The South African Defence Force physical training programme

Part I. Effect of 1 year's military training on endurance fitness


Summary

The effect of the South African Defence Force's (SADF) military training on the endurance fitness of recruits was investigated. Pre-military training maximal O₂ consumption (53.14 ml/kg/min) did not change significantly during the study. In contrast, lactate turnpoint (ml O₂/kg/min) and treadmill performance time were modestly enhanced (7.5% and 8% respectively; \( P < 0.05 \)) by the initial 10-week basic training programme. Further analysis of the results showed this endurance-training effect to be limited to recruits of average and, in particular, below-average fitness. The salutary effect of basic training on fitness levels was, however, transient, the values on completion of 1 year's military training being unaltered from those before conscription. This preliminary assessment of the SADF physical training programme suggests a need for the introduction of changes during and, in particular, after basic training.

Historically, the assumption that military tasks involve a substantial degree of strenuous physical effort has provided the rationale for ensuring fitness among military personnel. Despite considerable recent technological advancement and increasing mechanization a high level of physical fitness has remained an essential requisite of the modern-day South African soldier. Irrespective of the energy demands on their daily duties, all South African Defence Force (SADF) personnel require a significant reserve of physical work capacity in order to cope successfully with the emergency situations that have become an expected feature of today's military life. Furthermore, it has been suggested that physical conditioning or enhanced fitness also improves morale, sense of well-being, health and sedentary job performance — benefits desirable for all soldiers.

For these reasons, new SADF recruits participate in a rigorous exercise training programme during their initial months of military conscription (basic training). It is, however, at present not known whether the current conditioning programme, essentially unaltered during the past decade, does in fact induce the desired enhancement of functional capacity. This is particularly important in view of recent allegations that the effectiveness of the SADF basic training centres may be limited by the injurious nature of the physical training used.

In contrast with basic training, the emphasis on physical conditioning is often markedly reduced during the subsequent phases of military service, presumably because of the extensive time required for specialized task training. It is therefore possible that the recruit's capacity for physical work might progressively deteriorate after basic training, eventually reverting to levels similar to those existing before military conscription. This would obviously negate physical conditioning benefits derived during basic training. Moreover, the soldier's fitness might be inadequate to deal with a fighting situation.

Because of the absence of accurate scientific data relating to these hypotheses, this prospective longitudinal study was designed as an initial evaluation of the SADF basic training programme in terms of both physical fitness attained and exertion-related injuries sustained, and to document fitness changes during and after military conscription. The incidence and nature of exertion-related injuries sustained at an SADF basic training centre will be documented in Part III.

Subjects and methods

Because of the short time interval between the arrival of recruits and the start of basic training, as well as the need to complete baseline evaluations before initiation of the physical conditioning programme, the first group of recruits reporting in July 1982 for military conscription at the large SADF basic training centre under investigation was briefed on the proposed project. Of these recruits, 100 presumably healthy randomly nominated subjects were asked to volunteer for the study and informed consent was obtained.

Experimental procedures

Subjects were initially evaluated during the 10 days before basic training and then subsequently, using identical experimental
Physical conditioning during basic training

The 10-week basic training programme consists of 4 phases of conditioning:

**Phase 1** (weeks 1 and 2). A 3.2 km run 5 mornings each week with the recruit wearing shorts, vest and 'takkies' (plimsolls); light calisthenics for 40 minutes on 4 afternoons each week. Recruits were required to complete an activity history questionnaire before testing. Because cigarette smoking may influence maximal aerobic capacity, the number of cigarettes smoked per day was also recorded. Nude body weight and height were measured using a calibrated Detecto medical scale. To estimate percentage body fat (%BF) the sum of four skinfolds (biceps, triceps, subscapular and suprailiac), measured by Harpenden skinfold calipers, was used together with the formulae of Durnin and Rahaman and Siri. Anthropometric characteristics determined with a standard Martin-type anthropometer, sliding caliper, and steel tape, were employed together with skinfolds to calculate somatypes according to the Heath-Carter method.

