The South African Defence Force
physical training programme

Part II. Effect of 1 year's military training on muscular strength, power, power-endurance, speed and flexibility


Summary
The effect of the South African Defence Force (SADF) military training on recruits' muscular strength, power, power-endurance, speed and flexibility was investigated. In the entire study group, a significant enhancement by basic training was observed for the isokinetic muscular strength of the right elbow extensors alone (17% increase; P < 0.05). Stratification of training responses on the basis of initial fitness levels revealed significant improvements with basic training for all measures of muscular strength, power, power-endurance and speed, but not flexibility, in the below-average fitness group. For all variables the training effect was transient and values documented on completion of 1 year's military training differed insignificantly from those recorded before conscription. In contrast, with the exception of elbow extensor muscular strength, fitness levels of the average and above-average recruits were not increased by basic training. While further research to assess physical requirements of various military work and emergency situations is needed to evaluate the desirability of this observed selective enhancement of recruit fitness levels during basic training, it is evident that greater emphasis should be placed on flexibility training, and physical conditioning after basic training.

For a soldier to be physically fit he must be able to meet both the ordinary and the unusual demands of his daily life safely and effectively. From an occupational point of view, physical fitness for military personnel may therefore be defined as the degree of ability to execute specific physical tasks under specific ambient conditions. Because of the wide variety of physically demanding situations the soldier may be confronted with it is obvious that a high level of endurance fitness alone will not suffice. Muscular strength, power, power-endurance, speed and flexibility are all likely to be essential facets of physical fitness in the military context.

Many studies have assessed the efficacy of military training programmes in enhancing the endurance capabilities of recruits.1-5 Very little attention has, however, been paid to other components of physical fitness. This can be attributed, at least in part, to the lack of reliable objective measures. Accuracy without subjectivity while measuring muscular strength, power and power-endurance has, however, recently been greatly enhanced with the Cybex 11 dynamometer (Lumex; Bay Shore, NY). Reliability of measurement by the dynamometer has been well documented,4,6 and so this device was used to assess the influence of the South African Defence Force (SADF) physical training programme on muscular strength, power, and power-endurance. Speed and flexibility were also evaluated, but with the aid of less sophisticated test procedures.

Subjects and methods
The subjects were initially 93 medically fit, young adult South African National Servicemen whose physical characteristics and selection criteria were documented in Part I of this article.7 Because of injury, illness, death (2 subjects died in motor vehicle accidents while on leave from military training), and scheduling conflicts, the samples consisted of varying numbers for the different experimental parameters and test sessions.

Experimental procedures
The subjects were evaluated during the 10 days before starting basic training and again, using identical experimental procedures, during the final 10 days of basic training and on completion of their first year of military service. During the final test period only those subjects who had completed the previous 2 evaluations were investigated.

To obtain objective measurements of dynamic strength (defined as maximum slow-speed torque capability), power (defined as maximum fast-speed torque capability), and power-endurance (defined as number of repetitions to 50% fatigue during a maximum effort fast speed test), the Cybex 11 dynamometer was used.8 Briefly, the Cybex 11 consists of a lever arm of constant length which can be attached to a part of the body and carried through a range of motion. The lever arm is mechanically prevented from surpassing a preset and constant speed, and the offered resistance is proportional to the dynamic tension produced in the muscle at every point in its shortening range. The force applied by the subject is recorded externally as torque. Torque is a measure of force that acts about an axis of rotation and is determined by...
taking the cross-product of the length of the lever arm, measured from the axis of rotation to the point of application of the force, by the component of force that is perpendicular to the lever arm. A pen recorder attached to the apparatus provided a continuous tracing of torque curves throughout the entire range of movement. A detailed description of the principles of isokinetic testing can be found elsewhere.10

Subjects were given complete instructions concerning the test and then participated in a familiarization trial. The test protocol included an initial warm-up period on a Monark cycle ergometer.

