

## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATIONS

Laboratory tests are widely used by athletes of many different endurance sports in an effort to guide training, optimise race performance and monitor recovery. The science of sport is particularly exciting and challenging. The extent to which physiological factors are “trainable” as opposed to genetically determined is a topic of considerable debate (Bouchard et al., 1992). Sport Science can play an important role in the success of ultra marathon runners by helping the athletes to achieve their optimal fitness levels. Science has given us a unique insight into the anatomy of one of the most difficult races in the world, the Comrades Marathon.

Many physiological factors are related to successful endurance performance. Maximal oxygen uptake is generally considered to be a useful indicator of successful performance in endurance activities when the subjects are heterogeneous in terms of  $VO_2$  max (Costill et al., 1973; Farrel et al., 1979; Daniels, 1985; Vago et al., 1987; Noakes, 1988; Schneider & Pollack, 1991; Hawley, 1995).

It would appear, however, that the fraction of  $VO_2$  max that an athlete can sustain for prolonged periods is an even better indicator than  $VO_2$  max alone (Costill et al., 1973; Sjodin et al., 1982; Hawley, 1995). Recently, both sports physiologists (Noakes, 1988; Hawley, 1995) and coaches have recognised the importance of peak sustained power output as a predictor of endurance performance.

Other variables include fatigue resistance (Noakes, 1988; Hawley, 1995; Holtzhausen et al., 1996), anaerobic threshold (Vago et al., 1987; McLellan & Jacobs, 1989; Louanne et al., 1989; Keith et al., 1992; Hirokoba et al., 1992; Urhausen et al., 1993; Burke et al., 1994; Hawley, 1995), economy of motion (Hawley, 1995; Brisswalter et al., 1996; McArdle et al., 1996) and fuel utilisation (Vago et al., 1987; Hawley, 1995).

The purpose of the study was to assess experimentally the physiological status of a Comrades Marathon athlete and to examine the effect of training on the physiological parameters. The

testing programme indicates the athletes' strengths and weaknesses in relation to marathon running and provides baseline data for an individual training programme prescription.

Five male marathon athletes volunteered to take part in the study. All the subjects were training for the 1998 Comrades Marathon. They had been following a training programme for a minimum of four years. The first testing occurred eight months before the Comrades; thereafter, another five tests were undertaken. Following an anthropometric evaluation, a maximal incremental treadmill test was undertaken to ascertain the  $VO_2$  max and endurance fitness of the athletes. The physiological parameters measured were oxygen consumption ( $VO_2$  max), maximal heartrate (HR), lactate threshold, ventilatory threshold, respiratory exchange ratio (R), and oxygen pulse. Each subject's best running times for distances of 10, 21, 42, 50, 56 and 90km had been recorded during the previous year. Training distances were also recorded during the testing period. Each subject ran the Comrades Marathon with a Polar Vantage NV to determine race intensity, heartrate response during the race, percentage below the lactate threshold and percentage above the lactate threshold.

It has to be stated that the results obtained from the tests cannot be used to make conclusions about the population (all marathon athletes), because the sample is not big enough or random enough. Therefore, it is a **case study** of five Comrades Marathon athletes, who were training for the 1998 Comrades Marathon.

The anthropometric data did not change much during the training months. The most substantial change could be seen in the fat percentage of the athletes (2.45% decrease). Since energy cost of running is a function of body mass, one way to maximise performance is to reduce excess body fat. Previous studies indicated that lower fat-free body weight is one of the variables primarily characterising the faster endurance runners (Costill, 1967; Housh et al., 1988). With every 1% increase in percentage fat, the  $VO_2$  max is reduced by slightly more than 1% (Londeree, 1986). All of the athletes did, however, show a decrease in LBM (3.37%). Greater body mass in the trunk area appears to be advantageous in terms of running economy. Conversely, those individuals who possess greater percentages of their body mass in the arms and legs may be able to obtain higher  $VO_2$  max values because a greater proportion of their lean muscle mass is active during running (Bailey et al., 1991). Several

studies reported a high relationship between  $\text{VO}_2$  max, body composition and endurance performance (Noakes, 1990; Brandon et al., 1995; Brisswalter et al., 1996). Berg et al. (1998) found a strong linear relationship between  $\text{VO}_2$  max (L/min) and gross body mass for ectomorphs and mesomorphs, while these two variables are unrelated to endomorphs.

