EVALUATION OF THE SOUTH AFRICAN ARMY PHYSICAL TRAINING PROGRAMME : FITNESS ATTAINED AND INJURIES SUSTAINED

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To Mom, Dad, Tracey, and Kim

The great enemy of truth is very often not the lie - deliberate, contrived and dishonest - but the myth - persistent, persuasive and unrealistic. Too often we hold fast to the cliches of our forebears.

President John F. Kennedy,
Yale University Commencement,
1962.

ABSTRACT

Physical fitness has remained an essential requisite of modern-day armed forces. Despite considerable advances in the science of exercise training, the South African Army physical training programme has remained essentially unaltered for over a decade. Furthermore, it has been suggested that the efficacy of South African Army basic training centres might be limited by the injurious nature of the physical training modes used. The present 3-part investigation was therefore designed as an initial evaluation of the South African Army physical training programme in terms of both physical fitness attained and exertion-related injuries sustained.

In Part I of this study, the effect of 1 year South African Army training on endurance fitness was investigated. The pre-military training maximal O_2 consumption of 53.14 $m\ell.kg^{-1}.min^{-1}$ did not change significantly during the course of the study. In contrast, lactate turnpoint ($m\ell\ O_2.kg^{-1}.min^{-1}$) and maximal treadmill performance time were moderately enhanced (7.5% and 8% increase, respectively, $p < 0.05$) by the initial 10-week basic training programme. A further analysis of the results indicated that this endurance training effect was limited to the average and, in particular, the below-average fitness recruits. Although this could be regarded as an adequate situation, the effec= tiveness of the physical training was limited in that 17% of recruits were unable to complete the post-basic training exercise test as a result of exertion-related injuries; of these recruits more than 50% had initial below-average fitness levels. Furthermore, the observed beneficial effect of basic training on recruit endurance fitness levels was transient in nature, the values on completion of 1 year military training being essentially unaltered from those existing prior to military conscription. This

preliminary assessment of the South African Army physical training programme demonstrates a need for the introduction of changes during and, in particular, after basic training.

In Part II of this study, the effect of 1 year South African Army training on muscular strength, power, power-endurance, speed, and flexibility was investigated. When considering the entire study group, a significant enhance= ment 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 recruit fitness levels revealed significant ($p < 0.05$) improvements with basic training for all measures of muscular strength, power, power-endurance, and speed, but not flexibility, in the below-average fitness recruits. In contrast, with the exception of elbow extensor strength, fitness levels of the average and above-average recruits were not improved by basic training. Furthermore, for all recruit fitness groups, values documented on completion of 1 year military training differed insignificantly from those recorded prior to military conscription. Although further research (aimed at assessing the physical requirements of various military work and emergency situations) is needed to evaluate the desirability of the observed selective enhancement of recruit fitness levels, it is evident from the present data that greater emphasis should, at the very least, be placed on flexibility training and physical conditioning after basic training.

Finally, in Part III of this study the incidence and nature of exertion-related injuries sustained at a large South African Army basic training centre were studied.

A total of 404 separate injuries were incurred by 359 of 947 recruits during the 10-week basic training cycle. Of these injuries, 18.3% were sustained with (Group 1) and 81.7% without (Group 2) an obvious sudden acute precipitating event. Exertion-related injuries were responsible for a loss of 2 711 recruit-days of basic training. While the knee sustained the largest number of Group 2 injuries, lower-leg injuries resulted in the greatest loss of basic training time. Fourty two separate radiographically confirmed stress fractures were incurred by 39 recruits, the incidence of recruits with stress fractures being 4.12%, a value considerably higher than that of the United States Army. These data leave little doubt that the injurious nature of the South African Army basic training programme studied is costly in terms of training time lost and may prohibit large numbers of recruits from deriving the optimum conditioning benefits.

Parts of this thesis are to appear in the following publications:

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Gordon N F *et al*. Evaluation of the South African Defence Force physical training programme. Part III: Exertion-related injuries sustained at a South African Defence Force basic training centre. *South African Medical Journal (in press)*.

This is to certify that except for the technical help received from persons acknowledged in the text, this thesis is my own, unaided work. It is being submitted for the degree of Doctor of Philosophy in Medicine at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

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Note: The views, opinions, and findings contained in this thesis are my own and should not be construed as an official South African Defence Force position, policy, or decision, unless so designated by other official documentation.

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CHAPTER 1

INTRODUCTION AND AIMS

1.1 INTRODUCTION

Historically, the assumption that military tasks involve a substantial degree of strenuous physical effort has provided the rationale for ensuring fitness amongst military personnel. Despite considerable recent techno= logical 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 of their daily duties, all South African Army personnel require a significant reserve of physical work capacity in order to success= fully cope with the emergency situations that have become an expected feature of today's military life. Furthermore, the requirement for physical fitness need not be solely related to the physical demands of a soldier's job. In this respect, it has been suggested that physical training or enhanced fitness also imparts improved morale, sense of well-being, health, and seden= tary job performance (Shephard, 1977). Vogel *et al* (1978) have indicated that these benefits are desirable for all soldiers, irrespective of the actual physical demands of their job.

For the above reasons, all new South African Army recruits participate in an intensive exercise training programme during their initial months of military conscription (referred to as basic training). It is not known, however, whether the current physical condi= tioning programme, which has remained 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 South African Army basic training centres may be limited by the injurious nature of the physical training performed by the recruits (Cilliers and Gordon, 1983).

In contrast to 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 conceivable that a recruit's physical fitness might progressively deteriorate after basic training, eventually approaching levels similar to those existing prior to military conscription. This would obviously negate physical conditioning benefits derived during basic training. Moreover, the soldier's fitness might be inadequate when eventually confronted with a fighting situation.

1.2 AIMS OF STUDY

Because of the absence of accurate scientific data on the extent to which the above provisional hypotheses may be true, this prospective longitudinal study was designed as an initial evaluation of the South African Army basic training programme in terms of both physical fitness attained and exertion-related injuries sustained, and to document fitness levels on completion of 1 year military service. Without such information, future planning for improved South African Army physical conditioning programmes will remain in the realm of speculation.

The effect of military training on endurance fitness levels is dealt with in Part I of the study. In Part II, the influence of military service on muscular strength, power, power-endurance, speed, and flexibility will be examined. Finally, the incidence and nature of exertion-related injuries sustained at a South African Army basic training centre will be documented in Part III of the study.

CHAPTER 2

MILITARY PHYSICAL TRAINING : HISTORICAL BACKGROUND

2.1 THE PERIOD BEFORE THE FORMATION OF THE UNION OF SOUTH AFRICA : A WORLD HISTORY

2.1.1. ANCIENT SOCIETIES

Man has spent thousands of years emerging from his primitive state. From the age of the cavemen the way man has used his body, and not only his mind, has had an impact on society.

2.1.1.1 Egypt

The first light of civilization dawned in the rich agricultural plains of river valleys where transportation was readily available and sufficient food could be culti= vated in the same place generation after generation. Egypt, situated in the Nile valley where the soil is fertile, the sun favourable, and water easily accessible for crops and commerce, was one of the earliest cultures to emerge from barbarism.

Except for a brief period of their history, about the year 1500 BC, the Egyptians were not a conquering people, and therefore there was no need for promoting a military-type physical training programme for all citizens. Although little is known about physical training in the Egyptian military, van Dalen and Bennett (1971) have indicated that soldiers received instruction and drill in the martial arts from older professional warriors, many of whom were mercenaries. Egyptian soldiers are believed to have supplemented military exercises with various games and sports in order to develop skills that would be useful in war. Youths are reputed to have been sent to barrack schools where they underwent rigorous training in handling weapons, and *exercised to develop speed, strength, suppleness and agility* (van Dalen and Bennet, 1971). They also practiced wrestling, swimming, and war dances. Wrestling was a well developed art in Egypt; it was utilized by the warriors for physical conditioning and by the professionals for entertainment. It is generally believed that Egyptians wrestled from an upright position and did not permit any boxing blows such as the Greeks later used (van Dalen and Bennet, 1971).

2.1.1.2 China

The accepted history of China predates Christianity by approximately 2500 years. This oriental country was not only one of the earliest centres of civilization, but also one of the most enduring.

Although militarism existed, it did not cause the Chinese to focus their attention on physical training to the extent that it did in some cultures. Military duties were in fact regarded as a necessary evil rather than a national ideal; the national ideal was the aged scholar who was rewarded by an absence of physical labour (van Dalen and Bennet, 1971). Thus, the "desire for age" dominated the Chinese as intensively as the "pursuit for youth" dominates life in the Western World today. Such a point of view naturally discouraged excessive physical conditioning.

During the early development of the Chinese culture in the Chou dynasty (1122-249 BC), the general curriculum of the schools was almost entirely composed of literary studies (Monroe, 1919). However, the governmental examinations of the early years indicate that all national leaders were expected to possess some military efficiency (Monroe, 1919).

In later years, the government instituted special examinations for military men, and Chinese soldiers were not required to pursue an exhaustive literary training. In this respect, Laurie (1900) stated:

For the military service a very small knowledge of literature is needed. The special examination consists of physical exercises - the lifting of heavy weights, drawing the long bow, and the drill with the sword.

Many sports that developed in China were originally devised for their military usefulness (Gardiner, 1930). According to van Dalen and Bennett (1971), charioteering gave the Chinese the mobility that was the deciding factor in many of their victories. Archery was also stressed and various forms were studied; the cross bow came into use about the first century BC and the horseback style during the T'ang dynasty (618-907 AD). About 494 BC, stone throwing was a part of the military physical training programme. Various types of swords were developed and many styles of swordmanship evolved, particularly between 618 and 1127 AD. As was the case in Egypt, wrestling was important for men in the military; the period of the "Five Dynasties" (907-960 AD) is especially renowned for producing many famous Chinese wrestlers. Boxing was extensively developed for military purposes after Buddhidharma came to China about 527 AD. Football, one of the oldest Chinese sports, was first promoted as a military physical training mode; in *The Biography of Piao-Chi,* a general in the Han dynasty discloses that *when they were out in Mongolia the want of food robbed the (Chinese) army of its morale, but Piao-Chi dug holes in the ground and played football* (van Dalen and Sasajima, 1965).

2.1.1.3 Israel

Military training was essential for the Hebrews who were situated at the geographic crossroads of the ancient world and consequently subjected to frequent hostile assaults. For the nation to survive, its future warriors had to develop *strength, endurance and martial skills* (van Dalen and Bennett, 1971).

Without doubt, the early Hebrews admired attributes of physical strength, for some men are indicated in passages of the Scriptures to have been extremely strong. One instance of an exceptional display of strength, documented in *Genesis*, is when Jacob saw Rachel approaching and single-handedly rolled away from the mouth of a well the stone that ordinarily required the combined effort of shepherds to move. The familiar story of Samson provides another example of a hero's great physical power. Other feats of strength are attributed to David, Jonathan, Abishai, Eleazer, Joab, and Asakel, while Saul, the great war chief, is asserted to have gathered around him any strong men he saw.

Military physical training involved mainly training in the use of the bow and arrow, sword, shield, spear, and sling. Many passages in the Scriptures chronicle displays of skill that could not have been gained except through training and practice. For example, the following state= ments pertaining to the Hebrews are documented in the Scriptures: *And I will shoot three arrows on the side thereof, as though I shot at a mark (Sam.* 20:20); *He hath bent his bow and set me as a mark for the arrow (Lam. 3:12)*; and ... *seven hundred chosen men left-handed; everyone could sling stones at a hairbreadth, and not miss (Judg.* 20:16).

2.1.1.4 Greece

Three great peninsulae - the Spanish, the Italian, and the Balkan - extend from the European continent into the Mediterranean sea. The Balkans, the home of the ancient Greeks, served as the cultural bridge between the East and the West.

To fully understand the role of physical training in the Greek military, it is necessary to divide the Greek history into 4 eras: (i) Homeric era, prevailing from the prehistoric period down to the first Olympiad in 776 BC; (ii) Spartan era, prevailing throughout the entire history of Sparta; (iii) early Athenian era, prevailing from the first Olympiad to the end of the Persian Wars in 480 BC; and (iv) later Athenian era, or the "Golden Age" of Greece, lasting from the end of the Persian wars to the Macedonian conquest in 338 BC, and the "Hellenic Period", lasting until the formation of the Roman empire.

2.1.1.4.1 Homeric Era

Intermittent warfare prevailed during the Homeric era. Every citizen was a soldier and physical fitness was a necessity (Gardiner, 1910). The Greeks sought an all-round physical development. However, despite their extraordinary love of physical activities, they were not physical giants. Thus, Ridpath (1936) has stated:
They had not the height of the Barbarian or the muscular development of the Assyrians and Romans. It was rather in symmetrical activity than in massiveness or gigantic proportions that they surpassed the other races of their times. In beauty of body they were peerless .... No other people, indeed, were ever gifted with so great personal beauty ... and no others ever so much adored that gift.

The *Iliad* and the *Odyssey* give us an idea of the role played by sports in physical training during the Homeric era. In the *Iliad*, Book XXIII, Homer describes the funeral games held in honour of Patroclus, a friend of Achilles; events contested include a chariot race, boxing, wrestling, running, and javelin throwing. In the *Odyssey*, Homer documents other dramatic displays of athletic skills by Greek soldiers.

2.1.1.4.2 Spartan Era

By the eighth century BC the city-state of Sparta had begun the aggressive policy of invading the surrounding areas until the lower half of the Grecian peninsula was overcome. The Spartan government became increasingly militaristic and progress in other areas almost ceased. All citizens had only one profession - serving the state as soldiers.

Spartan physical training was designed to develop a "man of action" who possessed brute strength, physical endurance, unflinching courage, and military skill (van Dalen and Bennett, 1971). The Spartan Greeks had a very restricted concept of the purpose of physical training and they looked with contempt on athletic training for its own sake. The attitude of the Spartans toward athletics is best expressed in a poem of Tyrtaeus in which he declares that *he would set no store by speed of foot or skill in wrestling, apart from warlike might.* (Gardiner, 1910). Spartan physical training was training for war.

On the first day of school the Spartan youth was conscripted by the state. He would then remain in military service until at least the age of 50 years. The youths were grouped into companies of 64 boys, with one youngster selected as the leader. Of these companies, 4 were combined into a troop which was trained, disciplined, and directed by an *eiren*, a youth of about 20 years of age. Gymnastic exercises were the chief means of physi= cal conditioning for beginning youths. The gymnastics were graded in order to avoid injury. The initial training was also comprised of running and jumping which *conditioned the body and strengthened the legs* (van Dalen and Bennett, 1971). Exercises were gradually increased in degree and complexity, until the older youths were constantly performing military drills, hurling spears, practicing boxing, and developing wrest= ling skills. The Spartans recognized wrestling as a sport that would produce all-round physical development and train a man to take quick advantage of his opponent; 2 qualities that would be of use in time of war. Periodic testing by state officials, *ephors*, was adminis= tered to evaluate the boys' physical capacity. Examina= tions were particularly rigid for youths aged 18-20 years. Forbes (1929) has written: *And besides, it was written in the law that every ten days the youth stripped naked should pass in public review before the ephors. Now if they were solid and vigorous, resembling the work of a sculptor and the engraver, as a result of the gymnastic exercises, praise was accorded them; but if their physique displayed any flabbiness or flaccidity, with fat beginning to appear in rolls because of laziness, then were they beaten and punished.*

At the age of 20 years, the youths took the oath of allegiance to the state, and then began to engage in intensive military manoeuvers and in actual warfare. Until the age of 30 years, they were compelled to perform prescribed bodily exercises in addition to their military training. Even during war the Spartans were not released from their daily physical exercises, but the intensity and duration of the drills were mitigated. On other occasions, exercises were performed before breakfast and again, prior to the evening meal. In addition to these exercises, Greek law prescribed dancing as a physical training mode for the warriors. Dancing was utilized both for physical conditioning and as a means of welding troops into a complete military unit. Plutarch further states that *the military dance was an indefinable stimulus, which inflamed courage and gave strength to persevere in the paths of honour and valour.* (Vuillier, 1898).

At the age of 30 years, a man gained full citizenship and was expected to take a seat in the Spartan council. However, he still remained in military service until he was 50 years of age, and even at this age the state was able to request his continued military service.

2.1.1.4.3 Early Athenian Era

Until the sixth century BC, the Spartan and Athenian cultures were similar. Thereafter, Sparta grew more conservative and isolated, while Athens developed into a more liberal, progressive, and democratic society.

Athenians, in contrast to the Spartans, wanted youths to develop not only military skills and courage, but also the virtues and capacities needed for the peaceful progress of the nation. The Athenian ideal was to unite the "man of action" and the "man of wisdom" (van Dalen and Bennett, 1971).

On entry into school at the age of 7 years, youths did not embark immediately upon a strenuous physical training programme. Until 12 years of age, physical training consisted of light exercises and sports. In these early years, the boys were trained in "gesture", a type of exercise for the upper extremeties that was used in preparation for military training. Other activities included running, jumping, rope climbing, leapfrog, and ball games. The boys were also trained in javelin and discus throwing, but used a smaller discus than did adults (Gardiner, 1910).

Strenuous exercises were not introduced into the curriculum until the youngsters had undergone a few years of this general physical training. Older boys participated in a more vigorous programme of running, javelin and discus throwing, jumping, boxing, wrestling, and chariot racing. They continued these activities into adulthood, for men were expected to maintain the ability to perform these exercises and to participate in athletic contests.

The Olympic Games, the most celebrated of the national festivals, were held every 4 years, commencing in 886 BC (Gardiner, 1910). The games lasted 5 days in August. While the games were in progress, all waring tribes were expected to observe a truce.

2.1.1.4.4 Later Athenian Era

A new epoch in the Greek culture began after the victorious Persian Wars. Having defeated what was believed to be an almost invincible empire, the Athenians were filled with a sense of excitement, well-being, and self-confidence. As individuals and as a nation they were eager to expand and enjoy their new freedom and prestige.

Immediately after the Persian Wars, the citizens were still aware of the importance of physical fitness for military efficiency and continued to embrace the high ideals of the early Athenians. However, during the later Athenian period the Greeks became concerned with develop= ing a "man of wisdom" almost to the exclusion of the "man of action" (van Dalen and Bennett, 1971).

With the rise of intellectualism, the decline of military power, the replacement of citizen-soldiers by mercenaries, and the rapid rise of professional athletes, the interest of the Greek youth in physical training was diminished. Wealthy citizens were contemptuous of the old goals of physical conditioning, and a lack of exercise together with luxurious living began to take its toll. Critics who recognized this tried to warn the citizens.

Xenophon complained that the Athenians *not only neglect to make themselves fit, but mock at those who take the trouble to do so* (Marchant, 1928). He also emphasized Socrates' conviction that: *No citizen has a right to be amateur in the matter of physical training: it is part of his profession as a citizen to keep himself in good condition, ready to serve his state at a moment's notice. The instinct of self-preservation demands it likewise: for how helpless is the state of the ill-trained youth in war or danger!* (Gardiner, 1910).

Socrates appealed for the maintenance of physical fitness: *For in everything that men do the body is useful, and in all uses of the body it is of great importance to be in as high a state of physical efficiency as possible. Why, even in the process of thinking, in which the use of the body seems to be reduced to a minimum, it is a matter of common knowledge that grave mistakes may often be traced to bad health ... but a sound and health body is a strong protection to man* (Marchant, 1928).

Plato, a pupil of Socrates, contended that exercises should not be promoted as ends in themselves, but rather as a means of developing military fitness and healthy bodies to make healthy minds (Cubberley, 1920). In the *Protagoras* he advocated: *Then they send them to the master of gymnastics, in order that their bodies may better* *minister to the virtuous mind, and that they may not be compelled through bodily weakness to play the coward in War or on any other occasion* (Cubberley, 1920). Although peace was the state's ultimate objective, Plato stressed that it was necessary to be ready to fight if the state was threatened by a foreign aggressor (Forbes, 1929). He believed that the happiness of the state was so dependent upon physical fitness that the task of physical training could not be left to the parent. In his ideal society, the child was to be cared for by the family and a nurse until he was 3 years of age. From 3 until 6 years the youngster was to play in a nursery supervised by a responsible woman playground-director. From 6 to 16 years, he was required to attend a state school. The first 5 years here were to be spent in military and gymnastic training, and in mastering javelin throwing, archery, and horse riding. The next 5 years were to be devoted to the study of letters and instrumental music. From 16 to 20 years of age, the youth would have to do 2 or 3 years of gymnastic and military training. The programme was similar to the Ephebic College curriculum later adopted and included cross-country runs; patrols; practice in heavy arms, bows, and javelins; mock battles; and equestrian events (van Dalen and Bennett, 1971).

Likewise, Aristotle emphasized the military value of physical training, but indicated that conquest and war should not become the state's sole aim. He favoured athletics as a way of developing strong, healthy, well proportioned youths who would be able *to do all the things virtuous men must do in peace and war* (van Dalen and Bennett, 1971).

2.1.1.5 Rome

The Italian peninsula was the home of many tribal communities in ancient times. The smallest of these, Latium, was located near the Tiber River and the 7 Hills of Rome. This tiny political unit developed the force to extend its rule over the neighbouring tribes, the organizing ability to unite the Italian peninsula, and the dynamic power to rule the entire Mediterranean region.

Early Roman education stressed moral and military training more than intellectual attainment. For a nation that believed it was divinely elected to rule the world, physical training had one purpose: to make youths ready for war (van Dalen and Bennett, 1971). In contrast with Greek physical training, *Roman games and exercises were intended only to make men strong and skillful warriors; and it was not for beauty or form or grace of movement, but only for vigour and prowess in battle, that they were honoured by their fellow citizens* (Wilkens, 1878).

War was the prestige profession of the Romans and the army training programme was rigorous. The trainee was drilled in running, jumping, swimming, javelin throwing, and fencing. Soldiers also practiced archery and horse riding. Marches of about 30 km in distance were conducted 3 times a month, being covered at a speed of approximately 6 $km.hour^{-1}$ (van Dalen and Bennett, 1971). The soldier had to carry his armour, weapons, food, cooking utensils, and several long stakes whenever the army was on the move; the total pack was thought to have weighed up to 40 kg (van Dalen and Bennett, 1971).

Gradually, however, the emphasis on physical training for military purposes decreased and the Romans turned to exercise purely for entertainment, pleasure, and physical well-being.

2.1.2 MIDDLE AGES AND EARLY MODERN TIMES

2.1.2.1 <u>The Period Prior to the Renaissance</u>

As the warlike Germanic tribes gradually penetrated southern Europe, the corrupt and demoralized Roman government was unable to resist their advances or to continue providing essential law-enforcing services. With the government unable to protect and help them, frightened and frustrated people were forced to seek some manner of security.

Besides the church, at least 2 other institutions gradually evolved to answer this need; chivalry and feudalism.

2.1.2.1.1 Chivalry

Physical training formed the core of the chivalric curriculum in which youths were to acquire military prowess, social graces, and sporting skills (Cornish, 1901).

In childhood, the boy was taught various gymnastic exercises designed to strengthen his body. For squires the exercises became more rugged. Strength and endurance were developed by bearing heavy weights, running tremen= dous distances, springing on horseback fully armed without putting a foot in the stirrup, scaling walls with and without ladders, swimming with and without light armour, casting lances great distances, and striking heavy balls of wood with large racquets. Besides these exercises, youths practiced riding and managing arms, and attempted to develop the stamina needed to withstand hunger, heat, cold, and loss of sleep. Through active participation in sports of a warlike nature, youths were conditioned for their future life on the battlefield. It was held that *a youth must have seen his blood flow and felt his teeth* *crack under the blow of his adversary and have been thrown to the ground twenty times ... thus will he be able to face real war with hope of victory* (Cripps-Day, 1918).

The religious ideals connected with chivalry motivated young men to achieve the physical fitness and skill to fight for the cause of the church.

2.1.2.1.2 Feudalism

The rural, feudal society performed the services essential for survival after the fall of the Roman Empire, but such decentralized governments became inadequate during the later Middle Ages. By that time, important developments in warfare had occurred, particularly the invention of gunpowder, which greatly reduced the prestige of the knights.

The urban movement gained its first impetus from the crusades of the eleventh, twelfth, and thirteenth centuries. The townsmen of the later Middle Ages were never as devoted to physical training as were the knights, although they did perform military duties.

Regarding the use of sport as a physical training mode, in 1365 Edward III issued an edict declaring all sports illegal, with the exception of archery which had a military usefulness (Besant, 1906). Some 30 years later, Richard II passed a similar law, and the law was re-enacted by Henry IV in 1401 (Besant, 1906). In 1447 the Commons petitioned the king that *no person should use any unlawful plays as dice, quoits, football and such plays, but that every person mighty and able in body should use his bow, because that the defence of this land standeth much by archers* (Coulton, 1938).

2.1.2.2 The Renaissance

The seeds of progress sown in the Middle Ages came to bloom in the Renaissance. Between the fourteenth and seventeenth centuries 3 major movements swept Europe; Humanism, the first to emerge, was followed by Moralism and Realism.

2.1.2.2.1 Humanism

Italy was the nursery of the humanistic movement. Physical training was an integral part of early humanist education which sought the harmonious development of all aspects of man. Practically every great humanistic philosopher emphasized the need for devoting attention to physical conditioning. Many of the philosophers of the time engaged in "mind-versus-body" and "arms-versus-letters" debates, and sought to bring about a balance between these opposing forces.

Vegerius, who believed that arms as well as letters were of importance argued: *We cannot forestall the reality of war ... but by training and practice we can at least provide such preparation as the case admits* (Woodward, 1905). He advocated that youths engage regularly in games and exercises that would prepare them for military duties and stated: *So, too, our youth must learn the art of the sword ...; the use of the shield; of the spear; of the club; training either hand to wield the weapon. Further, swimming ..., running, jumping, wrest=ling, boxing, javelin throwing, archery, through horse=manship, in sport or in war - these are all needful to the full training of the soldier* (Woodward, 1905).

Vegius recommended physical exercise *for training the youth in the arts of war which seem to be necessary both privately and publicly for preserving safety.* (Fanning, 1933).

Likewise, Pope Pius II declared that: *Every youth destined to exalted position should further be trained in military exercises* (Woodward, 1905). Thus, the Italian humanists embraced the classical ideal of "a sound mind in a sound body".

The humanistic movement did not reach the rest of Europe until a century after it had vitalized Italy. Few humanists were as concerned with physical condition= ing as Thomas Elyot, a contemporary of Henry VIII. In *The Boke Named the Governour* (1883) he devoted particular attention to physical activities for youths. Running, hunting, and hawking were recommended, as was wrestling - but only if proper precautions were taken to prevent injury. He considered swimming to be an honourable exercise that would prove profitable in war. Other military activities such as horse-riding and managing the sword, battle-axe, and long bow, were favoured by Elyot.

Archery, which had risen in importance as a means of warfare, continued to hold that position during most of the fifteenth and sixteenth centuries. Henry VIII passed 3 acts obliging *every king's subject to practice shooting with the long bow* (Strutt, 1850). Roger Ascham's book *Toxophilus* (Giles, 1864) was a treatise on the art of shooting with the bow. However, despite Ascham's loyalty to bows and arrows, the English Army relegated them to a secondary position after 1588 when their experiment with firearms against the archers in the Spanish Armada proved highly successful; that battle sounded the death note of archery as a military weapon (van Dalen and Bennett, 1971).

2.1.2.2.2 Moralism

Humanism supplied the intellectual fuse for one of the most extensive and complex cultural transformations of modern times, the Protestant Reformation.

Although the Reformation and the Humanistic movement never coalesced, a close relationship existed between them. Nearly all reformers were humanists, but not all humanists were reformers.

During the Reformation the Protestant sects relegated physical training to an inferior position and intensively endeavoured to curb worldly pleasures.

Zwingli, the Swiss religious leader, appreciated the values of physical conditioning far more than most Protestant reformers (Reichenback, 1899). In his opinion, all sports and games had to be directed towards worthy purposes. He wrote: *Games played with one's companions, at proper times, I allow provided they are games that require skill and serve to train the body* (Reichenback, 1899). He advocated military training *so far as it was necessary for defence of the fatherland* (Reichenback, 1899).

2.1.2.2.3 Realism

As different sects became established, each tended to suppress individual judgement and to require unquestioning obedience to the authority of the church. Realism arose as a movement of protest to these conditions.

The realists once again reminded the pedagogy that man had a body that needed to be developed, as well as a mind. Juan Luis Vives (1492-1540) believed that the only purposes of exercise were to provide a regenerative force upon which the mind could draw when exhausted and to develop a vitalized body that would support greater mental powers (Woodward, 1924). Vives censured any overemphasis of physical training, and denounced the promotion of physical conditioning for increasing military efficiency as being incompatible with the Christian doctrine of love (Vives, 1913). In this last belief, Vives differed with the opinions of Francois Rabelais (1483-1553) and John Milton (1508-1674).

As regards physical conditioning, Rabelais' objectives were confined primarily to war (Rabelais, 1849). Similarly, Milton desired to utilize physical training for the duties of war (van Dalen and Bennett, 1971).

In his philosophical writings, Francis Bacon (1561-1626) briefly mentioned physical training. Bacon noted that *there seemeth to be a relation or conformity between the good of the mind and the good of the body* (Wright, 1900). He divided the *good of the body* into health, beauty, strength, and pleasure and recommended that athletic skill should be practiced sufficiently for use, but that excessive exercise could serve only for *mercenary ostentation* (Wright, 1900).

Perhaps more than any other writer of the day, Richard Mulcaster (1531-1611), headmaster of Merchant Taylor and St Paul's schools, insisted upon the importance of physical training. However, although Mulcaster (1581) recognized that exercise training could serve a military purpose, he was interested mainly in the value of exercise in ensuring good health.

2.1.2.3 Early Modern Times

The eighteenth century, known as the "Age of Enlighten= ment", marked a philosophical rebellion against the enslavement of the individual. During this period the importance of exercise for health, rather than military proficiency, was emphasized. Medical men began to study anatomy and physiology and a number of treatises appeared concerning exercises and their influence on health.

2.1.3 MODERN TIMES

During the nineteenth and early twentieth century the major developments in military physical training that were subsequently to influence the South African Army took place in Germany, Sweden, and England.

2.1.3.1 Germany

At the turn of the nineteenth century Germany was a conglomeration of some 300 sovereignties, ecclesias= tical states, and free cities. Politically these govern= ments were at variance with anything resembling harmonious thought or action, but culturally they shared many senti= ments. Fear of the Napoleonic shadow being cast over Europe finally united Germany.

For decades physical training in Germany paralleled the politics of the nation. In the early years, it was most pronounced during liberal movements only to be suppressed during reactionary periods.

The first protagonists of the benefits of exercise were political liberals under the vigorous and colourful leadership of Fredrich Ludwig Jahn (1778-1852). To Jahn, *physical education was not the goal; it was a means to a national end* (Kohn, 1967). German freedom and strength depended upon the youth of the state and therefore the supreme aim of physical training was to develop the power necessary to overcome any invasion. Unlike most leaders with militaristic aspirations, Jahn bolstered rather than crushed the spirit of individualism (von Raumer, 1860); men kept physically fit with the idea not only of securing freedom for their nation, but also greater personal freedom. In June 1811, Jahn, aided by a teaching colleague, Friedrich Friesen, opened his first "Turnplatz" (playground) on the outskirts of Berlin (van Dalen and Bennett, 1971). The playground was an enclosed rectangular area equipped with a small hut for dressing and a few roughly-made pieces of apparatus. In 1812, an enlarged "Turnplatz" was completed with additional and more elaborate facilities including a new running track (van Dalen and Bennett, 1971). When the War of Liberation broke out in 1813 Jahn and Friesen were among the first to join the armed forces seeking to free Germany from Napoleonic domination, and the "Turnplatz" was used to train soldiers (van Dalen and Bennett, 1971).