Each subject was then seated comfortably on a cushion platform with a backrest inclined at 15° from the vertical. The thigh of the test leg was immobilized by a velcro strap and the tibia was securely fastened to the lever arm at the ankle. The anatomical axis of rotation at the knee joint was aligned with the machine axis of rotation. Subjects were instructed to grip handles located at each side of the platform during muscular exertion. To obtain maximum knee flexion and extension strength measures each subject executed three repetitions at a speed of 60°/sec, with the left and then the right leg. A repetition constituted moving the leg from a 90° flexed position to full extension and back again. After a rest-period the speed was reset at 180°/sec in order to test power and power-endurance. Only the dominant leg was evaluated. Subjects were required to perform maximal complete repetitions until a criterion level of fatigue had been reached. The criterion fatigue level for this study was the repetition at which the extension torque level fell below 50% of the maximum extension torque level attained. The maximum extension torque level was used as an index of maximum instantaneous power for the knee extensor mechanism. The peak fast-speed torque attained during the initial test period was used as the 100% level for subsequent power-endurance evaluations performed after basic training and on completion of 1 year's military training.

Maximum torques for elbow flexion and extension were determined with the aid of the Cybex Upper-Body Exercise and Testing Table in order to minimize additive substitution of shoulder musculature in the movement pattern. The handgrip was set so that the subject's shoulder was in 45° abduction with the upper limb parallel to the input arm of the Cybex 11. Neutral positions of the shoulder relative to extension/flexion and the forearm relative to pronation/supination were established before each test and the axis of rotation at the elbow joint was aligned with the machine axis of rotation. After stabilization of the contralateral limb the torso stabilization strap was applied and tightened. The footrest was adjusted to ensure comfort. The subject then performed three maximum repetitions at a speed of 60°/sec, with the left and then the right arm. A repetition constituted moving the elbow joint from a fully flexed position to full extension and back again. During testing each effort was recorded on a single channel heat-sensitive recorder, integral of the Cybex 11 system, at a paper speed of 5 mm/sec. Maximum torque measures for slow-speed knee flexion and extension, and elbow flexion and extension, and fast-speed knee extension, were defined as the highest attained values recorded on the strip chart. Values for peak torque were expressed in units of Newton-metres (Nm). Strong verbal encouragement was given in order to push each subject to his true maximum torque capabilities.

Fig. 1. Effect of SADF military training on muscular strength for below-average recruits (mean ± SEM) (R = right; L = left; ext = extension; flex = flexion; B = before basic training; A = after basic training; 1 yr = on completion of 1 year's military training) (**p < 0.05 v. Band 1 yr).
Results

Effect of SADF military training on muscular strength

The effect of SADF basic training and subsequent military training on the maximal slow speed torque capabilities of the knee flexor/extensor and elbow flexor/extensor mechanisms is presented in Table I. The values recorded, with the exception of right elbow extension, were not significantly altered during the 1-year test period. The maximal right elbow extension torque capability was significantly greater after basic training than before military conscription (17%; \( P < 0.05 \)) and on completion of 1 year’s military training (15%; \( P < 0.05 \)).

Effect of SADF military training on power, power-endurance, speed and flexibility

Fast speed knee extension torque, knee extension power-endurance, time for a 50 m sprint, and flexibility were not significantly modified by basic training or subsequent military service (Table II).

Statistical methods

Significance of differences between experimental variables was analysed using one-way analysis of variance (ANOVA), followed by the Scheffe procedure when a significant F ratio was obtained. Statistical significance was established at the 0.05 confidence level.

Stratification of responses to military training on basis of initial fitness levels

For each fitness component investigated recruits were divided into three groups on the basis of initial values for the dependent...
TABLE I. EFFECT OF SADF MILITARY TRAINING ON MUSCULAR STRENGTH (MEAN ± SD)

<table>
<thead>
<tr>
<th>Muscular strength (Nm)</th>
<th>Pre-BT</th>
<th>Post-BT</th>
<th>Post-1 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right knee extension</td>
<td>221 ± 40</td>
<td>213 ± 41</td>
<td>217 ± 42</td>
</tr>
<tr>
<td>Left knee extension</td>
<td>208 ± 40</td>
<td>205 ± 41</td>
<td>211 ± 38</td>
</tr>
<tr>
<td>Right knee flexion</td>
<td>119 ± 29</td>
<td>125 ± 27</td>
<td>124 ± 24</td>
</tr>
<tr>
<td>Left knee flexion</td>
<td>114 ± 27</td>
<td>123 ± 28</td>
<td>122 ± 25</td>
</tr>
<tr>
<td>Right elbow extension</td>
<td>59 ± 18</td>
<td>69 ± 20*</td>
<td>60 ± 17</td>
</tr>
<tr>
<td>Left elbow extension</td>
<td>59 ± 19</td>
<td>64 ± 18</td>
<td>59 ± 16</td>
</tr>
<tr>
<td>Right elbow flexion</td>
<td>53 ± 13</td>
<td>55 ± 11</td>
<td>55 ± 11</td>
</tr>
</tbody>
</table>

Nm = Newton-metres; pre-BT = pre-basic training; post-BT = post-basic training; post-1 yr = on completion of 1 year's military training.