Subjects avoided strenuous physical activity for 24 hours before exercise testing and abated from meals, tea, coffee, cola beverages and cigarettes for at least 3 hours before exercise. All subjects were given an initial familiarization trial. For each subject, maximal O2 consumption (Vo2max), maximal heart rate (HRmax), lactate turnpoint (LaTtp), and other relevant cardiorespiratory variables were measured using a discontinuous graded treadmill exercise test. Subjects commenced walking on a Quinton (model 18 - 60) motor driven treadmill at a speed of 5 km/h and a gradient of 5%. The gradient remained constant and the speed was increased by 1.5 km/h with each successive 3-minute workload until volitional exhaustion. Subjects rested in the standing position for 1 minute between exercise bouts. Respiratory gas exchange was measured with a Cardio-Pulmonary Instruments Model 7000 Aerobic Metabolic System. Subjects breathed through a low resistance Hans Rudolph valve, the expired air being routed via a condenser unit into the input port of a dry rolling seal spirometer with a maximum capacity of 7.5 l. Volumetric displacement was converted into electrical impulses, which were counted over each 60 second period and subsequently further converted into volumetric units for processing and display by the data reduction package. Temperature was monitored by a thermal sensor located inside the spirometer chamber and employed for gas volume corrections. Expired air was sampled continuously from the exit port of the spirometer at a rate of 0.5 l/min for determination of mixed expired CO2 and O2 concentrations with an infrared absorption analyser and a polarographic O2 analyser respectively, at the end of each 60 second test interval. The gas analysers were calibrated by room air and standard concentrations of tank gas before and after each exercise test. The heart rate was read from the electrocardiogram (CM5 placement), which was continuously displayed on a Mennen oscilloscope, during the final 10 seconds of each 60 seconds of exercise. Peak heart rate and O2 consumption attained during exercise were taken as Vo2max and HRmax respectively.

Venous blood samples (approximately 2 ml) were obtained immediately on completion of each 3-minute work load from an antecubital vein through an indwelling vein infusion set (Venflon, Butterfly-19, Cat. No. 4590) kept patent with sterile heparinized saline (5 IU/l). Before sampling, approximately 1.5 ml of fluid was withdrawn and discarded. Blood samples were immediately placed in ice-cold 0.6N perchloric acid, the precipitated protein being removed by centrifugation, and blood lactate concentrations determined enzymatically. For each subject the relationship between blood lactate and submaximal O2 consumption was approximated by means of a biphasal linear regression model as described by Van Rensburg et al. LaTtp was defined as the O2 consumption at which blood lactate levels commenced to rise exponentially, and expressed as % Vo2max and ml O2/kg/min. Treadmill exercise performance time was calculated by subtracting the rest intervals from the total exercise test duration.

**Results**

**Pre-basic training medical evaluation**

Of the 100 recruits selected for this study 7 were not issued with full medical clearance for participation in all aspects of military training. Their results were therefore excluded from the study. Thus, the subjects initially comprised 93 medically-fit young adult South African national servicemen. The pre-basic training physical characteristics of these recruits are listed in Table I. Before starting national service the recruits smoked 4 ± 7 (mean ± SD) cigarettes/day, and their smoking habits did not change significantly during the study. Because of injury, illness, death (2 recruits in motor vehicle accidents while on leave from military training), scheduling conflicts, equipment malfunction, and voluntary decline, participation in certain evaluation procedures, the samples of recruits performing the different experimental procedures and test sessions varied in numbers.

| TABLE I. PRE-BASIC TRAINING PHYSICAL CHARACTERISTICS OF 93 SADF RECRUITS (MEAN ± SD) |
| Age (yrs) | 19.2 ± 3.2 |
| Height (cm) | 177.0 ± 6.5 |
| Weight (kg) | 67.5 ± 9.5 |
| Body fat (%) | 13.6 ± 3.2 |
| Endomorphy | 2.6 ± 0.8 |
| Mesomorphy | 4.4 ± 1.0 |
| Ectomorphy | 3.5 ± 1.1 |

**Effect of SADF basic training and subsequent military training on endurance fitness**

The effect of SADF military training on cardiorespiratory variables at maximal effort, LaTtp, and endurance performance is documented in Table II. The pre-basic training Vo2max of 53.14 ± 4.69 ml/kg/min did not change significantly during the test period. In contrast, LaTtp (ml O2/kg/min) and maximal treadmill exercise performance time were moderately (7.5% and 8% increase respectively) and statistically significantly enhanced by basic training. The observed endurance training effect was, however, transient and fitness levels were unaltered from the documented before military conscription on completion of 1 year's SADF military service.