Between 1840 and 1860, Hugo Rothstein (1810-1865), an officer in the German Army, became an adherent to the Swedish Ling system of gymnastics and imported it into Germany where he was successful in introducing some aspects of it into the schools and military (van Dalen and Bennett, 1971). This system utilized calisthenics, military gymnastics, fencing, bayonet and rifle drills, and corrective and aesthetic gymnastics. The philosophies of Rothstein are reflected in the following official statement: *School gymnastics should, by means of approp-riately selected and well-ordered exercises, promote the bodily development of the children, strengthen their* *health, habituate the body to a natural and pleasing carriage, increase the strength, endurance, and dexterity of the body in the use of its members, and secure the adoption of certain useful forms of dexterity, particularly with reference to future service under arms in the army of the Fatherland* (Hartwell, 1899).

After 1870 and until World War I, the Swedish Ling system coalesced with a system of organized gymnastics introduced by Adolph Spiess to form the German military physical training programme (van Dalen and Bennett, 1971).

2.1.3.2 Sweden

As in Germany after the Napoleonic defeats, Swedish philosophers, poets, intellectuals, and soldiers were fired with a desire to rebuild the prestige and honor of their country. At this time, Per Henrik Ling (1776-1839), who was to become the founder of the Swedish Ling system of gymnastics, was inspired to embark upon his life's work (Prytz, 1941). As a student in Copenhagen he engaged in fencing lessons and is said to have noticed an improvement in an afflicted arm. Thus, he became intrigued with the effect of exercise on the body. Patriotic motives impelled Ling to promote a form of exercise that would make his countrymen strong and capable of defending their fatherland. To achieve this end he extended physical training in 4 directions: military, medical, pedagogical, and aesthetic - he believed that all were interdependent (Prytz, 1941). In 1813 he helped establish the Royal Central Institute of Gymnastics, known as the GCI, at Stockholm. The first classes were held in 1814 and for the remaining 25 years of his life, Ling directed the Institute. Very early in his career, Ling introduced the posture-correcting element of Swedish gymnastics and devised a system of free-standing exercises. Free-standing exercises were particularly appealing to consisted of dull, rigid, routines.

2.1.3.3 England

The systematic physical exercises originating in Germany and Sweden in the post-Napoleonic period were brought to England early on. British officers travelling in Switzerland observed the gymnastic training that Phokion Clias was giving to troops. They were so impressed, that in 1822 they invited him to London to institute his work for the military (van Dalen and Bennett, 1971). He was given the rank of captain and made superin= tendent of physical training in the royal military and naval academies. Clias taught mainly the exercises of Jahn, and invented an apparatus called the "triangle" which was essentially a movable horizontal bar suspended by ropes from a swivel support in the ceiling. Clias was convinced that gymnastic training, in addition to enhancing fitness, could also impart those moral qualities and social graces essential to a well rounded personality, and urged that gymnastic instruction be extended to civilians as well as soldiers. Following an injury in 1825, Clias retired and returned to Switzerland.

Clias stimulated a brief interest in exercise in London which was revived about the middle of the nineteenth century when Archibald Maclaren (1820-1884), who had been operating a fencing school, opened a private gymnasium in Oxford in 1858. Two years later, the army asked him to revise its physical training programme (van Dalen and Bennett, 1971). Maclaren's manual, *A Military System of Gymnastic Exercises for the Use of Instructors* (1862), was subsequently adopted by the army, and his book, *System of Physical Education, Theoretical and Practical* (1869), is a classic in the field. Maclaren trained a group of non-commissioned officers, who after finishing their course with him returned to a new army gymnasium at Aldershot and created a school for the training of military physical training instructors. Maclaren was a research pioneer, and attempted to determine the appropriate exercise for each individual by photographing and measuring height and weight, and chest, bicep, calf, and thigh girths. He believed that games and sport alone where inadequate for military physical training and that additional exercises were required. However, despite Maclaren's efforts, the army eventually turned to the Swedish Ling system of gymnastics.

The Ling system was introduced to Britain by Lieutenant Govert Indebetou in 1838, Lieutenant C. Ehrenhoff in the early 1840s, and especially by Carl A. Georgii in 1850; all were graduates of the GCI in Sweden (van Dalen and Bennett, 1971). The Boer War of 1899-1902 drew attention to the importance of physical fitness for military proficiency. As a result, the Swedish Ling system of exercises was officially adopted by the navy in 1903 and the army in 1906 (van Dalen and Bennett, 1971).

2.2 THE PERIOD AFTER THE FORMATION OF THE UNION OF SOUTH AFRICA: PHYSICAL TRAINING IN THE SOUTH AFRICAN ARMY*

2.2.1 THE PERIOD PRIOR TO 1925

The South African Defence Act of 1912 resulted in the formation of the South African Permanent and Citizen Force Units. The physical training performed by these units during the 2 years prior to the First World War is not known. During the war years, horse-riding and outdoor living, in conjunction with marching and other military

*The information documented in this section was obtained by means of: i. consultation of numerous official and unofficial military documents; ii. interviews with relevant military personnel; and iii. consultation of the text's of Loubser (1961), Geyer (1969), and Goosen (1970).

activities, are believed to have been the major factors contributing to the physical well-being of the soldiers.

After the First World War the Permanent Force consisted mainly of mounted units whose daily routine comprised horsemanship, mounted and unmounted drill, and training with weapons. No structured physical training was performed between 1919 and 1923.

The first structured course in physical training was held at the South African Military School, Roberts Heights, during September and October 1922 (Physical and Recreational Course, No 7G). The course was conducted under the leadership of J.L. Higgin-Botham, an ex-English Warrant Officer, and was attended by 12 regimental non-commissioned officers. The syllabus consisted of exercises of Swedish origin, equitation, and spring-bayonet fighting. A series of exercises termed the *Permanent Force Physical Training Table* were introduced. The Table was designed to develop the various body-parts and commenced with marching and ended with breathing exercises.

Early in 1923, a general instructors qualification course was conducted at the Military School, once again under the supervision of Warrant Officer J.L. Higgin-Botham. Physical training was performed for 1 period each day, the remainder of the day being utilized for the study of other military-related subjects. Exercises were of Swedish origin and were known as the *Six Union Tables*. The physical training was supplemented with club-swinging activities, exercises on the horizontal and parallel bar apparatus, and rope-climbing. Participation in sports was left to the discretion of the students.

In 1923, Major T.H. Wand-Tetly of the British Army was seconded to the South African Military School. He attempted to conduct physical training in the South African Defence Force upon modern lines and was described as *a great physical educationalist, sportsman and organiser.*

In November 1923 "The First Long Course in Physical and Recreational Training" was held under the supervision of Major Wand-Tetly. The course was of 3 months duration and was attended by 21 students. Physical training tables were compiled on a more scientific basis. Physical training was supplemented by gymnastics, unarmed combat, ju-jitsu, and spring-bayonet fighting. The students also received instruction in athletics, swimming, boxing, wrestling, and equitation. The students were lectured to on physical training methods, anatomy, physiology, and a variety of relevant medical aspects. Major F.H. Weech of the South African Medical Unit assisted with the medically-orientated phases of the course.

"The Second Long Course in Physical and Recreational Training" was conducted by Major Wand-Tetly in February and March 1924. This course was attended by 35 students, 1 of whom (Sergeant P.L. Grobbelaar) was later to make a significant contribution to physical training in the South African Defence Force. Soon after the completion of the course Major Wand-Tetly returned to England. Fortunately, he had left a nucleus of trained instructors behind in South Africa.

2.2.2 THE PERIOD 1925 TO 1935

During the period 1925 to 1935 not much emphasis was placed on physical training in the South African Defence Force. At the South African Military College, Permanent Force cadets participated in physical training only for a few periods a week.

In 1927, after returning from a course in physical education at Aldershot, England, Sergeant P.L. Grobbelaar gave new impetus to physical training at the South African Police Training Depot. He organized a number of physical training instructor courses for the police and conducted these courses on a scientific basis. The South African Defence Force soon realized that they were lagging behind as regards physical training and accordingly selected 2 instructors from the South African Artillery Division, Corporal Schmidt and Corporal Carelson, to attend a 9-month course in physical training at the South African Police Training Depot. The course was comprehensive and comprised free-standing exercises, gymnastics, boxing, wrestling, spring-bayonet fighting, and life-saving. Lectures were given on anatomy, physiology, first-aid, and refereeing for various sports. Both instructors, on completion of the course, conveyed what they had learnt to the newly-formed Special Service Battalion.

The Special Service Battalion was formed in 1933 to provide employment for the thousands of young men adversely effected by the depression and drought prevailing at that time. The aim of the Special Service Battalion was to discipline these young men, improve their physical fitness, and provide them with a sound military knowledge. Thus, physical training formed the basis of all training in the Special Service Battalion. From 1934 up until the out= break of the Second World War this unit gave mass physical training displays annually in various parts of South Africa.

2.2.3 THE PERIOD 1935 TO 1959

The South African Defence Force authorities, in an attempt to maintain a high standard of physical fitness, selected Sergeant J.A. Wallis to attend a series of physical training courses at Aldershot in 1935. Sergeant Wallis returned to South Africa early in 1936 and immediately implemented what he had learned, at the South African Military College. At that stage, no formal establishment was in existence for the training of military physical training instructors. The first step towards the formation of such an establishment came in May 1937 when Sergeant Wallis conducted a 6-week physical training course and a "Games Leaders Course" at the South African Military College. This course was attended by 1 officer and 14 non-commissioned officers.

As a result of the wave of enthusiasm that was sweeping South Africa at the time, it was decided to send a Permanent Force officer, Lieutenant D.S. Pretorius, for overseas training, and to second aid from the British Army for the formation of a specialised physical training branch in the South African Defence Force. On completion of his overseas training at the Army School of Physical Training at Aldershot, early in 1937, Lieutenant D.S. Pretorius was posted to the newly formed Physical Training Branch at the South African Military College where he served as officer-instructor until 1954.

Early in 1938, Major F.S. Barlow and Warrant Officer G. Barber from the Army Physical Training Corps (United Kingdom) arrived at the South African Military College to assist with physical training. In 1939, the gymnasium then in existence was converted into a modern gymnasium together with offices, and named the "Physical Training Branch of the South African Military College". This branch was to be used as a centre for the training of South African Defence Force instructors. At the same time, the British Army physical training system, containing what was thought to be the best aspects of the various conti= nental military training systems, was introduced at the new branch of the College. Thus, when Major Barlow departed for England in 1940, he left behind a fully trained staff to continue the training of instructors. Warrant Officer Barber remained at the training branch until the termination of World War II.

On returning from a visit to a number of foreign armed forces, Captain D.H. Craven was appointed as "Organiser of Physical Training" in the South African Defence Force on 23 November 1939. In 1940 he was promoted to the rank of major and on 25 October 1940 subsequently issued an order stating that all members of the South African Defence Force must participate in a daily 45-minute physical training period. From that date on, physical training became a compulsory part of the military training programme in South Africa. Major Craven recommended that various sports and games be utilized for physical training in preference to the British system. The physical training programme introduced by Major Craven was adhered to until 1959.

2.2.4 THE PERIOD 1959 TO 1966

In 1959 a new physical training programme was introduced in the South African Defence Force. This system which was adhered to until 1966, recognized the fact that specific exercises could be utilized to develop the various compo= nents of physical fitness and that the intensity and volume of such training should be incremented on a pro= gressive basis. Physical training was generally performed for 45 minutes each day and consisted of the following:

i. *Marching and running* (4 minutes) - aimed at developing the leg muscles and to serve as a warm-up for the subsequent physical training.

ii. *Introductory exercises* (6 minutes) - aimed at improving co-ordination and to serve as a warm-up.

iii. *Breathing exercises* (1 minute) - aimed at developing the lungs.

iv. *Games* (4 minutes) - aimed at building team-spirit and at breaking the monotony of the training sessions.

v. *Posture exercises* (8 minutes) - aimed at developing the muscles involved in sitting, standing, and walking.

vi. *Conditioning exercises* (10 minutes) - aimed primarily at the development of strength-fitness.

vii. *General physical activities* (10 minutes) - aimed at promoting general physical fitness through competition.

viii. *Calming exercises* (2 minutes) - aimed at cooling-off after exercise.

During this period, the Republic of South Africa was formed (1961).

2.2.5 THE PERIOD 1966 TO 1970

In 1966, a text entitled *Guide to Battle Physical Training* was compiled by the Physical Training Branch of the South African Military College, Voortrekkerhoogte. The Guide listed the following 6 aims of physical training:

i. *To prepare the recruit physically and mentally for war.*

ii. *To maintain the trained soldier's physical fitness for his particular role in war.*

iii. *The promotion and maintenance of good health and physical well-being of ... employed men and sedentary workers.*

iv. *... to produce general muscular development.*

v. *To develop self-confidence.*

vi. *To develop other soldierly qualities.*

In order to achieve the above aims, a "group" training plan was devised. The purpose of this was to *ensure that all men receive physical training which is suited to their standard of fitness and service requirements.*

As with the physical training programme introduced in 1959, the basic principle involved was that of "progressive physical training". This was achieved by gradually increasing the resistance to a movement, the cadence, the distance covered, and the complexity of a movement. Progression was believed to be the key to the prevention of exertion-related injuries and it was stated in the Guide that: *The most important single factor in the prevention of accidents is a strict adherence to the principle of gradual and controlled progression.*

Recruits were expected to perform physical training 3 times each week, both during and after basic training. Each physical training session was of 40 minutes duration and divided into 5 parts as follows:

Part I - *Mobility and Limbering Up* (7 minutes). This included an initial *brisk and stimulating game* followed by exercises for the shoulders, arms, trunk, and legs. No mention is made, however, of flexibility training per se.

Part II - *Minor Game* (1 minute). A brief team game was recommended to further prepare the recruits for the more strenuous exercise which was to follow.

Part III - *Strengthening* (12 minutes). A variety of exercises which utilized the recruits own body weight for resistance were proposed for the strengthening of the shoulders, trunk, abdominal muscles, and back. In addition, exercises utilizing rifles, logs, medicine balls, shells, and fellow recruits were outlined.

Part IV - *Agility and Endurance* (18 minutes). These activities were to be performed in teams. Walking and running were recommended for enhancing endurance fitness. The correct technique involved in walking and running was explained at great length. It was recommended that: *A quick walk of about 4 miles per hour should begin the road work; At first, the distance should NOT be more than a mile, and should be increased gradually to a maximum distance of two miles; When the men can cover the distance in good time and with little fatigue, the training can be stepped up to a slow run with occasional short sprints, and then reverting back to a good walking pace;* and *The unit must be grouped, by means of grading tests, into ability groups for endurance training.* The training was to progress to the stage were endurance exercise could be performed with *full kit over rough ground.*

Part V - *Carriage and Breathing* (2 minutes). Breathing exercises were recommended for the purpose of cooling-off after training.

In 1967, the "National Service" system was introduced, and all male South African citizens between the ages of 17 and 65 were compelled by law to participate in 9 months of military training.

2.2.6 THE PERIOD AFTER 1970

In December 1970, Colonel C.P. Goosen submitted a doctoral thesis to the University of the Orange Free State, the contents of which comprised a 435-page analysis of the South African Army's *Guide to Battle Physical Training* (1966).

In his thesis, Colonel Goosen criticized the physical training programme of the South African Army and suggested numerous alterations. Principally because his thesis did not contain scientific research data supporting his views, the majority of his recommendations were not introduced by the South African Army. However, his suggestions that physical training instructors at each separate unit be permitted to alter the training programme as thought necessary to meet their own particular requirements and that physical training be performed more frequently than recommended in the guide, were officially approved. Besides this, the programme outlined in 1966 remained essentially unaltered.

During the period in which Colonel Goosen compiled his thesis, Commandant S.C. Burger conducted a study which attempted to assess the effect of the South African Army physical training programme on endurance fitness. In this study endurance fitness was assessed on the basis of the time for a 1.5 mile run performed with the recruit wearing field uniform and carrying his rifle. This test was in fact a modified version of the 12-minute *Cooper test* (Cooper, 1968). Testing was conducted under the supervision of Captain de Villiers Lamprecht from the Military Medical Institute. On the basis of the results of this study, the "Committee for Standardisation of Physical Education and Sports Apparatus" subsequently published an order instructing all South African Army units to perform a

1.5 mile run test on a sample of recruits on completion of each month of military training. Units were requested to test recruits in the following numbers:

- 50 recruits, for units with more than 1 000 recruits;
- 30 recruits, for units with more than 500 recruits;
- 20 recruits, for units with more than 100 recruits;
- 10 recruits, for units with less than 100 recruits.

Although recruits were to be selected on a random basis, the recruits who could not perform the test for any reason were to be replaced by other recruits. Thus, this evaluation process did not take into account the element of feasibility of the training programme in terms of injuries incurred.

It is evident from interviewing instructors in the South African Army that they soon realized that a simple way of ensuring that their unit performed adequately in this test was to instruct their recruits to perform the 1.5 mile run as part of their physical training programme. Thus, although originally intended as a monthly physical fitness test, the 1.5 mile run gradually became an accepted part of the recruit physical training programme. Today, the metric version of the 1.5 mile run, ie the 2.4 km run, is performed on a daily basis by many basic training centres in South Africa. Likewise, the 3.2 km run utilized by certain units for recruit training was originally devised as an evaluation procedure.

Thus, at the time of the present study the South African Army physical training programme utilized by basic training centres was essentially the same as that outlined in 1966, with the addition of frequent 2.4 km or 3.2 km training runs supposedly performed at near-maximal effort. In contrast to basic training, the precise nature of the physical training utilized during the remainder of military service was left largely to the discretion of each unit's instructors and differed throughout the South African Army.

In 1974, National Service was extended to a period of 12 months. In January 1977, National Service was lengthened to its present 2-year duration.

CHAPTER 3

PHYSICAL FITNESS COMPONENTS IN THE MILITARY CONTEXT: INTERPRETATION AND ASSESSMENT

3.1 DEFINITION OF MILITARY PHYSICAL FITNESS

Despite considerable recent advances in the field of exercise science there exists a lack of agreement amongst researchers concerning the actual definition of the term "physical fitness". This situation has arisen largely because physical fitness is in fact a generalized term, the precise interpretation of which is likely to be determined primarily by the context in which it is applied.

Over the years, numerous definitions of physical fitness have been proposed. Certain scientists have avoided any narrow definition of physical fitness.

De Vries (1980) has simply stated: *Physical fitness may be arbitrarily defined as the composite of at least five major components (motor fitness, physical working capacity, body weight, relaxation and flexibility), and each major component is composed, in turn, of measurable elements of physical performance ....*

Likewise, Åstrand and Rodahl (1977) wrote in their inter= nationally renowned *Textbook of Work Physiology* : *In a very broad sense, physical performance or fitness is determined by the individual's capacity for energy out= put (aerobic and anaerobic processes and oxygen transport), neuromuscular function (muscle strength, co-ordination and technique), joint mobility, and psychological factors (eg motivation and tactics).*

Other researchers have recognized the specificity of physical fitness.

In 1966 the "Committee on Exercise and Physical Fitness of the American Medical Association" defined fitness as, *the general capacity to adapt and respond favorably to physical effort*, and further indicated that: *The degree of physical fitness depends on the individuals state of health, constitution, and present and previous physical activity.* In amplification of this definition, the Committee offered an explanatory statement that is particularly applicable to the military: *An individual is physically fit when he is able to meet both the ordinary and the unusual demands of his daily life safely and effectively.*

More recently, Lamb (1978) proposed a similar definition of physical fitness that may likewise be extrapolated to the military: *Physical fitness is the capacity to meet the present and potential physical challenges of life with success.*

However, of the numerous definitions of physical fitness documented in the literature, Karpovich's (1965) appears to be the most pertinent in the military context: *From an occupational point of view, physical fitness may be defined as the degree of ability to execute a specific physical task under specific ambient conditions.*

3.2 BASIC COMPONENTS OF MILITARY PHYSICAL FITNESS

Despite increasing mechanization and automation of military tasks, today's soldier must be capable of coping with a variety of physically demanding occupational and emergency situations. Therefore, it is evident that if Karpovich's (1965) interpretation of physical fitness is to be complied with, no single fitness component alone will suffice. Thus, to be considered physically fit in the military sense it is essential that the modern-day soldier possess all of the basic physical fitness components ie endurance, strength, power, local muscular endurance, speed, and flexibility.

3.2.1 ENDURANCE FITNESS

The ability to supply energy for activities lasting more than 90 sec depends on the consumption and utilization of O_2 (Brooks and Fahey, 1984). Because most military-related physical activities require more than 90 sec, the consumption of O_2 provides the energetic basis of the soldier's existence.

Endurance fitness, otherwise known as cardiorespiratory or aerobic fitness, defines the ability to perform pro= longed exercise. Traditionally, exercise physiologists have utilized the maximum rate at which O_2 can be con= sumed ($\dot{V}O_2$ max) as the principal determinant of the maximal capacity to perform endurance exercise (Strydom and Jooste, 1979). More recently, attention has focused on the use of the "anaerobic threshold" (Wasserman and McIlroy, 1964) as a measure of endurance fitness per se.

3.2.1.1 <u>$\dot{V}O_2$ max</u>

3.2.1.1.1 Historical Background

In their pioneering study, Liljestrand and Stënstrom (1920) demonstrated, in a single subject, that O_2 consump= tion increases with running speed up to a critical speed above which no further increase in O_2 consumption occurs, despite the subject being capable of increasing his running speed.

Subsequently, in 1923 Hill and Lupton observed the same phenomenon in their study of athletes, and suggested that O_2 consumption could not exceed this plateau because of limitations imposed by the circulatory and respiratory systems; ie a $\dot{V}O_2$ max had been attained. Although this view constitutes the classical concept of the physiological meaning of $\dot{V}O_2$ max, more recent work has demonstrated that the respiratory system does not limit O_2 consumption during maximal effort (Rowell, 1974). Thus, $\dot{V}O_2$ max is currently assumed to equal the product of maximal cardiac output and arteriovenous O_2 difference, and therefore to specify the maximal functional capacity of the cardiovascular system.

In 1938, Robinson used an approach similar to that of Hill and Lupton (1923) to investigate the effects of age and sex on $\dot{V}O_2$ max, but the topic was only systematized and adequate criteria developed for determining $\dot{V}O_2$ max with the studies of Åstrand (1952) in Sweden and Taylor's group in the United States (1955).

3.2.1.1.2 Determinants of the Upper Limit of O_2 Consumption During Exercise

Given the obvious importance of $\dot{V}O_2$ max for setting the upper limit of aerobic metabolism and the functional capacity of the cardiovascular system, it is important to understand the factors that limit $\dot{V}O_2$ max.

Researchers have considered 2 possible limiting factors. Firstly, that $\dot{V}O_2$ max is limited by the ability to transport O_2 from the lungs to the working musculature ie a cardiovascular limitation. Secondly, that $\dot{V}O_2$ max is limited by the respiratory capacity of contracting muscles ie a peripheral metabolic limitation. Several lines of evidence support the former postulate of a cardio=

vascular limitation of $\dot{V}O_2$ max:

i. If $\dot{V}O_2$ max is limited by circulatory transport of O_2 to working muscle, then the addition of extra muscle groups to those already eliciting a $\dot{V}O_2$ max should not effect the $\dot{V}O_2$ max. Many studies have revealed that $\dot{V}O_2$ max during arm ergometry, or cycling with 1 leg, is less than that during cycling with 2 legs (Åstrand and Rodahl, 1977; Clausen, 1977). Furthermore, $\dot{V}O_2$ max on a bicycle ergometer is approximately 7% less than while running at a gradient on a treadmill (Wyndham *et al*,1966a; McArdle *et al*, 1973; Miyamura *et al*, 1978), presumably because of the greater muscle mass involved in running. However, the implications of these studies are contradicted by studies where combined arm and leg work failed to increase $\dot{V}O_2$ max above that obtained during running (Åstrand and Saltin, 1961; Stenberg *et al*, 1967; Kamon and Pandolf, 1972). Thus, it is evident that once a critical mass of muscle is utilized during exercise, $\dot{V}O_2$ max becomes indepen= dent of muscle mass. This observation implies that $\dot{V}O_2$ max determined using treadmill exercise has a cardiovascular rather than peripheral limitation.

ii. Several researchers have found an increase in $\dot{V}O_2$ max when the arterial O_2 content was raised, either by increasing the partial pressure of O_2 or by increasing ambient air pressure (Taunton *et al*, 1970; Wyndham *et al*, 1970; Shephard, 1974), an observation supporting a circulatory limitation of $\dot{V}O_2$ max.

iii. Recent research findings have demonstrated a high correlation between $\dot{V}O_2$ max and leg muscle mitochondrial content (Booth and Narahara, 1974; Ivy *et al*, 1980a). However, this does not necessarily imply a limitation of $\dot{V}O_2$ max by muscle respiratory capacity. In fact, Henriksson and Reitman (1977) have indicated that during the course of leg muscle training and detraining, muscle mitochondrial capacity increases relatively more than does $\dot{V}O_2$ max (130% versus 19%), but increases in $\dot{V}O_2$ max persist longer than does the improvement in muscle respiratory capacity during detraining. Their observations therefore demonstrate an independence of $\dot{V}O_2$ max and muscle respiratory capacity and point to the cardiovascular system as imposing the upper limit on O_2 consumption.

3.2.1.1.3 Techniques for Assessing $\dot{V}O_2$ max

As in many areas of exercise physiology, the results of tests of $\dot{V}O_2$ max are influenced by the methods of measure= ment used. Scientists have assessed $\dot{V}O_2$ max using both direct and indirect methods.

3.2.1.1.3.1 Indirect Techniques

3.2.1.1.3.1.1 Maximal Tests

Maximal performance tests that have been used to predict $\dot{V}O_2$ max include: i. field tests such as the 1-mile timed run (Cureton, 1947), the 15-minute run (Balke, 1954), and, the best known and most widely utilized of all, the 12-minute all-out run (*Cooper test*)(Cooper, 1968); and ii. laboratory tests such as that advocated by Bruce *et al* (1973).

In well-motivated young men, the coefficient of correlation between distance run and the directly measured $\dot{V}O_2$ max may be as high as 0.90 (Cooper, 1968). However, a review of 37 reports by Shephard in 1982 indicated that correlations range from 0.40 to 0.90. This is to be expected since $\dot{V}O_2$ max is a measure of capacity whereas a maximal per= formance test assesses factors other than capacity alone, eg endurance fitness per se and mechanical efficiency. Furthermore, the accuracy of this type of testing depends on a number of factors, including previous running experience, knowledge of an appropriate pace, the consis= tency of the running surface, and environmental conditions. Thus, although maximal performance tests such as that advocated by Cooper (1968) are useful measures of endu= rance fitness, especially when applied to large groups of subjects, their use as an accurate indicator of $\dot{V}O_2$ max in a research situation cannot be justified.

Of the maximal laboratory tests used for $\dot{V}O_2$ max predic= tion, the Bruce protocol (Bruce *et al*, 1973) is perhaps most frequently used. In this test $\dot{V}O_2$ max is predicted from the treadmill stage attained. In young men, Liang's group (1982) observed a correlation of 0.94 between the Bruce treadmill stage and the directly measured $\dot{V}O_2$ max. However, other researchers have reported differences of as much as 18% between the actual and predicted values (Cumming, 1977, 1978). The major limitations of this method of predicting $\dot{V}O_2$ max are that a small advantage of endurance fitness greatly extends the endurance time and may thereby overestimate the $\dot{V}O_2$ max considerably, and it is assumed that all subjects have a similar mechanical efficiency of exercising and tolerate a similar accumu= lation of anaerobic metabolites.

3.2.1.1.3.1.2 Submaximal Tests

Methods of predicting $\dot{V}O_2$ max from submaximal test procedures have been presented and discussed at great length by various researchers including Åstrand and Ryhming (1954), Wyndham *et al*(1959), and Maritz *et al* (1961).

These methods consist of measurements of heart rate and O_2 consumption at 1 or more work loads and extrapolation to a predicted maximal heart rate. The application of these methods is based largely on 3 common assumptions:

i. The relationship between heart rate and O_2 consumption is linear throughout the entire work range.

ii. The individual O_2 consumption at any work load, and thus the mechanical efficiency of the subject, deviates little from the population mean. This is an especially important assumption when, as is frequently the case, measurement of O_2 consumption is not part of the test.

iii. The individual's maximal heart rate differs little from the mean of a suitable population.

As regards the first assumption, although the relationship between heart rate and O_2 consumption is linear at low work rates, it is asymptotic at near maximal work levels; the rate at which the heart rate tends to this asymptotic value is faster than that of the O_2 consumption (Maritz *et al*, 1961). Thus, during exercise performed on a cycle ergometer the average difference between the extrapolated and the directly measured $\dot{V}O_2$ max is approximately 0.3 $\ell.min^{-1}$, the estimate being lower than the actual measurement (Cardus, 1978).

The second assumption is troublesome in that although mechanical efficiency is the same for the majority of individuals, this is not always the case (Shephard, 1978).

In regard to the final assumption, the maximal heart rate of an individual can be assumed to be that of the population in question with, at best, a possible error of 10% (Powles *et al*, 1979).

The end result is that the predicted $\dot{V}O_2$ max often shows systematic errors of up to 10%, while individual values generally show a scatter of $\pm$ 10% about the mean error (Shephard *et al*, 1968). Thus, the role of submaximal tests in predicting $\dot{V}O_2$ max can be best summed up by the following statement of Shephard (1984): *The present consensus is that* (submaximal) *prediction procedures give a useful indication of fitness levels in large populations. If applied to an individual, they provide a simple index of week-to-week variations of aerobic power, but on any one occasion, the range of possible error is too large to provide more than a very crude index of aerobic fitness.*

3.2.1.1.3.2 Direct Techniques

3.2.1.1.3.2.1 Criteria for the Attainment of $\dot{V}O_2$ max

A practical difficulty in ascertaining whether a subject has in fact attained his $\dot{V}O_2$ max is that a considerable proportion of individuals do not display a satisfactory plateauing-off of O_2 consumption, particularly when work bouts are intervened by little or no recovery, as is often the situation. This difficulty has led to proposals of various criteria for measuring $\dot{V}O_2$ max.

Taylor *et al* (1955) consider that $\dot{V}O_2$ max has been reached when, for men running at 11.2 km.hour^{-1} with the grade being increased by 2.5% with each successive work bout, 2 successive determinations differ by less than 150 $m\ell.min^{-1}$. This criterion was based on their finding (Taylor *et al*, 1955) that the mean O_2 consumption increment for a 2.5% grade increase on 30 separate occasions was 299.3 $m\ell.min^{-1}$, with a standard deviation of 86.5 $m\ell.min^{-1}$ and a range of 159-470 $m\ell.min^{-1}$.

Wyndham (1974) has indicated that because in some subjects virtually no levelling-off occurs in the curve of O_2 consumption against work load, some relaxation of the criterion for judging $\dot{V}O_2$ max is required. He suggests that it is acceptable to take as the $\dot{V}O_2$ max the mean of 2 O_2 consumptions obtained at 2 successive increases in work load which produce the maximum heart rate in the individual.

Similarly, Shephard (1982) has listed the following alternative criteria of maximum effort:

i. a heart rate close to the age-predicted maximum;

ii. a respiratory exchange ratio of 1.15 or more; and

iii. a high arterial lactate level (11-16 $mmol.\ell^{-1}$ in a young man).

More recently, Wilmore *et al* (1985) suggested that the attainment of 1 or more of the following criteria is adequate evidence that $\dot{V}O_2$ max has been reached:

i. plateau or decrease in O_2 uptake with an increased rate of work;

ii. a respiratory exchange ratio in excess of 1.10; and

iii. a peak heart rate consistent with that predicted on the basis of the subject's age.

