

CHAPTER 3

METHODS AND PROCEDURES

3.1 INTRODUCTION

In this chapter the methods and procedures followed in this study will be discussed. The research approach used in stress fracture research can be quantitative or qualitative in nature ((Kinnear & Taylor, 1996; Thomas & Nelson, 2001).

The qualitative paradigm concentrates on investigating subjective data, in particular, the perceptions of the people involved. The intention is to illuminate these perceptions and, thus, gain greater insight and knowledge. The quantitative paradigm concentrates on what can be measured. It involves collecting and analysing objective (often numerical) data that can be organised into statistics (Kinnear & Taylor, 1996; Thomas & Nelson, 2001). This study utilized a qualitative research approach which will be discussed further in this chapter.

Additionally several methods have and can be used to investigate stress fractures as outlined in 2.5. These include clinical trials, case-control studies, case series, cross-sectional studies, or surveys, 'mixed' study designs and prospective cohort studies (Brukner *et al.*, 1999; Thomas & Nelson, 2001).

The latter was the chosen for this study as it is considered a 'strong' design as accurate comparisons can be drawn between the injured and the uninjured

groups. These comparisons then lead to true assessment of the incidences and risks which may lead to casual inferences been drawn (Brukner *et al.*, 1999; Thomas & Nelson, 2001).

3.2 RESEARCH APPROACH

This study followed a **quantitative research approach** and the two quantitative research techniques that were used are known as Observation Technique and Experimentation.

3.2.1 Observation Technique

This technique provides a means of obtaining data and is a descriptive method of researching certain problems. In this study, the Observational Technique was used in keeping record of all military participants who developed a stress fracture. This was done via the military medical computerised system, as all military medical visits to the unit sick bay are captured onto this system. Additionally the diagnosis, as well as the results of any radiology / scans, was also captured together with treatment given (Thomas & Nelson, 2001).

3.2.2 Experimentation

This technique attempts to establish a cause-and-effect relationship. That is, an independent variable (in this case the PT Programme) is manipulated to judge the effect upon a dependant variable (fitness results). Additionally, correlation statistics were used to establish the cause-and-effect relationship (Thomas & Nelson, 2001).

3.3 RESEARCH DESIGN

A research design is the basic plan that guides the data collection and analysis phases of the research project. "It is the framework that specifies the type of

information to be collected, the sources of data and the data collection procedure” (Kinnear & Taylor, 1996: 129). The current study was done in the form of an experiment. Pre-test and Post-test measures were taken for the EG (who all underwent BT) on biokinetic and bone density measurements. Fitness test results were also compared to a CG who had undergone BT in the year prior to the EG. The limitation of the findings of this study is that it can only be generalised to the people from the same sample group.

The prospective design implies that the participants were assembled at the beginning of the study, in this case at the start of 12 weeks of BT, according to their exposure to a risk factor. They were followed over the predetermined 12-week period, during which, injury occurrence was monitored and recorded. This is considered a ‘strong’ design as it enables accurate comparisons to be made between the injured and the uninjured groups. These comparisons then lead to true assessment of the incidences and risks which may then lead to casual inferences been drawn. The limiting factor of this type of design is that in order to have enough statistical power, particularly for detection of small differences, sample sizes have to be large. Additionally rigorous inclusion criteria, as well as drop out rates over the course of the study limit the number of available, suitable participants.

3.4 A 12-WEEK PT PROGRAMME FOR BT

Prior to the start of BT, a 12-week PT Programme was designed and developed by the researcher. The reason for the new 12-week PT Programme was two-fold:

- Firstly, no clearly outlined, formal, PT Programme was being followed by BT participants during BT in the South African Military Health and Medical Service, and
- Secondly, to ensure that all participants undergoing BT followed a scientifically based progressive exercise programme.

A detailed daily 12-week PT Programme was developed in conjunction with a PT Manual. Due to the length and size of both the detailed PT Programme as well as the PT manual, they have been included electronically in the enclosed CD. The purpose of the PT manual was to clearly explain all the exercises used in the PT Programme, so that the PT Instructors would know exactly how to execute the exercises, as well as to ensure uniformity in the methodology of instruction.

3.4.1 Aim of the PT Programme

The main aim of the PT Programme was to develop the physical fitness of the participants in order to assist in making them combat ready. Physical fitness can be defined as the healthy and efficient functioning of various body systems that allows one to engage in activities of daily living, recreation and leisure (DOD policy on Physical Training, DOD Instruction: SG no 00006/2000). Physical fitness can be classified into seven fitness components, namely: cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, speed, power and agility (American College of Sports Medicine, 2006). (Please refer to pp.1-10 in the PT Manual on the enclosed CD for the detail regarding the definition and method of developing each specific component).

Based on previous practical undocumented experience, the researcher found that many BT recruits had very little experience with formal exercise instruction and that their activity levels, prior to the start of BT, were low. This group indicated, in a questionnaire prior to their start of BT that their previous activity levels included participation in sport (84%).

The types of sport mostly included soccer (49.3%), followed by netball (15.1%) and running (13.2%). Only 1.1% indicated that they participated in gymnasium activity. Additionally, the level of participation was mostly on a social level (66.9%) with the remaining third competing at club, provincial or national level. Participants were divided in their opinion regarding the intensity of participation

with 39.2% indicating low intensity, 29.1% reporting medium intensity and the remaining 31.8% reporting high intensity of participation.

This lack of previous experience with formal physical activity, combined with the relatively short period of 40 minutes 5 times per week for 12 weeks (available for formal PT) resulted in the aim of the PT Programme then to develop the basic fitness components, namely cardiorespiratory endurance, muscular strength and muscular endurance (American College of Sports Medicine, 2006). Additionally, flexibility training was included due to its possible role in injury prevention (Hughes, 1985; Giladi *et al.*, 1987; Giladi *et al.*, 1991; Milgrom *et al.*, 1994).