**Stratification of training effect on basis of initial fitness level**

In an attempt to determine why the recruits showed no average improvement in Vo2max with basic training in the present study,
below-average fitness category responded to basic training with marked, statistically significant improvements in VO₂ max (ml/kg/min, 8% increase), LAₚ (ml O₂/kg/min, 20% increase; %VO₂ max, 11% increase), and treadmill performance time (22% increase) (Fig. 1). Furthermore, while the %BF of the entire study group remained unaltered during military training (Table III), basic training significantly reduced %BF of those of below-average fitness. The salutary effect of basic training on VO₂ max, LAₚ, exercise performance and %BF could, however, not be observed on completion of 1 year's military service in these recruits. In contrast with the below-average fitness recruits the average recruits failed to enhance their VO₂ max significantly during basic training (Fig. 2). Moreover, the VO₂ max of the above-average fitness recruits tended to decrease together with LAₚ and exercise performance during military training (Fig. 3).

### TABLE II. EFFECT OF SADF MILITARY TRAINING ON LAₚ AND SELECTED MAXIMAL CARDIORESPIRATORY VARIABLES (MEAN ± SD)

<table>
<thead>
<tr>
<th>Pre-BT</th>
<th>Post-BT</th>
<th>Post 1 yr</th>
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<tbody>
<tr>
<td>VO₂ max (l/min)</td>
<td>3.62 ± 0.58</td>
<td>3.72 ± 0.54</td>
</tr>
<tr>
<td>VO₂ max (ml/kg/min)</td>
<td>53.14 ± 4.69</td>
<td>55.04 ± 4.41</td>
</tr>
<tr>
<td>LAₚ (% VO₂ max)</td>
<td>71.7 ± 10.8</td>
<td>74.6 ± 8.7</td>
</tr>
<tr>
<td>R</td>
<td>1.09 ± 0.04</td>
<td>1.08 ± 0.03</td>
</tr>
<tr>
<td>VE (l/min)</td>
<td>128.6 ± 13.5</td>
<td>131.5 ± 14.1</td>
</tr>
<tr>
<td>VCO₂ (l/min)</td>
<td>3.95 ± 0.65</td>
<td>4.02 ± 0.60</td>
</tr>
<tr>
<td>HRmax (beats/min)</td>
<td>196 ± 7</td>
<td>194 ± 7</td>
</tr>
<tr>
<td>T (min)</td>
<td>20.8 ± 2.8</td>
<td>22.5 ± 2.7*</td>
</tr>
</tbody>
</table>

For VO₂ max (l/min), VO₂ max (ml/kg/min), R, VE, VCO₂, HRmax, and T — N = 85 pre-BT; N = 65 post-BT; and N = 53 post 1 yr.

For LAₚ (% VO₂ max) and LAₚ (ml/kg/min) — N = 83 pre-BT; N = 64 post-BT; and N = 52 post 1 yr.

VO₂ max = maximal O₂ consumption; LAₚ = lactate turnpoint; R = respiratory exchange ratio; VE = pulmonary ventilation; VCO₂ = CO₂ output; HRmax = maximal heart rate; T = performance time; pre-BT = pre-basic training; post-BT = post-basic training; and post 1 yr = on completion of 1 year's military training.

% VO₂ max = percentage VO₂ max; LAₚ = lactate turnpoint; %BF = percentage body fat; LBM = lean body mass; pre-BT = pre-basic training; post-BT = post-basic training; post 1 yr = on completion of 1 year's military training.