* P < 0.05 v. pre-BT and post-1 yr.

Variables. For the below-average recruits maximal slow speed torque capability of the right knee extensors (9% increase; P < 0.05), left knee extensors (9% increase; P < 0.05), right knee flexors (19.5% increase; P < 0.05), left knee flexors (24% increase; P < 0.05), right elbow extensors (37.5% increase; P < 0.05), left elbow extensors (31.5% increase; P < 0.05), right elbow flexors (21.5% increase; P < 0.05), and left elbow flexors (18% increase; P < 0.05) were significantly enhanced by basic training (Fig. 1). For all variables, this beneficial effect was transient in nature and the values recorded on completion of 1 year's military training differed insignificantly from those observed at first. In contrast, only the right and left elbow extensor maximal slow speed torque capabilities

Fig. 3. Effect of SADF military training on muscular strength for above-average recruits (mean ± SEM) (R = right; L = left; ext = extension; flex = flexion; B = before basic training; A = after basic training; 1 yr = on completion of 1 year's military training).
were significantly increased (17.5% and 14% respectively; \( P < 0.05 \)) by basic training for the average recruits (Fig. 2). As was the case for the below-average recruits, this extensor mechanism strength enhancement was no longer evident on completion of 1 year's military training. For the above-average recruits, all strength variables, including elbow extension, failed to increase to a statistically significant degree with basic training and remained unchanged from pre-basic training levels on completion of 1 year's military service (Fig. 3).

Similarly, maximal fast speed knee extensor torque capability (11% increase; \( P < 0.05 \)), power-endurance (21% increase; \( P < 0.05 \)) and sprint time (4% decrease; \( P < 0.05 \)) were significantly enhanced for the below-average recruits by basic training (Fig. 4). Flexibility, however, failed to improve for the below-average recruits. The measures of power, power-endurance, speed and flexibility were not significantly modified by basic training for the average (Fig. 5) and above-average recruits (Fig. 6). For all groups the values recorded on completion of 1 year's military training were essentially unaltered from those at the beginning.

**Discussion**

**Pre-basic training fitness levels**

The concept of isokinetic exercise was developed during the early 1960s by J. J. Perrine and first reported by Hislop and Perrine in 1967. Since that time isokinetic exercise has been used as a therapeutic modality in clinical settings; as a training mode for sportsmen; as a means of examining the relationships between force and velocity, and muscle agonist/antagonist action; and as a scientific, objective testing device. A review of the isokinetic exercise literature, however, shows two major deficiencies. The first is the lack of standardization of the test procedure; and the second is that although relative comparisons can be made between injured and uninjured limbs for a given individual, with the possible exception of knee flexion/extension slow speed torques, the normative data are sparse. Because a similar situation exists for the measures...
of speed and flexibility used in this study, it is not possible to make a meaningful scientific comparison between the present pre-training fitness levels and those documented for foreign armed forces.

**Effect of SADF basic training on muscular strength, power, power-endurance, speed and flexibility**

For the entire study group, a significant enhancement by basic training was observed only for the muscular strength of the right elbow extensors. In their investigation of the effects of 6 weeks of US Army basic training on the maximal voluntary isometric strength of the elbow flexors/extensors and knee flexors/extensors for 186 recruits, Vogel et al. similarly documented significant improvements for elbow extension alone. Although the precise cause is beyond the scope of the present data, one might reason that the elbow extensors are utilized to a large degree in the majority of upper-body calisthenic exercises performed during basic training. Considerable further speculation must, however, be entertained when attempting to explain the present greater strength enhancement for the right than left elbow extensor mechanism. One possible explanation is that all recruits are required to carry their rifles in their right hand with the elbow extended.