3.4.2 Design of the PT Programme

The design of the BT PT Programme had to comply with the following logistical limitations present in the BT environment:

- Large groups need to undergo the training simultaneously, thus the exercises needed to be simple, clear and be completed within a small personal space.
- No individual training weights were available, thus exercises were designed based on resistance offered by own body weight and progressed to the use of solid timber wooden poles (2.1m in length by 25cm in diameter).
- As already mentioned in 3.4.1, many of the new participants had no previous experience in formal exercise activities, thus exercises needed to be simple and be easily corrected by the PT instructor. Consequently, the main aim of the PT Programme was to develop the basic fitness components.

The PT Programme was designed based on the scientific principles of specificity, overload, FITT (Frequency, Intensity, Time and Type) and progression (Rudzki & Cunningham, 1999; American College of Sports Medicine, 2006).

The principle of specificity, technically, states that the type of demand placed in the body, controls the type of adaptation that will occur. Specificity suggests that the activities selected should provide the outcome represented by that day's class objectives (DOD policy on Physical Training, DOD Instruction: SG no 00006/2000). Thus all training programmes, in the military context, must be specific to developing the energy system(s) predominantly used during the performance of the activity in question (Fox *et al.*, 1989).

The energy systems used during military combat cannot be isolated, as the situation determines the specific activity required. Additionally, it is only after BT that the participants then pursue a more specific form of military training, eg medical orderly or foot soldier. The Programme followed during BT therefore needed to evenly develop all three energy systems, namely, ATP-PC strength, oxygen system and the ATP-PC/ lactic acid system (Fox *et al.*, 1989).

The principle of overload - progressively placing greater – than - normal demands on the musculature of the body - suggests that individuals involved with activities designed to improve muscular strength, and/or muscular endurance, will need to increase their workload periodically throughout the course of the programme. Specifically, to develop muscular strength, the overload principle dictates increasing the resistance against the muscles involved to a level greater than that used before.

To develop muscular endurance, the overload principle dictates increasing the number of repetitions, increasing the length (time) of the repetition, decreasing the rest interval between activities or a combination of two or three methods.

The amount of increase must be appropriate for the age and fitness level of the participants (Fox *et al.*, 1989; American College of Sports Medicine, 2006).

As the participants training together did not have homogeneous fitness levels, it was very difficult to apply the principle of overload, and thus the PT Programme designed included the use of maximal repetitions. This was advantageous as it allowed each participant to perform to the best of his/ her ability, however the risk was that the participant did not work to his/ her maximum, but did just enough to keep up with the group.

The principle of progression refers to incorporating a systematic approach to increasing frequency of exercise, the volume of repetitions and/or the intensity of the activity. To avoid injuries, appropriate progression and appropriate goal setting is essential. This Programme followed an average of 10% weekly progression, as advocated in the literature to be a safe yet effective progression rate (Heyward, 2002). The FITT principle was applied and Table 3.1 summarizes how to apply the FITT (Frequency, Intensity, Time and Type) principle, based on fitness level goals (Heyward, 2002).

As military combat performance can be viewed as an athletic performance, the frequency, as well as the duration of the PT training was dictated by the PT policy (DOD policy on Physical Training, DOD Instruction: SG no 00006/2000) which stipulated that PT would take place 5 times per week for a period of 40 minutes. The only variables that could then be manipulated were the intensity and the type of physical activity followed.

Table 3.1: Application of training principles to develop muscular strength and muscular endurance based on fitness goals

Training principles applied to muscular strength and muscular endurance, based on fitness goals			
	Base health-related fitness	Intermediate health-related fitness	Athletic performance fitness
Frequency	2-3 times per week; allow for minimum one-day rest between training sessions	3-4 times per week; alternating upper - and lower - body segments will allow for consecutive training days	4-5 times per week; training activities are specific to sport participation
Intensity	Very light, less than 40% of a "projected" maximal effort	Light to moderate, 50%-70% of "projected" maximal effort	Specific load adaptation required for sport participation
Time	2-3 sets of 6-8 (strength) / 10-12 (endurance) repetitions	2-3 sets of 6-8 (strength) / 10-12 (endurance) repetitions	2-3 sets of 6-8 (strength) / 10-12 (endurance) repetitions
Type	Body weight, single and multijoint activities involving major muscle groups	Resistance exercise such as leg press, bench press, pull-ups additional presses and pulls	Advanced sport-specific, multi-joint lifts (clean pulls, power presses, Olympic style lifts)
Overload	Not necessary to bring components to overload during base level	Introduce one of the components of overload; 1-2 times per week	Programme design should stress variable intensities and durations to bring student into overload; 2-3 times per week
Progression and specificity	Let student get the idea of correct movement. Progression is minimal	Introduce programme design and incorporate variation	Specific sets, repetitions, and exercises to meet desired outcomes

The intensity of training can be calculated either indirectly by monitoring heart rate, or directly, by determining the workload intensity at the anaerobic threshold. However, as 185 BT recruits had to train together in large groups and no funds were available to provide each participant with his/her own heart rate monitor, the intensity of training was difficult to control and manipulate.

The type of physical activity used in the programme design was determined by the resources available, as well as by what the researcher deemed to be the most appropriate for the development of the participants' physical fitness. This saw the introduction of using wooden poles, as a means of increasing resistance in a synchronised and organised manner.

3.4.3 Quantification (Energy Expenditure) of BT and PT Programme

The Energy Expenditure for the BT programme followed in this study was derived by calculating the Basal Metabolic Rate (BMR) – the energy that is necessary to maintain life or organ function in the body (Stedman's Medical Dictionary, 2000). This was determined by taking weight, age and sex into consideration. The daily kilojoules used for men and women were calculated as 6832.5 kJ/day and 5910 kJ/day respectively. Therefore, the average BMR was 6371.25 ~ 6371.3 kJ/day. The average activity levels were expressed as multiples of BMR (meaning regular daily movements and activity), excluding the PT Programme.