The statistics indicated that some of the  $\text{VO}_2$  max parameters changed during the eight-month time period. It has been found, however, that some of the maximum parameters did not change to a great extent ( $\text{VE}/\text{VO}_2 = 0.01\%$ ,  $\text{VO}_2/\text{HR} = 1.3\%$ ,  $\text{VO}_2$  max = 3.54%,  $\text{VO}_2$  absolute = 0.98%,  $\text{RQ} = 0.58\%$ ,  $\text{VT} = 4.31\%$ ,  $\text{VE} = 0.73\%$ ); and speed and heartrate showed a decrease at the maximal exercise intensity (speed = -4.94%, heartrate = -4.37%). There was a greater improvement in parameters measured at threshold level ( $\text{VE}/\text{VO}_2 = 1.45\%$ ,  $\text{VO}_2/\text{HR} = 5.43\%$ ,  $\text{VO}_2$  max = 5.73%,  $\text{VO}_2$  absolute = 6.62%,  $\text{RQ} = 1.70\%$ ,  $\text{VT} = 4.19\%$ ,  $\text{VE} = 7.78\%$ , speed = 9.10% and heartrate = 6.34%).

Two important physiological variables are important in evaluating distance-running abilities. One is the velocity at anaerobic threshold – the pace at which blood lactate just starts to rise substantially. Marathon pace is slightly slower than this. Once  $\text{VO}_2$  max has been raised to as high a level as possible without inordinate additional training volumes, anaerobic development will make the additional difference between being optimally fit and marginally fit. The study of Noakes et al. (1990) shows that the physiological variables determining success at distances from 10-90km are not different, at least in marathon and ultramarathon specialists. This suggests that with appropriate training for longer distance events, the fastest 10km runners will also be the fastest marathon and ultramarathon runners. Athletes 1, 2 and 3 showed a very good speed at the lactate threshold (17.5-, 17.0- and 18.0 km/hr) in May before the Comrades Marathon. This correlates with the Comrades Marathon times that they achieved: 6h12 for athlete 1, 6h06 for athlete 2 and 6h08 for athlete 3. Athletes 4 and 5 indicate lower threshold speeds (16- and 14 km/hr). Their respective times achieved (8h41 and 9h18) were also much lower than those of athletes 1, 2 and 3.

Results indicated a decrease in all the athletes' (1–5) heart rate at maximal intensity and an increase in heart rate at lactate threshold intensity, except for athlete 1 who showed no difference at maximal intensity. Thus, training prescriptions based on heart rate at designated

metabolic markers with subsequent heart rate monitoring will enable coaches and athletes to monitor training intensity accurately. The ability, then, to sustain a high heart rate during prolonged exercise could be hypothesised to be necessary for a fast pace and fast finish time. According to this statement, athletes 1-5 improved their threshold heart rates, which is a very important improvement for Comrades Marathon athletes.

Only athlete 1 indicated a decrease in  $VE/VO_2$  at both lactate threshold (-11.74%) and maximal intensity (-8.03%). Athletes 3 and 4 showed an increase at lactate threshold intensity (13.81% and 10.12%). Athlete 5 showed an improvement only at the lactate threshold intensity (-2.27%). In healthy young adults, this ratio is usually maintained at approximately 25 L during submaximal exercise up to approximately 55% of the oxygen uptake. Thus, a decrease in  $VE/VO_2$  at ventilatory threshold indicates a better oxygen extraction potential, and is therefore advantageous for marathon athletes. Thus, although athletes 3 and 4 indicated an increase in  $VE/VO_2$ , all the athletes' (1–5) ventilatory equivalent are still below 30L, which is ideal for marathon runners.