Because of the increasing use of continuous test protocols or protocols incorporating short rest inter= vals between work bouts, $\dot{V}O_2$ max is now commonly defined as simply being the highest O_2 consumption attained during a graded exercise test continued until volitional exhaustion (Smyth *et al*, 1984; Gordon *et al*, 1985 a,b,c,d,e,f). In physically active, well-motivated subjects $\dot{V}O_2$ max values obtained in this way generally do not differ from values defined by levelling-off criteria (Gordon *et al*, 1985c).

3.2.1.1.3.2.2 Laboratory Methodology

Laboratory methodology may exert a profound influence on $\dot{V}O_2$ max. Research has indicated that the laboratory itself should be kept cool (Dimri *et al*, 1980). Rowell *et al* (1964) have suggested that a dry-bulb temperature of 17°C is optimal for maximal effort.

Jones and Haddon (1973) advise that $\dot{V}O_2$ max measurements be made after a good night's sleep, and that alcohol and food be avoided immediately prior to the test. Shephard *et al* (1968) further recommend that the subject be given a preliminary familiarization trial.

Respiratory gas analysis can be invalidated by either poor timing of sample collection (Phillips and Ross, 1967) or errors of gas analysis itself (Cormack and Heath, 1974; Jones and Kane, 1979). If the duration of the exercise test is to be utilized as an experimental parameter, accurate control of the treadmill belt speed or ergometer calibration is essential (Jones and Kane, 1979; Wilmore *et al*, 1982). Jones and Kane (1979) suggest that a useful overall check on both ergometer loading and gas analysis procedures is provided by regular biological calibration, using subjects with a known $\dot{V}O_2$ max.

Directly measured $\dot{V}O_2$ max has been reported by some authors to be higher in the morning (Wojtczak-Jaroszowa and Banaskiewicz, 1974) and by others to be higher in the late afternoon (Yamaji *et al*, 1981). In contrast, certain investigators have found no circadian rhythm of $\dot{V}O_2$ max (Faria and Drummond, 1982; Reilly and Brooks, 1982).

3.2.1.1.3.2.3 Laboratory Ergometers

Since the initial work of Liljestrand and Stënstrom in 1920, an impressive variety of ergometric exercise testing devices have been utilized for the direct measurement of $\dot{V}O_2$ max. The relative merits of the disparate test modes have been extensively discussed in the literature (Anderson *et al*, 1971; Shephard, 1984; Wilmore, 1984). Laboratory ergometers that have been used widely include:

i. The treadmill. The treadmill is the most commonly used instrument for direct measurement of $\dot{V}O_2$ max (Anderson *et al*, 1971; Shephard, 1984). Despite a number of disadvantages such as high cost, bulk, noise, generation of anxiety in certain persons, some risk of falling, and difficulty in performing ancillary measurements (eg blood sampling and blood pressure recording), treadmills appear to be preferred by those who undergo physiological assessment and scientists who conduct the tests. Because, walking and running are natural activities most individuals have little difficulty adjusting to the treadmill and any initial awkwardness is generally easily overcome by a preliminary familia= rization trial. Further advantages of treadmill testing are that the pace is set by the machine rather than the subject, and the final value obtained is generally a centrally-rather than peripherally-limited maximum, unlikely to be enhanced by the addition of a secondary task (Shephard, 1977). Regarding the actual treadmill protocol utilized, results generally vary little in active, well-motivated subjects with factors such as the rate of approach to a maximum (Shephard, 1984), continuous versus discontinuous tests (Gordon *et al*, 1985c), increase of treadmill slope or speed (Gibson *et al*, 1979), or running versus walking (McArdle *et al*, 1973).

ii. The cycle ergometer. Recently there has been a shift away from the use of cycle ergometers to the use of treadmills (Wilmore, 1984). The major objections to the use of cycle ergometers for direct $\dot{V}O_2$ max determination are that the task is self-limited, mechanical impairment of muscle blood flow may be induced by high power outputs (Nagle, 1973), and localized fatigue of the quadri= ceps muscles may result in the premature termination of exercise thereby preventing subjects from attaining their true $\dot{V}O_2$ max. The net result is that $\dot{V}O_2$ max is on average 7 to 8% below the tread= mill value (Kamon and Pandolf, 1972; Boileau, 1977; Miyamura *et al*, 1978). On the other hand, the major advantages of cycle ergometers are that their cost is relatively low, they are readily transportable, the subject is relatively stationary and the risk of injury is extremely low, certain individuals do not feel as threatened by a cycle as with a treadmill, they can often be easily calibrated, and ancillary measurements can be easily performed.

iii. Arm crank ergometers. Various types of arm crank and wheelchair ergometers have been utilized in the physiological assessment of contestants in sports that rely heavily on arm work and those who have lost the use of their lower limbs (Wicks *et al*, 1977; Boles *et al*, 1982; Sawka *et al*, 1982). However, the $\dot{V}O_2$ max developed during arm work is only about 70% of that achieved during uphill treadmill running (Shephard, 1984) and although such tests are suitable for persons not capable of performing treadmill exercise, their use is therefore severely limited when an accurate assessment of the maximal functional capacity of the cardiovascular system is desired.

iv. Step tests. Step tests are the least expensive and most portable of the various ergometric devices used for the measurement of $\dot{V}O_2$ max. Furthermore, certain investigators have observed a similar $\dot{V}O_2$ max value with stepping and treadmill running (Wyndham *et al*, 1966a). However, it is generally believed that step tests are more approp= riate for submaximal work tests (Shephard, 1984; Wilmore, 1984) since the stepping rate or bench height needed for maximal exertion may be impossible for certain subjects to comply with and may consti= tute a safety hazard for others.

v. Swimming ergometers. Early research with swimming used free swimming, the equipment being placed on portable carts alongside the pool. More sophisti= cated methods have been recently described by Åstrand and Englesson (1972) and di Prampero *et al* (1974). However, due to the high cost of these modes, testing of swimmers is commonly conducted using tethered swimming as outlined by Costill (1966). Bonen *et al* (1980) have documented almost similar $\dot{V}O_2$ max values for the different swimming test modes. It must, however, be stressed that swimming ergometers should be utilized only when testing trained swimmers.

3.2.1.1.3.2.4 Specificity of Testing

Recently, researchers have identified the important fact that there exists a high degree of specificity for both the testing and training of individuals using various ergometric devices (Magel *et al*, 1975). Misleading and erroneous data may be generated if care is not taken when selecting appropriate test modes. In this respect, Stromme *et al* (1977) concluded that in the evaluation of $\dot{V}O_2$ max, it is important to select a work task which allows optimal use of the specifically trained muscle fibres if the efficacy of the conditioning programme in question is to be adequately evaluated.

3.2.1.2 Anaerobic Threshold

3.2.1.2.1 Historical Background

Du Bois-Reymond, in 1860, was amongst the first researchers to identify and quantitate lactate formation within skeletal muscle (Rothschuh, 1973). Subsequently, in 1891, Trasaburo Araki while working in Hoppe-Seyler's laboratory in Strassburg described hypoxia-induced lactic acid formation.

In 1907, Walter Morley Fletcher and Frederick Gowland Hopkins published a classic paper in the history of the anaerobic threshold entitled, *Lactic Acid in Amphibian Muscle*. In this work they demonstrated that:

i. muscle contained little lactate at rest;

ii. an increase in lactate concentration could be initiated by mechanical injury or irritation;

iii. lactate can be produced by muscle under anaerobic conditions;

iv. muscle fatigue was accompanied by a rise in lactate; and

v. lactate formation was depressed by hyperoxia.

In 1909, Ryffel, in his paper in the *Proceedings of the Physiological Society*, showed in man that *violent muscular exercise* produces a considerable rise in the blood lactate concentration.

Classical studies conducted in the early twentieth century by Claude Gordon Douglas (1927) and his co-workers (Christiansen *et al*, 1914) indicated that a series of work rates could be performed without an increase in blood lactate concen= tration from the resting level, but as the rate of work was elevated beyond a certain point the concentration of lactate in the blood began to rise. Douglas (1927) further observed that the bicarbonate concentration was lowered by the rise in blood lactate and in fact stated in his paper in the *Lancet* in 1927 that breathing was stimulated in order *to expel the CO_2 set free as the sodium bicarbonate concentration in the blood diminished.*

In 1924 A.V. Hill and his colleagues introduced the concept that the increase in blood lactate during exercise was induced by an inadequacy of O_2 available for the energy requirements of the active musculature.

More recently, Naimark, Wasserman, and McIlroy (1964) described a continuous graded exercise protocol that could detect the initial increase in blood lactate by measuring breath-by-breath ventilatory changes without the necessity of drawing blood. Wasserman and McIlroy (1964) termed the point at which blood lactate started to rise and pulmonary ventilation increased out of proportion to the O_2 consumption the *anaerobic threshold.* Around the same time, Hollman (1961) independently described the noninvasive determination of the anaerobic threshold. Wasserman and Davis and their colleagues (1973, 1979, 1982) later refined the noninvasive procedures for determining the anaerobic threshold, and altered their definition of the anaerobic threshold to: *the level of* *work on O_2 consumption just below that at which metabolic acidosis and changes in gas exchange occur.*

Today, the anaerobic threshold is widely used by exercise physiologists to assess the point where blood lactate starts to rise during exercise. However, in recent years the term "anaerobic threshold" has been the target of considerable controversy (Davis, 1985; Brooks, 1985), with the accuracy of the word "anaerobic" and the word "threshold" being questioned.

3.2.1.2.2 Course of Events During Incremental Exercise: A Basis for the Classical Concept of the Anaerobic Threshold

The classical concept of the anaerobic threshold is as follows. With increasing levels of low-intensity physical activity, the contracting muscles extract an increasing amount of O_2 from the blood. This results in a lower fraction of O_2 being present in the expired air (F_EO_2). At the same time, greater amounts of CO_2 are generated and expired, resulting in an increase in the fraction of CO_2 in the expired air (F_ECO_2). At such exercise levels, O_2 consumption, pulmonary ventilation, CO_2 production, and heart rate increase in a linear fashion. This initial phase of exercise involves predominantly aerobic metabolic processes and the concentration of lactate in the blood remains at resting levels.

At some particular exercise intensity, which generally corresponds to between 40 and 60% $\dot{V}O_2$ max (Skinner and McLellan, 1980; Hagberg, 1984), O_2 consumption and heart rate continue to rise linearly, but there is an initial increase in the blood lactate concentration to approxima= tely twice the resting value (about 2 mmol.ℓ^{-1}). Because of its low pK, lactic acid will be almost completely dissociated and it is buffered by the bicarbonate system

(Wasserman *et al*, 1967) (ie lactic acid + sodium bicarbonate $\longrightarrow$ sodium lactate + carbonic acid). The dissociation of carbonic acid results in an in= creased CO_2 production and a continuous rise in F_ECO_2 (ie $H^+ + HCO_3^- \rightleftharpoons H_2CO_3 \rightleftharpoons CO_2 + H_2O$). In an attempt to compensate for the impending metabolic acidosis due to higher levels of H^+ and CO_2, the respiratory centre is stimulated to increase the pulmonary ventila= tion. Thus, this phase of incremental exercise is characterized by a nonlinear increase in pulmonary venti= lation and CO_2 production, an increase in F_EO_2 without a corresponding decrease in F_ECO_2, and a rise in blood lactate concentration. The onset of these physiological changes corresponds to the anaerobic threshold described by Wasserman's group (1964).

With the transition to exercise intensities corresponding to approximately 65 to 90% $\dot{V}O_2$ max (Skinner and McLellan, 1980), O_2 consumption and heart rate continue their linear rise; they ultimately begin to plateau at near-maximal work levels. At the onset of such exercise intensities the blood lactate concentration is about 4 $mmol.\ell^{-1}$ and begins to increase rapidly. The production of CO_2 continues to rise and a further increase in pulmonary ventilation occurs in an attempt to compensate for the marked increase in blood lactate concentration. Because the hyperventila= tion cannot compensate adequately for the metabolic acidosis, there is a fall in F_ECO_2 while the F_EO_2 continues to increase. Thus, this phase of incremental exercise is characterized by a further nonlinear rise in pulmonary ventilation ("break-away ventilation"), a drop-off in F_ECO_2, and a marked rise in blood lactate concentration. The onset of these physiological changes corresponds to the anaerobic threshold noted by Mac Dougall (1978) and Kinderman *et al* (1979).

3.2.1.2.3 Mechanism for Blood Lactate Rise During Incremental Exercise

Hill's group (1924) and Wasserman and McIlroy (1964) originally suggested that the increase in blood lactate during incremental exercise was directly related to the onset of local muscle hypoxia. Indeed, Wasserman (1964) used the word "anaerobic" to indicate that the O_2 supply was inadequate for the active muscle's energy needs to be exclusively supported by aerobic metabolic pathways alone. Three lines of evidence, however, suggest that hypoxia might in fact not be the cause of the initial blood lactate rise observed at submaximal work intensities:

i. Jobsis and Stainsby (1968) have demonstrated, in situ, that well-oxygenated muscles produce lactate.

ii. Ivy's group (1981) have indicated that the point of increase in blood lactate can be altered by substrate availability which has no effect on the delivery of O_2 to the active muscles.

iii. Hagberg (1984) has recently suggested that if muscle was hypoxic at a submaximal work rate which elicited a rise in blood lactate prior to exercise conditioning, O_2 consumption would be expected to be higher at this given work rate after training if lactate production was to be reduced. However, exercise training that alters the work rate at which the blood lactate concentration starts to rise does not increase the consumption of O_2 at submaximal levels of work (Hickson *et al*, 1978; Hagberg *et al*, 1980).

It is evident from the above that while lactate will undoubtedly be produced by skeletal muscle if O_2 delivery is compromised to a significant extent during exercise, in normal conditions lactate production cannot definitely be attributed to a state of absolute hypoxia within the muscle.

Although the precise reasons for the rise in blood lactate at submaximal work are presently the subject of much controversy (Davis, 1985; Brooks, 1985), it is currently held that the blood lactate concentration is the net result of lactate produced by an imbalance between glycolysis and oxidative metabolism (Hagberg, 1984) and lactate removal from the blood (Brooks, 1985). Mechanisms other than hypoxia which may be responsible for the imbalance between glycolysis and oxidative metabolism, and hence lactate production, include the pattern of muscle fibre recruitment during exercise and enzymatic activity regulation (Gladden, 1984). However, an incontro= vertible resolution of this debate must await the development of techniques which will allow the measurement of O_2 partial pressures in small volumes of muscle tissue in exercising humans at the anaerobic threshold.

3.2.1.2.4 Limitations of Blood Lactate Concentration as a Precise Indicator of Muscle Metabolism

A fundamental premise of the anaerobic threshold concept is that the change in muscle and blood lactate concentra= tions occur almost simultaneously during incremental exercise. Several lines of evidence suggest that this may be true only in very specific exercise conditions:

i. Harris *et al* (1968) have demonstrated that there is a time delay associated with lactate diffusion from muscle to blood.

ii. Hermanson and Vaage (1977) have observed that a substantial amount of lactate may accumulate within the muscle before entering the blood.

iii. Above a certain concentration, lactate diffusion may be hindered during exercise (Jorfeldt *et al*, 1978).

iv. Green's group (1983) has recently shown that the elevation in muscle anaerobic glycolysis may precede the onset of blood lactate accumulation during a progressive exercise test.

Thus, it is evident that although the blood lactate concentration may provide useful information regarding muscle metabolism during exercise, it might not accurately reflect the precise metabolic state at a specific time during incremental exercise.

3.2.1.2.5 Validity of Pulmonary Ventilation as an Indicator of Blood Lactate Levels

The classical anaerobic threshold concept predicts that increments in blood lactate concentration mediate increments in pulmonary ventilation. However, a number of research observations indicate that this may in fact not be the case:

i. Segal and Brooks (1979) have observed significantly lower blood lactate responses but significantly higher pulmonary ventilations at given work rates in glycogen-depleted subjects. Subsequently, Hughes *et al* (1982) and Heigenhauser *et al* (1983) have documented similar findings.

ii. Work performed by Hagberg's group (1982) has shown that during incremental exercise, patients with McArdle's disease, who lack the enzyme phosphorylase, do not produce lactate. However, these patients demonstrate a definite ventilatory anaerobic threshold.

iii. Green *et al* (1983) and Powers *et al* (1984) have recently documented an uncoupling of the anaerobic thresholds as determined by blood lactate and ventilatory changes during incremental exercise in normal subjects.

Thus, although no less than 5 teams of researchers (Davis *et al*, 1976; Reinhard *et al*, 1979; Ivy *et al* 1980; Caiozzo *et al*, 1982; Yoshida *et al*, 1982) have documented a close agreement between the anaerobic thres= hold determined noninvasively and by blood lactate, the observed correlations might in fact be coincidental.

3.2.1.2.6 Relation of Anaerobic Threshold to $\dot{V}O_2$ max

Traditionally, $\dot{V}O_2$ max has been accepted as the index of the capacity of an individual to perform prolonged submaximal exercise. However, recent research has indi= cated that although $\dot{V}O_2$ max per se does set the upper limit of an individual's maximal endurance capacity and is of importance during submaximal exercise, $\dot{V}O_2$ max and the actual ability to perform submaximal work are limited by disparate mechanisms (Gleser and Vogel, 1973; Holloszy *et al*, 1977; Gollnick and Saltin, 1982; Karlsson and Jacobs, 1982; Tesch *et al*, 1982). More specifically, $\dot{V}O_2$ max appears to be more related to cardio= vascular factors (eg cardiac output), while skeletal muscle metabolic factors (eg respiratory enzyme activity) seem to play a greater role in determining both the anaerobic threshold and the ability to perform submaximal exercise. This postulate is supported by the following observations:

i. Muscle oxidative enzymes increase nearly 100% with endurance conditioning (Saltin and Rowell, 1980; Gollnick *et al*, 1982) while maximal cardiac output and $\dot{V}O_2$ max increase to a much smaller extent.

ii. Correlations between mitochondrial respiratory enzyme activity and the anaerobic threshold (expressed in terms of absolute work rate) are generally superior to those found between enzyme activity and $\dot{V}O_2$ max (Sjodin *et al*, 1981; Tesch *et al*, 1981).

iii. In one study (Coyle *et al*, 1983), highly trained coronary artery disease patients and matched healthy runners were capable of running at the same O_2 consump= tion prior to reaching their anaerobic threshold, implying that they had similar peripheral metabolic capacities. However, the $\dot{V}O_2$ max values of the patients were 18% lower than those of the healthy runners since their maximal cardiac output was depressed by 17%.

iv. After endurance conditioning, subjects are often able to work closer to their $\dot{V}O_2$ max before attaining their anaerobic threshold indicating that submaximal exercise capacity increases more than $\dot{V}O_2$ max with training.

Thus, $\dot{V}O_2$ max and anaerobic threshold are, within limits, determined by disparate physiological mechanisms. Available research indicates that while $\dot{V}O_2$ max is more dependent on cardiovascular factors relating to maximal cardiac output (Rowell, 1974), the anaerobic threshold is better related to skeletal muscle respiratory enzyme activity. However, it is essential to realize that when the anaerobic threshold is expressed in absolute terms it is directly dependent on $\dot{V}O_2$ max. Therefore, it appears that $\dot{V}O_2$ max determines the upper limit of the capacity (or potential) to perform endurance exercise while the actual ability to perform endurance exercise (ie endurance fitness per se) is modulated by the anaerobic threshold.

3.2.1.2.7 Relation of Anaerobic Threshold to Endurance Performance

Although the theoretical basis of the anaerobic threshold has recently come under much criticism, numerous studies have indicated that this parameter is related to endurance performance (Costill *et al*, 1973; Farrell *et al*, 1979; Komi *et al*, 1981; Sjodin and Jacobs, 1981; Coyle *et al*, 1983; Hagberg and Coyle, 1983; Tanaka *et al*, 1983; Allen *et al*, 1985). More specifically, of all the various indices proported to predict endurance performance, the anaerobic threshold expressed in $m\ell\ O_2.kg^{-1}.min^{-1}$ has yielded the highest correlation with endurance performance in a number of studies (Farrell *et al*, 1979; Robinson and Sucec 1980; Thorland *et al*, 1980; Tanaka *et al*, 1981, 1983, 1984; Kumagai *et al*, 1982).

However, while it is attractive to theorize that the relationship between the anaerobic threshold and the ability to perform endurance exercise is cause-and-effect in nature, little data are available to confirm this. In fact, although metabolic acidosis accompanying excessive muscle lactate production is thought to limit short-duration endurance performance, lactate is not believed to be a limiting factor for exercise durations such as those utilized in the studies demonstrating a correlation between endurance performance and anaerobic threshold. In this respect, Hagberg (1984) has stated in a recent review of the physiological implications of the anaerobic threshold: *It is more likely that the blood lactate level* (anaerobic threshold) *may provide an index of some other physiological signal which is actually the mechanism limiting performance in prolonged steady-state competitive events.* Because prolonged, relatively high-intensity exercise is probably ultimately limited by muscle glycogen depletion (Rosell and Saltin, 1973; Noakes and McArthur, 1985), the close relationship between the anaerobic threshold and endurance performance perhaps relates to the rate of muscle glycogen utilization being 18-19 times faster during anaerobic glycolysis compared to oxidative phosphorylation for the same energy yield (Davis, 1985).

3.2.1.2.8 Methodology of Blood Lactate Anaerobic Threshold Determination

Because of the unresolved controversies (Davis, 1985; Brooks, 1985) surrounding the precise interpretation of anaerobic threshold determinations, an ideal and standardized mode for evaluating this parameter has yet to be established.

The anaerobic threshold determined from blood lactate levels during exercise is likely to vary according to a number of factors, the principal being as follows:

i. The precise definition of the point at which the anaerobic threshold occurs. The point at which the anaerobic threshold (as determined from blood lactate) occurs has been defined as being: a. just below the onset of blood lactate accumulation (Ivy *et al*, 1981); b. at the onset of an abrupt rise in blood lactate (Davis *et al*, 1976; Dennis *et al*, 1982); c. a blood lactate level of 2.2 $mmol.\ell^{-1}$ (Londeree and Ames, 1975); d. a 1 $mmol.\ell^{-1}$ increase in blood lactate above those levels at 40 to 60% of $\dot{V}O_2$ max (Farrel *et al*, 1979 ; Coyle *et al*, 1983; Hagberg *et al*, 1983); e. a blood lactate level of 2.5 $mmol.\ell^{-1}$ (Allen *et al*, 1985); f. a blood lactate level of 4 $mmol.\ell^{-1}$ (Kinderman *et al*, 1976; Sjodin and Jacobs, 1981; Heck *et al*, 1985); and g. the intercept of 2 linear regression lines, the one being drawn for low and the other for high work loads (Williams *et al*, 1967, 1968; Senay and Kok, 1977; van Rensburg *et al*, 1982).

ii. Site of blood sampling. In the various studies, blood samples have been drawn from many sites (arteries, capillaries, and veins). A technical problem with interpreting the findings of such studies is pointed out by the recent study of Yoshida *et al* (1982). They found that the anaerobic threshold is systematically higher if values derived from venous blood are compared with those obtained using arterial blood. The investi= gators suggested that the likely cause for this finding was the uptake of lactate from the forearm muscles before the blood reached the antecubital vein.

iii. Type of exercise. In 1976 Davis *et al* determined the anaerobic threshold during leg exercise performed on a treadmill and a bicycle ergometer, and during arm cranking. No significant difference was found for the anaerobic threshold expressed relative to $\dot{V}O_2$ max between the leg exercise modes. However, arm cranking anaerobic threshold values were lower. Postulated mechanisms for the lower values during arm work included a smaller muscle mass, inexperience with arm cranking, different muscle fibre patterns between the arms and legs, and lack of uniform motor recruitment in arm work. As regards the smaller muscle mass, Stamford *et al* (1978) have suggested that this mechanism is not tenable in view of their documentation of no difference in relative anaerobic threshold values during cycling with 1 and 2 legs.

iv. Duration of work loads. Researchers have utilized work loads ranging from 1 minute (Wasserman *et al* 1973) to 10 minutes (Allen *et al*, 1985) in duration. Due to the delay in diffusion of lactate from the contracting muscle to the blood, work loads of short duration are likely to over= estimate the anaerobic threshold. In this respect, Stamford *et al* (1978) have suggested that work bouts of at least 3 minutes duration are necessary for the accurate determination of the anaerobic threshold. In agreement, Kindermann's group (1980) recommend 3-minute work loads with the treadmill slope set at 2 to 5% for the simulta= neous assessment of anaerobic threshold and $\dot{V}O_2$ max.

v. Rate of increase of work rate. The possibility that the anaerobic threshold may be influenced by the rate of the increase in work rate is supported by the finding of Hughson and Green (1982) that slow ramp testing yields lower anaerobic threshold values than those found for fast ramp testing.

Finally, as is the case with $\dot{V}O_2$ max, studies reported by Kindermann *et al* (1979) and Withers *et al* (1981) suggest that the alteration that occurs in the anaerobic threshold with exercise training is in part a function of the specific movement patterns executed in training. Thus, if the effect of a specific exercise training programme on anaerobic threshold is to be evaluated, exercise testing and training should be performed utilizing a similar exercise mode.

3.2.2 STRENGTH-FITNESS

It is evident from a compilation of the most recent publications on the topic (O'Shea, 1985) that strength-fitness is essentially comprised of 3 separate factors, namely strength, power, and local muscular endurance.

3.2.2.1 Historical Background of Strength-Fitness

The recognition of strength-fitness as an essential component of physical fitness can be traced to ancient times. Stutley and Stutley (1977) have indicated that over 5000 years ago, ancient Indians pursued strength-fitness through sacrifices offered to the gods at festivals and through ceremonial drinking of a hallucinogenic liquor, *vajepeya*, the "drink of strength".

Later, the mystical origins of strength-fitness yielded some of their grip on the minds of ancient man, and by the time of Athens and Sparta, although the gods still received tribute for this gift, the value of exercise training was recognized. Indeed, Milo of Crotona, a military hero who lived in Greece in the sixth century BC is attributed with having first implemented progressive resistance training; he is said to have hoisted a baby bull on his shoulders everyday to improve his level of strength-fitness and as the bull grew heavier with age his strength-fitness progressively increased (Bullfinch, 1959). However, the Greeks in fact failed to grasp the significance of this concept and it was the Romans who subsequently adapted the Spartan strength-fitness training principles and in so doing originated weight training (Zeigler, 1973).

Strength-fitness training principles in existence before World War II may be assessed in large from McFadden's (1940) *Encyclopaedia of Health and Physical Culture* which was compiled over a 30-year period by numerous researchers. No originality was claimed by the editorial board for the strength-fitness training principles discussed, since they were believed to be universally accepted. In this respect, the encyclopaedia contains familiar principles such as: *Offer a progressive degree of resistance*, and lift *within 10% of the utmost limit* when working with weights. The views cited were in fact probably not much different from those under which the Roman centurions trained (Zeigler, 1973). However, signs of a deeper understanding of the subject are evident from observations such as that of Morpurgo in 1897 that as muscles increase their strength-fitness they simulta= neously increase in size.

More recently, a greater understanding has been developed regarding the concept of strength-fitness. Yet, the situation is still best summed up by the following statement made by Brooks and Fahey (1984) in their recent textbook on the subject of exercise physiology: *Strength*(-fitness)*training is a controversial area of exercise physiology as a result of many poorly conducted studies, the difficulty in conducting long-term research, problems associated with extrapolating the results of animal studies to humans and of untrained subjects to athletes, and the rampant commercialism connected with various types of strength*(-fitness) *training equipment.*

3.2.2.2 Definition of Strength

The definition of strength documented in the *Pocket Oxford Dictionary* (1984), ie *the quality or extent or manner of being strong*, appears at a first glance to be a simple and unequivocal one. However, when further pursued this definition actually becomes more equivocal because the word *strong* can be interpreted as *having powers of resistance, tough, powerful, muscular, healthy,* and *capable of exerting great force.* Thus, it is not surprising that strength has been defined by researchers in many different ways over the years.

In 1935, Steidler attempted to overcome the many inter= pretations of strength and defined it as *the maximum display of contractile power.* This interpretation was subsequently adopted on a widespread basis by one of the pioneers of strength physiology, De Lorme, in his many studies (De Lorme, 1945; De Lorme *et al*, 1948; De Lorme and Watkins, 1948, 1951). This definition fails, however, in that it simply substitutes one undefined concept (power) for another (strength).

Later, Clarke (1966) attempted to reduce the ambiguity of the term "strength" by stating that *muscular strength ... is the tension muscles can apply in a single maximum contraction.* Although this definition makes the concept much less ambiguous, it leaves unclear whether skeletal mechanisms are presumed to act to reduce the applied tension ie whether strength is to be defined by the internal tension of the muscle or by the external and greatly reduced forces impressed by the limb on an external resistance. This point was later clarified by Müller (1970), who defined strength as *the maximum force that can be exerted against an immovable resistance by a single contraction.* However, this definition although more comprehensive than previous ones is still incomplete in that while strength may be measured as a force, it is not a force itself. Therefore, perhaps the most valid definition of strength is that proposed by Morehouse and Miller in 1971 when they defined strength as *the ability to exert tension* (force) *against resistance.*

Finally, Heusner (1985) has recently indicated that the following factors must be taken into consideration when interpeting the term strength:

i. Strength refers to the effective biomechanical force that results from 1 maximal voluntary muscular contraction - any more than 1 contrac= tion introduces a component of local muscular endurance.

ii. Strength does not incorporate a velocity component.

3.2.2.3 Definition of Power

In contrast to the term "strength", the definition of muscular power as *the rate of doing work* or *the energy output per unit time* is universally accepted (Travers and Campbell, 1974; Laird and Rozier, 1979; Sapega and Drillings, 1983). However, the term "power" has been applied too loosely in the literature and is often used synonymously with the terms "strength" and "speed". In actuality power may be defined as being the product of force times speed. Research has shown (Osternig *et al*, 1983) that as the speed of muscular contraction increases, the maximum muscular force development (ie strength) declines. Up to a point, maximum muscular power becomes greater with increasing contractile velocity, even though force development declines (Meiss, 1976). With further increases in contractile velocity, however, power output decreases. Thus, it can be seen that although power is directly dependent on both force (strength) and speed, it should not be used interchangeably with these terms.

3.2.2.4 Definition of Local Muscular Endurance

Researchers are generally agreed upon the definition of local muscular endurance as being the length of time, or number of repetitions, that a specific muscular contraction can be performed (Mathews and Fox, 1976; Heusner and Van Huss, 1978; de Vries, 1980). An equivalent way of describing local muscular endurance is to define it as the duration of time that a specified amount of work with a given muscle or muscle group can be performed (Heusner, 1985).

Local muscular endurance can be separated physiologically from cardiovascular endurance by attributing all energy - fatigue relationships at the muscle fibre level to local muscular endurance and then viewing cardiovascular endurance as total body endurance (Mathews and Fox, 1976; Heusner, 1985). It is also important to realize that when local muscular endurance is evaluated utilizing an absolute load, investigators have found the relationship between strength and local muscular endurance to range from r = 0.75 to r = 0.97 (Caldwell, 1963; Start and Graham, 1964), but when a relative load is utilized (ie a given percentage of the individual maximal voluntary contraction) the relationship is virtually nil (Caldwell, 1963; Start and Graham, 1964) or even negative (Heyward, 1975). Thus, if local muscular endurance is to be considered independently of strength, it must be evaluated as relative rather than absolute endurance.

3.2.2.5 Types of Muscular Contractions and Their Role in Strength-Fitness

When a muscle fibre contracts, the actin and myosin filaments of the myofibrils slide in toward each other. Although the fibres respond this way in a contraction, the actual length of the muscle itself may remain unchanged, decrease, or increase. The terms used to identify the separate types of muscular contraction are "static" and "dynamic".