All the BT activities could be classified as light levels of activity, thus a BMR of 1.5 was used for males and females for calculation purposes. The average total minutes on the training program with basic exercises was 45 minutes, four times per week. Thus 1350 kJ was used for PT four times per week. The average kJ used for BT per day was calculated by averaging three hours of exercise per day, resulting in 8485.7 kJ used per day.

3.5 METHODS

As the study was conducted on military personnel, during military training and military time, the rules and habits of the military had to be abided by. This influenced the methodology employed and the study design chosen. The aim of BT is to create a combat ready soldier, therefore, it was not possible to have a

true control group, with regard to the PT Programme, as all the participants had to follow the same programme (Casez *et al.*, 1995).

In order to evaluate the effect of the PT Programme on physical fitness, Pre-test and Post-test measures were taken for the EG (who were subjected to a new PT Programme). These measures were taken on fitness test results, and then were also compared to the fitness test results of a CG, who had undergone BT in the year prior to the EG.

Additionally, the participants acted as their own controls, as those that developed stress fractures were compared to their matched counterparts, who did not develop stress fractures. Pre-test and Post-test biokinetic-, bone density-, as well as fitness test parameters were measured. This same method has been followed by other researchers successfully (Taimela *et al.*, 1990; Milgrom *et al.*, 1994; Rosendal *et al.*, 2003; Armstrong *et al.*, 2004; Välimäki *et al.*, 2005; Lappe *et al.*, 2005; Rauh *et al.*, 2006; Shaffer *et al.*, 2006).

The risk of this was that should the incidence of stress fractures be statistically insufficient or non-existent, the interpretation of results would then become difficult.

The methodological approaches employed were as follows:

3.5.1 Participant selection

A high incidence of shin splints and stress fractures was observed in female participants, in the South African National Defence Force, during BT in the beginning of 2005 (Wood & Krüger, 2007). It was for this reason that this study was conducted specifically on BT participants. The Arm of Service used was decided upon, based on logistical and financial constraints.

Participants utilised were volunteers from the South African Health and Medical Service intake, who started their BT on 03 July 2006 and completed it on 05 October 2006. This particular group of Basic trainees was selected for the following logistical reasons:

- This BT group reported and cleared in at the Military Health Training Formation in Pretoria. The procedures followed in the Pre-testing of these participants required specialised equipment, which was only available to military participants at 1 Military Hospital, located in Pretoria.
- This BT group also returned to the Military Health Training Formation in Pretoria at the end of their BT, thus then logistically, ideally located near 1 Military Hospital for the Post-testing.
- Since the researcher was also located in Pretoria the management and control of the execution of the study was ideal.

3.5.2 Sample

A sample can be defined as a subset of a population and sampling plan, as a design, scheme of action or procedure that specifies how the participants are to be selected in a survey study (Rosnow & Rosenthal, 1996). A distinction is made between probability and non-probability sampling. In this study, use was made of a non-probability sampling method. This type of sampling method can be described as the selection of a population element to be part of the sample, based in some part, on the judgment of the researcher (Kinnear & Taylor, 1996).

There is a number of sampling procedures that fall into this category. A sample of convenience was used in this study and consisted of 185 BT candidates who underwent 12 weeks of BT. Additionally, 198 participants from the previous year's BT fitness results, were used as controls to compare fitness changes.

The study started with 185 participants - 100 male and 85 female. After 12 weeks of BT, two participants dropped out of the study, both female, having resigned from the South African National Defence Force.

3.5.3 Informed consent

All participants that reported for BT at the Military Health Training Formation in July 2006, were addressed by the researcher and informed of the aim of the study, the reasons for the study and the procedures of the study. Any questions that arose were answered by the researcher. The participants were then asked to volunteer and once the volunteers had been identified, each volunteer completed and signed an informed consent form prior to participating in the study (Appendix A).

3.6 PROCEDURES

The procedures that were followed are outlined in chronological order below:

3.6.1 Ethical approval from the South African Defence Force Ethics Committee

Ethical approval was obtained from the South African Defence Force Ethics Committee (Ethical clearance number SG/R&D/2-Jun-06/ 083) to conduct the study. As ethical approval was not obtained for blood turnover markers, this could not be done. The medical personnel at 1 Military Hospital, staff of the Military Health Training Formation in Pretoria, as well as in Lohatla, were marked to assist in the project. Relevant documentation and letters were written by the researcher to obtain their support.

3.6.2 Ethical approval from the Medical Faculty of the University of Pretoria

Ethical approval was obtained from the Medical Faculty of the University of Pretoria (Project number 57/2006) to conduct the study. Ethical approval was obtained for blood turnover markers; however, as the South African Defence Force Ethics Committee did not grant approval for this, it had to be excluded.

3.6.3 Financial approval for Bone Density tests

Financial approval was obtained to conduct 70 Bone Density tests on the female participants. This was based on the recent history of a high incidence of stress fractures in female participants (Wood & Krüger, 2007). Due to the high cost factor involved, only 70 randomly selected female participants underwent full Bone Density scans.

3.6.4 Logistical planning details for Pre-testing procedures

Prior to departing for their 12 weeks of BT in Lohatla, the participants were in Pretoria for a period of five days. Careful planning took place to ensure that all participants completed all the necessary physical tests. Table 3.2 outlines the practical programme followed, in order for the participants to complete all their testing in the allocated time. An information session was held on the day of arrival and the procedure detailed in 3.5.3 was followed.