### TABLE III. EFFECT OF SADF MILITARY TRAINING ON WEIGHT, % BF AND LBM (MEAN ± SD)

<table>
<thead>
<tr>
<th>Pre-BT</th>
<th>Post-BT</th>
<th>Post 1 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>67.8 ± 9.5</td>
<td>68.3 ± 8.3</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>13.6 ± 3.2</td>
<td>13.0 ± 2.4</td>
</tr>
<tr>
<td>LBM (kg)</td>
<td>58.4 ± 7.2</td>
<td>59.4 ± 6.8</td>
</tr>
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</table>

% BF = percentage body fat; LBM = lean body mass; pre-BT = pre-basic training; post-BT = post-basic training; post 1 yr = on completion of 1 year's military training.

They were divided into three groups on the basis of their initial LAₚ (ml O₂/kg/min). The LAₚ expressed as ml O₂/kg/min was selected for this purpose because endurance performance changes have been shown to be more directly accounted for by this variable than other physiological attributes. Recruits in the above-average fitness category responded to basic training with marked, statistically significant improvements in VO₂ max (ml/kg/min, 8% increase), LAₚ (ml O₂/kg/min, 20% increase; %VO₂ max, 11% increase), and treadmill performance time (22% increase) (Fig. 1). Furthermore, while the %BF of the entire study group remained unaltered during military training (Table III), basic training significantly reduced %BF of those of below-average fitness. The salutary effect of basic training on VO₂ max, LAₚ, exercise performance and %BF could, however, not be observed on completion of 1 year's military service in these recruits. In contrast with the below-average fitness recruits the average recruits failed to enhance their VO₂ max significantly during basic training (Fig. 2). Moreover, the VO₂ max of the above-average fitness recruits tended to decrease together with LAₚ and exercise performance during military training (Fig. 3).

Fig. 1. Effect of SADF military training on endurance fitness levels of 15 below-average fitness recruits (mean ± SEM) (VO₂ max = maximal O₂ consumption; LAₚ = lactate turnpoint; T = performance time; HRmax = maximal heart rate; B = before basic training; A = after basic training; 1 yr = on completion of 1 year's military training) (** P < 0.05 v. B and 1 yr).
Fig. 2. Effect of SADF military training on endurance fitness levels of 19 average fitness recruits (mean ± SEM) (V̇O₂ max = maximal O₂ consumption; LAₜₐₚ = lactate turnpoint; T = performance time; HRₜₐₚ = maximal heart rate; B = before basic training; A = after basic training; 1 yr = on completion of 1 year’s military training) (** P < 0.05 v. B and 1 yr).

Discussion

Pre-basic training endurance capacity, fitness and % BF

The pre-basic training V̇O₂ max of 53.14 ml/kg/min is considerably higher than the value of 47.7 ml/kg/min documented by Wyndham’s group in 1966 for 80 fit young South African white males. Before the findings of the two studies can be compared, methodology and subject populations must be equated. Although both studies utilized similar exercise testing procedures, no explicit mention is made of Wyndham et al.’s subject sampling methods, or the ages, health status and leisure time physical activity levels of their subjects. This is of utmost importance since 7 subjects initially presumed fit were excluded from our investigation after medical screening, while a physical activity questionnaire revealed that 3 subjects had participated in endurance sports on a provincial level, 6 on a club level, and a further 7 had begun an endurance training programme in preparation for military service. Therefore, it is not possible to interpret our findings as indicating an improvement in maximal aerobic capacity of young South African males during the past 2 decades, although this postulate cannot be ignored.

Additional problems including mode of exercise, extrapolation of results of indirect tests, and effects of altitude on V̇O₂ max are confronted when making comparisons with foreign armed forces. However, although comparisons should be viewed with caution, it is apparent that the V̇O₂ max of the present SADF recruits compares favourably with the values of 42.0 ml/kg/min, 46.7 ml/kg/min, 50.7 ml/kg/min and 55.1 ml/kg/min recently reported for male British, Canadian, US and Finnish recruits, respectively.

Research has indicated that measures other than V̇O₂ max alone may be important determinants of endurance fitness. One such measure, the popularity of which has recently increased dramatically, is the ‘anaerobic threshold’. The measured ‘anaerobic threshold’ is, however, affected by a wide variety of experimental settings including site of blood sampling, precise definition of the point at which the ‘anaerobic threshold’ ensues, use of invasive versus noninvasive procedures, and exercise protocol employed. The present LAₜₐₚ therefore cannot be scientifically equated with the ‘anaerobic thresholds’ of previous studies with different methodology (the term ‘lactate turnpoint’ is used in preference to ‘anaerobic threshold’ when referring to the present O₂ consumption-blood lactate relationships in order to avoid any implication of causality).