3.2.2.5.1 Static Muscular Contraction

Static muscular contraction is commonly referred to as isometric muscular contraction. The term isometric literally means same or constant ("iso") length ("metric"). Thus, Mathews and Fox (1976) define an isometric contrac= tion as being *one in which tension is developed but there is no change in the external length of the muscle.*

Advantages of isometric contractions for strength-fitness enhancement include:

i. Little equipment is required.

ii. The technique is easily learned.

The disadvantages include:

i. It is difficult to determine objectively the amount of force exerted.

ii. This form of muscular contraction is difficult to perform when certain specific muscle groups are utilized.

iii. Gains in strength-fitness are believed to be range specific with minimal overflow to surrounding portions of the range (Walmsley and Swann, 1976).

Thus, although Hettinger and Müller may have caused a stir back in 1953 when they observed that 6 sec of isometric exercise at 75% of maximum induced a marked increase in strength, this exercise mode is now seldomly used for strength-fitness training.

3.2.2.5.2 Dynamic Muscular Contraction

Åstrand and Rodahl (1977) have stated that: *If the muscle varies its length when activated, the contraction is dynamic.* Dynamic muscular contractions are usually further classified as being isotonic or isokinetic in nature (Mathews and Fox, 1976).

3.2.2.5.2.1 Isotonic Contractions

Isotonic contractions constitute one of the most familiar types of muscular contractions. The term isotonic literally means same or constant ("iso") tension ("tonic"). However, isotonic contractions are usually interpreted as being contractions in which the muscle shortens (referred to as a concentric contraction) or lengthens (referred to as an eccentric contraction) against a movable load, with the muscular tension varying somewhat over the full range of motion (Mathews and Fox, 1976). Thus, the term "isotonic", although widely accepted, is actually a misnomer. Berger (1982) prefers the use of the term allodynamic since "allo" means "not the same". He further indicates that during an allodynamic contrac= tion, *the number of contracting fibres is greater at one point in the joint range and less at all other joint angles.*

Advantages of "isotonic" contractions for strength-fitness enhancement include:

i. Objective measures are easily obtained.

ii. They can be accomplished by a variety of techniques and equipment, often of low cost.

The disadvantages include:

i. The contractions are usually performed at about 60 degrees.sec^{-1}, thus not allowing functional velocities to be achieved.

ii. Maximal loading occurs only at the weakest part of the range of motion and submaximal work is in fact therefore generally the rule.

3.2.2.5.2.2 Isokinetic contractions

As is the case with isotonic contractions, perusal of the literature leads to some confusion regarding the exact definition of the term "isokinetic". Whereas most authors state that isokinetic muscular contractions are those that involve a constant time period within which the contraction is performed, there is no agreement as to whether it is the limb or the muscle which is moving under the constant conditions. Thistle *et al* (1967), Moffroid *et al* (1969), and De Lateur *et al* (1972) present the viewpoint that isokinetics refers to a type of muscular contraction which accompanies a constant angular velocity of the limb. A second viewpoint is offered by Hislop and Perrine (1967), Perrine (1968), and Van Oteghen (1975) who consider isokinetics as a term referring to a constant linear rate of muscular contraction. Practically, it must be noted that the instrumentation currently available for isokinetic measurement and training is based on the provision of a resistance which can be overcome only at a preset velocity. It follows that manufacturers of such equip= ment understand isokinetics to be that type of contraction which results from constant angular velocity of a limb. Mathematically, Hinson *et al* (1979) have provided evidence that a constant rate of limb movement is not accompanied by a constant linear rate of muscular contraction.

Isokinetic contractions are also sometimes referred to as "accomodating resistance exercise" because they involve exercise performed at a fixed speed while at the same time presenting a resistance which accomodates to the muscular ability to generate tension (Brooks and Fahey, 1984). Thus, resistance varies to exactly match the force applied throughout the entire range of motion.

Advantages of isokinetic contractions for strength-fitness enhancement include:

i. The ability to quantitatively manipulate velocity.

ii. The ability of present-day isokinetic devices to accommodate to muscle-tendon and length-tension ratios, and to changes in skeletal leverage, skeletal and muscular fatigue, and pain.

iii. At least theoretically, the muscle may be loaded to 100% of capacity throughout the entire range of motion.

The disadvantages include:

i. Presently, minimal diagonal or functional patterns of movement can be performed.

ii. Equipment is currently extremely expensive and not particularly transportable.

iii. Eccentric muscular contractions cannot be performed.

As regards the use of different exercise modes for enhancement of strength-fitness, as early as 1922, Hill stated: *In order to obtain the maximum work from a contracting muscle, it is necessary to oppose its contraction at every stage by a force which it is only just able to overcome. The use of a smaller opposing force wastes some of the mechanical energy, while a larger opposing force stops the contraction altogether.* It is apparent that of the different modes currently available, isokinetics comes closest to fulfilling Hill's criteria for an optimal mode of strength-fitness training.

3.2.2.6 Determinants of Muscular Force

The single factor that is common to all components of strength-fitness (ie strength, power, and local muscular endurance) is muscular force. Stone (1985) has recently concluded after reviewing the available literature on the topic that the amount of force produced by muscular contractions is largely determined by the following physiological factors:

i. The number of motor units involved.

ii. The frequency (rate) of motor unit firing.

iii. Synchronization of motor units.

iv. The pattern of motor unit and whole muscle contraction.

v. The degree of neuromuscular inhibition.

vi. The muscle fibre type.

3.2.2.7 Measurement of Strength-Fitness

3.2.2.7.1 Early Apparatus for Strength-Fitness Assessment

Although man has undoubtedly competed with his rival in feats requiring strength-fitness since pre-historic times, it was not until the modern historical era that attempts were made to assess strength-fitness scientifically. In retrospect, the measuring of strength-fitness has been the concern of scientists ever since the experiments conducted by the French researcher De La Hire in 1699 in which he compared the ability of men to carry weights with that of horses.

While strength, power, and local muscular endurance have over the years been measured by many different indirect performance tests and test batteries requiring minimal apparatus, a variety of scientific instruments have been developed and utilized for strength-fitness assessment.

The first person to use an instrument which was called a *dynamometer* was an Englishman by the name of Graham (Bullard,1886). Subsequently, Desaguliers, a Frenchman who was a professor at the University of Oxford in England adapted this device and developed a machine which consisted of *a large wooden frame and stout uprights to offer points* *of support or resistance, and handles attached to a crossbar which moved a steelyard;* by hanging weights on the latter, the force used could be directly determined (Bullard, 1886).

Since that time, many pieces of apparatus have been developed for the purpose of measuring strength-fitness, including spring steel dynamometers such as those devised by Regnier in 1807 (Amar, 1920), Sargeant in 1897, Smedley in 1900, and Schmier in 1945; mercurial dynamo= meters (Kellog, 1893); pneumatic dynamometers (Geckler, 1939); the "ergograph" (Hellebrandt and Kelso, 1948); tensiometers (Clarke, 1948); strain gauge dynamo= meters (Tuttle, 1950), and force plates (O'Shea, 1985). The various methods, have been limited largely in that they have generally not been able to measure all components of strength-fitness (ie strength, power, and local muscular endurance), have involved primarily isometric muscular contractions, and have been restricted in use to only a few specific muscle groups.

3.2.2.7.2 The Cybex II Isokinetic Dynamometer

Recently, a new method has been developed, making it possible to determine dynamic strength, power, and local muscular endurance without the limitations of the previously mentioned modes of strength fitness assessment - the Cybex II isokinetic dynamometer.

Thistle and co-workers (1967) attribute the origins of the isokinetic testing principle to James J. Perrine, a view supported by Kusakin (1971) who affirms that Perrine built the first isokinetic device (Cybex) in 1965. It should, however, be noted that over 50 years ago Levin and Wyman designed a constant-velocity ergometer to speci= fically control muscle shortening speed, and achieved their purpose by regulating with a needle valve the oil flow between 2 connected chambers (Levin and Wyman, 1927). This precision-made, finely balanced isokinetic ergo= graph was widely used for many years in muscle experi= ments. Asmussen's group (1965) also built a motor-driven isokinetic machine to test concentric forces. However, there seems little doubt that the current interest in isokinetics stems from the commercial availability of Perrine's isokinetic machine.

Briefly, the Cybex II isokinetic dynamometer 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 provides a continuous tracing of torque curves throughout the entire range of movement. Strength (as represented by the maximum slow-speed torque capability), power (as represented by the maximum fast-speed torque capability), and local muscular endurance (referred to as "power-endurance" and as represented by the number of repetitions to 50% fatigue during a maximum effort, functional-speed test) can be determined using the Cybex II isokinetic dynamometer for a variety of muscle groups. The precise methodology involved in performing the various tests is documented in a handbook entitled *Isolated-Joint Testing and Exercise... A Handbook for Using Cybex 11 and the UBXT.*

3.2.3 FLEXIBILITY

3.2.3.1 Definition

Two types of flexibility, "static" and "dynamic", have been described (Mathews and Fox, 1976). Static flexi= bility can be defined simply as the range of possible movement at any given articulation (Wells and Dillon, 1952; Leighton 1955; De Vries, 1980; Shephard, 1982). Dynamic flexibility is defined as the opposition or resistance of a joint to motion (Mathews and Fox, 1976; De Vries, 1980; Shephard, 1982). Dynamic flexibility is concerned with the forces that oppose movement over any range rather than the range itself and is more difficult to assess than static flexibility. Little attention has therefore been given by researchers to dynamic flexibility.

It is important to realize, when defining flexibility, that flexibility is in fact specific to a given joint or combination of joints. Thus, because an individual is a composite of many joints, some of which may be unusually flexible, some relatively inflexible, and some average, flexibility should be defined with reference to the specific joints in question and not as whole body flexi= bility (Shellock and Prentice, 1985).

3.2.3.2 Physiology of Flexibility

3.2.3.2.1 Structural Limits to Flexibility

The structural limits to flexibility are bone; muscle; ligaments and other structures associated with the joint capsule; tendons and other connective tissues; and skin. Limitations by bony structures are confined to certain joints. However, in all joints the soft tissues provide the major limitation to the range of joint motion (Mathews and Fox, 1976).

3.2.3.2.2 Myotatic Reflexes

3.2.3.2.2.1 Stretch Reflex

The stretch reflex protects a stretched muscle from being overstretched. Intrafusal and extrafusal muscle fibres lengthen as a muscle is stretched. The resultant deformation of sensory end organs within the spindles activates the stretch reflex which stimulates the stretched muscle to contract. The stretch reflex is sensitive to both dynamic and static stretching. The force and rate of the contraction induced by the stretch reflex are directly proportional to the rate of stretching (Beaulieu, 1981). Thus, if a muscle is stretched rapidly, the resultant contraction will be more forceful than if the muscle is stretched slowly.

3.2.3.2.2.2 Inverse Stretch Reflex

In contrast to the stretch reflex which only responds to stretching, the inverse stretch reflex responds to both stretching and contracting. Thus, the inverse stretch reflex prevents overstressing of the muscle as a result of too much tension from active contraction or over=stretching.

The sensory receptors associated with the inverse stretch reflex are believed to be located in the Golgi tendon organ (de Vries, 1980). When a muscle contracts, the Golgi tendon organ discharges to inhibit the contraction and in so doing relaxes the muscle. Recently, it has been suggested, however, that forceful contractions may in fact not induce complete subsequent relaxation of the muscle via the inverse stretch reflex (Moore and Hutton, 1980).

The inverse stretch reflex has a higher threshold to stretch than does the stretch reflex (de Vries, 1980). Once the intramuscular tension produced by stretching and the resultant stretch reflex contraction reaches threshold tension, the inverse stretch reflex is initiated and in an attempt to reduce the muscle tension, relaxes the muscle under stretch.

3.2.3.3 Techniques Designed to Enhance Flexibility

Beaulieu cites 4 separate stretching techniques which are commonly utilized to enhance flexibility, namely: i. ballistic; ii. passive; iii. contract-relax, a modified version of the proprioceptive neuromuscular facilitation technique; and iv. static. Research has indicated that all 4 modes of stretching are capable of improving flexibility, but no single technique is agreed to be predominantly more effective (Landreth, 1957; de Vries, 1962; Carr, 1971; Hartley-O'Brien, 1980; Sady *et al*, 1982). However, certain of the techiques are thought to involve a greater injury risk than others.

3.2.3.3.1 Ballistic Stretching

This technique utilizes bouncing movements, the force of which stretches the muscle (Weber and Kraus, 1949). Because the force of the muscular contraction evoked by the stretch reflex is proportional to the rate of stretching (Beaulieu, 1981), the tension created in the muscle during ballistic stretching is more than double that created during slow stretching (Walker, 1961). This increases the risk of injury and is therefore considered to be the least desirable stretching technique.

3.2.3.3.2 Passive Stretching

This technique involves the application of an external force to increase flexibility (Beaulieu, 1981). When performed in the correct manner, passive stretching may be extremely effective. However, incorrect technique results in the stretching of soft-tissues beyond their limits, thereby predisposing to injury (Beaulieu, 1981).

3.2.3.3.3 Contract-Relax Technique

The contract-relax stretching technique is based on the assumption that a prestretch contraction will stimulate firing of the Golgi tendon organ and relax the muscle via the inverse stretch reflex. However, Moore and Hutton (1980) have indicated that the prestretch contraction promotes lingering facilitation of the contracted muscles and stretching actually may take place in the presence of a greater tension. Thus, this technique may also produce an increased risk of soft-tissue injury.

3.2.3.3.4 Static Stretching

This technique involves a slowly applied stretch to the muscles, followed by maintaining the muscle in a lengthened position (De Vries, 1962). As the stretch is held, the tension produced in the muscle by the stretch and stretch reflex contraction reaches threshold level, and initiates the inverse stretch reflex. This permits the muscle to relax and be stretched further (De Vries, 1980). Beaulieu (1981) has stated that: *Compared to other techniques, static stretching produces the least amount of tension and is the safest method of improving flexibility.*

3.2.3.4 <u>Measurement of Flexibility</u>

Flexibility may be assessed by 2 basic types of measures ie measures of single joint-action or composite joint-action.

3.2.3.4.1 Single Joint-Action Measures of Flexibility

Over the years, a variety of instruments have been used for assessing single joint-action flexibility (Moore, 1949; McCue, 1953; Defibaugh, 1964). Of these, the Leighton flexometer appears to be the most objective (Harris, 1967). In 1942 Jack R. Leighton devised this instrument, which consists of a weighted circular dial with a weighted needle enclosed in a case attached to the body-part by a strap. Leighton (1942) reported this instrument to be highly reliable, valid, and objective. Reliability estimates ranged from 0.889 to 0.997 for test-retest of 2 trials in his original study (Leighton, 1942). Other advantages proposed by Leighton are that his flexometer takes measurements in units universal to all movements (degrees); that they are free from effects of variation in length and breadth of body segments; that the instrument is applicable to measuring actions of all body segments; and that positioning over the lines of the bones of the joint being measured is not necessary, since the flexometer uses gravity as the origin. Subsequently, many researchers have substantiated the reliability of the Leighton flexo= meter; some reported reliabilities are 0.911 to 0.972 (Hupprich and Sigerseth, 1950), 0.916 to 0.997 (Greey, 1955), and 0.929 to 0.988 (Laubach and McConville, 1966).

3.2.3.4.2 Composite Measures of Flexibility

Since the description by Cureton in 1941 of 4 tests of composite body flexibility, numerous researchers have either developed new tests or revised existing ones.

3.2.3.4.2.1 Cureton's Tests and Revisions of Them

Cureton (1941) developed 4 tests of flexibility. He used sliding wood calipers to measure 3 of them: trunk flexion, trunk extension, and shoulder flexibility. For the fourth test, ankle flexibility was determined by tracing the dorsal aspect of the foot with the ankle in flexion and extension and measuring the angle between the two. The test-retest reliabilities for the tests were: trunk flexion, 0.958; trunk extension, 0.715; shoulder ele= vation, 0.850; and ankle flexibility, 0.728. Cureton's tests were subsequently revised by McCloy and Young (1954) and Hall (1956).

3.2.3.4.2.2 Toe Touch Flexibility Tests

Included in the renowned Kraus-Weber test for minimum muscular fitness is a pass-fail test for touching the toes (Kraus and Hirschland, 1954). In 1957 Buxton extended the Kraus-Weber test to include a more discriminating scoring method; the subject stands on a 6-inch-high bench and his downward reach is measured on a scale marked in 0.5-inch intervals. Buxton (1957) reported a test-retest reliability of 0.95 for children ranging in age from 6 to 15 years.

The standing-reach test described by Scott and French in 1950 is essentially the same as Buxton's test except that a 20-inch scale is used. Test-retest reliability of 0.93 was reported for college women (Scott and French, 1950). While Scott and French discouraged bobbing when performing the test, Wells and Dillon (1952) obtained a test-retest reliability estimate of 0.96 for the standing-bobbing test. However, they developed the sit-and-reach test to eliminate the fear element of a standing test.

Research has shown the results obtained using the adapted Kraus-Weber test, the standing-reach test, and the sit-and-reach test to be extremely similar. Broer and Galles (1958) reported a correlation of 0.90 between the sit-and-reach test and the standing-bobbing test, while Mathews *et al* (1957) documented correlations of 0.95 for the adapted Kraus-Weber and Leighton's hip flexion-extension tests and 0.74 for Leighton's test and the sit-and-reach test.

Today, the standing-bobbing test and the sit-and-reach test are amongst the commonest flexibility tests in use. However, it must be emphasized that no single flexibility test can give a satisfactory index of the total flexibility characteristics of an individual since flexibility is extremely specific to each particular joint or group of joints (Harris, 1967).

3.2.4 SPEED

3.2.4.1 Definition

The term "speed", like other attributes of human per= formance, is shrouded in confusion because of the lack of a clear-cut definition that is acceptable to all exercise physiologists. Hunsicker (1974) suggests that the simplest description of speed probably restricts it to running speed as demonstrated by sprinting ability. Other more complex definitions incorporate the concepts of speed of various body parts and reaction time. In any event, speed has been defined and recognized in many forms.

As was indicated for flexibility, it is probably incorrect to speak of a fast or slow individual since research suggests that speed has very little generality. Indeed, an individual with a fast arm movement may well have slow leg movement (Jensen and Fisher, 1979). In fact, this specificity extends even to the type of task and the direction of movement (Henry, 1960; Clarke and Henry, 1961; Sinning and Forsyth, 1970).

The relation of speed to muscular power has contributed towards further controversy surrounding the definition of this physical fitness factor. As early as 1951 Larson and Yocom pointed out that speed was highly correlated with muscular power. In later years, Fleishman (1964) went as far as claiming that there was a difficulty in isolating a separate speed factor. This view is not universally accepted, since Simons (1969), using the technique of factor analysis (as did Fleishman), has definitely identified a distinctive factor of speed. It must, however, be noted that whereas those researchers who tend to recognize a distinctive physical fitness component of speed refer to speed of movement (such as running), others, like Fleishman (1964), refer to various factors of speed, including speed of change of direction, a factor considered by many to reflect agility rather than speed per se.

3.2.4.2 Determinants of Running Speed

Research into this area of physical fitness has not been performed on a widespread basis. However, it is evident that running speed consists of 2 basic components. The first, acceleration, is believed to be determined by the shape of the individual's force-velocity curve for his active muscles, and thus by muscle temperature and the proportion of type II muscle fibres (Shephard, 1982). The second, maintenance of speed, depends more upon the efficiency of neuromuscular co-ordination, particularly an ability to restrict unnecessary activity in antagonistic muscles (Marsden *et al*, 1977).

Despite the paucity of scientific research data on the subject, some information on 2 interesting questions regarding running speed is available, ie is the maximum speed limited by the maximum rate of leg alteration, and do increases in running speed result from increasing length of stride or rate of leg movement?

In a simple experiment by Slater-Hammel in 1941 it was shown that the rates of leg alteration in sprinting were

3.10-4.85.sec^{-1}. Because considerably higher rates are possible in cycling (5.5 to 7.1), he concluded that speed in running is not limited in this way. However, it is important to realize that the validity of this conclusion might not be absolute in view of the different biomechanics involved in running and cycling. Hubbard (1939), on the other hand, conclusively demonstrated that increases in running speed result from increasing stride length rather than simply the rate of leg movement.

3.2.4.3 Measurement of Running Speed

Running speed is a relatively simple fitness component to evaluate. It is, however, essential that correct distances be chosen in order to minimize the effect of local muscular endurance on running speed. Havlicek and Cechvala (Simri, 1974), using a photoelectric time registration device, have suggested that 50 m is an ideal distance for boys 11-18 years of age and 40 m the ideal distance for girls of the same age group. For adminis= trative purposes, 50 m is most commonly used for girls as well as boys.

A test using a flying (running) start is preferred to one using a crouching start in order to minimize the effects of technique (Simri, 1974). A standing start is, however, often used as a compromise between the crouch and flying starts. Celikovsky's group have reported corre= lations of 0.85 and upwards between the results of races with a flying start and races with a standing start in boys and girls aged from 6 to 18 years, but for inexplicable reasons these correlations are down to around 0.50 in boys and girls aged 12 years (Simri, 1974).

Tests for evaluating running speed can be administered to individual persons or couples. Matsuda (1967) reported no significant differences in the results of 40 children aged

6 years and 45 aged 12 years, whom he evaluated using both methods. He suggests, however, that this may be the result of pairing of runners of differing ability which caused the winner to slow down near the finish.

Marmis *et al*(1969) recommend that each subject be allowed 2 attempts and that the faster time be utilized. He further suggests that a rest of at least 10 minutes be allowed between runs.

Simri (1974) suggests that tests be held on a flat and straight surface. The speed tests should be held on days with no extreme temperatures, rain, or great wind velocity (above 2 $m.sec^{-1}$). A starting pistol or visual device should be used for starting, and at least 1 timekeeper per runner is desirable. Times should be recorded with stopwatches accurate to at least 0.1 sec.

CHAPTER 4

STUDIES EVALUATING MILITARY PHYSICAL TRAINING: FITNESS ATTAINED AND EXERTION-RELATED INJURIES SUSTAINED

4.1 EFFECT OF MILITARY TRAINING ON PHYSICAL FITNESS

4.1.1 SOUTH AFRICAN ARMY

Previously, 3 studies have attempted to assess the efficacy of the South African Army basic training programme and 1 study has evaluated the South African Army physical training instructor course.

4.1.1.1 de Lange's Study

In 1965, de Lange evaluated the physical fitness of 75 matric students (age 18.4$\pm$0.5 years) and 75 South African Army recruits (age 19.4$\pm$1.3 years). The soldiers were selected, on a random basis, from a group of 210 recruits who had just completed 3-months basic training at a centre in Voortrekkerhoogte. The students were chosen from 5 separate Transvaal high schools. Strength (chin-ups), power (standing long-jump), speed (60-yards shuttle-run) and endurance (800-feet shuttle-run) were evaluated by means of a battery of physical performance tests. The strength and power of the 2 test groups did not differ significantly. The recruits recorded faster times for the 60-yards shuttle-run (13.51$\pm$0.67 sec) than the students (13.88$\pm$0.67 sec). In contrast, the time for the 800-feet shuttle-run was faster for the students (92.72$\pm$5.19 sec) than the recruits (94.76$\pm$5.59 sec). A physical fitness index compiled by de Lange (1967) from the results of the various tests yielded an identical value for the recruits and the students. On the basis of this study it was concluded that:

i. Matric students are *sufficiently physically fit to undergo the military training programme compiled for our Army's recruits.*

ii. Physical fitness levels attained whilst at school are not enhanced by the basic training programme of the South African Army.

The conclusions reached by de Lange (1967) were, however, obviously limited by the use of a cross-sectional rather than longitudinal study design. In particular, it has been suggested (Putter, 1964) that the physical fitness of South African matriculants declines markedly after leaving school and it was therefore possible that the basic training programme might in fact have been effective in that it returned the recruits' fitness to levels existing while at school.

4.1.1.2 Scholtz's Study

Scholtz (1968) subsequently conducted a study in which he:

i. Tested the physical fitness of 48 South African Army recruits before and after 9 weeks of basic training.

ii. Compared the physical fitness of these recruits before basic training with that of matric and standard 9 students.

iii. Compared the physical fitness of 133 South African Army recruits on completion of basic training with that of 133 matric and standard 9 students.

Physical fitness components were evaluated as follows:

i. *Strength* - chin-ups and parallel bar dips.

ii. *Power* - standing long-jump.

iii. *Co-ordination* - "bar snap test".

iv. *Speed* - 100-yards sprint.

v. *Local muscular endurance* - 2-minute sit-up test.

vi. *Physical endurance* - 440-yards run and 800-feet shuttle-run.

vii. *Organic fitness* - Gallagher and Brouha 4-minute step-test (Gallagher and Brouha, 1943). This test was only performed by the recruits.

Basic training did not improve the recruits' performance in chin-ups, standing long-jump, or the Gallagher and Brouha step-test. In contrast, the ability to perform parallel bar dips, "bar snap test", sit-ups, 100-yards run, 440-yards run, and 800-feet shuttle-run was enhanced by basic training. A physical fitness-index calculated from all the tests utilized was considerably (11.6%) higher on completion than before basic training.

Regarding the comparison between the students and the recruits, the performance of the students was superior to that of the recruits pre-basic training for all tests with the exception of chin-ups and parallel bar dips. However, after basic training the performance of the students and the recruits was similar for all tests except parallel bar dips (recruits performed better) and standing long-jump (students performed better).

Scholtz concluded that:

i. The South African Army basic training programme *contributes a powerful, positive stimulus to promote physical fitness.*

ii. The physical fitness level of recruits entering the South African Army is *so poor that they first have to undergo a basic training of at least nine*

> *weeks ... in order to be able to be compared favourably with Standard Ten pupils.*

The validity of Scholtz's conclusion regarding the efficacy of the basic training programme must, however, be seriously questioned because, of the 7 physical fitness components investigated, 3 were in fact not enhanced by basic training. Furthermore, although specificity of testing is desirable when evaluating physical fitness of sportsmen who are to participate in a particular sport or athletic event, data derived from the use of performance tests for the fitness assessment of soldiers may be misleading when the tests form part of their weekly training programme (as was evidently the case for certain of the tests used by Scholtz). The reason for this is that the ability to perform many such tests may simply be improved as a result of better technique or external mechanical efficiency rather than an enhanced fitness per se.

4.1.1.3 Burger's Study (unpublished military report)

In 1970, Commandant S.C. Burger assessed the effect of South African Army physical training on the endurance fitness of recruits stationed at 7 units. Endurance fitness was evaluated by means of the time taken to complete a 1.5-mile run, the recruits wearing field uniform and carrying their rifle. The study was cross-sectional in design: 30 national servicemen from each unit were tested monthly, but the same recruit was never tested more than once during the study. Recruits were selected on a random basis. However, 45 recruits were selected each month and only 30 were tested. Thus, injured recruits could be replaced by uninjured recruits. The study was of 9 months duration (at the time of this study the entire duration of National Service was 9 months). The time for the 1.5-mile run improved from the pre-basic training group mean of of 16.02 min to 12.94 min after 8 weeks of basic training (~ 19% improvement), and remained improved as compared to pre-basic training levels throughout the remainder of national service. It is not known, however, whether the 1.5-mile run formed part of the recruits' daily physical training programme, as is presently the case; this is of importance because a considerable degree of technique is involved in running while wearing field uniform and carrying a rifle. Irrespective of this, the major limitation of this study is that it did not take into consideration the feasibility of the physical training used in terms of its injurious nature.

4.1.1.4 Cilliers and Gordon's Study

Since the time of the above-mentioned early studies, no further attempts have been made at assessing the South African Army physical training programme. However, Cilliers and Gordon (1983) did investigate the efficacy of the South African Army physical training instructor course. Their study indicated that although the 11-week course is effective in increasing the physical work capacity of the participants (evaluated using maximal treadmill duration and physical work capacity for a heart rate of 170 beats.min^{-1} during a cycle ergometer test), its feasibility is severely limited by the injurious nature of the training used (7 of their original 24 subjects were forced to withdraw from the course as a result of exertion-related injuries). Furthermore, they suggested that it was likely that *an approach to training which increases the predisposition to the development of stress fractures and other overuse injuries is learned during the PT instructor course, and transmitted by the qualified instructors to their military recruits*, and questioned the effectiveness of the South African Army basic training centres. This study emphasized the need for a scientific study aimed at assessing the efficacy of the South African Army basic training programme in terms of both physical fitness attained and injuries sustained.

4.1.2 FOREIGN ARMED FORCES

4.1.2.1 Effect of Basic Training on Endurance Fitness

A number of studies assessing the effect of military basic training on the endurance fitness of armed forces of countries including Britain, Canada, Czechoslovakia, Denmark, Finland, Norway, Sweden, and the United States have been performed. The essential findings of these studies are documented in Tables 1,2, and 3. According to the results of these studies endurance fitness, as measured either by direct or indirect tests, generally improves during basic training. However, in many of the studies the magnitude of the improvement was in fact minor. In this respect, the studies performed by Patton *et al* (1980) on United States Army recruits and Viitasalo and Vainikka (1982) on Finnish Army recruits indicate that the degree of improvement in endurance fitness derived during basic training may be dependent largely on the pre-basic training conditioning level; recruits with the lowest endurance fitness levels prior to basic training derived the greatest endurance training benefits in their studies.

4.1.2.2 Effect of Basic Training on Other Physical Fitness Components

The effect of military basic training on fitness components other than endurance has been poorly studied.

As regards strength-fitness, a review of the available literature reveals 4 studies, 1 of which has been reported only in abstract form.

TABLE I : EFFECT OF BASIC TRAINING ON THE ENDURANCE FITNESS OF BRITISH, CANADIAN, CZECHOSLOVAKIAN, DANISH, AND NORWEGIAN RECRUITS

	Britain	Canada	Czechoslo=vakia	Denmark	Norway
Researchers	Vogel *et al*	Myles and Allen	Bürger and Klimes	Hartling	Staff
Year	1978	1979	1973	1975	1973
Number of Recruits	254	238	25	137	56
Duration of Training	2.3 months	13 weeks	2 months	3 months	7 weeks
Mode of Testing	Cycle ergometer	Cycle ergometer	Cycle ergometer	Cycle ergometer	Cycle ergometer
Parameter	$\dot{V}O_2$ max, $m\ell.kg^{-1}.min^{-1}$(P)	$\dot{V}O_2$ max, $m\ell.kg^{-1}.min^{-1}$(P)	$\dot{V}O_2$ max, $\ell.min^{-1}$(P)	$\dot{V}O_2$ max, $m\ell.kg^{-1}.min^{-1}$(P)	$\dot{V}O_2$ max, $\ell.min^{-1}$(P)
% Change	+7.9	+14	+13.7	+6	+19

Abbreviations: $\dot{V}O_2$ max = maximal O_2 consumption;
P = predicted values

TABLE II : EFFECT OF BASIC TRAINING ON THE ENDURANCE FITNESS OF FINNISH AND SWEDISH RECRUITS

	Finland	Finland	Finland	Sweden	Sweden
Researchers	Viitasalo *et al*	Vainikka	Viitasalo and Vainikka	Linderholm	Knuttgen *et al*
Year	1977	1978	1982	1967	1973
Number of Recruits	183	58	41	24	8
Duration of Training	3 months	3 months	4.5 months	4 months	1 month
Mode of Testing	12-minute run	Cycle ergometer	12-minute run	Cycle ergometer	Cycle ergometer
Parameter	Distance, meters	$\dot{V}O_2$ max, $m\ell.kg^{-1}.min^{-1}$(D)	Distance, meters	$\dot{V}O_2$ max, $\ell.min^{-1}$(P)	$\dot{V}O_2$ max, $m\ell.kg^{-1}.min^{-1}$(D)
% Change	+2.9	+2.3	+2.2	+11	+8.6

Abbreviations: $\dot{V}O_2$ max = maximal O_2 consumption;
D = directly determined values;
P = predicted values

TABLE III : EFFECT OF BASIC TRAINING ON THE ENDURANCE FITNESS OF UNITED STATES RECRUITS

	United States Army	United States Army	United States Military Academy	United States Army	United States Military Academy
Researchers	Vogel *et al*	Kowal *et al*	Daniels *et al*	Patton *et al*	Daniels *et al*
Year	1977	1978	1979	1980	1982
Number of Recruits	186	85	29	87	11
Duration of Training	7 weeks	6 weeks	6 weeks	7 weeks	6 weeks
Mode of Testing	Treadmill	Cycle ergometer	Treadmill	Treadmill	Treadmill
Parameter	$\dot{V}O_2$ max, $m\ell.kg^{-1}.min^{-1}$(D)	$\dot{V}O_2$ max, $m\ell.kg^{-1}.min^{-1}$(P)	$\dot{V}O_2$ max, $m\ell.kg^{-1}.min^{-1}$(D)	$\dot{V}O_2$ max, $m\ell.kg^{-1}.min^{-1}$(D)	$\dot{V}O_2$ max, $m\ell.kg^{-1}.min^{-1}$(D)
% Change	+8	+11.3	+2	+3.7	+2.7

Abbreviations: $\dot{V}O_2$ max = maximal O_2 consumption;

D = directly determined values;

P = predicted values.