Table 3.2: Detailed outline of practical programme followed to complete testing of all variables

STRESS FRACTURE RESEARCH PROGRAMME: 03/07-08/07/2006							
Day	Time slots	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Monday	07H00-17H30	Clearing in, information session, informed consent, activity questionnaires.					
Tuesday 1	07H00-11H00	DEXA	KIT	ECG		Fitness	IT & Bio
Tuesday 2	11H00-13H00				ECG		
Tuesday 3	14H30-17H30			Fitness	Fitness		
Wednesday 1	07H00-11H00	IT & Bio				ECG	KIT
Wednesday 2	11H00-13H00		ECG	IT & Bio		KIT	
Wednesday 3	14H30-17H30	Kit	IT & Bio				Fitness
Thursday 1	07H00-11H00						
Thursday 2	11H00-13H00	Fitness	Fitness	KIT		IT & Bio	ECG
Thursday 3	14H30-17H30						
Friday 1	07H00-11H00				IT & Bio		
Friday 2	11H00-13H00	ECG				IT & Bio	
Friday 3	14H30-17H30						
Saturday	07H00-17H00	Catch up	DEXA	Catch up			

Key:

ECG- *Electrocardiogram, resting blood pressure and heart rate variability (the results of the resting blood pressure were included in this study, however, the other parameters were outside the scope of this study and were done to reach the objectives of a different study)*

Fitness- *Standardised Military Fitness tests*

IT- *Isokinetic testing on the Cybex 340*

Bio- *Biokinetic evaluation which included resting blood pressure, resting heart rate, anthropometry (height, body mass, skinfolds, somatotyping, waist-hip), skeletal alignment (leg length, Q angle and foot type) and flexibility (hip external rotation, ankle dorsiflexion & ankle plantarflexion)*

DEXA- *Full bone scan done on a dual energy absorptometry on the Lunar Prodigy*

KIT- *Issue of army kit at the Logistical stores.*

For practical execution of the testing the all the female participants were randomly divided into groups one and two (35 participants in each) according to the table of random numbers, and the remaining female participants were placed into group three (Thomas & Nelson, 2001). The male participants were also randomly divided into groups three to six with 30 participants per group, according to the table of random numbers (Thomas & Nelson, 2001). Each group started at a station and rotated to the next ie A to B, B to C etc. Care was taken that the isokinetic and biokinetic evaluations were not completed on the same day as the fitness tests, to provide sufficient recovery time.

3.6 TESTING PROTOCOL

A similar testing protocol was adopted for both Pre- and Post-testing procedures. The only difference was that the physical activity questionnaire was only completed at the start of the study.

3.7.1 Health and Physical Activity Questionnaire

Once the informed consent had been obtained, participants completed a questionnaire which provided a detailed history of sport participation, as well as health and medical history information (Appendix B) (Lee & Nieman, 2007).

3.7.2 Biokinetic evaluation

The participants underwent a biokinetic evaluation which included the following:

3.7.2.1 Anthropometric evaluation

3.7.2.1.1 Height (standing)

Equipment: Stadiometer

Procedure: Height was calculated to the nearest 0, 1 centimeter (cm) with a stadiometer. Height, defined as the distance between the soles of the feet and the vertex, was taken whilst the participant stood up straight, barefoot, with heels, gluteus maximus, upper-back and back of head against the anthropometer. The ears, acromion, greater trochanter, back of patella and front of calcaneus were in the same vertical line. The angle of the eye and the upper hole of the ear were on the same horizontal level. Measurement was taken at the end of a deep inhalation. No asymmetry was allowed (Smit, 1979; Eston & Reilly, 2001).

3.7.2.1.2 Body mass

Equipment: Detecto standing scale

Procedure: Participants were weighed, in kilograms (kg), on a calibrated medical scale wearing only underwear, running shorts and a t-shirt. Each participants' mass was calculated to the nearest 0, 1 kg (Eston & Reilly, 2001).

3.7.2.1.3 Body Mass Index

The Body Mass Index (BMI) is a measure of the lean mass and fat mass components. It is used in epidemiologic research and has a moderately high correlation ($r_{xy} = 0.69$) with body density. It was calculated using the following formula:

$$BMI = \frac{mass}{height^2}$$

Where Mass is measured in kilograms and height in meters (Morrow *et al.*, 2000).

The following ratings have been applied to the BMI (kg.m^{-2}) (American College of Sport Medicine, 2006:58):

- Underweight: <18.5
- Normal: 18.5-24.9
- Overweight: 25.5-29.9
- Obesity, class:
 - I: 30.0-34.9
 - II: 35.0-39.9
 - III: ≥ 40

3.7.2.1.4 Skinfolds

Equipment: Skinfold caliper (Harpenden John Bull)

Procedure: A manual skinfold caliper was used to determine the participant's percentage body fat and somatotype. The Harpenden John Bull skinfold calliper has an accuracy of 99.00% and a repeatability measurement of 0.20 mm (Irazusta *et al.*, 2006). The 'six skinfold method" was used (Yuhasz, 1974). All skinfold measurements were measured on the right side in millimeters (mm). The researcher pinched the skin at the appropriate site to raise a double layer of skin and the underlying adipose tissue, but not the muscle. The calipers were applied 1 cm below and at right angles to the pinch, and a reading was recorded two seconds later. The mean of the two measurements was taken. If the two measurements differed greatly, a third was done and the median value was taken (International Standards for Anthropometric Assessment, 2001).

Triceps



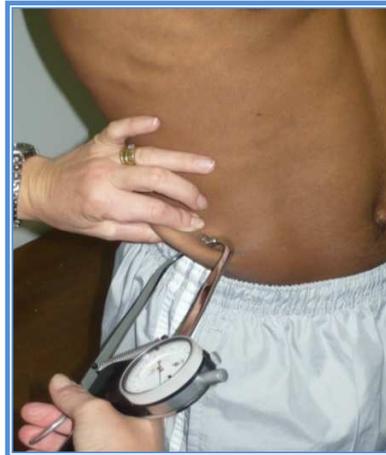
The participant assumed a relaxed standing position with the left arm hanging by its side. The right arm was relaxed, with the shoulder joint slightly externally rotated and elbow extended by the side of the body. The skinfold was taken vertically, parallel to the long axis of the arm, on the landmark (which was at the level of the mid-point between the acromion and the olecron processes), on the mid-line of the posterior surface of the arm and over the triceps muscle (International Standards for Anthropometric Assessment, 2001).

