM}$$

AFM	=	absolute fat mass (kg).
Sum of skinfolds	=	sum of triceps, subscapular, supra-iliac, abdominal, thigh, calf.
S	=	measured height (cm).
3.25	=	mean standard deviation for fat component.
12.13	=	mean phantom value for fat component

$$\text{RFM} = (\text{AFM}/\text{MBM}) \times 100$$

RFM	=	relative fat mass (%)
AFM	=	absolute fat mass (kg)
MBM	=	measured body mass (kg)

Absolute muscle mass (kg) and percentage (%)

$$\frac{(\text{Sum of CG} / 5 \times 2.99) + 25.55}{(170.18 / S)^3} = \text{AMM}$$

AMM	=	absolute muscle mass (kg)
Sum of CG	=	sum of corrected arm, chest, thigh and calf girths and the uncorrected forearm girth
S	=	measured height (cm)
1.99	=	mean phantom standard deviation for muscle component
25.55	=	mean phantom value for muscle component

$$\text{RMM} = (\text{AMM} / \text{MBM}) \times 100$$

RMM = relative muscle mass (%)
 AMM = absolute muscle mass (kg)
 MBM = measured body mass (kg)

Lean body mass (kg)

$$\text{Lean body mass (g)} = \text{S}(0.0553\text{CTG}^2 + 0.0987\text{FG}^2 + 0.0331\text{CCG}^2) - 2445$$

S = stature

CTG = corrected mid thigh girth

FG = forearm girth

CCG = corrected calf girth

2. Somatotype (endomorph, ectomorph and mesomorph)

Endomorphy:

$$\text{ENDO} = [-0.7182 + 0.1451 (x)] - [0.00068 (x^2)] + [0.0000014 (x^3)]$$

x = sum of triceps, subscapular and supra iliac skinfolds

Mesomorphy:

$$\text{Meso} = [(0.858 \times \text{H}) + (0.601 \times \text{F}) + (0.188 \times \text{AG}) + (0.161 \times \text{CG})] - (\text{S} \times 0.131) + 4.50$$

H = largest humerus diameter (cm)

F = largest femur diameter (cm)

AG = corrected arm girth (cm)

CG = corrected calf girth (cm)

S = stature (cm)

Ectomorphy:

$$\text{ECTO} = (\text{SMR} \times 0.732) - 28.38$$

$$\text{SMR} = \text{stature (cm)} / \text{mass}^{0.333} (\text{kg})$$

Body mass index

(kg/m²)

Ideal body mass (kg)

Ideal body mass (kg) = Fat free mass/ (100 – TF%)

TF% = target % body fat

3.3.2 Lung-function testing

Lung-function tests were performed on the Schiller CS 100 - Ergo-spirometry-module; Flow-sensor SP-160. All the subjects were familiar with the lung-function test procedures. Two trials were given to each subject, to allow a degree of learning. The results were also visible to the subjects, thus encouraging them to use maximum effort. Subjects perform the test standing in front of the recorder and wearing a noseclip. The subject exhales as rapidly and completely as possible, following a maximal inspiration. Forced vital capacity (FVC) was measured in litres. The tidal volume was then divided by the FVC to calculate the percentage of lung filling during the VO₂ max test.

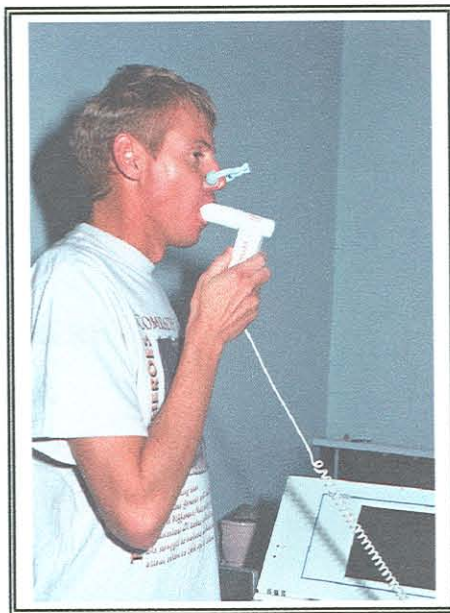


Figure 11 Lung-function test performed on the Schiller CS 100

3.3.3 Maximal oxygen uptake (VO₂ max)

The VO₂ max was determined by use of an inclined electrically driven treadmill protocol. Schiller CS 100 gas analyser, with ECG-Module, flow-sensor SP-160 and a Quintin treadmill

(model 24-72) were used to determine the endurance fitness of the marathon athlete. Before each test analysers were calibrated with gas mixtures of known concentrations.

After a five-minute warm-up period at 10 km/h, the subjects started the test running at 12 km/h on a constant slope of 2%. The speed was increased every 3 minutes by 2 km/h until 16 km/h was reached. The treadmill speed was then increased by 1 km/h every 2 minutes until exhaustion. The subjects received strong verbal encouragement to continue as long as possible. The subjects constantly wore a mask that covered the mouth and nose during the entire phase of gas collection. Gas samples were recorded every 10 seconds.

All the athletes reach a VO_2 max according to the following criteria:

1. heart rate of at least 95% of maximal heart rate of the subject;
2. respiratory exchange ratio at least 1.1;
3. severe exhaustion;
4. plateau or decreasing of the VO_2 max; and
5. lactate values of at least 8 mmol/L (MacDougal et al., 1991).

The physiological parameters measured were:

- oxygen consumption (VO_2 max);
- heartrate (HR);
- respiratory exchange ratio (RER);
- oxygen equivalent (VE/VO_2);
- carbon dioxide equivalent (VE/VCO_2);
- carbon dioxide production (VCO_2);
- respiration rate (RR);
- tidal volume (VT);
- lactate threshold;
- ventilatory threshold;
- oxygen pulse (ml O_2 /HT); and
- metabolic equivalents (METS).