At the 1977 American College of Sports Medicine annual meeting, Vogel *et al* presented data on the effect of 7-weeks United States Army basic training on the strength of 186 male recruits aged 21.1±2.3 years. Strength was measured by maximal voluntary isometric contractions of the elbow flexors and extensors and knee flexors and extensors. Basic training induced a significant improve= ment for elbow extension strength alone.

In 1980, Knapik *et al* examined the effect of 7-weeks basic training on the maximum voluntary isometric strength of 769 male United States Army recruits, aged 19.8±2.7 years. The training programme consisted primarily of calisthenic, strengthening, running, and marching activities. All activities were of progressively increasing exercise intensity. Calisthenics and strengthening activities were performed for about 1 hour each day, 5-6 days per week, beginning with 5 repetitions the first day and progressing to about 12 repetitions by the end of training. Maximal voluntary isometric strength was determined for the upper torso flexors, leg extensors, and trunk extensors. Basic training resulted in significant increases in the strength of the upper torso flexors (4.2%), leg extensors (9.7%), and trunk extensors (8.1%). However, the authors indicated that the improvements were less than those that could be expected from a specific weight training programme.

Daniels *et al* (1982) subsequently evaluated the changes that occurred for the maximal isometric strength of 11 male United States Military Academy cadets during a 7-week military field training programme. All cadets were 18-21 years of age at the beginning of the study. Three muscle groups were evaluated: upper torso flexors, leg extensors, and trunk extensors. Significant increases in the strength of the upper torso flexors (7.7%) and leg extensors (9.3%), but not the trunk extensors, were noted.

In 1982 Viitasalo and Vainikka reported on the effect of 5-months Finnish basic training on the maximal isometric strength of 75 male recruits. The recruits were divided into a normal and additional training group. Both groups participated in the normal recruit training programme during the first 2 months of basic training. After this, the additional training group participated in a circuit training programme as well as the normal training programme. The circuit training programme incorporated the following exercises: dips, sit-ups, standing long-jumps, push-ups, reverse sit-ups, and vertical jumps. The maximal muscular strength was measured in terms of isometric strength of the trunk extensors, trunk flexors, leg extensors, and arm extensors. None of the parameters increased significantly for either of the 2 groups. No significant differences were observed between the normal and additional training groups. However, when the results were analysed further by dividing recruits into those with below and above average strength, significant increases were noted for leg extension and trunk flexion strength for the below average recruits of both the normal and additional training groups.

The above studies indicate that only minor improvements in strength occur during basic training, and suggest that the improvements may be limited to those recruits with below average levels at the onset of basic training.

No scientific studies assessing the effect of modern-day military basic training on additional physical fitness components have been reported in the available literature.

4.1.2.3 Effect of Military Training Performed After Basic Training on Physical Fitness

Of the above military basic training studies, only 2 assessed the effect of the remainder of military training on physical fitness.

In addition to evaluating 11 United States Military Academy cadets before and after basic training, Daniels *et al* (1982) tested the cadets in their study on comple= tion of their first and second years of military training. Endurance fitness, expressed in terms of $\dot{V}O_2$ max ($m\ell.kg^{-1}.min^{-1}$), was not significantly enhanced by basic training and remained unaltered over the 2-year study period. No data are available for the leg extensor strength on completion of 2 years of training. Upper torso strength, but not trunk extensor strength, increased by 10.2% ($p < 0.01$) during the subsequent military training period. However, it is important when interpreting these data to realize that United States Military Academy cadets are pre-selected on the basis of physical fitness (this is evident from the pre-training $\dot{V}O_2$ max of 58.5 ± 3.5 $m\ell.kg^{-1}.min^{-1}$) and the results of this study cannot necessarily be extrapolated to routine United States Army training.

The remaining study is that performed by Myles and Allen (1979) on Canadian soldiers. This cross-sectional study suggested that although basic training induces a marked increase in indirectly determined $\dot{V}O_2$ max, endurance fitness generally deteriorates to the pre-training state after recruits *are assigned to their trades and classifi= cations*.

4.2 LOWER EXTREMITY EXERTION-RELATED INJURIES INCURRED DURING MILITARY BASIC TRAINING

4.2.1 STUDIES OF LOWER EXTEMITY EXERTION-RELATED INJURIES DURING BASIC TRAINING

Exertion-related injuries of the lower extremeties have plagued military recruits for centuries (Breithaupt, 1855). Despite increasing mechanization, these injuries continue to be a major hazard for modern-day recruits (Stacy and

Hungerford, 1984). Such injuries are of utmost importance in that they not only result in an increased cost of medical care, but they may also impair the efficacy of basic training centres by causing a loss of training time.

Despite the apparent enormity of this problem (Cilliers and Gordon, 1983), no comprehensive data are currently available for South African Army recruits. For foreign armed forces, the situation is not much better; only 3 comprehensive studies reporting the incidence of exertion-related injuries have been documented in the literature. However, these studies do provide a glimpse of the magnitude of the problem.

In 1976, Bensel studied 879 United States Marines under= going 11-weeks basic training at the San Diego, California, Marine Recruiting Depot. This investigation was aimed at determining whether the use of tropical combat boots would reduce the incidence of lower extremity injuries normally incurred using the standard leather combat boot. During the basic training period under investigation 325 of the 879 recruits were injured, the overall incidence of injury being 37%. The average amount of training time lost was 3 days per injury. This study is limited, however, in that it dealt only with injuries below the knee and other studies performed on civilian runners indicate that approximately 20-40% of all debilitating training injuries in fact involve the knee itself (James *et al* 1978; Krissoff and Gerris, 1979; Clement *et al*, 1981; Maughan and Miller, 1981). Incidentally, the wearing of tropical combat boots was not found to be beneficial as regards injury prevention.

Kowal (1980) subsequently studied exertion-related injuries in United States Army recruits at Fort Jackson, South Carolina. The intent of this prospective study was to focus on and identify *exercise-related injuries and performance-limiting conditions* that result from an 8-week basic training programme when performed by female recruits. Some comparative data were, however, collected on injuries sustained by the male counterparts of these female recruits. The overall incidence of lower extremity injuries to females during the study period was 62% (215 of 347) and for males 26% (202 of 770). The average injury sustained by the female recruits resulted in 13 days of lost training time. No data on time lost for males were presented.

Most recently, Captain R.J. Stacy and Major R.L. Hungerford of the New Zealand Ministry of Defence (1984) assessed injury rates during basic training at the Army Training Group, Waiouru, New Zealand. The duration of basic training was 10 weeks. Following an analysis of injuries sustained by 5 basic training periods involving a total of 159 recruits it was noted that there was a marked similarity between the rate and type of *work-related* injuries. Significant data obtained on these recruits are as follows:

i. *Work-related* injuries were sustained by $65.4 \pm 6.7\%$ of the recruits, amounting to 85.5 ± 8.8 injuries per 100 recruits.

ii. *Work-related* injuries resulted in an average of 104 ± 24.9 days off work, ie 3.3 ± 0.9 days per recruit.

Because of this observed excessive injury incidence, the following changes were introduced into the training programme for 2 subsequent basic training periods (78 recruits):

i. No running in boots for the first 5 weeks of training.

ii. Introduction of boots for general purposes progressively over this period.

iii. Physical training to be done only in approved running shoes.

These changes resulted in a highly significant (38.5%) fall in the number of injuries per 100 recruits ie from 85.5±8.8% to 52.6±5.4% and the time off work (53.9%) ie 104±24.9 days to 48±19.8 days.

4.2.2 STRESS FRACTURES

Of the various exertion-related injuries incurred during military training, stress fractures have been investigated in the greatest detail.

4.2.2.1 Incidence of Stress Fractures During Military Training

Stress fractures (also referred to in the literature as Deutschlanders, fatigue, boot, march, insufficiency, exhaustion, spontaneous, or pseudo fractures) have been a recognized hazard of military training since their initial literary coverage in 1855 by Breithaupt, a military physician who described the oedematous painful feet of Prussian Army recruits following long marches.

In the United States Army an early indication of the magni= tude of the problem was provided in 1967 by Morris and Blickenstaff when they reported on more than 700 recruits treated at Fort Ord, California, over a 3-year period.

An accurate assessment of the actual incidence of stress fractures amongst United States Army recruits was subse= quently obtained in 1974 when a survey of all basic training centres revealed that 4.88% of trainees sought medical care for stress injuries of bone (Scully and Besterman, 1982). This survey provided an impetus to seek methods for the prevention of stress fractures in United States Army recruits. Recent modifications of their basic training programme, based on a knowledge of the physiologic response of bone to repetitive mechanical loading, have cummulated in an acceptable stress fracture incidence of approximately 1% amongst male United States Army recruits (Protzman and Griffis, 1977; Scully and Besterman, 1982).

No data pertaining to the actual incidence of stress fractures amongst recruits of other foreign armed forces are available.

4.2.2.2 Aetiology and Prevention of Stress Fractures During Military Training

Many conflicting hypotheses have been postulated over the years regarding the aetiology of stress fractures. These have included traumatic inflammation of tendon sheaths, nutritional deficit, polyhypovitaminoses, local periostitis secondary to haematogenous sepsis, intermittent trauma to bone, and prolonged muscular action on bone (Worthen and Jandklowitz,1978; Black, 1982).

Currently, it is believed that stress fractures develop when the rate of accumulation of stress induced damage and the ensuing osteoclastic resorption of injured bone exceed the rate of repair by osteon maturation and periosteal new bone formation (Scully and Besterman, 1982). Because stress is a function of the force exerted per unit area of a load-bearing structure, it is readily apparent that as the load-bearing area is diminished during this phase of excessive osteoclastic resorption the stress generated by a set load will increase considerably, thereby enhancing stress-induced bone damage and hence stress fracture development. Johnson *et al* (1963) have indicated, however, that should the inciting activity be discontinued during this critical period, cavities produced by the osteoclastic cutting cones will be filled with osteoblasts. Furthermore, this process will frequently be augmented by periosteal and occasionally endosteal lamellar bone depositions which, together with the osteoid in the newly formed osteons, becomes calcifiable in 8 to 10 days and a few hours thereafter has accreted 60 to 70% of the mineral salts that it will acquire (Scully and Besterman, 1982). This results in an increased cross-sectional area of load-bearing bone, reducing the stress generated by a given load and consequently the predisposition to stress fracture (Evans and Riolo, 1970).

Acknowledgement of the above-noted considerations lead to the suggestion by Colonel Thomas J. Scully and Major Gerald Besterman of the United States Army (1982) that if the incidence of stress fractures is to be minimized, stress induced bone remodeling should be considered to be the skeletal goal of military physical conditioning programmes. To achieve this they recommend the implementation of 2 major changes in the design of military basic training programmes:

i. The concept of "cyclic-progressive" physical training should be adopted in preference to purely "progressive" physical training in order to facilitate limited fatigue damage to bone, and then permit damaged bone to be repaired by osteonization and periosteal new bone formation during a period of relative rest prior to initiating a new cycle of bone remodeling during more intensive physical training. In accordance with the present knowledge of the rate of bone remodeling and the fact that the majority of United States Army trainees with clinically apparent stress fractures report an onset of symptoms between the tenth and twelfth days of training (Scully and Besterman, 1982), this period of rest should occur during the third week of physical training.

ii. The extent of stress-induced bone damage which is incurred prior to the rest period must be controlled by altering the number of repetitions of activities which impose high skeletal stresses eg jumping exercises, exercising while excessively fatigued, and performing weight-bearing activities while wearing combat boots.

These recommendations were evaluated in 1974 on a group of 440 basic trainees at Fort Knox, Kentucky (Scully and Besterman, 1982). Their basic training programme was modified by the elimination only of running, jumping, and "double timing" during the third week of training. Another group of 440 recruits performed the unmodified basic training programme and served as the control group. In comparison to the control group who sustained a 4.8% stress fracture rate, the group undergoing modified basic training sustained a 1.6% stress fracture rate. Of special importance is the fact that the recruits participating in the modified basic training programme achieved final physical training test scores which were equal to the control group and to those previously achieved by the same training companies. Thus, this study suggests that modifications of training techniques may help reduce the high incidence of stress fractures in military trainees.

CHAPTER 5

EVALUATION OF THE SOUTH AFRICAN ARMY PHYSICAL TRAINING PROGRAMME - PART I : EFFECT OF ONE YEAR NATIONAL SERVICE ON ENDURANCE FITNESS

5.1 INTRODUCTION

In recent years, foreign armed forces have recognized endurance fitness as the major component of military physical fitness; the documentation of at least 15 publications in the scientific literature since 1967 aimed at assessing the effect of military training on endurance fitness attests to this. This situation has arisen largely as a result of the nature of present-day physically demanding military tasks coupled with the identification of numerous potential physiologic and psychologic benefits associated with superior endurance fitness levels (Shephard, 1982).

Likewise, the South African Army has recognized the importance of endurance fitness in the military context (Goosen, 1970; Cilliers and Gordon, 1983). Currently, a considerable portion of the South African Army basic training programme is devoted to the enhancement of endurance fitness. Furthermore, recruits are supposedly encouraged to maintain adequate levels of endurance fitness during the remainder of their military training and undergo endurance fitness testing, by means of a 2.4 km or 3.2 km run, at regular intervals. However, the efficacy of the endurance training modes currently propogated by the South African Army have yet to be scientifically evaluated. This would appear to be of considerable concern because the training methods used have remained essentially unaltered for over a decade, despite considerable advances in this particular field of exercise science during the period in question (Haskell, 1985). Moreover, the findings of a recent study of the South African Army physical training instructors' course lead Cilliers and Gordon (1983) to in fact question the effectiveness of the South African Army basic training programme.

To help clarify the situation, the present study investi= gated the effect of the South African Army basic training programme and the remainder of the first year of military training on endurance fitness.

5.2 METHODS

5.2.1 SUBJECTS

Because of the short time interval between arrival of recruits and their commencement with basic training, and the essential need to complete baseline evaluations prior to initiation of the physical conditioning programme, the first group of recruits reporting for military con= scription at the large South African Army basic training centre under investigation was briefed regarding the proposed project. Of these recruits, 100 presumably healthy randomly nominated subjects were asked to volunteer for the study and informed consent was obtained.

5.2.2 EXPERIMENTAL PROCEDURES

Subjects were initially evaluated during the 10 days before basic training and then subsequently, using identical experimental procedures, during the final 10 days of basic training and on completion of 1 year military service. During the final test period only those subjects who had completed the previous 2 evaluations were investigated.

Recruits were required to complete a physical activity history questionnaire prior to their initial test. Because cigarette smoking may influence maximal aerobic capa= city (Dressendorfer *et al*, 1983), the number of cigarettes smoked per day was recorded at all 3 test sessions.

Nude body weight and height were measured using a cali= brated Detecto medical scale. To estimate percentage body fat the sum of 4 skinfolds (biceps, triceps, subscapular, and suprailiac), measured using Harpenden skinfold calipers in accordance with the techniques described by Smit (1979), were used together with the formulae of Durnin and Rahaman (1967), and Siri (1961). Anthropometric character= istics, determined with a standard Martin-type anthropo= meter, sliding caliper, and steel tape, were employed together with skinfolds to calculate somatotypes according to the Heath-Carter method (Heath and Carter, 1956).

Subjects avoided strenuous physical activity for 24 hours before exercise testing and abstained from meals, tea, coffee, cola beverages, and cigarettes for at least 3 hours prior to exercise. All subjects were given an initial familiarization trial. For each subject, $\dot{V}O_2$ max, maximal heart rate, lactate turnpoint*, and other relevant ventilatory variables were measured using a discontinuous graded treadmill exercise test (Gordon *et al*, 1985b). Subjects commenced walking on a calibrated Quinton (model 18-60) motor driven treadmill at a speed of 5 $km.hour^{-1}$

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* The term "lactate turnpoint" is used in preference to the term "anaerobic threshold" when referring to the present O_2 consumption-blood lactate relationships in order to avoid any implication of causality.

and gradient of 5% (Kindermann *et al*, 1980). The gradient remained constant and the speed was increased by 5 km.hour^{-1} with each successive 3-minute work load, till volitional exhaustion (Kindermann *et al*, 1980). 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 Measurement System (Gordon *et al* , 1985b). 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-sec 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 spiro= meter at a rate of 0.5 ℓ.min^{-1} for determination of mixed expired CO_2 and O_2 concentrations with an infrared absorbtion CO_2 analyzer and a polarographic O_2 analyzer respectively, at the end of each 60-sec test interval. The gas analyzers 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 sec of each 60 sec of exercise. Peak heart rate and O_2 consumption attained during exercise were taken as $\dot{V}O_2$ max and maximal heart rate, respectively (Smyth *et al*, 1984; Gordon *et al*, 1985a, b,c,d,e,f). Venous blood samples (~ 2 mℓ) were obtained immediately on completion of each 3-min work load from an antecubital vein through an indwelling vein infusion set (Venisystems, Butterfly-19, Cat. No. 4590) kept patent with ~ 0.7 mℓ sterile heparinized saline (5IU.ℓ$^{-1}$). Before sampling, ~1.5 mℓ of fluid was withdrawn and discarded. Blood samples were immediately placed in ice-cold 0.6N perchloric acid, the precipitated protein removed by centrifugation, and blood lactate concentrations determined enzymatically (Noll, 1974). For each subject the relationship between blood lactate and submaximal O_2 consumption was approximated by means of a biphasal linear regression model as described by van Rensburg *et al* (1982). Lactate turnpoint was defined as the O_2 consumption at which blood lactate levels commenced to rise exponentially, and expressed in relative (% $\dot{V}O_2$ max) and absolute (mℓ O_2.kg^{-1}.min^{-1}) terms. Treadmill exercise performance time was calculated by subtracting the rest intervals from the total exercise test duration.

5.2.3 PHYSICAL CONDITIONING DURING BASIC TRAINING

The 10-week basic training programme consisted of 4 phases of conditioning as follows:

Phase 1 (weeks 1, 2) - a 3.2 km run was performed 5 mornings each week with the recruit wearing shorts, vest, and "takkies"; light calisthenics were performed for 40 minutes on 4 afternoons each week (refer to *Guide To Battle Physical Training*, 1966, for further details).

Phase 2 (weeks 3 - 5) - a 3.2 km run was performed 5 mornings each week with the recruit wearing field uniform (ie long trousers, long sleeve shirt, metal-helmet, web-belt, and combat boots); "battle physical training" was performed for 40 min on 4 afternoons each week(refer to *Guide To Battle Physical Training*, 1966, for further details).

Phase 3 (weeks 6 - 8) - a 3.2 km run was performed 5 mornings each week with the recruit wearing field uniform and carrying his rifle; "rifle physical training" was performed for 40 min on 4 afternoons each week (refer to *Guide To Battle Physical Training*, 1966, for further details).

Phase 4 (weeks 9, 10) - a 3.2 km run was performed 5 mornings each week with the recruit wearing field uniform and webbing, and carrying his rifle; "buddy physical training" was performed for 40 min on 4 after= noons each week (refer to *Guide to Battle Physical Training*, 1966, for further details).

5.2.4 STATISTICAL METHODS

Significance of differences between experimental variables was analysed using one-way analysis of variance (ANOVA), followed by the Scheffé procedure when a significant F-ratio was obtained. Statistical significance was established at the 0.05 confidence level. Values are expressed as mean ± standard deviation.

5.3 RESULTS

5.3.1 PRE-BASIC TRAINING MEDICAL EVALUATION

Of the 100 recruits selected for this study, 7 were not issued with full medical clearance by their unit for parti= cipation in all aspects of military training. The results of these recruits were therefore totally 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 IV. However, because of injury (Table V), illness, death (2 recruits in motor vehicle accidents while on leave from military training), scheduling conflicts, equipment malfunction, and volun= tarily declining participation in certain evaluation procedures, the samples of recruits performing the different experimental procedures and test sessions consisted of varying numbers.

The pre-basic training physical activity questionnaire indicated that 3 subjects had previously participated in endurance sports on a provincial level and 6 subjects on a club level, and that an additional 7 subjects had commenced with an exercise training programme in prepara= tion for military conscription.

TABLE IV : PRE-BASIC TRAINING PHYSICAL CHARACTERISTICS OF SOUTH AFRICAN ARMY RECRUITS

Age (year)	19.2 $\pm$ 3.2
Height (cm)	177 $\pm$ 6.5
Weight (kg)	67.8 $\pm$ 9.5
Body fat (%)	13.6 $\pm$ 3.2
Endomorphy	2.6 $\pm$ 0.8
Mesomorphy	4.4 $\pm$ 1
Ectomorphy	3.5 $\pm$ 1.1

Values are mean $\pm$ SD. n = 93.

TABLE V : EXERTION-RELATED INJURIES PREVENTING RECRUITS FROM COMPLETING POST-BASIC TRAINING ENDURANCE FITNESS TEST

BELOW-AVERAGE FITNESS RECRUITS:

- stress fracture
  (3 recruits)
- "shin splints"
  (1 recruit)
- "runners knee"
  (2 recruits)
- achilles tendinitis
  (1 recruit)
- ankle sprain
  (1 recruit)

AVERAGE FITNESS RECRUITS:

- stress fracture
  (1 recruit)
- shin splints
  (1 recruit)
- "runners knee"
  (1 recruit)

ABOVE-AVERAGE FITNESS RECRUITS:

- "runners knee"
  (1 recruit)
- achilles tendinitis
  (1 recruit)
- lower-back injury
  (1 recruit)

5.3.2 EFFECT OF SOUTH AFRICAN ARMY BASIC TRAINING ON ENDURANCE FITNESS

The effect of military training on cardiorespiratory variables at maximal effort, lactate turnpoint, and endurance performance is documented in Table VI. The pre-basic training $\dot{V}O_2$ max of 53.14 ± 4.69 $m\ell.kg^{-1}.min^{-1}$ did not change significantly during the test period. In contrast, lactate turnpoint ($m\ell\ O_2.kg^{-1}.min^{-1}$) and maximal treadmill exercise performance time were modera= tely enhanced (7.5% and 8% increase, respectively, $p < 0.05$) by basic training. The observed endurance training effect was transient in nature, however, and the recruit fitness levels were unaltered from those documented before military conscription on completion of 1 year military training (Figure 1).

5.3.3 STRATIFICATION OF TRAINING EFFECT ON BASIS OF INITIAL FITNESS LEVEL

In an attempt to determine why the recruits showed no average improvement in $\dot{V}O_2$ max with basic training in the present study, they were divided into 3 groups on the basis of their initial lactate turnpoints ($m\ell\ O_2.kg^{-1}.min^{-1}$). The lactate turnpoint expressed as $m\ell\ O_2.kg^{-1}.min^{-1}$ 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 (Farell *et al*, 1979; Robinson and Sucec, 1980; Thorland *et al*, 1980; Tanaka *et al*, 1981, 1983, 1984; Kumagai *et al*, 1982).

Recruits in the below-average fitness category responded to basic training with marked, statistically significant improvements in $\dot{V}O_2$ max ($m\ell.kg^{-1}.min^{-1}$, 8% increase), lactate turnpoint ($m\ell\ O_2.kg^{-1}.min^{-1}$, 20% increase; % $\dot{V}O_2$ max,

TABLE VI : EFFECT OF SOUTH AFRICAN ARMY TRAINING ON EXERCISE PERFORMANCE, LACTATE TURNPOINT, AND SELECTED MAXIMAL CARDIORESPIRATORY VARIABLES

	Pre BT	Post BT	Post 1 year
$\dot{V}O_2$ max ($\ell.min^{-1}$)	3.62±0.58	3.72±0.54	3.69±0.51
$\dot{V}O_2$ max ($m\ell.kg^{-1}.min^{-1}$)	53.14±4.69	55.04±4.41	52.98±3.99
LA_{tp} (% $\dot{V}O_2$ max)	71.7±10.8	74.6±8.7	70.2±8.5
LA_{tp} ($m\ell.kg^{-1}.min^{-1}$)	38.39±6.67	41.26±5.17***	37.17±4.57
R	1.09±0.04	1.08±0.03	1.09±0.03
$\dot{V}E$ ($\ell.min^{-1}$)	128.6±13.5	131.5±14.1	129.4±12.8
$\dot{V}CO_2$ ($\ell.min^{-1}$)	3.95±0.65	4.02±0.60	4.03±0.59
HR_{max} ($beats.min^{-1}$)	196±7	194±7	195±6
T (min)	20.8±2.8	22.5±2.7***	20.6±1.6

Values are mean ± SD. For $\dot{V}O_2$ max ($\ell.min^{-1}$), $\dot{V}O_2$ max ($m\ell.kg^{-1}.min^{-1}$), R, $\dot{V}E$, $\dot{V}CO_2$, HR_{max}, and T n = 85 Pre BT; n = 65 Post BT; and n = 53 post 1 year. For LA_{tp} (% $\dot{V}O_2$ max) and LA_{tp} ($m\ell.kg^{-1}.min^{-1}$) n = 83 pre BT; n = 64 Post BT; and n = 52 Post 1 year.

Abbreviations: $\dot{V}O_2$ max = maximal O_2 consumption; LA_{tp} = lactate turnpoint; R = respiratory exchange ratio; $\dot{V}E$ = pulmonary ventilation; $\dot{V}CO_2$ = CO_2 output; HR_{max} = maximal heart rate; T = treadmill exercise performance time; Pre BT = pre-basic training; Post BT = post-basic training; and Post 1 year = on completion of 1 year military training.

*** $p < 0.05$ versus Pre BT and Post 1 year.

TABLE VII : EFFECT OF SOUTH AFRICAN ARMY TRAINING ON WEIGHT, PERCENT BODY FAT, AND LEAN BODY MASS

	Pre BT	Post BT	Post 1 year
Weight (kg)	67.8±9.5	68.3±8.3	69.4±10.3
Body Fat (%)	13.6±3.2	13.0±2.4	13.8±3.5
LBM (kg)	58.4±7.2	59.4±6.8	59.7±7.6

Values are mean ± SD. n = 93 Pre BT; n = 84 Post BT; n = 62 Post 1 year.
Abbreviations: LBM = lean body mass; Pre BT = pre-basic training; Post BT = post-basic training; Post 1 year = on completion of 1 year military training.

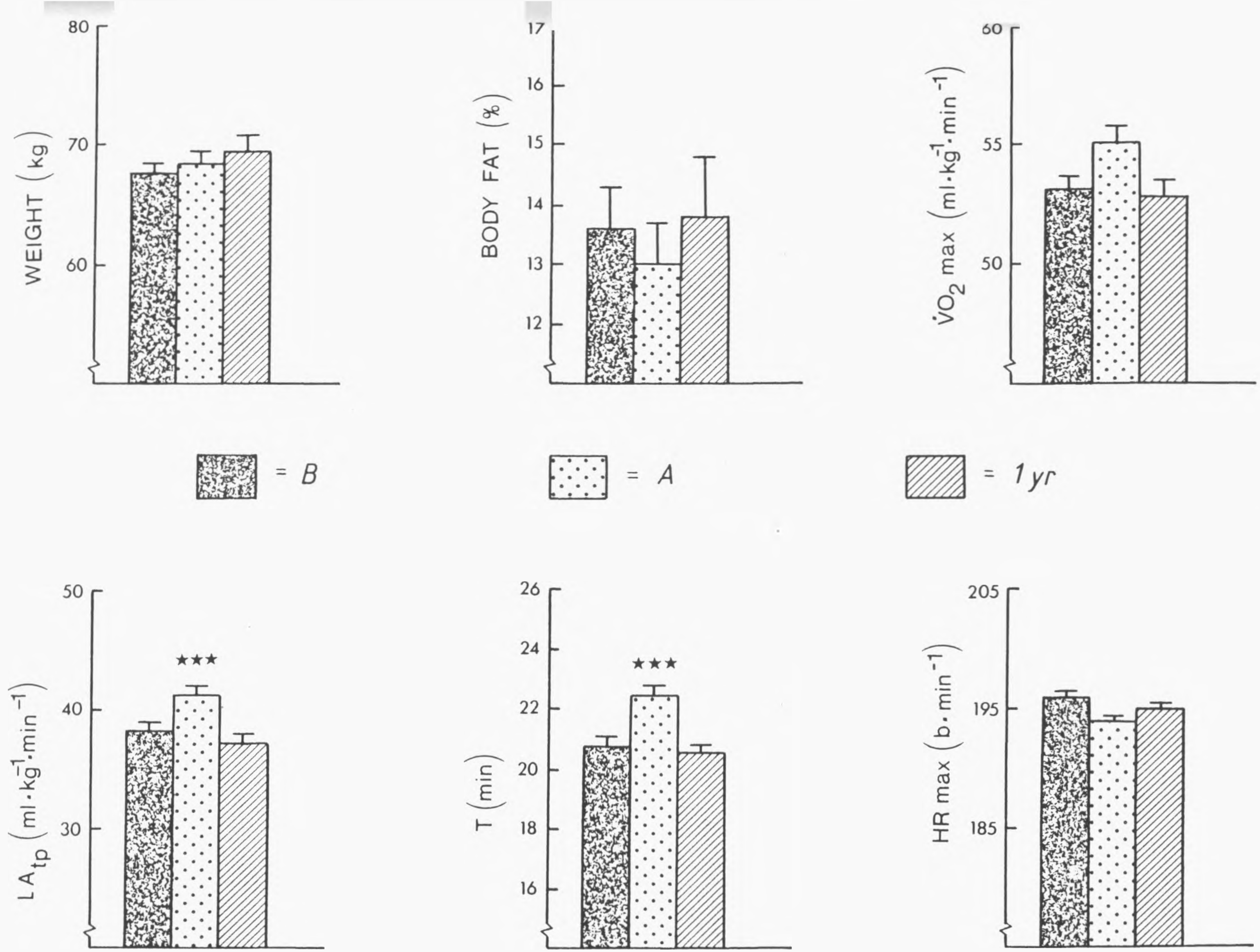

FIGURE 1 : EFFECT OF MILITARY TRAINING ON ENDURANCE FITNESS. Values are mean $\pm$ SEM. Abbreviations: $\dot{V}O_2$ max = maximal O_2 consumption; LA_{tp} = lactate turnpoint; T = performance time; HR max = maximal heart rate; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training. B: n = 93 for WEIGHT and BODY FAT; n = 85 for $\dot{V}O_2$ max, T, and HR max; and n = 83 for LA_{tp}. A: n = 84 for WEIGHT and BODY FAT; n = 65 for $\dot{V}O_2$ max, T, and HR max; and n = 64 for LA_{tp}. 1 yr: n = 62 for WEIGHT and BODY FAT; n = 53 for $\dot{V}O_2$ max, T, and HR max; and n = 52 for LA_{tp}. ***$p < 0.05$ versus B and 1 yr.