Subscapular



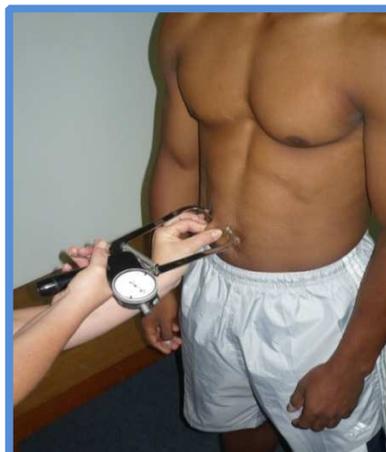
The participant assumed a relaxed standing position with the arms hanging by its sides. The line of the skinfold was determined by the natural fold lines of the skin (International Standards for Anthropometric Assessment, 2001).

Supraspinale



The participant assumed a relaxed standing position with arms hanging by its sides. The fold runs medially downward at about a 45° angle as determined by the natural fold of the skin (International Standards for Anthropometric Assessment, 2001).

Abdominal



The participant assumed a relaxed standing position with the arms hanging by its sides. The vertical skinfold was taken 5cm adjacent to the umbilicus to the right side (International Standards for Anthropometric Assessment, 2001).

Front thigh



The participant assumed a seated position on the front edge of the box with the torso erect and the arms hanging by its sides. The knee of the right leg was bent at a right angle. The researcher stood facing the right side of the seated participant on the lateral side of the thigh. The site was marked parallel to the long axis of the thigh, at the mid-point of the distance between the inguinal fold and the superior margin of the anterior surface of the patella (while the leg was bent). The skinfold measurement was taken with the knee bent at the marked site (International Standards for Anthropometric Assessment, 2001).

Medial calf



The participant assumed a relaxed standing position with the arms hanging by its sides and the right foot placed on a box. The right knee was bent at 90°. The fold taken was parallel to the long axis of the leg (International Standards for Anthropometric Assessment, 2001).

3.7.2.1.5 Breadths

Equipment: Small sliding calliper

Procedure: Breadths are widths measured at standard anatomical sites and were measured to the nearest 0,1 cm. The sites were first marked and care was taken that the calliper was not too tight or too loose, and lying flat against the skin (Carter, 2002).

Biepicondylar humerus



The participant assumed a relaxed seated position. The right arm was raised anteriorly to the horizontal and the forearm was flexed at right angles to the arm. The distance between the medial and lateral epicondyles of the humerus was measured. This was done by gripping the small sliding caliper correctly, using the middle fingers to palpate the epicondyles of the humerus, starting proximal to the sides. Firm pressure was placed on the crossbars to compress the subcutaneous tissue (International Standards for Anthropometric Assessment, 2001).

Biepicondylar femur



The participant assumed a relaxed position with the hand clear of the knee region. The right leg was flexed at the knee to form a right angle with the thigh. The greatest distance between the lateral and medial epicondyles of the femur was measured. With the caliper in place, the author used her middle fingers to palpate the epicondyles of the femur beginning proximal to the sites. Firm pressure was applied on the crossbars in order to compress the subcutaneous tissue (International Standards for Anthropometric Assessment, 2001).

3.7.2.1.6 Girths

Equipment: Flexible steel tape measure

Procedure: Girths are circumferences measured at standard anatomical sites and were measured to the nearest 0,1 cm. The sites were first marked and care was taken that the tape was not too tight or too loose, and lying flat on the skin (Carter, 2002).

Biceps



The participant assumed a relaxed standing position with the left arm hanging by its side. The participant's right arm was raised anteriorly to the forearm supinated

and flexed at 45-90° to the arm. The researcher stood to the side of the participant and asked the participant to tense the elbow flexors and the participant was then encouraged to contract the arm muscles, as strongly as possible, while the author took the measurement at the peak of the Biceps. The greatest girth of the arm was measured and recorded (International Standards for Anthropometric Assessment, 2001).

Calf



The participant assumed a relaxed standing position with arms hanging by its sides. The feet were separated and the weight evenly distributed. The participant stood in an elevated position and the author placed the tape around the calf where the maximum girth of the calf was measured and recorded (International Standards for Anthropometric Assessment, 2001).

3.7.2.1.7 Anthropometric derivatives

From the above measurements, the following was derived:

- The sum of the 6 skinfolds,
- Lean body mass,

- Fat mass,
- Somatotype and
- Percentage body fat (%).
 - The % body fat was calculated using Yuhasz equation for males and females (Yuhasz, 1974):

Males % body fat

$$= (0.1051 \times \text{sum of triceps, sub scapular, supraspinale, abdominal, front thigh, calf}) + 2.585$$

Females % body fat

$$= (0.1548 \times \text{sum of triceps, sub scapular, supraspinale, abdominal, front thigh, calf}) + 3.580$$

3.7.2.1.8 Waist

Equipment: Flexible steel tape measure

Procedure: The waist measurement was taken at the narrowest waist level, or if this was not apparent, at the mid point between the lowest rib and the top of the hip bone (iliac crest) with the tape lying horizontal, and flat against the skin (Welborn *et al.*, 2003).

3.7.2.1.9 Hip

Equipment: Flexible steel tape measure

Procedure: The hip girth measurement was taken over minimal clothing, at the level of the greatest protrusion of the gluteal muscles with the tape lying horizontal and flat. The participant stood erect with his/her weight evenly distributed on both feet and legs slightly parted (Welborn *et al.*, 2003).

3.7.2.1.10 *Waist/hip ratio*

The waist to hip ratio was calculated using the following formula (Welborn *et al.*, 2003):

$$WHR = \frac{Gw}{Gh}$$

Where:

WHR = *Waist to Hip Ratio (WHR)*

Gw = *waist girth and"*

Gh = *hip girth"*

Table 3.3 gives general guidelines for acceptable levels for hip to waist ratio (Welborn *et al.*, 2003).