Likewise, before interpreting and comparing the %BF values we recorded, one must be cognizant of the limitations and advantages of the methods used in the various studies. Densitometric underwater weighing techniques are generally considered the more accurate methods of determining body composition. However, estimates of %BF from skinfolds correlate reasonably well with recordings obtained by densitometry, and it thus appears feasible to interpret the 13.6 %BF observed in our study as characteristic of an active population. Moreover, the %BF of SADF recruits falls comfortably within the 13.6 - 17.1% and 12.5 - 17.6% ranges documented for US and British soldiers respectively.
Effect of SADF basic training on endurance capacity and fitness

A review of endurance training studies performed on young adult males indicates that moderate intensity programmes of relatively short duration can be expected to induce a change in VO\textsubscript{2 max} of approximately 10%.\textsuperscript{32} Similar data on alterations in 'anaerobic threshold' are scarce but suggest that this parameter may be more responsive to endurance conditioning than VO\textsubscript{2 max}.\textsuperscript{33-35} As a group, the SADF recruits displayed an insignificant increase in VO\textsubscript{2 max} accompanied by only moderate improvements in LA\textsubscript{a} after basic training.

The reasons why a conditioning programme of the present duration, frequency and intensity did not enhance these parameters more were unclear until the recruits were subdivided on the basis of their initial endurance fitness levels as assessed by their LA\textsubscript{a} expressed in ml O\textsubscript{2}/kg/min. This procedure revealed that the basic training programme provided the below-average and possibly the average, but not the above-average fitness recruits with an adequate training stimulus. Whether or not this is adequate will depend largely on the fitness requirement for subsequent job assignments and emergency situations, a factor currently undergoing investigation in the SADF.

However, in the assessment of a physical training regimen data pertaining to injuries sustained should be included in order to incorporate the element of feasibility of the particular approach. It is therefore noteworthy that 17% (14) of the recruits reporting for the post-basic training test session were unable to perform or complete the graded treadmill exercise test because of exertion-related injuries incurred during basic training. This fact considerably alters the interpretation of the present results of the actual efficacy of the SADF basic training programme.

While the programme could be considered effective in enhancing or maintaining endurance fitness levels in the majority of uninjured recruits, its feasibility is severely limited by the injurious nature of the conditioning modes used. This is seemingly applicable to recruits with low initial fitness levels who comprised more than 50% (8) of those injured. Although the incidence and nature of exertion-related injuries will be discussed in detail in Part III of this study and are considered to be multifactorial in origin, the present findings suggest that if all recruits are to derive significant improvements in endurance fitness and if the risk of injury induced by training is to be minimized, then it would appear to be prudent to stratify and train recruits in accordance with their pre-basic training fitness levels as is currently the situation in the US Army.

Endurance fitness levels on completion of 1 year's SADF military service

On completion of 1 year's SADF military service recruit fitness levels were insignificantly altered from those before military conscription but were less than those attained during basic training. The deterioration in endurance fitness after basic training is most evident when analysing the results of the
recruits who improved most significantly during basic training, i.e. the below-average fitness recruits. The major limitation of these findings is the likelihood that although physical training is to a large degree standardized at all SADF basic training centres, this is not true of the remainder of military service. Thus, while the need to increase the emphasis on physical training in certain SADF units after basic training has been established beyond doubt by the present results, further research will be needed before extrapolating this conclusion to the entire SADF.

Conclusions

This initial assessment of the efficacy of the SADF physical training programme has demonstrated the need for the introduction of changes during and, in particular, after basic training. Recruits should probably be categorized and receive basic training programmes that have demonstrated the need for the introduction of changes during and, in particular, after basic training. Such an approach, when coupled with adherence to scientifically validated physical training principles, is likely to ensure optimum development and maintenance of endurance fitness, thereby enhancing the effectiveness of the SADF.

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