11% increase), and treadmill performance time (22% increase) (Figure 2). Furthermore, while the percentage body fat of the entire study group remained unaltered during military training (Table VII), basic training induced a significant reduction in the percentage body fat of the recruits in the below-average fitness category. The salutary effect of basic training on $\dot{V}O_2$ max, lactate turnpoint, exercise performance, and percentage body fat could not be observed, however, on completion of 1 year military service in these recruits. In contrast to the below-average fitness recruits, the average recruits failed to significantly enhance their $\dot{V}O_2$ max during basic training (Figure 3). Moreover, the $\dot{V}O_2$ max of the above-average fitness recruits in fact tended to decrease together with lactate turnpoint and exercise performance with military training (Figure 4).

5.4 DISCUSSION

5.4.1 PRE-BASIC TRAINING ENDURANCE CAPACITY, FITNESS, AND PERCENTAGE BODY FAT OF SOUTH AFRICAN ARMY RECRUITS

The pre-basic training $\dot{V}O_2$ max of 53.14 $m\ell.kg^{-1}.min^{-1}$ documented in this study of South African Army recruits is considerably higher than the value of 47.7 $m\ell.kg^{-1}min^{-1}$ reported by Wyndham *et al* in 1966(b) for 80 young South African Caucasian males. Before the results of the 2 studies can be compared, methodology and subject populations must be equated. While both studies utilized a discontinuous treadmill protocol for exercise testing, a number of addi= tional factors which, in combination, might have exerted a significant influence on the values recorded by Wyndham's group are not clear. In particular, although it is implied that their subjects were active, fit young men and stated that they had *not undergone specialized training for*

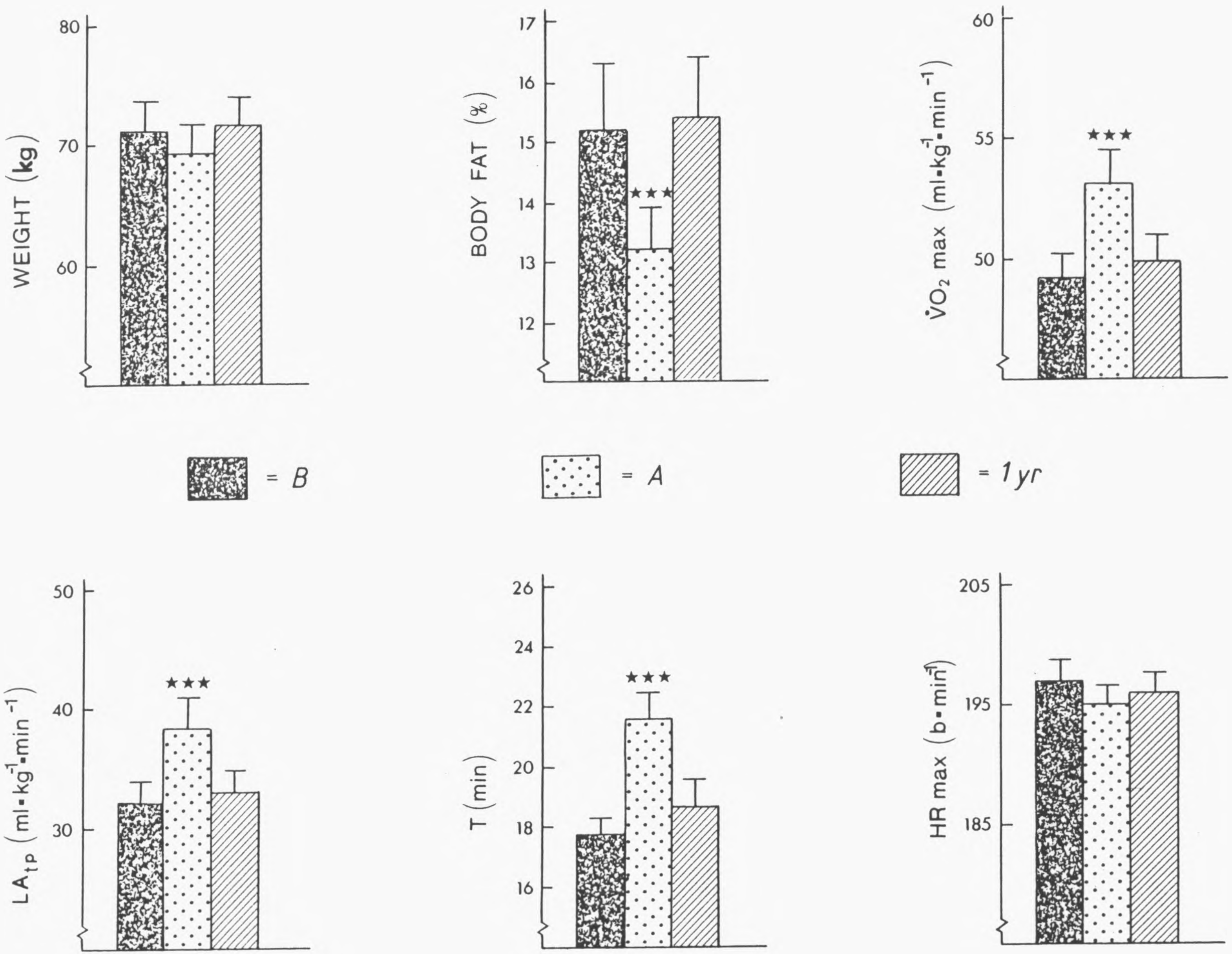

FIGURE 2 : EFFECT OF MILITARY TRAINING ON ENDURANCE FITNESS LEVELS OF BELOW-AVERAGE FITNESS RECRUITS. Values are mean $\pm$ SEM. n = 19. Abbreviations: $\dot{V}O_2$ max = maximal O_2 consumption; LA_{tp} = lactate turnpoint; T = performance time; HR_{max} = maximal heart rate; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training. ***$p < 0.05$ versus B and 1 yr.

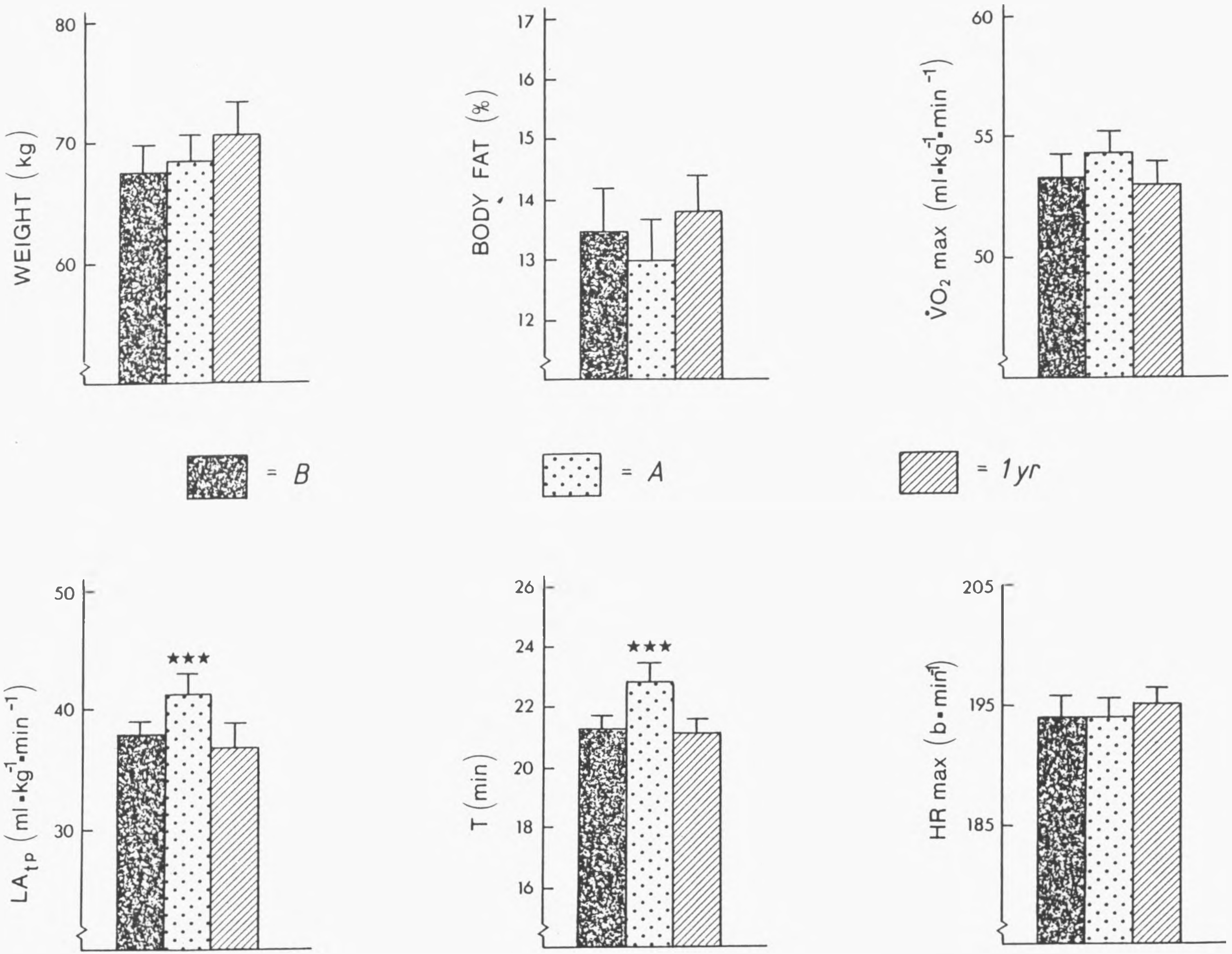

FIGURE 3 : EFFECT OF MILITARY TRAINING ON ENDURANCE FITNESS LEVELS OF AVERAGE FITNESS RECRUITS. Values are mean ± SEM. n = 19. Abbreviations: $\dot{V}O_2$ max = maximal O_2 consumption; LA_{tp} = lactate turnpoint; T = performance time; HR_{max} = maximal heart rate; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training. ***$p < 0.05$ versus B and 1 yr.

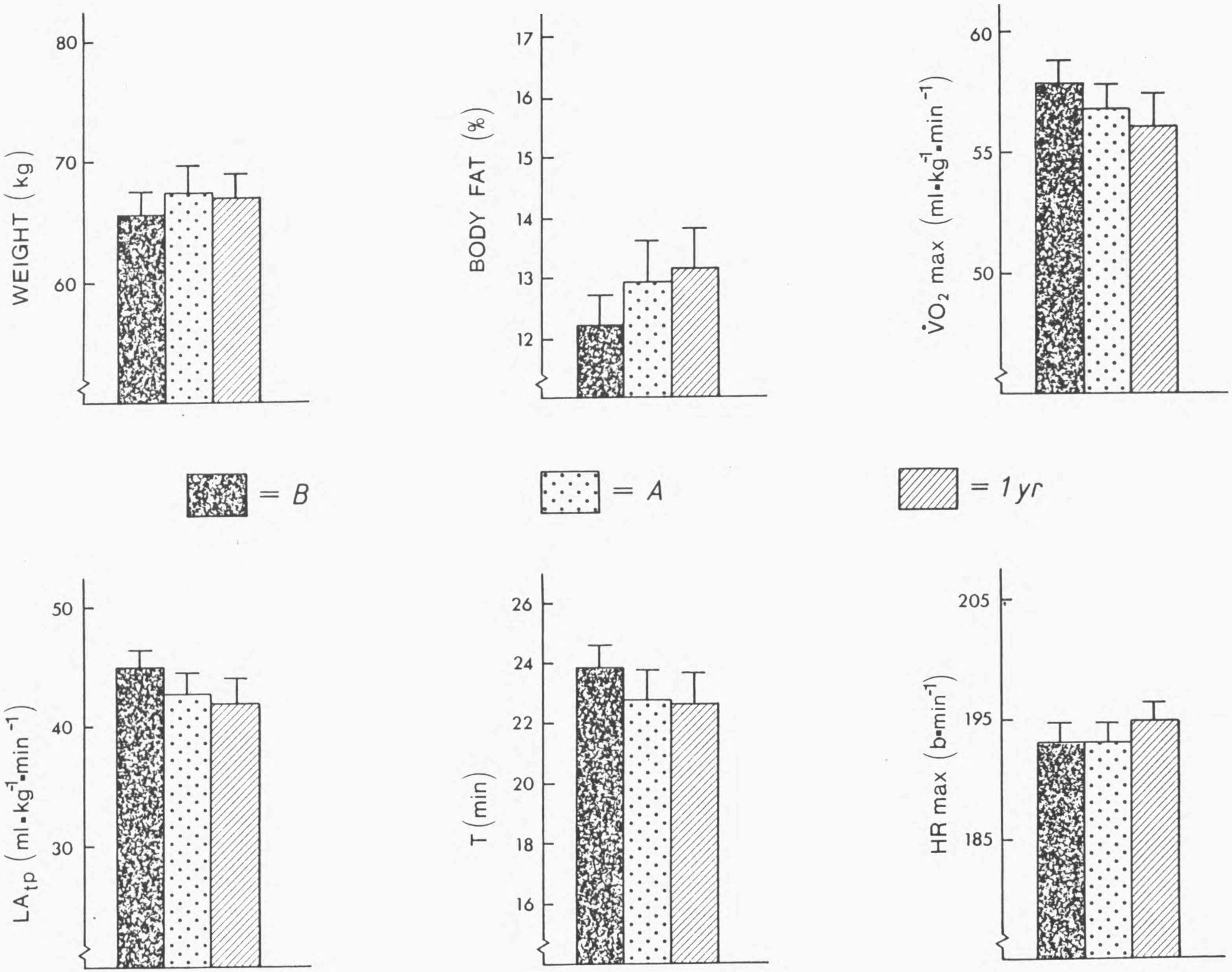

FIGURE 4 : EFFECT OF MILITARY TRAINING ON ENDURANCE FITNESS LEVELS OF ABOVE-AVERAGE FITNESS RECRUITS. Values are mean ± SEM. n = 18. Abbreviations: $\dot{V}O_2$ max = maximal O_2 consumption; LA_{tp} = lactate turnpoint; T = performance time; HR_{max} = maximal heart rate; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training.

athletics or other sporting events, no explicit mention is made of the subject sampling methods used 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 the present study after medical screening while a physical activity questionnaire revealed that 3 subjects participated in endurance sports on a provincial level, 6 subjects on a club level, and a further 7 subjects had commenced with an endurance training programme in preparation for military conscription, prior to testing. It is therefore not possible to interpret our findings as being indicative of an improvement in the maximal aerobic capacity of young South African males during the past 2 decades, although this postulate cannot be entirely ignored.

Additional problems including mode of exercise (Wilmore, 1984), extrapolation of the results of indirect tests (Shephard, 1984), and effects of altitude on $\dot{V}O_2$ max (Buskirk *et al*, 1960) are confronted when making comparisons with recruits of foreign armed forces. However, while such population comparisons should be viewed with extreme caution because they depend significantly on accurate methodological corrections and similarity of samples, it is apparent from the present results that the $\dot{V}O_2$ max of South African Army recruits compares favourably with the values of 42.0 $m\ell.kg^{-1}.min^{-1}$, 46.7 $m\ell.kg^{-1}.min^{-1}$, 50.7 $m\ell.kg^{-1}.min^{-1}$, and 55.1 $m\ell.kg^{-1}.min^{-1}$ recently reported for male British (Vogel *et al*, 1978), Canadian (Myles *et al*, 1979), United States (Vogel *et al*, 1977), and Finnish (Vainikka, 1978) recruits, respectively. It is also note=worthy that the South African Army recruits far exceed the requirements for being placed in the "high" category of the American Heart Association's cardiorespiratory fitness classification (Committee on Exercise, 1972), and fall into the "excellent" category of the aerobic capacity classifications of Balke and Ware (1959) and Cooper (1968). The present maximal aerobic capacities are, however, less than those documented for endurance athletes (Wilmore, 1984) and select military populations such as United States Air Force Academy cadets (53.7-57.9 $m\ell.kg^{-1}.min^{-1}$) (Harger and Ellis, 1975), United States Military Academy cadets (59.4 $m\ell.kg^{-1}.min^{-1}$) (Daniels *et al*, 1979), and South African Army physical training instructors (58.85 $m\ell.kg^{-1}.min^{-1}$) (Cilliers and Gordon, 1983).

The anaerobic threshold is known to occur at a higher fraction of $\dot{V}O_2$ max in trained subjects compared to their sedentary counterparts (Åstrand and Rodahl, 1977). However, the measured anaerobic threshold is influenced 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 (see Chapter 3). The present lactate turnpoints therefore cannot be scientifically equated to the anaerobic thresholds of previous studies where different methodology has been applied. In particular, an exponential rise in venous lactate was the criterion for attainment of lactate turn=point in this study, a factor which is likely to explain the high lactate turnpoints of the subjects relative to those documented in studies where the point of departure of linearity of arterial or capillary blood was used to define the anaerobic threshold .

Likewise, prior to interpreting and comparing the percentage body fat values obtained in this study, one must be cognizant of the limitations and advantages of the methods used in the various studies. The percentage body fat values documented in this study are in fact no more than estimates of the actual percentage body fat. Densitometric underwater weighing techniques are generally considered the more accurate methods of determining body composition (Behnke and Wilmore, 1974). However, these methods are extremely time consuming and were not considered feasible for the present study because of the necessity of completing pre- and post-basic training evaluations in a short time interval. Because estimates of percentage body fat from skinfolds have been found to be reasonably well correlated with body fat values obtained by densitometry (Haisman, 1970; Behnke and Wilmore, 1974), it nonetheless appears feasible to interpret the 13.6% body fat obtained for recruits in this study as being depictive of an active population and supportive of the recruits' high maximal aerobic capacities. In addition, the percentage body fat of South African Army recruits falls comfortably within the 13.6 - 17.1% and 12.5 - 17.6% ranges documented in the literature for United States (Pascale *et al*, 1956; Krzywicki and Chinn, 1967; Knapic *et al*, 1983) and British (Behnke and Wilmore, 1974; Amor 1978; Vogel *et al*, 1978) soldiers, respectively.

5.4.2 EFFECT OF SOUTH AFRICAN ARMY BASIC TRAINING ON ENDURANCE CAPACITY AND FITNESS

A review of endurance training studies performed on young adult males indicates that improvements in $\dot{V}O_2$ max of up to 20% may be elicited (Pollock, 1973). Moderate intensity conditioning programmes of relatively short duration can be expected to produce a change of ~ 10% (Pollock, 1973). Data relating to alterations in anaerobic threshold consequent on endurance conditioning are relatively scarce but suggest that this measure of endurance fitness is more responsive to exercise training than is $\dot{V}O_2$ max (Davis *et al*, 1979; Ready and Quinney, 1982; Dennis *et al*, 1982, 1984).

As a group the South African Army recruits in this study displayed an insignificant change in $\dot{V}O_2$ max accompanied by only moderate improvements in lactate turnpoint after basic training. The reasons why a conditioning programme of this duration, intensity, and frequency did not induce a greater enhancement of these parameters were unclear until the recruits were subdivided into 3 groups on the basis of their initial endurance fitness levels as assessed by their lactate turnpoint expressed as $m\ell\ O_2.kg^{-1}.min^{-1}$. This procedure revealed that the basic training programme provided the below-average and possibly the average fitness recruits, but not the above-average fitness recruits, with an adequate training stimulus. Whether or not this is an adequate situation will be dependent largely upon the fitness requirement for subsequent job assignments and emergency situations, a factor currently undergoing investi= gation in the South African Army. 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 regarding the actual efficacy of the 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 are 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 such training is to be minimized, it would appear prudent to stratify and train them in accordance with their pre-basic training fit= ness levels (as is currently the situation in the United States Army).

5.4.3 ENDURANCE FITNESS LEVELS ON COMPLETION OF 1 YEAR MILITARY TRAINING

On completion of 1 year military training recruit fitness levels were insignificantly altered from those existing prior to military conscription but less than those attained during basic training. The deterioration in endurance fitness after basic training is most evident when analyzing the results of the recruits who attained the most significant improvements during basic training ie 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 South African Army basic training centres, the same is not true concerning the remainder of military service. Thus, while the need to increase the emphasis on physical training in certain South African Army 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 South African Army.

5.4.4 CONCLUSIONS AND RECOMMENDATIONS

This initial assessment of the efficacy of the South African Army physical training programme has demonstrated the need for the introduction of changes during and, in particular, after basic training. In this respect, recruits should probably be categorized and trained during basic training on the basis of their pre-entry endurance fitness levels (endurance fitness could be assessed by means of a simple field-test such as the time for a 2.4 km run). As regards the remainder of military training, the physical training programmes utilized by the various units of the South African Army should be evaluated on an individual basis and the emphasis on physical fitness should be increased where thought necessary. Such an approach, when coupled with the adherence to scientifically validated physical training principles, is likely to ensure the optimum development and maintenance of endurance fitness during military training thereby enhancing the effectiveness of the South African Army.

CHAPTER 6

EVALUATION OF THE SOUTH AFRICAN ARMY PHYSICAL TRAINING PROGRAMME - PART II : EFFECT OF ONE YEAR NATIONAL SERVICE ON STRENGTH, POWER, POWER-ENDURANCE, SPEED, AND FLEXIBILITY

6.1 INTRODUCTION

For a soldier to be physically fit he must be able to meet both the ordinary and the unusual demands of his daily military 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. As earlier mentioned, in view of the wide variety of physically demanding situations with which the soldier may be confronted 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 can be found that have assessed the efficacy of military training programmes in enhancing the endurance capabilities of recruits (see Tables I, II, and III). 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 for the dependent variables. Accuracy without subjectivity while measuring muscular strength, power, and power-endurance has, however, recently been greatly enhanced with the Cybex II isokinetic dynamometer. Reliability of measurement of the dynamometer has been well documented (Moffroid *et al*, 1969; Alexander and Molnar, 1974; Pipes and Wilmore, 1975) and the present investigation therefore utilized this device to assess the influence of the South African Army 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.

6.2 METHODS

6.2.1 SUBJECTS

The subjects for the investigation initially comprised 93 medically fit, young adult South African National Servicemen whose physical characteristics and selection criteria are documented in Part 1 of the study. Because of injury, illness, death (2 subjects 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.

6.2.2 EXPERIMENTAL PROCEDURES

The subjects were evaluated during the 10 days prior to their commencement with 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 II isokinetic dynamometer was used. The 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 the Cybex II cushion platform with the 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 3 repetitions at a speed of 60° sec^{-1}, with the left and then 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^{-1} 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 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 II. Neutral positions of the shoulder relative to extension/flexion and the forearm relative to pronation/supination were established prior to 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 subject comfort. The subject then performed 3 maximum repetitions at a speed of $60°.sec^{-1}$, with the left and then 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 II system, at a paper speed of $5mm.sec^{-1}$. 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-meter (Nm). Strong verbal encouragement was given for all performances with the intent of pushing each subject to his true maximum torque capabilities.

Flexibility of the lower back and hamstrings was measured using a procedure adapted from that originally described by Scott and French (1950) and Wells and Dillon (1952). In this test the subject stands on a firm platform with knees straight and legs together, letting the arms and trunk relax forward with the hands in front of a vertical scale attached to the anterior aspect of the platform. In this position, the subject bobs downward 4 times and on the fourth reach holds the position of maximum forward-downward flexibility. The zero line of the scale corresponds to the upper surface of the platform and the minus values are toward the subject. The score is the most distant point reached and held on the fourth movement. Both knees remain extended throughout the measurement. Each subject was given 3 attempts and the best recording was taken as the measure of flexibility.

Speed was assessed by recording the time taken to complete a 50-m sprint. The subject executed the performance by sprinting through a designated 50-m distance. Each sprint was performed with a 10-m running start. Time was recorded by 3 researchers with stopwatches accurate to one hundredth of a second. The mean of the 2 most similar recordings was designated as the sprint time. Subjects were given 2 trials and the best performance was utilized, as recommended by Simri (1974).

Because the present investigation was not intended to be a comparative study, power and speed recordings were not converted to their physiologically correct units of measure.

6.2.3 STATISTICAL METHODS

Significance of differences between experimental variables was analysed using one-way analysis of variance (ANOVA), followed by the Scheffé procedure when a significant F-ratio was obtained. Statistical significance was established at the 0.05 confidence level. Values are expressed as mean ± standard deviation.

6.3 RESULTS

6.3.1 EFFECT OF SOUTH AFRICAN ARMY TRAINING ON MUSCULAR STRENGTH

The effect of 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 VIII. The values recorded prior to commencement with basic training, 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%, $p < 0.05$) or on completion of 1 year military training (15%, $p < 0.05$) (Figure 5).

TABLE VIII : EFFECT OF SOUTH AFRICAN ARMY TRAINING ON MUSCULAR STRENGTH

	Pre BT	Post BT	Post 1 Year
Right knee extension (Nm)	221±40	213±41	217±42
Left knee extension (Nm)	208±40	205±41	211±38
Right knee flexion (Nm)	119±29	125±27	124±24
Left knee flexion (Nm)	114±27	123±28	122±25
Right elbow extension (Nm)	59±18	69±20***	60±17
Left elbow extension (Nm)	59±19	64±18	59±16
Right elbow flexion (Nm)	53±13	55±11	55±11
Left elbow flexion (Nm)	47±11	48±11	48±10

Values are mean ± SD. Pre BT n = 93; Post BT n = 84 for all para= meters except right elbow flexion/extension where n = 83; Post 1 year n = 62.

Abbreviations : Pre BT = pre-basic training; Post BT = post-basic training; Post 1 year = on completion of 1 year military training.

*** $p < 0.05$ versus Pre BT and Post 1 year.

6.3.2 EFFECT OF SOUTH AFRICAN ARMY 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 (Figure 6 and Table IX).

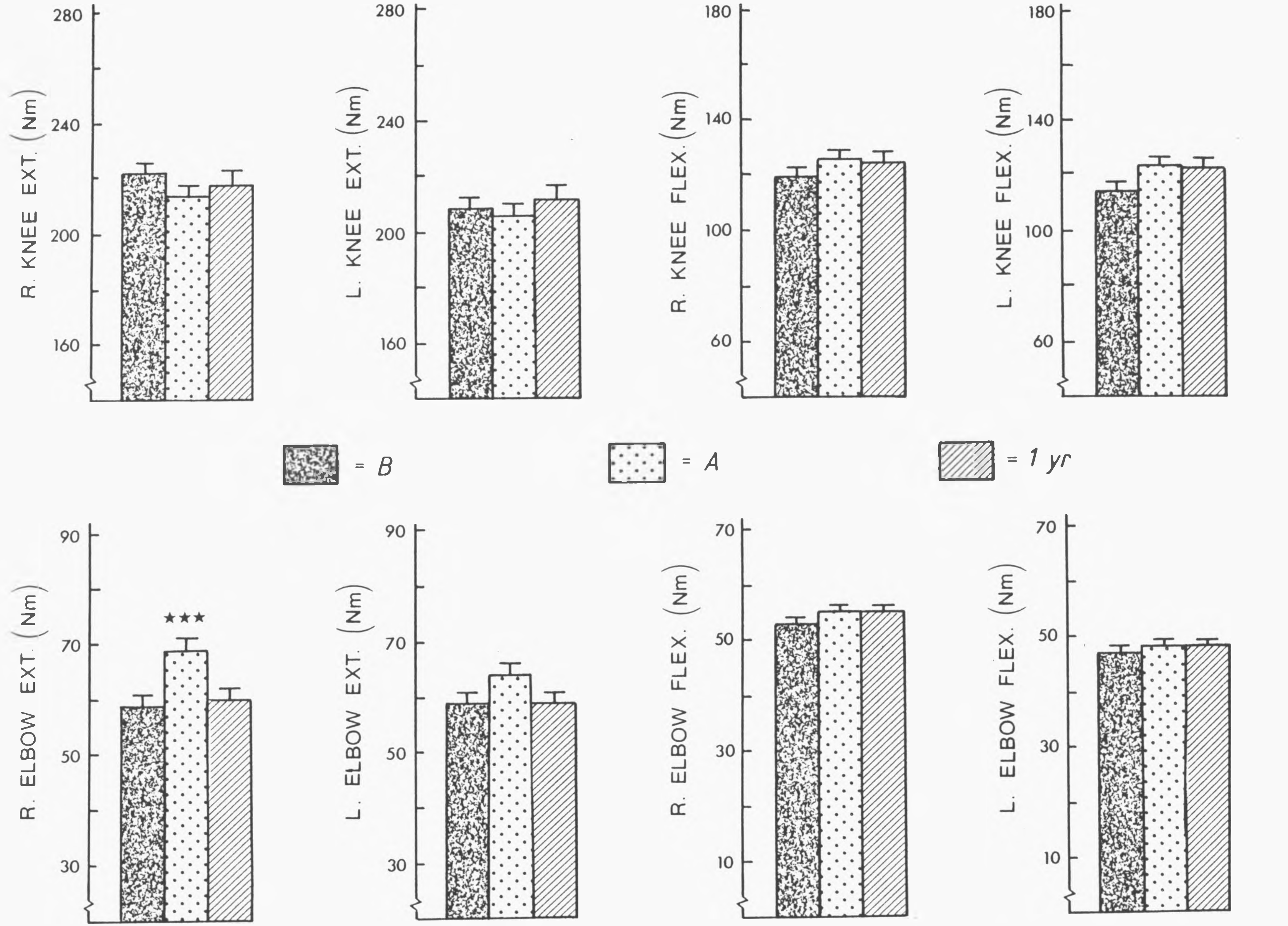

FIGURE 5 : EFFECT OF MILITARY TRAINING ON MUSCULAR STRENGTH.
Values are mean ± SEM. Abbreviations: R = right; L = left; EXT. = extension; FLEX. = flexion; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training. B: n = 93. A: n = 84, except for R. ELBOW EXT/FLEX where n = 83. 1 yr: n = 62. *** $p < 0.05$ versus B and 1 yr.