Table 3.3: Acceptable levels for hip to waist ratio

	Acceptable		Unacceptable		
	Excellent	Good	Average	High	Extreme
Male	< 0.85	0.85 - 0.90	0.90 - 0.95	0.95 - 1.00	> 1.00
Female	< 0.75	0.75 - 0.80	0.80 - 0.85	0.85 - 0.90	> 0.90

3.7.2.2 *Blood pressure*

Equipment: Mercury sphygmomanometer, cuff and stethoscope

Procedure: The sphygmomanometer was placed on a bench where the participant could not see the mercury column. Blood pressure was recorded after the participant had rested quietly for 5 minutes, and this measure preceded all the other measures in the session. The participant was seated with the arm

resting on the bench, the elbow approximately at the level of the heart. A medical officer placed the cuff and attached it over the upper arm and then increased the pressure to approximately 180 mmHg.

The stethoscope was placed over the brachial artery in the cubital fossa. The pressure was released at a rate of approximately 2 mm per second. The pressure at which the first sounds were heard (systolic pressure) and the pressure when all sounds disappeared (diastolic pressure) was recorded (American College of Sports Medicine, 2006).

3.7.2.3 Resting heart rate

Equipment: Stopwatch

Procedure: Upon completion of the blood pressure test, the medical officer then took the resting heart rate at the wrist of each participant. He placed his index and middle fingers together on the left wrist, about 1cm on the inside of the joint, in line with the index finger. On feeling the pulse, the number of beats the medical officer felt within a one minute period was recorded (American College of Sports Medicine, 2006).

3.7.2.4 Flexibility evaluation

The following static flexibility tests, that directly measured the amount of joint rotation in degrees, were selected: ankle plantarflexion, ankle dorsiflexion and hip external rotation. They were selected based on their role as potential stress fracture risk factors (Hughes, 1985; Giladi *et al.*, 1987; Giladi *et al.*, 1991; Milgrom *et al.*, 1994).

3.7.2.4.1 Hip external rotation

Equipment: Goniometer

Procedure The participant assumed a sitting position. The goniometer was centered over the anterior part of the patella with the fixed arm positioned perpendicular to the floor and the moving arm placed over the anterior midline of the lower leg, using the crest of the tibia and point midway between the malleoli for reference. The participant sat with knees flexed 90°, with a rolled towel placed under the femur. The measurement was taken as the amount of rotation, in degrees, completed in external hip rotation with the distal end of the femur acting as the stabilizer. Participants were instructed not to rotate and laterally tilt the pelvis when executing the movement (Heyward, 2002).

3.7.2.4.2 Ankle dorsiflexion and plantarflexion

Equipment: Goniometer

Procedure: The participant assumed a sitting position. The goniometer was positioned over the lateral aspect of the lateral malleolus with the stationary arm being the midline of the fibula, using the head of the fibula as reference, and the moving arm was placed parallel to lateral aspect of the fifth metatarsal, with the tibia and fibula providing the stabilization. The participant sat on the end of the table with knees flexed and ankles positioned at 90°. The measurement was taken as the amount of rotation, in degrees, completed in dorsiflexion and in plantarflexion (Heyward, 2002).

3.7.2.5 Biomechanical parameters

3.7.2.5.1 Leg length

Equipment: Flexible steel tape measure

Procedure: The participant assumed a supine position. The distance from the superior iliac crest to the medial malleolus was measured on the left and right leg and recorded, by the medical officer, to the nearest 0,1cm (Heyward, 2002).

3.7.2.5.2 Q angle

Equipment: Goniometer

Procedure: The participant assumed a standing position. The Q - angle was measured as the acute angle (Q) formed by a line from the tibial tuberosity through the midpoint of the patella, and a line from the anterior superior iliac spine through the midpoint of the patella (Brody, 1980; Clement & Taunton, 1981). This angle represents the degree of deviation of the patellar tendon from the line of pull by the quadriceps muscles on the patella (Cowan *et al.*, 1996). The Q - angle for each knee was measured, by the same technician, in degrees and recorded.

3.7.2.5.3 Foot type

Equipment: Power chalk, black board

Procedure: The participant assumed a standing position. The participants placed their feet in white chalk and were then asked to stand, with their weight evenly distributed on both legs, onto a blackboard, leaving a visible footprint. The medical officer then categorised each foot as being flat, normal or high arched, based on his observation of the imprint formed (Table 3.4).

Table 3.4: Foot type categorisation based on footprint

Foot type		
Flat foot	Normal foot	High Arched Foot
		

3.7.2.6 Isokinetic testing

Equipment: Cybex 340 System (Cybex, Division of Lumex, Inc., 2100 Smithtown Avenue, Ronkonkoma, New York, 11779).

Method: Isokinetic testing involves the assessment of maximal muscle tension throughout a range of joint motion set at a constant angular velocity (American College of Sports Medicine, 2006). All isokinetic testing was performed at 1 Military Hospital, on a computerised isokinetic dynamometer. All testing was done as outlined in the Cybex 340: Extremity Testing and Rehabilitation System User's Manual, 1988. All study participants underwent isokinetic testing to determine upper and lower leg isokinetic strength.

3.7.2.6.1 Knee extension / flexion

The following positioning, stabilisation and set-up procedure was followed for the knee extension/ flexion test:

- Warm-up for 7 minutes on a stationary bicycle
- The dynamometer was rotated to the right side,
- The long input adapter was attached and the adjustable arm was installed,
- The participant was positioned in a seated position at a 0° tilt,
- The seat, dynamometer axis and dynamometer height was adjusted to align with the axis of rotation,
- The shin pad was positioned just above the medial malleolus and was strapped tightly to the participant's leg with a Velcro belt,
- The participant's pelvis and torso was stabilized by tightly securing the 3-point safety belt and lap belts,
- Verbal introduction on the isokinetic concept of exercise was given,
- Warm-up (3 submaximal, 3 maximal repetitions) with a 30 seconds rest,
- Maximal test at slow velocity (60 °/s), 5 repetitions,

- The patient was instructed to begin the test in full flexion with the heel touching the kick pad, and keep arms crossed over chest throughout all test bouts;
- This was then repeated on the left leg.