All the athletes showed an increase in the oxygen pulse at lactate threshold and maximal intensity, except for athlete 5. Athlete 5 indicated a lower maximum heart rate (174 – 163 beats per minute) and his training was not very high in distance trained. The athletes' average improvement in lactate threshold is 5.43% compared to the 1.3% at maximal intensity. All the athletes' (1–5) oxygen pulse is within the ideal range of 20 –25 mlO<sub>2</sub>/HR.

A very positive improvement in the  $VO_2$  is shown at lactate threshold (5.73%) and maximal intensity (3.54%). Powers et al. (1983) demonstrated that the oxygen uptake measured at the ventilatory threshold was a better predictor of distance running success than either  $VO_2$  max or running economy (Louanne et al., 1989; Schneider et al, 1991). In this context, Yoshida et al. (1992) documented that endurance training induces an improvement of mitochondrial respiratory function resulting in a reduced production of lactate during heavy exercise. According to Yoshida et al. (1992), the positive improvement in the  $VO_2$  max (5.73%) and speed (16.67%) at lactate threshold intensity can be related to their endurance training.

A decrease in the RQ values (at lactate threshold intensity) in marathon athletes is advantageous; thus the decrease in both lactate threshold (-1.7%) and maximal intensity (-

0.58%) is a positive improvement. As a result of high volumes of endurance training and less speed work it is possible to have a decrease in the lactate tolerance and therefore a decrease in RQ values. The athletes speed at lactate threshold had, however, improved; this is an indication of the improvement of their aerobic system.

Lower ventilation, particularly over a prolonged effort (e.g. the Comrades Marathon), would mean, on a ratio basis, less oxygen to the respiratory muscles and more to the working skeletal muscles (Fox et al., 1993). Thus manipulation of the amount of ventilatory work necessary at a given running velocity could alter overall running economy (Bailey et al., 1991). However, tidal volume increased in both maximal (4.31%) and lactate threshold intensity (4.19%). The increase indicates a better percentage lungfilling with exercise at maximum and at lactate threshold intensity. All the athletes' lungfilling was below 65% of vital capacity, thus the improvement in  $V_T$  does not affect the running economy negatively.

Minute ventilation showed a small increase in maximal intensity (0.73%) and an increase of 7.78% at lactate threshold intensity. Endurance trained athletes demand a lower  $V_E$  than do untrained athletes (Bailey et al., 1991). Athletes 1 and 4 have exercise induced asthma and they indicate the highest minute ventilation (134.5 and 143.8 L respectively). Their values did, however, improve during their training for the Comrades. The other athletes indicate a relative low  $V_E$  (below 120 L). The level of  $V_E$ , with its removal of  $CO_2$ , thereby serves as the major determinant of arterial  $H^+$  ion concentration during this submaximal long-term work (i.e. at workloads ranging from a long training run to marathon or ultradistance racing). These changes in volume and rate dynamics are controlled automatically to optimise mechanical efficiency while maintaining normal blood  $O_2$  and  $CO_2$  concentrations. Thus, it is unwise for coaches or athletes to attempt voluntary regulation of breathing patterns (Martin & Coe, 1997).

A positive correlation was found between the actual Comrades time ( $p < 0.05$ ) and the distance trained. Athlete 2 had the highest training distance (4463km), and completed the Comrades in the fastest time (6h06). Athletes 3, 1, 4 and 5 followed him, in that order. Noakes (1992) states that elite runners perform best in the marathon and ultramarathon races when they train between 120 to 200 km per week, with an increasing likelihood that they will perform

indifferently when they train more than 200 km per week. None of these athletes trained more than 200 km per week. The studies of Scrimgeour et al. (1986), which report that athletes training less than 60 km a week have as much as 19% less running economy than athletes training more than 100 km a week, might support this suggestion. Most of athlete 5's training distance was below 60 km per week, thus, according to Scrimgeour et al. (1986) it is possible that athlete 5 was less economical than the other runners.