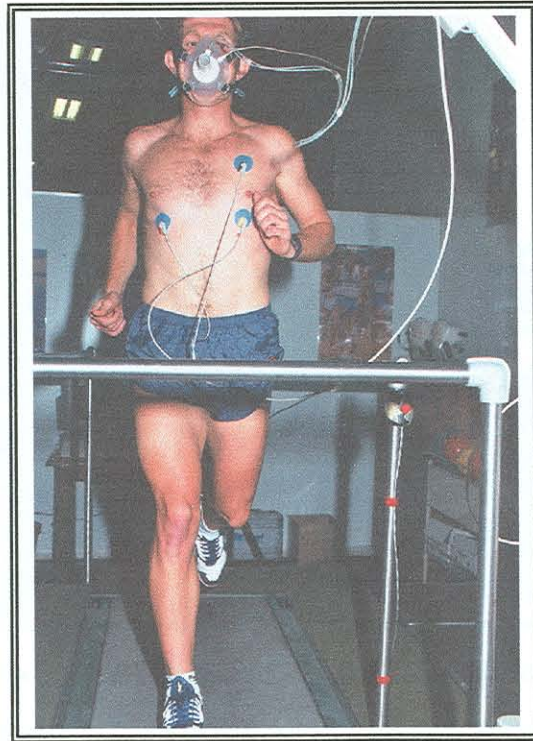


Figure12: VO₂ max test performed on the Quintin treadmill (model 24-72), using the Schiller CS 100-gas analyser, with ECG-Module and flow-sensor SP-160.

3.3.4 Measuring blood lactate

Lactate was determined in the same laboratory setting on the treadmill on a fixed 2% inclination simultaneously with the VO₂ max test. Blood lactate tests were performed with an Accurex BM lactate meter (manufactured by Boehringer and Mannheim), requiring a lancet puncture of a fingertip to obtain a small sample of peripheral blood. Blood lactate samples were collected during the test at the end of each workload. Measuring time is only 60 seconds. Lactate was plotted against heartrate to determine the onset of lactate accumulation (OBLA 4 mmol/L).

3.3.5 Distances and running times

Each subject's best running times for the 10, 21, 42, 50, 56 and 90 km had been recorded during the preceding year. Training distances were also recorded during the testing period (October 1997 to May 1998) as a total of kilometres done per month.

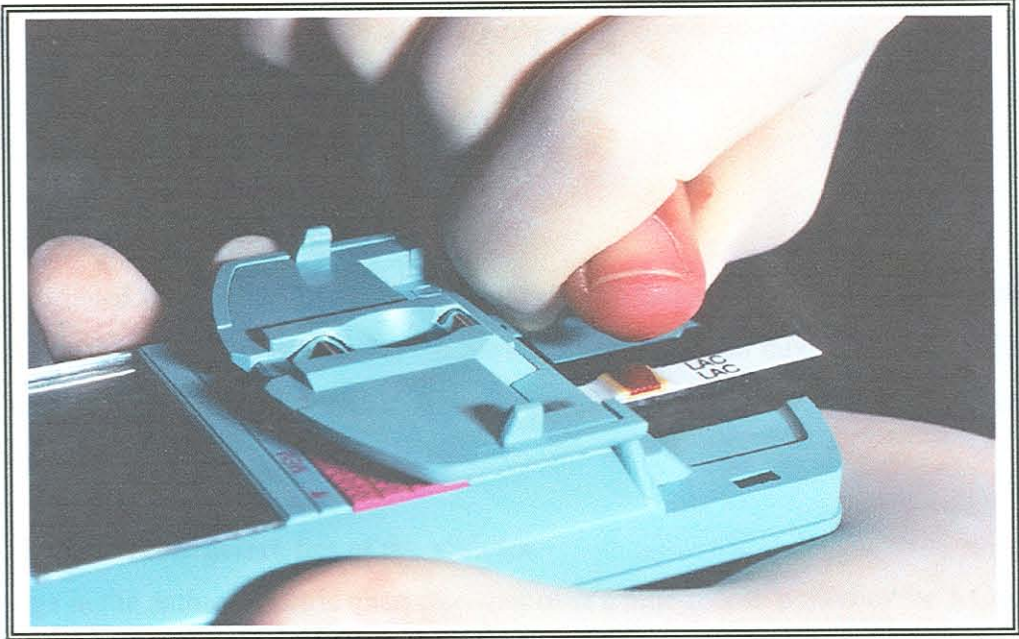


Figure 13: Blood lactate test performed with an Accurex BM lactate meter (manufactured by Boehringer and Mannheim).

3.3.6 Heartrate response during the Comrades Marathon

Each subject ran the Comrades Marathon with a Polar Vantage NV to determine race intensity. Data was there after analysed with the polar interface plus with training advisor software for Windows. Heartrate response was measured every 5 seconds during the race. The software of the interface program allows the user to calculate heartrate response as a percentage below the lactate threshold, percentage above the threshold, average heartrate and maximal heartrate. The athletes attempted to stay in the 2 to 3 mmol/L training zone by adjusting pace throughout the course of the Comrades Marathon.

3.3.7 Statistical analysis

Statistical calculations were done with time-related information data over a period of eight months. Progression analysis showed the percentage improvement in this time period. The test sample consists of 5 marathon athletes. Because of the small sample, the Spearman's rank correlation coefficient tests were used. It has to be stated that the results obtained from the test cannot be used to make conclusions about the population (all marathon athletes), because this is not a random sample.