After the test the peak isokinetic knee extension and knee flexion torque was recorded as well as the quadriceps to hamstring ratio.

3.7.2.6.2 Ankle plantar/dorsiflexion

All participants were instructed to wear flat tennis-style shoes. The following positioning, stabilisation and set-up procedure was followed for the ankle plantar/dorsiflexion test:

- Warm-up for 7 minutes on a stationary bicycle,
- The '340 position chair method' was chosen,
- The dynamometer was rotated and positioned to the right side for the reclined 340 chair,
- The back height was adjusted to the lowest position,
- The short input adapter was attached and the plantar / dorsiflexion footplate was installed,
- The patient was instructed to lie prone with the foot flat on the footplate, with ankle neither inverted nor everted,
- The participant was instructed to slide so that the ankle was lined up with the dynamometer input shaft and to keep the knee of the test limb (right) locked in full extension throughout the movement,
- The ankle was secured with the footplate belts as well as with the 340 thigh stabilization belts,
- Verbal introduction to the isokinetic concept of exercise was given,
- Warm-up (3 submaximal, 3 maximal repetitions) with a 30 seconds rest,

- Maximal test at slow velocity (30 °/s), 5 repetitions,
- The participant was instructed to begin the test in full dorsiflexion;
- This was then repeated on the left ankle.

After the test, the peak isokinetic ankle dorsiflexion and ankle plantarflexion was recorded.

3.7.2.7 Isometric handgrip test

3.7.2.7.1 Handgrip strength test

The purpose of this test was to measure grip or forearm muscle strength. Handgrip strength is important for military training, as the hands are used for weapon handling and lifting equipment. Additionally, hand strength is often a good indicator of general body strength (Heyward, 2002).

Equipment: Handgrip dynamometer (Jamar hydraulic hand dynamometer).



Procedure: The participant first held the dynamometer in the dominant hand in line with the forearm, hanging by the thigh. Maximum grip strength was then determined without swinging the arm. The better of two trials for each hand was

recorded according to the prescribed protocol. The values listed below (in kilograms) give a guide to expected scores for adults (Heyward, 2002).

Table 3.5: Ratings for Handgrip strength test (Heyward, 2002).

Rating	Males (kg)	Females (kg)
Excellent	> 64	> 38
Very good	56-64	34-38
Above average	52-56	30-34
Average	48-52	26-30
Below average	44-48	22-26
Poor	40-44	20-22
Very poor	< 40	< 20

3.7.3 Bone density

Seventy randomly selected female participants underwent Bone Densitometry analysis at the Pretoria Heart Hospital.

Equipment: Dual-Energy X-ray Absorptiometry (DEXA) scanner (Prodigy; GE/Lunar Corporation, Madison, WI).

Procedure: The participant assumed a supine position. The DEXA was used to measure BMD (g), BMC (g) and body composition with lean mass (g) and fat mass (g). DEXA can distinguish regional as well as whole body parameters of BMD, BMC and body composition. As such, it is considered a reference standard, and the latest body composition research uses this method. BMD, BMC and body composition was determined at various body regions (total body, arms, legs and trunk), the lumbar vertebrae, and hip regions (total hip, femoral neck, trochanter and femoral shaft) (Mazess *et al.*, 1990; Heyward, 2002).

Prior to the start of the test, each participant was fully briefed on what the test would entail. The Bone Density Test is a simple, painless non-invasive procedure. The participants were also asked to wear comfortable clothing. Clothing that had zippers, underwires or metal buttons was removed prior to the test.

The participant lay on the whole-body DEXA scanner, with the X-ray sources mounted beneath the table and the detector overhead. The participant was asked to lie still whilst the DEXA scanned with photons that were generated by two low-dose X-rays at different energy levels. The body's absorption of the photons at the two levels was measured. The ratios were then used to predict BMC, BMD, total body fat and fat-free mass. Each test took 20 minutes to complete (Mazess *et al.*, 1990).

Additionally, to minimise variability (diagnostic and monitoring) measurements were made on the same DEXA instrument, namely the LUNAR DPX, at the Pretoria Heart Hospital, with the same two radiographers completing both the Pre and Post tests on their respective participants (Beshgetoor *et al.*, 2000; Phillipov *et al.*, 2001; Bemben *et al.*, 2004). A high resolution, computer-generated image of the skeleton, allowed for correction of possible position errors (Beshgetoor *et al.*, 2000).



The results for BMD were given in g/cm^2 and expressed in the form of two scores:

- **T-score** — reflects the amount of bone the participant has compared with a young adult of the same sex with peak bone mass. A score above -1 is considered normal. A score between -1 and -2.5 is classified as osteopenia, the first stage of bone loss. A score below -2.5 is defined as osteoporosis. The T-score is used to estimate the individual's risk of developing a fracture.
- **Z-score** — reflects the amount of bone the participant has compared with other people in the same age group and of the same size and sex.

Measurements were also given for body composition from the total body scan with lean mass (g) and fat mass (g). The reproducibility for total body measurements was 0.7% (Heyward, 2002).

3.7.4 Standard fitness test

The standard fitness test, consisting of five components was executed in the following sequence, as prescribed by the DOD policy on PT 2000. The 2.4km running test was executed as the first component of the battery test. Participants then had a maximum rest period of 15 minutes, but not less than 10 minutes, after the 2.4km running test. This was followed by the sit-up test, the push-up test and the shuttle run test. The last component of the battery test was the 4km walk test. A rest period of 2 minutes was given between these components. The component description and execution was as follows:

3.7.4.1 Sit-ups

Equipment: Stopwatch

Procedure: The sit-ups were executed with the knees bent at a 90° angle, the feet fixed, the hands were kept on the ears, and the elbows pointing forwards, touching the knees with every sit-up. The arms were bent and pressed against the ears throughout the exercise. This position prevented the bent arms from shooting upward and facilitating the upward movements. The exercise had to be repeated, without a rest or a break in rhythm. A pause was allowed only when the body was in the active rest position (on top). The total number of sit-ups performed in 2 minutes was recorded.