The relationship between the lactate threshold and the actual heart rate response indicated that none of the athletes could complete a 90km race at the lactate threshold intensity. It has been found that the athletes could only keep their heart rate above a certain percentage of the lactate threshold only for the duration of the race (30.3% above 95% of the lactate threshold, 58.3% above 90% of the lactate threshold and 77.3% above 85% of the lactate threshold). As a result of deteriorated running economy, especially during the last 20km, none of the athletes could complete the race between 2-4-mmol/L lactate. Optimal times in marathon and similar events are achieved by performing at 97 to 100% of lactate threshold (Hagberg, 1984). There is good evidence that both the lactate  $\dot{V}O_2$  and the lactate  $\dot{V}O_2$  (absolute) has a positive correlation with the percentage of time that the heart rate was above 90% and 95% of lactate threshold ( $p < 0.05$ ). No significant evidence was found that the corresponding maximum  $\dot{V}O_2$  has any relation to the percentage of time that the heart rate was above a certain level of lactate threshold ( $p > 0.05$ ). Powers et al. (1983) demonstrated that the oxygen uptake measured at the ventilatory threshold was a better predictor of distance running success than either  $\dot{V}O_2$  max or running economy (Louanne et al., 1989; Schneider et al, 1991).

Athletes 1, 2 and 3 were in the top 5% of the 1998 Comrades Marathon, and athletes 4 and 5 in the top 19% and 31% respectively. Therefore all the athletes were successful Comrades athletes. A positive correlation was found between the actual Comrades time ( $p < 0.05$ ) and the distance trained. Athlete 2 had done the highest trained distance (4463km), and completed the Comrades in the fastest time (6h06). Athletes 3, 1, 4 and 5 followed him, in that order.

It seems that more interval training and gymnasium work would be necessary to build enough of the stamina endurance which is an important parameter for Comrades athletes. Laboratory testing can help the athlete to optimise his running potential. Physiological parameters of

importance are an improvement at lactate threshold intensity and not at maximum intensity because those parameters simulate the race intensity.

The following recommendations are made to expand the knowledge of the physiological parameters of importance for ultra marathon athletes:

- Further adequate tests of experimental modifications of training load need to be made using athletically relevant outcome measures rather than laboratory variables, which, because laboratory conditions feel unnatural to the athlete, can impair the accuracy of the tests. Field testing, which simulates the natural environment for the athlete, should be undertaken as well.
- Effects of different treadmill protocols on peak sustained power output and OBLA. McConnel's (1988) findings suggest that a continuous protocol with workstage durations of 1 minute or less may be the most efficient in terms of testing time for obtaining  $VO_2$  max in runners and may be perceived as being less difficult by the runner.
- The measurement of lactate levels during and at the end of the Comrades Marathon. At the end of a marathon, trained athletes' blood lactic acid is only two to three times that found at rest (Costill et al., 1967).
- An examination of the difference between black and white Comrades athletes with similar  $VO_2$  max values. Bosch et al. (1990) show that subelite black runners matched with white runners for best 42 km marathon time had slightly lower  $VO_2$  max values than white runners, but compensated for this by sustaining a significantly higher %  $VO_2$  max during the marathon races.
- An examination of a gymnasium programme specially designed for Comrades athletes on the eccentric strength and recovery time when completing the down run. The impact on a downhill can increase as much as eight times the athlete's bodyweight (McGee, 1998). Therefore, the importance of eccentric contraction exercises to improve muscle endurance and decreased risk of injury has to be taken into account in the development of a gymnasium programme.