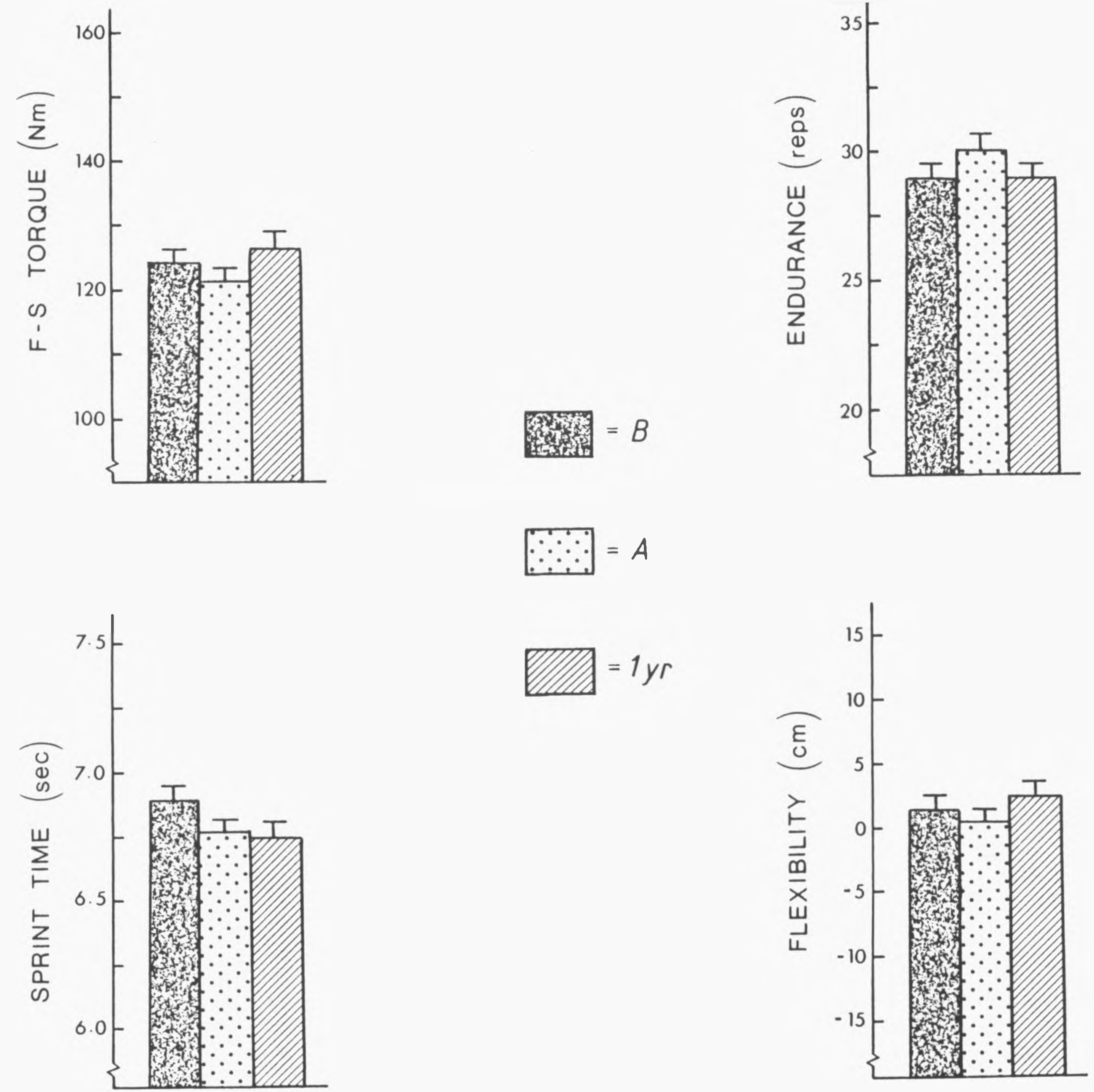

FIGURE 6 : EFFECT OF MILITARY TRAINING ON MEASURES OF POWER, POWER-ENDURANCE, SPEED, AND FLEXIBILITY. Values are mean ± SEM. Abbreviations: F-S = fast-speed; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training. B: n = 93. A: n = 84, except for speed where n = 79. 1 yr: n = 62, except for speed where n = 60.

TABLE IX : EFFECT OF SOUTH AFRICAN ARMY TRAINING ON MEASURES OF POWER, POWER-ENDURANCE, SPEED, AND FLEXIBILITY

	Pre BT	Post BT	Post 1 Year
Fast-speed knee extension torque (Nm)	124±21	121±20	126±20
Knee extension power-endurance (repetitions)	29±4	30±6	29±5
Time for 50-m sprint (sec)	6.87±0.45	6.75±0.47	6.74±0.44
Flexibility (cm)	1±8	0±9	2±7

Values are mean ± SD. Pre BT n = 93; Post BT n = 84 for all parameters except speed where n = 79; Post 1 year n = 62 for all parameters except speed where n = 60.

Abbreviations : Pre BT = pre-basic training; Post BT = post-basic training; Post 1 year = on completion of 1 year military training.

6.3.3 STRATIFICATION OF RESPONSES TO MILITARY TRAINING ON BASIS OF INITIAL FITNESS LEVELS

For each fitness component investigated, recruits were divided into 3 groups on the basis of their initial values for the dependent 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 (Figure 7). For all variables, this beneficial effect was transient in nature and the values recorded on completion of 1 year military training differed insignifi=

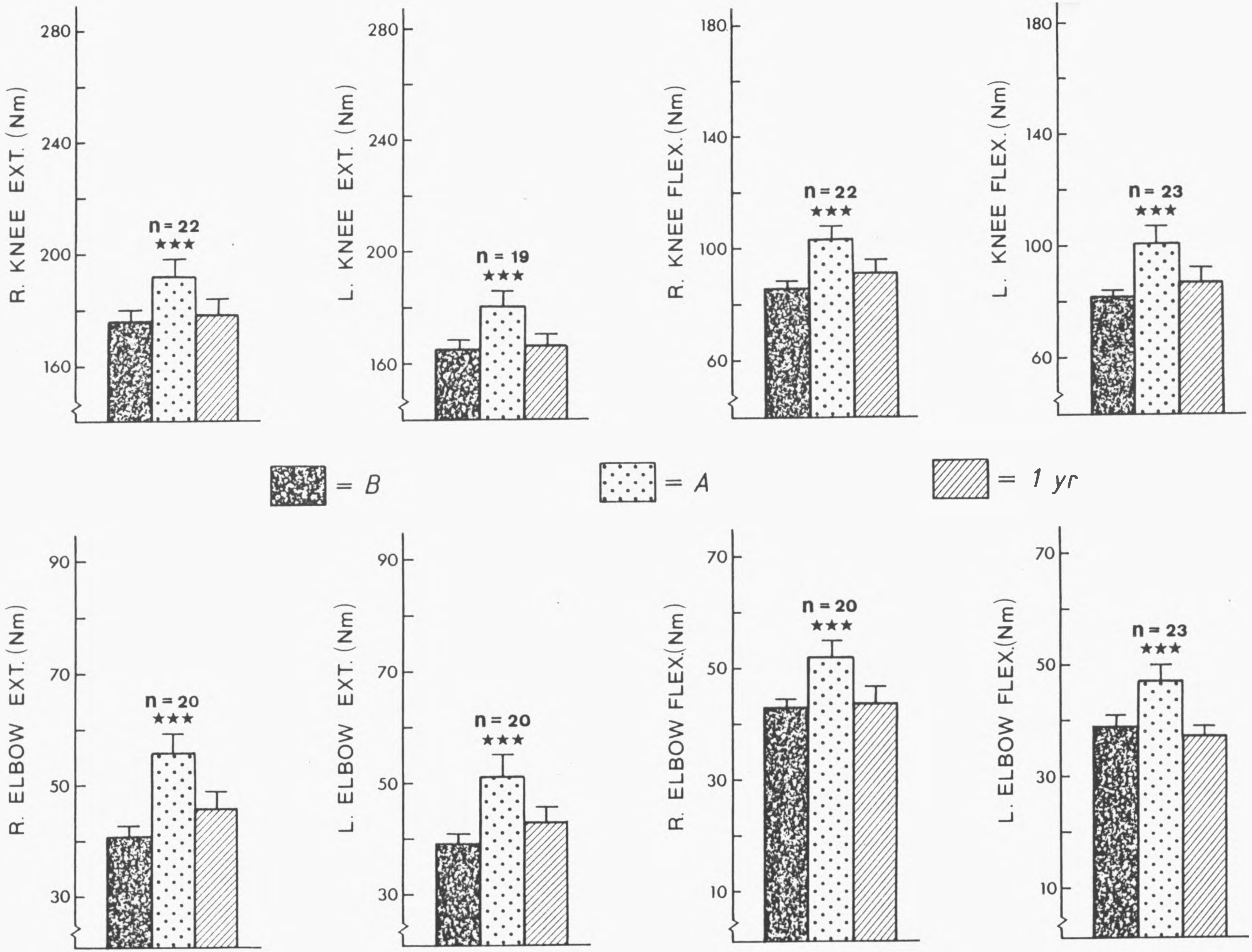

FIGURE 7 : EFFECT OF MILITARY TRAINING ON MUSCULAR STRENGTH FOR BELOW-AVERAGE RECRUITS.
Values are mean $\pm$ SEM. Abbreviations: R = right; L = left; EXT. = extension; FLEX. = flexion; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training. *** $p < 0.05$ versus B and 1 yr.

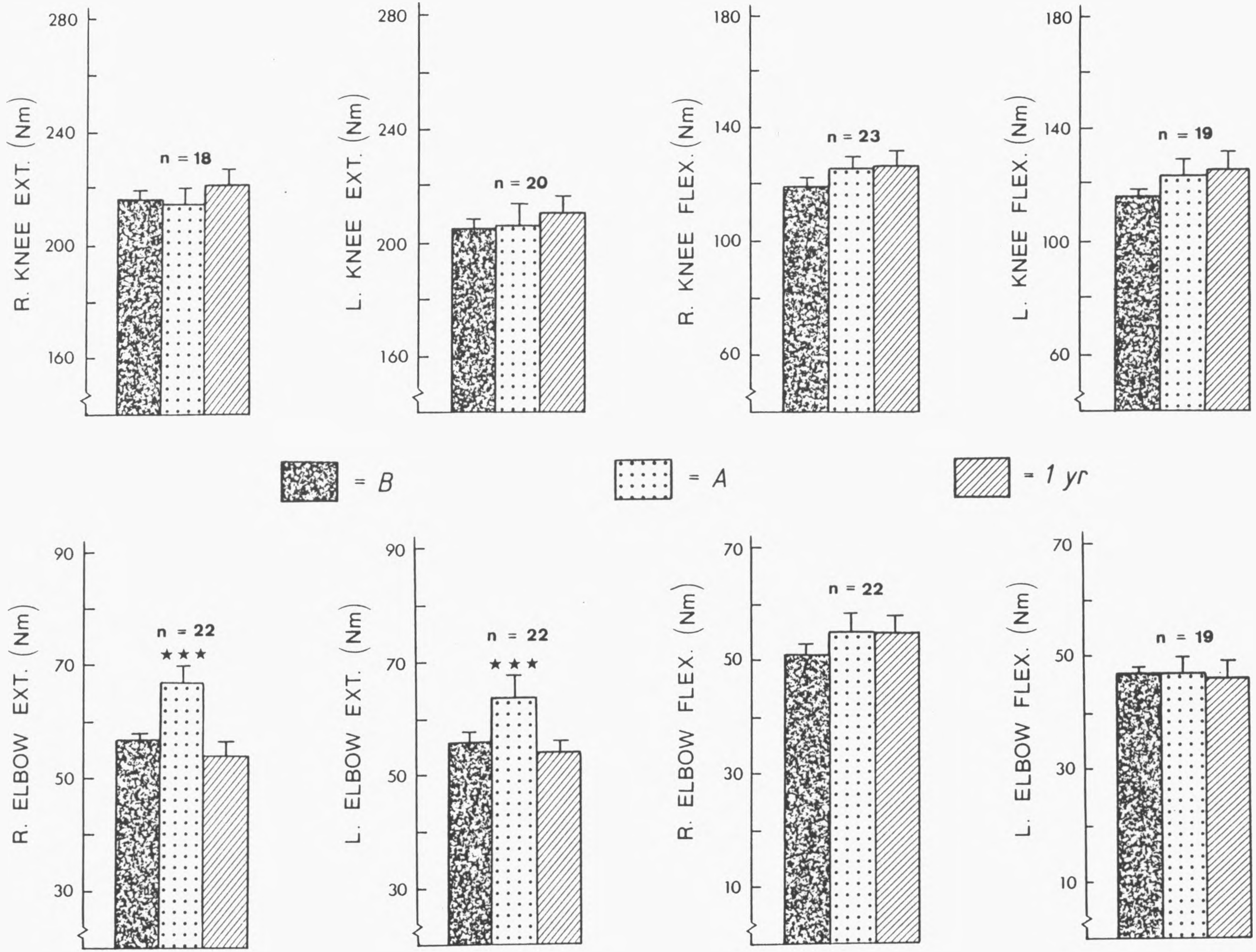

FIGURE 8 : EFFECT OF MILITARY TRAINING ON MUSCULAR STRENGTH FOR AVERAGE RECRUITS.
Values are mean $\pm$ SEM. Abbreviations: R = right; L = left; EXT. = extension; FLEX. = flexion; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training. *** $p < 0.05$ versus B and 1 yr.

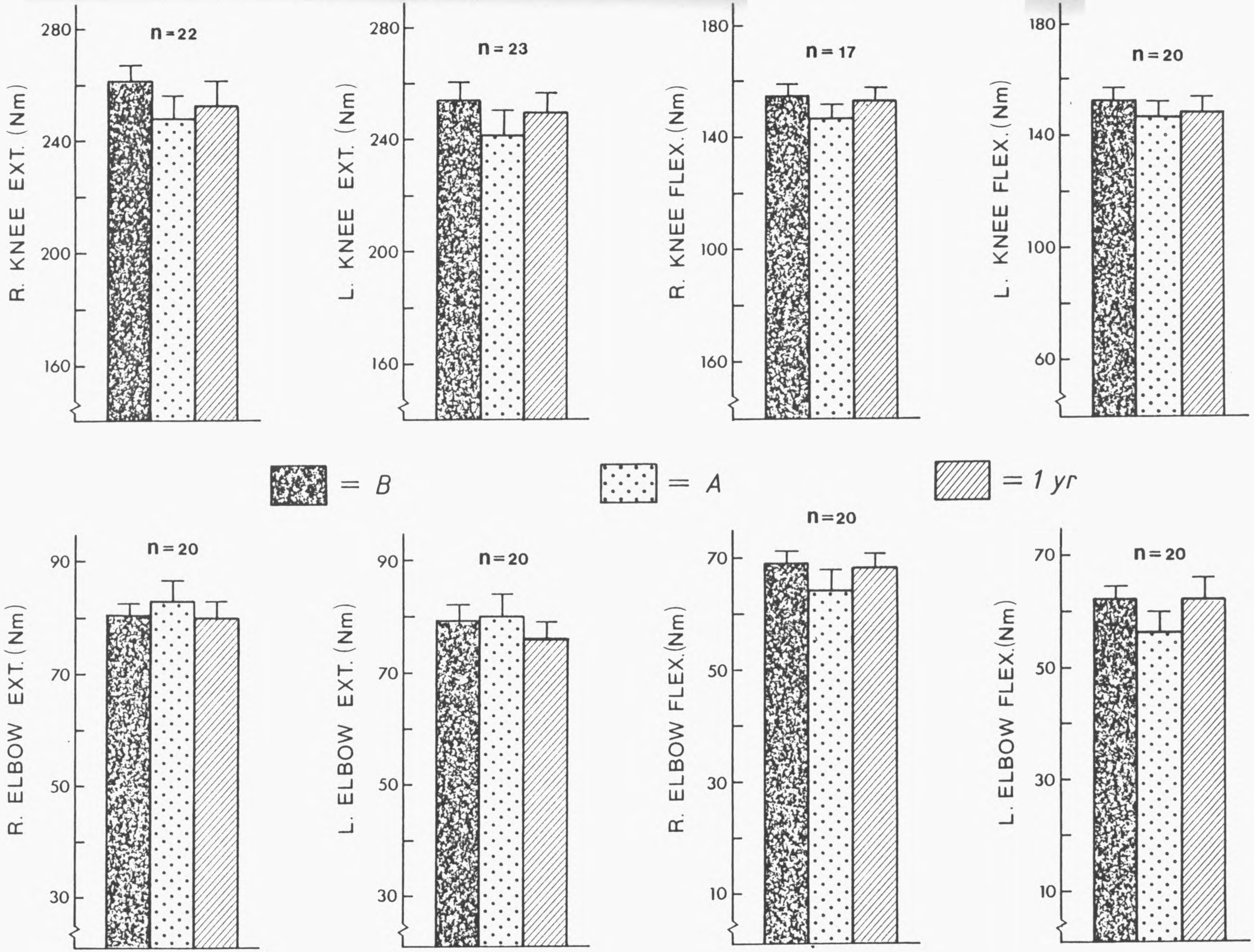

FIGURE 9 : EFFECT OF MILITARY TRAINING ON MUSCULAR STRENGTH FOR ABOVE-AVERAGE RECRUITS. Values are mean $\pm$ SEM. Abbreviations: R = right; L = left; EXT. = extension; FLEX. = flexion; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training.

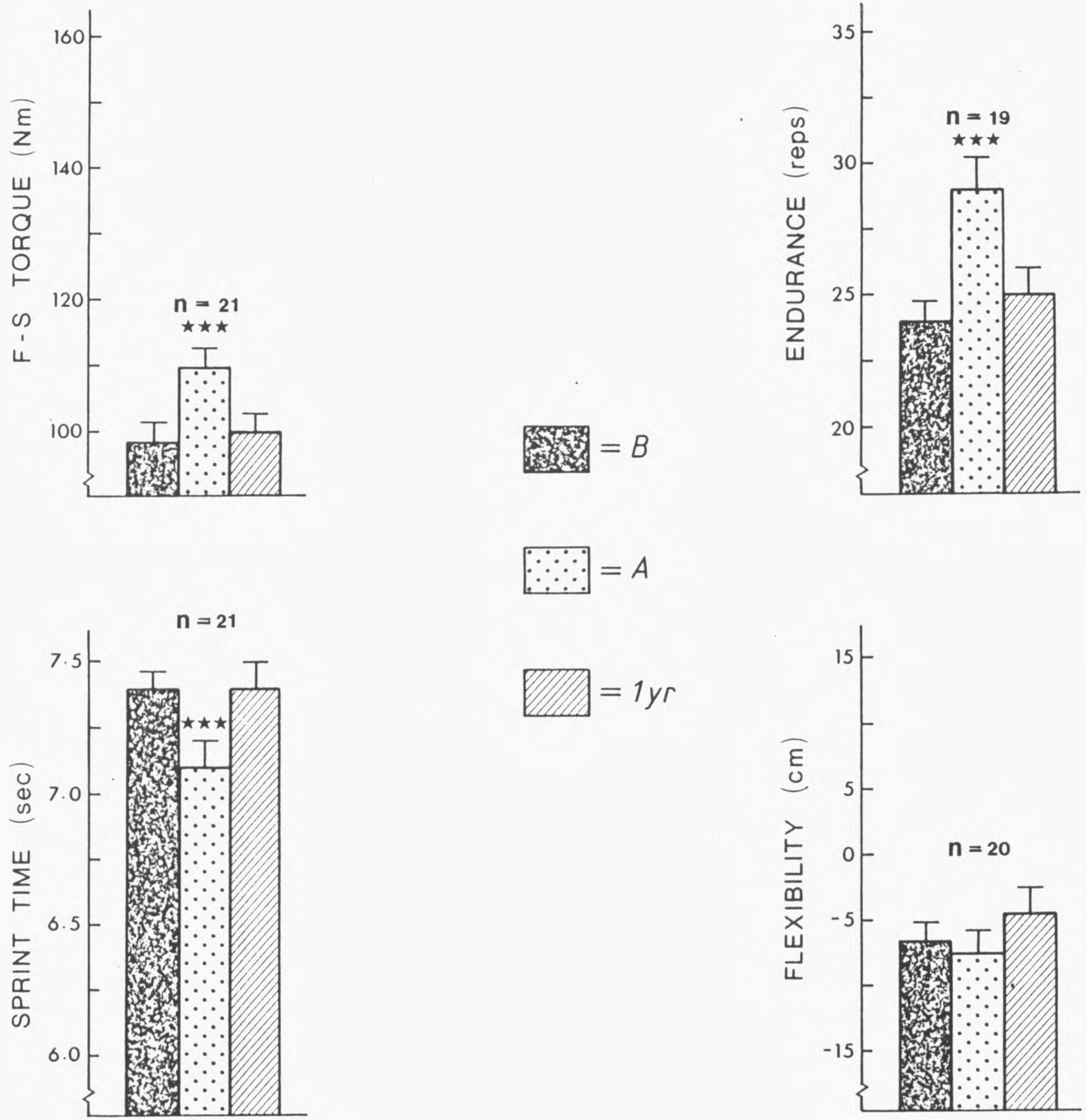

FIGURE 10 : EFFECT OF MILITARY TRAINING ON MEASURES OF POWER, POWER-ENDURANCE, SPEED, AND FLEXIBILITY FOR BELOW-AVERAGE RECRUITS. Values are mean ± SEM. Abbreviations: F-S = fast-speed; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training. *** $p < 0.05$ versus B and 1 yr.

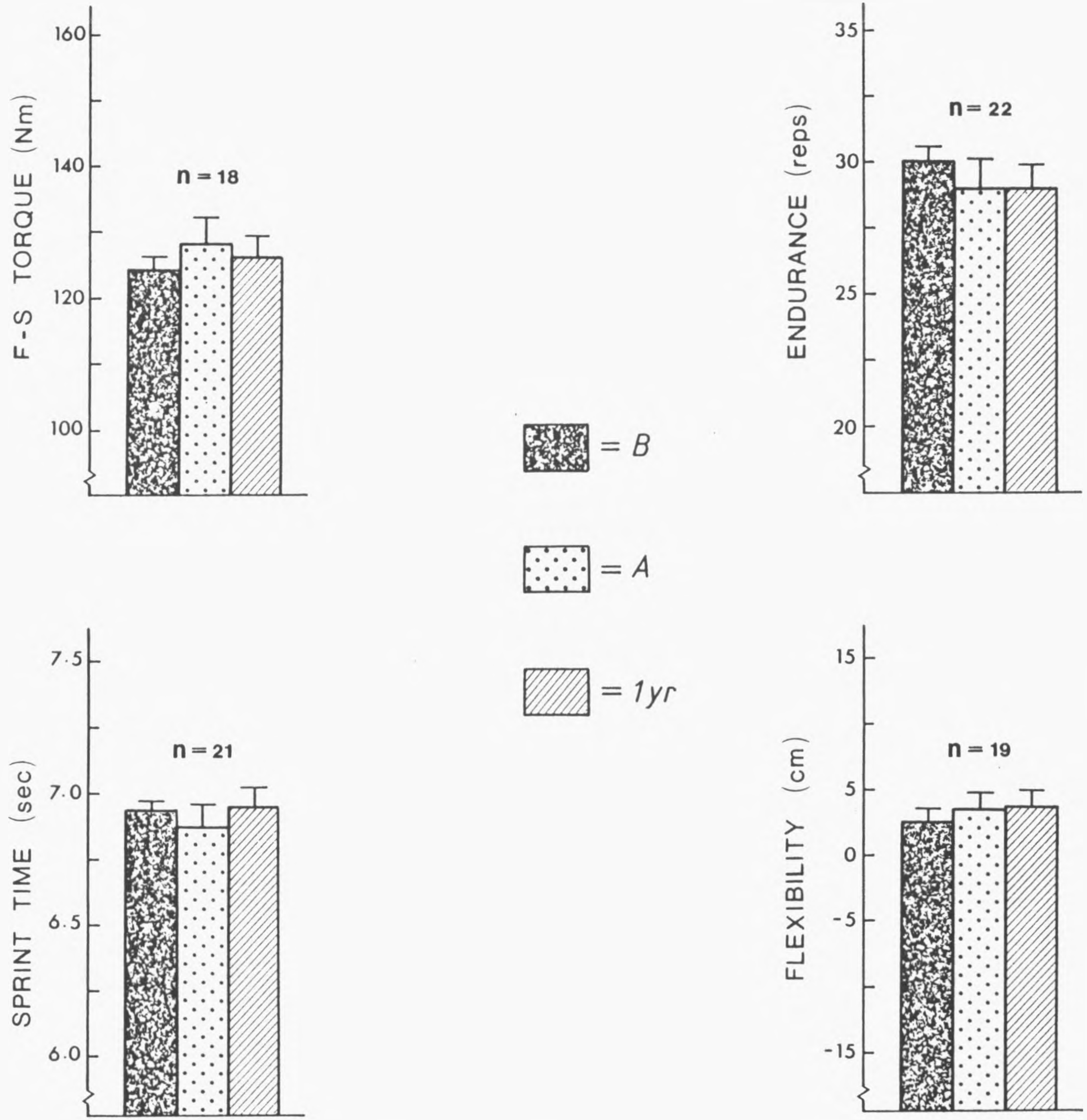

FIGURE 11 : EFFECT OF MILITARY TRAINING ON MEASURES OF POWER, POWER-ENDURANCE, SPEED, AND FLEXIBILITY FOR AVERAGE RECRUITS. Values are mean $\pm$ SEM. Abbreviations: F-S = fast-speed; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training.

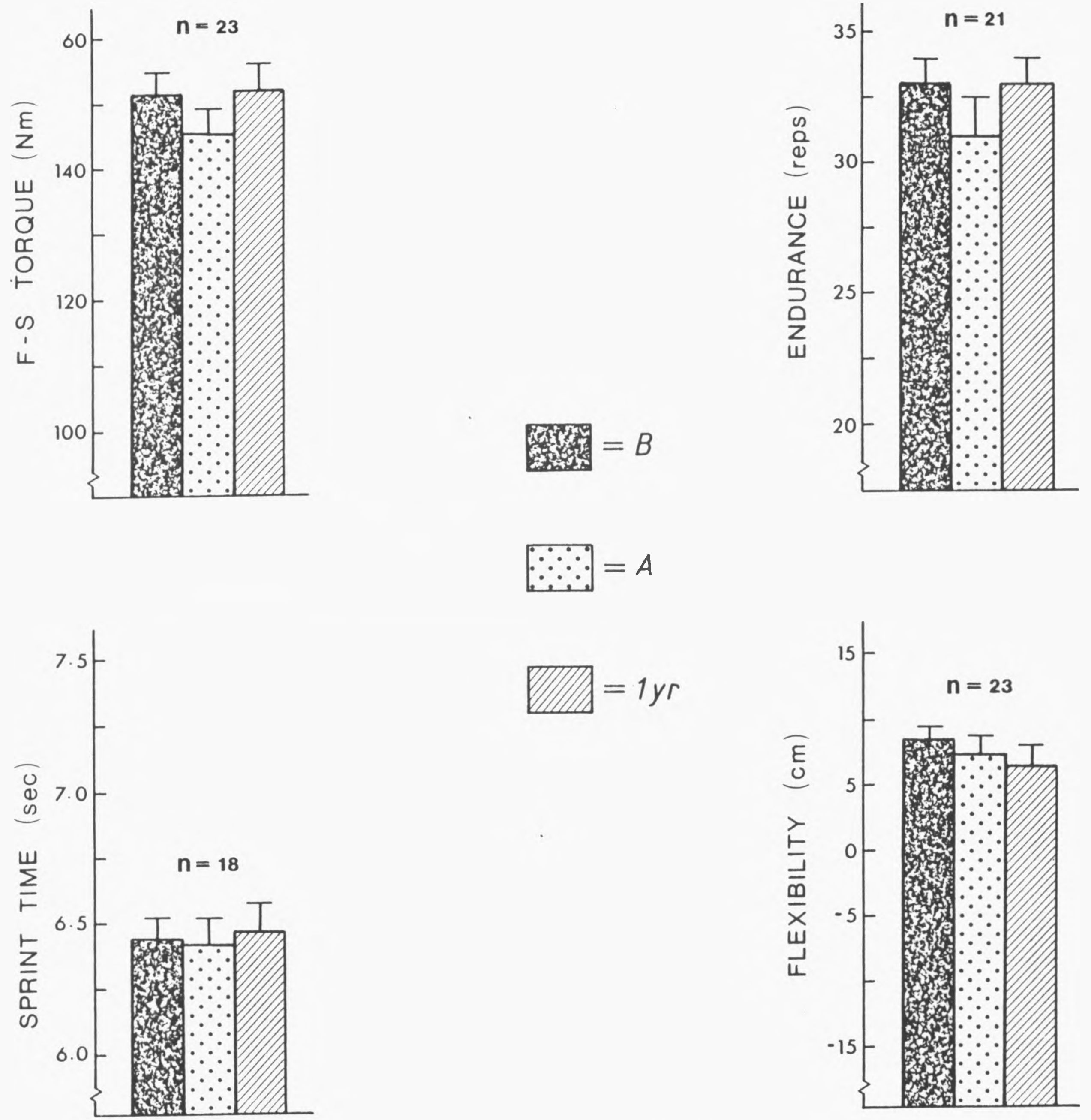

FIGURE 12 : EFFECT OF MILITARY TRAINING ON MEASURES OF POWER, POWER-ENDURANCE, SPEED, AND FLEXIBILITY FOR ABOVE-AVERAGE RECRUITS. Values are mean ± SEM. Abbreviations: F-S = fast-speed; B = before basic training; A = after basic training; 1 yr = on completion of 1 year military training.

cantly from those observed prior to military conscription. In contrast, only the right and left elbow extensor maximal slow-speed torque capabilities were significantly increased (17.5% and 14%, respectively, $p < 0.05$) by basic training for the average recruits (Figure 8). As was the case for the below-average recruits, this extensor mechanism strength enhancement was no longer evident on completion of 1 year 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 military training (Figure 9).

Likewise, 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 (Figure 10). 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 (Figure 11) and above-average recruits (Figure 12). For all groups the values recorded on completion of 1 year military training were essentially unaltered from those existing prior to military conscription.

6.4 DISCUSSION

6.4.1 PRE-BASIC TRAINING RECRUIT FITNESS LEVELS

Since the publication of Hislop and Perrine's paper on isokinetics in 1967, isokinetic exercise has been used as a therapeutic modality in clinical settings (Elsner *et al*, 1983); as a training mode for sportsmen (Pipes and Wilmore, 1975); as a means for examination of the relationships between force and velocity, and muscle agonist/antagonist action (Thorstensson *et al*, 1976); and as a scientific, objective testing device (Goslin and Charteris, 1979). A review of the isokinetic literature, however, evidences 2 major deficiencies. The first is the prevalent lack of standardization of the precise test procedure during isokinetic evaluation. The second is that although relative comparisons can be made between injured and uninjured limbs for a given indivi= dual, with the possible exception of knee flexion/ extension slow-speed torques, scarce isokinetic norma= tive data are available; this is particularly true for military populations. 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-basic training fitness levels and those documented for recruits of foreign armed forces.

6.4.2 EFFECT OF SOUTH AFRICAN ARMY BASIC TRAINING ON MUSCULAR STRENGTH, POWER, POWER-ENDURANCE, SPEED, AND FLEXIBILITY

When considering 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 United States Army basic training on the maximal voluntary isometric strength of the elbow flexors/extensors and knee flexors/ extensors for 186 recruits, Vogel *et al*(1977) similarly documented significant improvements for elbow extension alone. Although the precise cause for this finding 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 administered during basic training. Considerable further speculation must be entertained, however, 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 to the findings of this study, Viitasalo and Vainikka (1982) failed to demonstrate statistically significant increases in the maximal voluntary isometric strength of the elbow extensors during Finnish basic training, whereas Knapik *et al*(1980) recently recorded small but significant improvements in isometrically-assessed knee extensor strength for 750 male United States Army basic trainees. Osternig *et al* (1977) have indicated, however, 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 the present findings to 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 (O'Shea, 1966; Wilmore, 1974; Pipes and Wilmore, 1975). 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 specific strength training apparatus, and the large variation in the trainability of the individual recruits. Regarding the latter, Müller (1970) has postulated that strength increases in an almost exponential manner with training. Initially, training induces rapid strength gains which are subsequently followed by gradual increases until a limiting strength is attained whereupon no further increases in strength are 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 smaller than the average of the entire recruit group at the beginning of basic training in the present study.

Likewise, power, power-endurance, and speed were selec= tively improved during basic training so that the recruit sample became more homogeneous in respect to these fitness components. As was suggested for endurance fitness, the desirability of this situation, which has also been reported to ensue during Finnish basic training (Viitasalo and Vainikka, 1982), will be largely dependent 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-endur= ance, and speed. If the objective is to challenge and improve the fitness levels of each recruit, then the South African Army basic training programme has not succeeded. It is apparent from the present study, however, that the flexibility of South African Army 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, compound flexibility measures such as the stand-and-reach test are generally regarded as being acceptable for determining intraindividual flexibility improvements (see Chapter 3). The present results are therefore suggestive of a need to increase the emphasis on flexibility enhancement during South African Army basic training. This would appear to be of particular concern because an adequate amount of flexibility is believed to be important not only for superior physical performance but also for injury prevention (Shellock and Prentice, 1985).