In contrast with our findings, Viitasalo and Vainikka failed to demonstrate statistically significant increases in the maximal voluntary isometric strength of the elbow extensors during Finnish basic training, whereas Knapik et al. more recently recorded small but significant improvements in isometrically assessed knee extensor strength for 750 male US Army basic trainees. Osternig et al. have, however, indicated that measures of maximal isokinetic strength in a group of subjects cannot be used to predict the isometric strength capabilities of the same group, even at the same angle within the range of joint movement.

While methodological differences therefore preclude a scientific comparison of our findings with those of previous studies, which have employed different test procedures, it is...
evident that strength increases induced by military basic training programmes are considerably smaller than those found in specific strength-training studies.\textsuperscript{6,19,20} This situation is likely to arise from the interplay of a variety of factors including the more general nature of military physical training programmes, the lack of access to strength-training apparatus, and the large variation in the trainability of the individual recruits. Regarding the latter, Müller\textsuperscript{21} has postulated that strength increases in an almost exponential manner with training. Initially, training induces rapid strength gains followed by gradual increases until a limiting strength is attained, with no further increases possible. Thus, the less trained a muscle group is at the beginning of the training period, the more it will gain in strength. In accordance with this hypothesis, the largest strength gains occurred in recruits who had maximal slow speed isokinetic torques below average for the group at the beginning of basic training.

Similarly power, power-endurance and speed were selectively improved during basic training so that the recruit sample became more homogeneous in respect of these fitness components. As was suggested for endurance fitness,\textsuperscript{7} the desirability of this situation, also reported during Finnish basic training,\textsuperscript{16} will largely depend on the physical fitness requirement for subsequent work assignments and emergency situations. If the objective of basic training is to bring all recruits up to a reasonably good standard of fitness, the present data suggest that this might have been accomplished for muscular strength, power, power-endurance and speed. If the objective is to challenge and improve the fitness levels of each recruit, then the SADF basic training programme has not succeeded. It is, however, apparent that the flexibility of South African basic trainees is not supplemented by the current basic training programme. While recognizing the need to test specific body parts in measuring flexibility and the fact that flexibility may be specific to the way it is measured,\textsuperscript{22} compound flexibility measures such as the stand and reach test are generally regarded as acceptable for determining intra-individual flexibility improvements.\textsuperscript{23} The present results there-
fore suggest a need to increase emphasis on flexibility enhancement during SADF basic training. This is of particular concern because adequate flexibility is believed to be important not only for superior physical performance but also for injury prevention.24

Fitness levels on completion of 1 year’s military service
The fitness components studied differed insignificantly from pre-basic training levels on completion of the first year of military service. Improvements derived by the below-average recruits during basic training were essentially lost during the subsequent portion of military service, indicating a markedly reduced emphasis on physical conditioning. Our results therefore highlight the need for greater attention to physical conditioning after basic training. Additional research will, however, be needed to determine the limitations of our observation when extrapolated to other units in the SADF.

Conclusion
The present study indicates that the SADF basic training programme conditioning benefits appear to be limited exclusively to those recruits with below-average muscular strength, power, power-endurance and speed. Further research aimed at assessing the physical requirements of various work and emergency situations will be required to elicit whether or not this is a satisfactory situation. It is, however, evident from this investigation that increased emphasis should be placed on flexibility training and physical conditioning after basic training.

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REFERENCES

Nuus en Kommentaar/News and Comment

The sound of music
Having a piece of music persistently repeating itself in the mind can be very irritating, but not many have the experience of an elderly arthritic lady with otosclerosis who was described in the New England Journal of Medicine (Allen. N Engl J Med 1985; 313: 642). She was referred for neurological opinion with it. Apart from otosclerosis and rheumatoid arthritis she was found to be quite healthy with no suggestion of psychosis. The mystery was partly solved when the patient was specifically asked about aspirin ingestion; she was found to be taking 12 tablets a day; and her serum salicylate level was 36 mg/dl (therapeutic range 0 - 30). When her aspirin intake was reduced to 6 tablets per day, the music in her head stopped. Although salicylates are known to cause tinnitus and hearing loss, the mechanism by which they caused ‘songs in the head’ in this patient remains a mystery.