6.4.3 RECRUIT FITNESS LEVELS ON COMPLETION OF 1 YEAR 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. The undesirability of this observation is obvious and the present results therefore highlight the need for greater attention to be given to physical conditioning after basic training. Additional research will be needed, however, to deter= mine the limitations of this observation when extra= polated to other units of the South African Army.

6.4.4 CONCLUSIONS AND RECOMMENDATIONS

The present study indicates that the South African Army 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 an adequate situation. It is, however, evident from this investigation that increased emphasis should be placed on flexibility training during basic training, and physical conditioning after basic training, at least in certain South African Army units (as was recommended in Part 1 of the study, the physical training modes used by the various units after basic training for the enhancement of strength, power, power-endurance, speed, and flexibility should be assessed on an individual basis, and altered where thought necessary).

CHAPTER 7

EVALUATION OF THE SOUTH AFRICAN ARMY PHYSICAL TRAINING PROGRAMME - PART III : EXERTION-RELATED INJURIES SUSTAINED AT A SOUTH AFRICAN ARMY BASIC TRAINING CENTRE

7.1 INTRODUCTION

The excessive demands imposed on the musculoskeletal system during military training continue to be of utmost concern in today's more technologically orien= tated armed forces (Bensel, 1976; Kowal, 1980; Stacy and Hungerford, 1984). This fact is most evident in the conditioning of new recruits making the sudden transition from civilian to military life who are subjected to an intensive programme of physical training during their basic military training. Besides imposing substantial medical costs, high rates of unnecessary and potentially avoidable injuries can prevent military recruits from performing their daily training for extended periods, as well as reducing the morale of injured trainees. In this respect, Cilliers and Gordon (1983) have recently suggested that the efficacy of South African Army basic training centres may be limited by the particularly injurious nature of the physical training used.

From years of experience in the conduct of military physical training programmes, physicians, physical educationalists, and physical training instructors of the South African Army have developed many provisional hypotheses for the aetiology of exertion-related injuries sustained during basic training and how to prevent them. However, for a number of reasons, principally the lack of comprehensive and reliable descriptive data on the actual extent of the problem, these postulates have not been tested. Thus, for the most part, exertion-related injuries have been accepted as an inevitable by-product of the South African Army basic training programme.

As an initial step to determine the true incidence and nature of these injuries, all exertion-related injuries sustained by the July 1982 intake at one South African Army basic training centre were studied.

7.2 METHODS

7.2.1 DEFINITION OF AN INJURY

For the purpose of this study an injury was defined as one which was related to physical conditioning during basic training and was severe enough to prevent the recruit from returning to normal activities for at least 1 day after medical consultation. This defini= tion was chosen in order to exclude those injuries that were:

i. trivial and did not result in a loss of basic training time;

ii. sustained during the course of military training but not as a result of physical conditioning; and

iii. incurred by recruits while on leave from basic training.

7.2.2 CLASSIFICATION OF INJURIES

Injuries were classified further according to the presence (Group 1) or absence (Group 2) of an obvious sudden acute precipitating event. This classification was employed in preference to the more traditional "extrinsic - intrinsic" categorization of injuries to avoid confusion arising as to the role of various objects utilized during physical training (eg poles during "battle physical training") in the possible aetiology of the injuries.

7.2.3 DATA COLLECTION

A 10-week cycle of basic training, extending from July through September 1982 and involving 947 recruits, was studied. The medical officers assigned to the basic training centre under investigation were required to complete a standard questionnaire for each recruit presenting to the unit's sickbay with an injury. In addition, the unit's medical records in which all sick reports are listed were consulted together with indivi= dual medical files when necessary to ensure the complete and accurate gathering of the required information.

The collected data were analysed to determine:

i. the overall number and incidence of injuries;

ii. the type of injuries;

iii. the anatomical sites of injuries; and

iv. the basic training time lost as a result of injuries.

The loss of basic training time was calculated taking into account those days on which no basic training was performed for reasons such as week-end leave.

A radiographic diagnosis was required to confirm all stress fractures reported in this study. Stress fractures were sub-grouped according to anatomical location and training date on which the diagnosis of a stress fracture was first entertained by one of the unit's medical officers.

7.3 RESULTS

7.3.1 OVERALL NUMBER AND INCIDENCE OF INJURIES

A total of 404 separate exertion-related injuries were sustained by 359 recruits during the 10-week basic training cycle. Of these, Group 2 injuries comprised the vast majority (81.7%), involving 307 recruits. In contrast, Group 1 injuries were incurred by 71 recruits and represented 18.3% of all injuries. The overall incidence of injury, expressed as a percentage of the total number of recruits engaged in basic training, was 37.9%, the incidence of Group 1 injuries being 7.5% and Group 2 injuries 32.4%.

7.3.2 ANATOMICAL SITES OF INJURY

Of the 74 Group 1 injuries documented in this study, 21 involved the ankle, 16 the lower-back, and 11 the knee. The remaining 26 Group 1 injuries were sustained at a variety of different anatomical locations.

Figure 13 illustrates the number of Group 2 injuries located at the various anatomical sites. As can be seen, these injuries were confined almost exclusively to the lower limbs, pelvis, and lower-back. The knee sustained the greatest number of injuries (112), representing 33.9% of Group 2 injuries and 27.7% of all injuries. The knee was followed in order of frequency of injury by the lower-leg, achilles tendon, lower-back, ankle, foot, heel, pelvis, thigh, neck, and wrist.

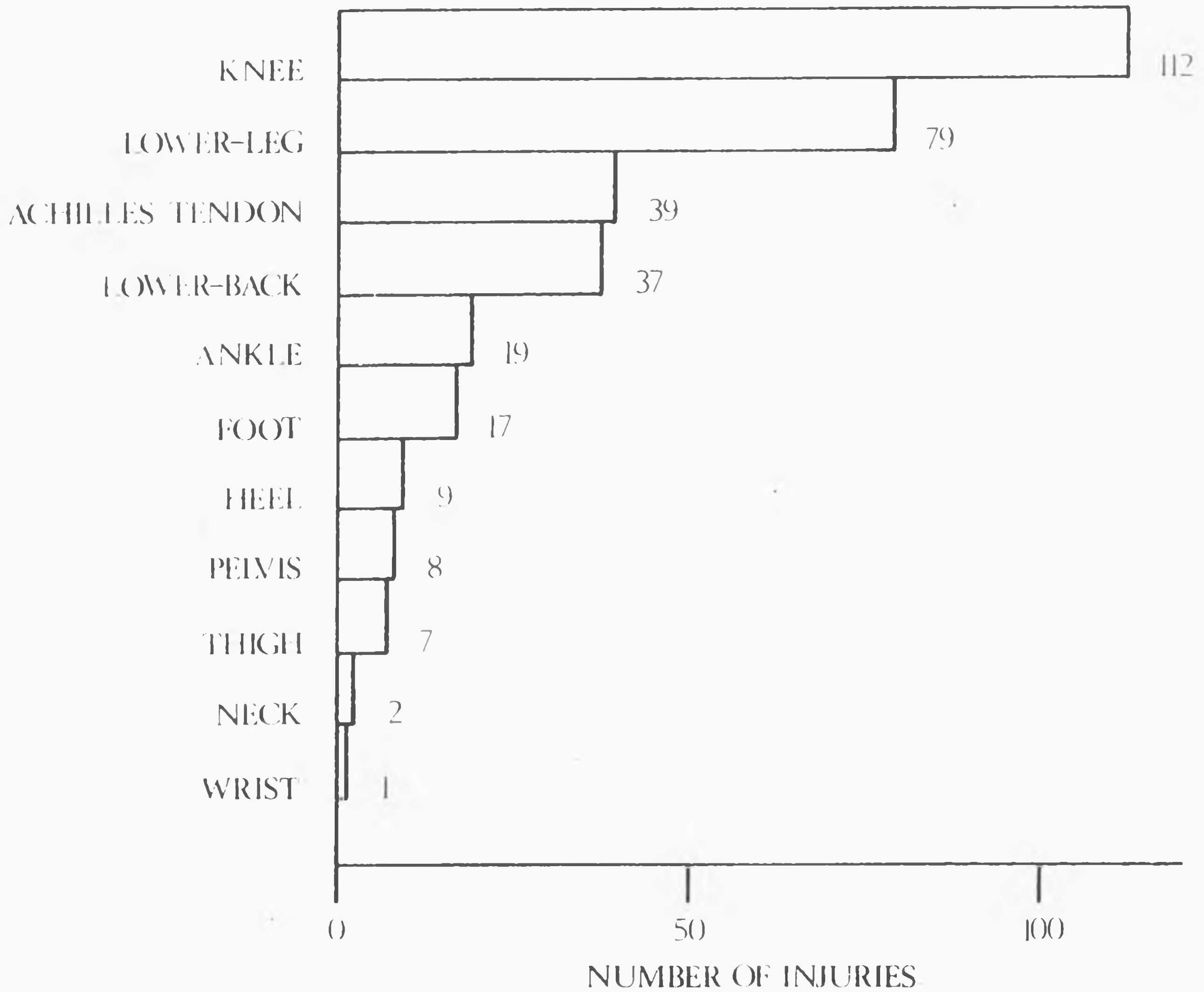

FIGURE 13 : NUMBER OF EXERTION-RELATED INJURIES SUSTAINED WITHOUT AN OBVIOUS SUDDEN ACUTE PRECIPITATING EVENT AT DIFFERENT ANATOMICAL SITES.

7.3.3 LOSS OF BASIC TRAINING TIME

Exertion-related injuries were responsible for a loss of 2711 (5.1%) out of a total of 53032 recruit-days of basic training (947 recruits participating in 56 days of training equals 53032 recruit-days of basic training), the average time lost per injury being 6.7 days. Training time lost as a result of Group 1 injuries was 432 recruit-days (5.8 days.injury^{-1}) while Group 2 injuries caused a wastage of 2279 recruit-days of basic training (6.9 days.injury^{-1}). Figure 14 shows the number of training days lost as a result of Group 2 injuries located at the different anatomical sites. While the knee sustained the largest number of injuries, the lower-leg caused the greatest loss of basic training time (966 recruit-days), accounting for 35.6% of the total number of training days lost because of exertion-related injuries.

7.3.4 STRESS FRACTURES

Fourty two separate stress fractures were sustained by 39 recruits, the incidence of recruits with stress fractures being 4.12%. Stress fractures resulted in a loss of 826 recruit-days of basic training. The relationship between the number of recruits presenting with clinical symptoms and signs suggestive of stress fracture, subsequently confirmed radiographically, and the week of the basic training cycle, is presented in Figure 15. Peaks occurred during the fourth (7 recruits), eighth (10 recruits), and tenth (6 recruits) weeks of basic training. The distribution of stress fractures with regard to anatomical location is displayed in Figure 16. Tibial stress fractures developed with the greatest frequency (35 stress fractures). Of these, 23 involved the proximal one-third, 4 the middle one-third, and 8 the distal one-third of the tibia. Femoral stress

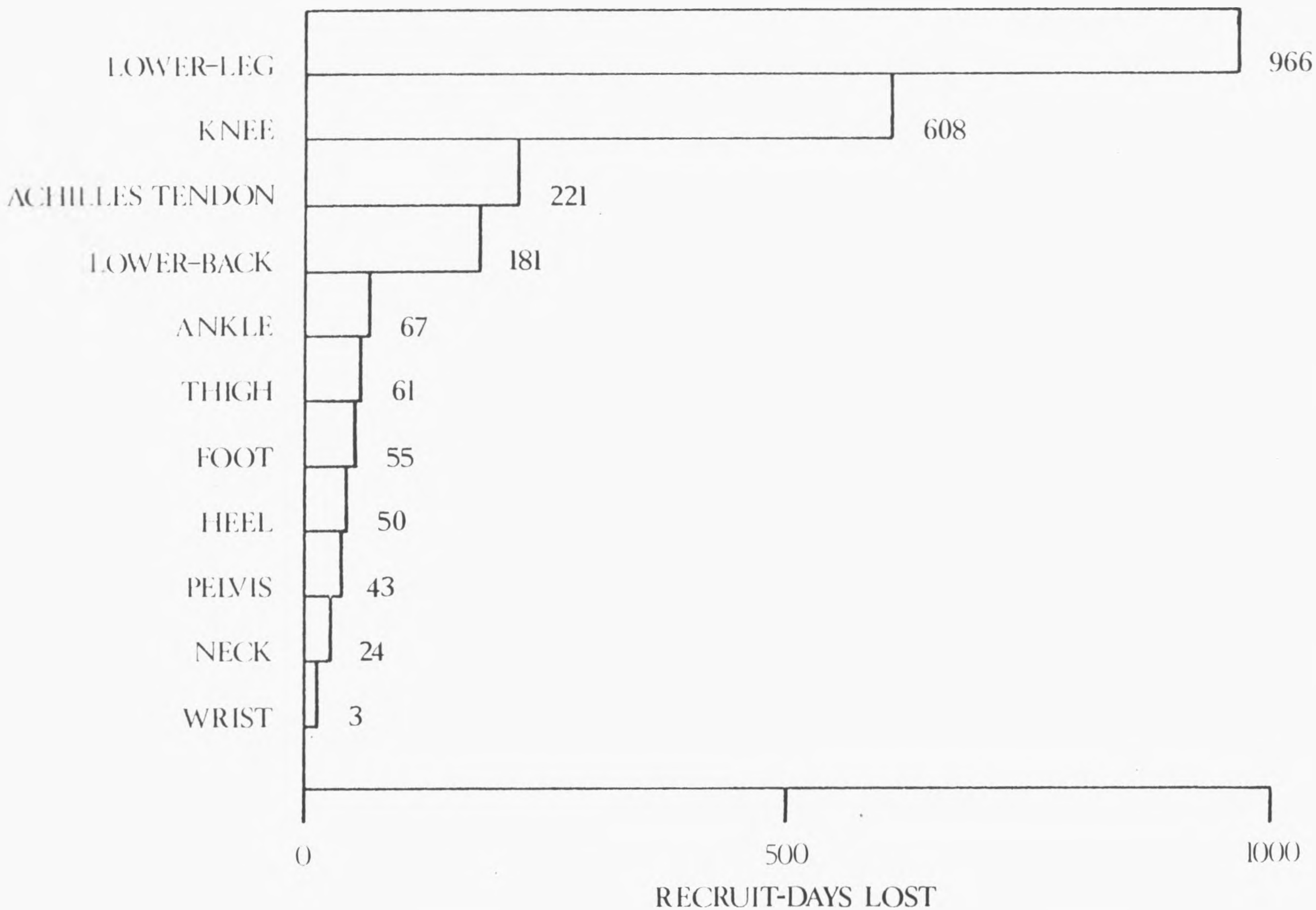

FIGURE 14 : LOSS OF BASIC TRAINING TIME AS A RESULT OF EXERTION-RELATED INJURIES SUSTAINED WITHOUT AN OBVIOUS SUDDEN ACUTE PRECIPITATING EVENT AT DIFFERENT ANATOMICAL SITES.

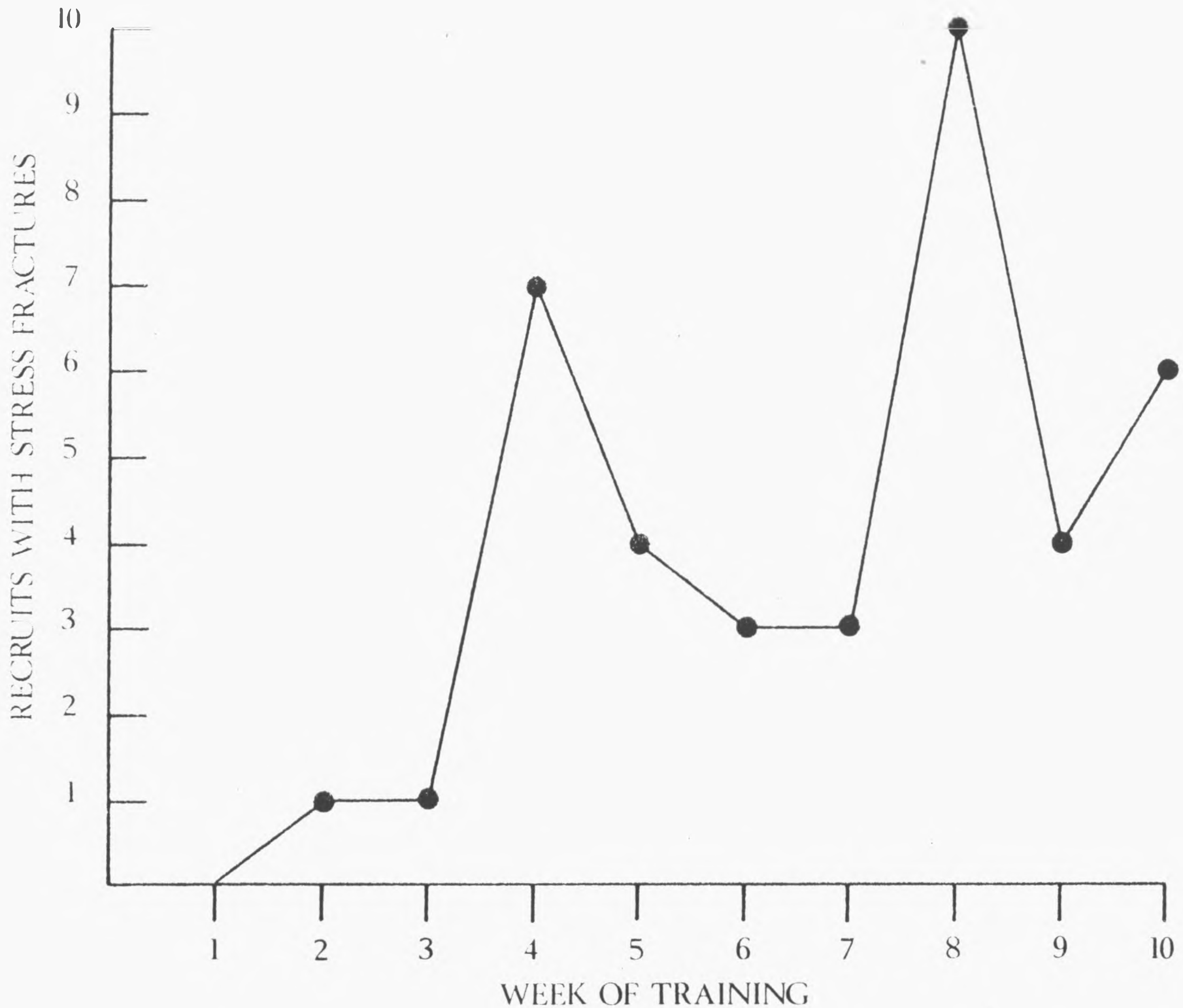

FIGURE 15 : RELATIONSHIP BETWEEN THE NUMBER OF RECRUITS PRESENTING WITH CLINICAL SYMPTOMS AND SIGNS SUGGESTIVE OF STRESS FRACTURE, SUBSEQUENTLY CONFIRMED RADIO= GRAPHICALLY, AND THE WEEKS OF THE BASIC TRAINING CYCLE.

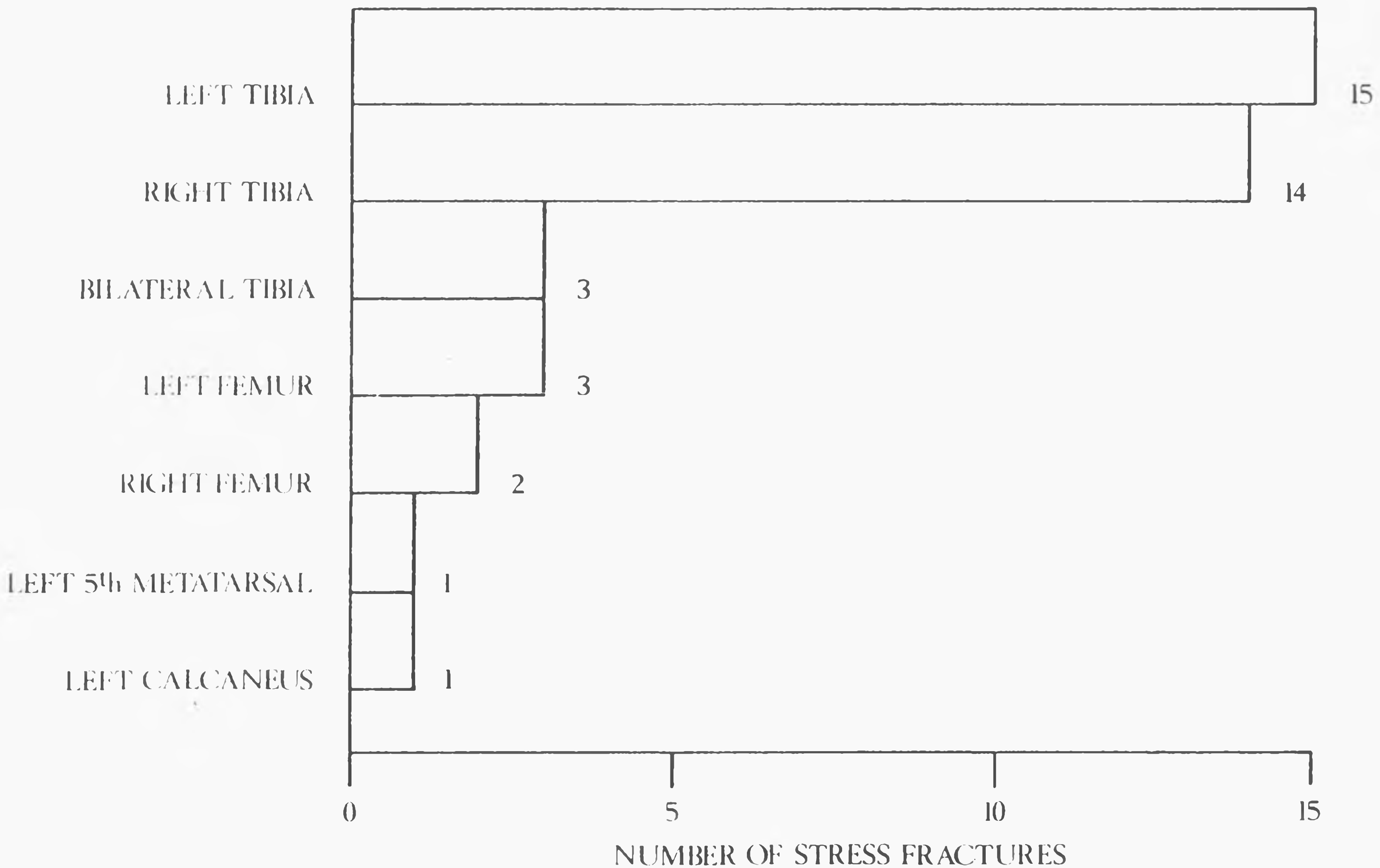

FIGURE 16 : NUMBER OF STRESS FRACTURES SUSTAINED AT DIFFERENT ANATOMICAL SITES.

fractures were located at the femoral neck (1 subject), femoral shaft (2 subjects), and distal femur (2 subjects). Stress fractures were distributed fairly evenly between both legs, 19 occurring in the right leg and 23 in the left leg.

7.4 DISCUSSION

7.4.1. INCIDENCE OF EXERTION-RELATED INJURIES

During the 10-week South African Army basic training cycle 37.9% of recruits (359 of 947 recruits) sustained one or more exertion-related injuries severe enough to prevent their return to normal military training for at least 1 day after medical consultation. Although considerable insight has been gained regarding the salutary effects of military physical conditioning programmes on recruit endurance fitness levels (see Chapter 4), little information is available concerning the risk of injury induced by such training. In fact, as mentioned in Chapter 4, a review of the available literature reveals only 3 substantial studies of the incidence of exertion-related injuries in military populations, all of which need further amplification to delineate the true magnitude of the problem. To recap, in one study Kowal (1980) reported a 26% (202 of 770 recruits) and 62% (215 of 347 recruits) injury incidence for male and female United States Army recruits, respec= tively, participating in 8 weeks of co-educational military basic training. However, for the purposes of his study an injury was defined as *any disability that was incurred during or as a result of physical training-conditioning which required attention from the medical facility* and it is likely that many of the injuries documented by Kowal would not have qualified as injuries in the present investigation. Therefore, although a note of caution is appropriate regarding a direct compa=

rison between the two studies, it does appear that the South African Army injury incidence compares unfavourably with that reported by Kowal for male United States Army recruits. On the other hand, however, the additional investigations were a prospective study of United States Marines which recorded a 37% incidence (325 of 879 recruits) of below-knee injuries (Bensel, 1976), and a recent study documenting an alarming 65.4% incidence of *work-related* injuries amongst New Zealand Army recruits undergoing 10 weeks of basic training (Stacy and Hunger= ford, 1984). Thus, while it is obvious that the lack of documentation of similarly performed descriptive studies in the available literature precludes an accurate scientific comparison of our findings to those of foreign armed forces, it is apparent that the present excessive injury rate is not unique to the South African Army. Any further speculation must be made with extreme caution.

7.4.2 OVERUSE INJURIES DURING BASIC TRAINING

The vast majority of exertion-related injuries documented in this study were sustained without an obvious sudden acute precipitating event and can, for practical purposes, be essentially regarded as overuse injuries. The term "overuse injury" is generally interpreted as the pain that ensues after excessive use of the musculoskeletal system during physical activity, including pain syn= dromes arising in the presence of normal structural anatomy as well as those that develop in the presence of structural abnormalities which are unveiled by exercise (Orava, 1980). Regarding the pathogenesis of these injuries, constant repetitive stressing of the musculoskeletal system during exercise is thought to induce not only physiological adaptations which enhance performance, but also microscopic lesions in the involved tissues. Orava (1981) has suggested that this microtrauma occurs consequent upon a disproportion be= tween the strength of the musculoskeletal tissues and the total strain of physical training and ultimately summates to produce injury.

In the military, stress fractures have been recognized as the severest of overuse injuries since their initial literary coverage in 1855 by Breithaupt. The present stress fracture incidence (4.12%), although similar to that (4.88%) reported in 1974 for United States Army recruits (Scully and Besterman, 1982), is considerably higher than the current United States Army stress fracture incidence of ~1% (Protzman and Griffis, 1977; Scully and Besterman, 1982). It should further be noted that the incidence and anatomical locations of stress fractures reported in the present study are limited by a variety of factors including recruits who did not present for medical evaluation because of a lack of symptoms or a strong desire to continue basic training irrespective of their physical well-being, the diagnostic capabilities of the basic training centre's medical officers, and the use of a radiographic diagnosis. Regarding the diagnostic capabilities of the medical officers, analysis by anatomic distribution showed the tibia to be the commonest site of stress fracture, a finding which differs from that of other armed forces where the foot has been most frequently implicated in male recruits (Gilbert and Johnson, 1966; Rückert and Brinkmann, 1978). The lower incidence of stress fractures of the foot in South African Army recruits might result from a different physical training requirement or possibly from an inability of our medical officers to detect many of these fractures. Regarding the latter, calcaneal stress fractures surprisingly often present with little or no tenderness over the inferior plantar aspect of the heel but with considerable tenderness, on pressure, on both sides of the calcaneus as well as along the course of the Achilles tendon (Rückert and Brinkmann, 1978). It is interesting that in one study (Rückert and Brinkmann, 1978) 17% of recruits with stress fractures of the calcaneus were initially falsely diagnosed as having tenosynovitis. Concerning the use of radiographs in the diagnosis of stress fractures, standard skeletal radiography requires an approximately 50% change in bone density for deline= ation and diagnosis of trabecular lesions (Greany *et al*, 1983). Stress fractures of trabecular bone may appear normal on radiographs for 10 - 21 days before resorption and proliferation associated with the healing process produce perceptible increases in bone matrix density (Greany *et al*, 1983). It is therefore feasible that a number of stress fractures incurred during the latter portion of basic training might have been missed in the present study. Moreover, a significant number of stress fractures require minimal new bone to support new loading forces and approximately one-half of all lesions fail to demonstrate any radiographic change (Greany *et al*, 1983). Thus, the use of a confirmatory radiograph to make a diagnosis of stress fracture could have resulted in a large percentage of false negative diagnoses thereby underestimating the actual incidence of stress fractures; the extent to which this may be true will only be established by employing skeletal scintigraphy as a diagnostic aid in a future study. Finally, the author is cognizant of the possibility that the incidence and location of stress fractures may differ in other South African Army basic training centres from that of the present study. It must be emphasized, however, that this investigation was conducted purely as an initial step in determining the true state of the problem.

In civilian populations, overuse injuries are known to ensue most frequently in response to prolonged weight-bearing physical activities and the anatomical locations of injury documented in this study are in fact similar to those observed in long distance runners (James *et al*, 1978). In this respect, the present incidence of injury by anatomical location indicates that the knee was the most common site of injury, Group 2 knee injuries accounting for 27.7% of all exertion-related injuries. This figure is in close agreement with the 29% incidence reported by James *et al* (1978) for civilian runners seeking medical treatment. Incidences of 25% (Krissoff and Gerris, 1979), 41.7% (Clement *et al*, 1981), and 32% (Maughan and Miller, 1981) have also been documented for knee disorders amongst runners. The present injuries do differ from those of runners, however, in that lower-back injuries comprised a relatively high percentage of the injuries sustained. Although it was not the intention of this study to elucidate the precise aetiology of the various exertion-related injuries, it seems likely that high rates of lower-back injuries amongst military recruits may be related to the practice of running while carrying heavy loads such as backpacks, poles, and even fellow recruits, as well as the execution of calisthenics designed to strengthen the lower-back muscles with incorrect tech= nique. As to the possible aetiology of overuse injuries in the lower-limbs, James *et al* (1978) have suggested that training errors, anatomical factors, shoes, and surfaces are contributory in runners and it is probable that these factors can be extrapolated to the military context.

7.4.3 CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this study has documented a disturbingly high incidence of exertion-related injuries at one South African Army basic training centre. While it is not possible, for a variety of reasons, to make an accurate comparison between these findings and those of foreign armed forces, it appears that the incidence of stress fractures, one of the severest military exertion-related injuries, may be considerably higher in the South African Army than in the United States Army. Moreover, the present data leave little doubt that the injurious nature of the South African Army basic physical training programme studied is costly in terms of training time lost and may prohibit large numbers of recruits from deriving the optimum conditioning benefits. Experience from the United States Army shows that the incidence of exertion-related injuries can be significantly reduced by simple and inexpensive techniques (ie training modifica= tions and not running in combat boots) which do not impair the basic goal of producing physically conditioned soldiers*. In this respect, it is of interest that in the present study the majority of recruits with stress fractures reported to the medical facility after the third week of training, and if the previously discussed

*Since presenting the data and recommendations documented in Parts I, II, and III of this study to the South African Army authorities, a number of changes have been evaluated and proven successful in 2 separate (as of yet unpublished) trials involving the Special Forces and 2 other South African Army basic training centres; these changes resulted in a stress fracture incidence of ~ 1% in both trials and the attainment of the desired physical fitness levels. The changes are to be introduced in 1986 at all South African Army basic training centres and include the following: i. all running is performed in running shoes and not combat boots or "takkies"; ii. the 2.4 km all-out run is used for fitness testing and not training (daily endu= rance training is performed predominantly at submaximal speeds); iii. the concept of "cyclic-progressive" rather than purely "progressive" physical training is used; iv. a wider variety of strength-fitness exercises are employed with the aim of enhancing all possible muscle-groups which may be of military importance (the correct technique of performing these exercises is emphasized); v. flexibility training is used as part of the warm-up prior to physical training; vi. physical training is conducted on a more controlled and structured basis; and vii. all recruits are required to undergo fitness testing: the feasibility of the training used in terms of injuries sustained can thus be taken into account when evaluating the efficacy of the various South African Army basic training centres.

(see Chapter 4) principle of "cyclic-progressive" physical training is to be utilized by the South African Army, the first period of relative rest should occur during the third week of basic training, as is recommended by Scully and Besterman (1982) for United States Army recruits.

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