3.7.4.2 Push-ups

Equipment: Stopwatch

Procedure: The push-ups were executed from a prone position with a stretched body and bent arms (women executed the push-up with their knees on the ground). The exercise consisted of raising and lowering the body without bending it, by using the knees or the toes as a fulcrum. When the arms were

bent, the chest had to touch the partner's fist, which was placed underneath the participant's chest in line with the palms of his/her hand. A uniform rhythm had to be maintained throughout, otherwise the test was stopped. A pause was allowed only when the body was in the active rest position (on top). The total number of push-ups performed in 2 minutes was recorded.

3.7.4.3 10 x 22 m Shuttle Runs

Equipment: Stopwatch

Procedure: A distance of 22 m was run, 10 times without any breaks. The participant started behind the starting line, ran to the 22 m mark and turned around on or over the mark. When the participant reached the starting line for the first time, he had completed two laps. The time taken to complete 10 laps was timed and recorded.

3.7.4.4 2.4 km Run

Equipment: Stopwatch

Procedure: The test was conducted over a distance of 2.4 km on a flat surface. The first half of the distance (1,2 km) was run to a turning point, and the second half was run over the same route, back to the starting point. The time taken to complete the distance was timed and recorded.

3.7.4.5 4km Walk

Equipment: Stopwatch

Procedure: The test was executed on a flat, circular route of 4 km. No running or jogging was allowed. The time taken to complete the distance was recorded.

3.8 TWELVE WEEK BT PERIOD

The participants then travelled to Lohatla on Sunday, 9 July 2006, and commenced their 12-week BT.

3.8.1 BT programme

A standardised BT programme was followed (Appendix Copy Disk- A). The main aim of this Programme was to ensure a combat ready soldier at the end of the 12-week period. Activities included drill, regimental aspects, compliments and saluting, CHATSEC course, general military aspects, musketry, shooting, signal training, mine awareness, map reading, buddy aid, field craft, water orientation, parade rehearsal and PT. It is difficult to quantify the BT programme, however, since the same standardised programme was followed by all the study participants, it acted as its own control. Additionally, the same BT programme was followed by the previous year, except for a different PT programme.

3.8.2 Menstrual history questionnaire

In the fifth week of BT all 83 female participants were requested to complete a questionnaire which provided detailed insight into their menstrual history, prior to BT, as well as into changes which may have occurred during the initial part of BT. This questionnaire was repeated at the end of the 12-week period (Appendix C).

3.8 STATISTICAL ANALYSIS

The information obtained from the sample was captured onto computer and analysed by means of the Statistical Product and Service Solutions package. Data were only analysed for cases where complete information was available. Thus, the base size differs for the different types of tests done by the BT candidates. The following statistical procedures were used to analyse the data:

3.9.1 Descriptive statistics.

Descriptive statistics are primarily aimed at describing the data and were used to describe the sample, as well as to give insight into the candidate's responses to the Health and Physical Activity questionnaires. The mean, range and standard deviations were used to describe the results of all biokinetic, bone density and fitness tests. The following descriptive statistics were used: frequencies, mean, range and standard deviations. A brief definition of the latter three follows:

3.9.1.1 Mean

Mean is generally what is meant by the word 'average'. The mean is the total of the scores divided by the number of scores (Howell, 1992). Certain disadvantages are associated with the mean: *"It is influenced by extreme scores, its value may not actually exist in the data, and its interpretation, in terms of the underlying variable being measured, requires at least some faith in the interval properties of the data"* (Howell, 1992: 33).

3.9.1.2 Range

The range is a measure of distance – the distance from the lowest to the highest score. It has the undesired property of being dependent on the sample size because the more values that you have, the farther apart the largest and the smallest of those values are likely to be (Howell, 1992).

3.9.1.3 Standard deviation

The standard deviation is the positive square root of the variance, which can be defined as the sums of squared differences between scores and their means (Tabachnick & Fidell, 1996). The more variability there is in a group of responses, the higher the value of the variance and subsequently the standard

deviation, the more homogeneous the group responses, are the lower the value (Kranzler & Moursund, 1995).

3.9.2 Inferential statistics

Inferential statistics can be defined as follows: “*Test hypotheses about differences in populations on the basis of measurements made on samples of participants*” (Tabachnick & Fidell, 1996 : 9).

3.9.2.1 Chi-square analysis

Chi-square analysis was used to determine whether statistically significant relationships existed between the group membership (experimental vs. control), and the pass or fail rates of the groups on all fitness tests. Chi-square tests are used when there are two nominal variables and determination of whether these variables are independent of one another is needed. The data are cast in what is commonly referred to as a contingency table (Howell, 1992).

This technique gives an indication of whether there is a statistically significant relationship between two variables. The coefficient does not, however, give an indication of the strength or direction of the relationship.

3.9.2.2 T-tests for Dependant samples

This test is used when there are two matched samples, often called repeated measures, where the same participant responds on two occasions, and a test on the difference between their two means is performed (Howell, 1992).

This test was used to determine whether statistically significant differences existed between the Pre- and Post-test measurements of the EG on biokinetic and bone density data. This analysis was repeated for males and females.

3.9.2.3 T-tests for Independent samples

The results of fitness tests were analysed by means of this procedure, in order to test for statistically significant differences between the EG and CG on all measurements taken. The T-test assesses the statistical significance of the difference between two independent sample means (Hair *et al.*, 1998). Statistical significance will be reported at the 5% level of significance.

3.9.2.4 Friedman's rank test for *k* correlated samples

This test is the distribution free analogue of the one-way, repeated measures analysis of variance. *"It is a test on the null hypothesis that the scores of each treatment were drawn from identical populations, and it is especially sensitive to population differences in central tendency"* (Howell, 1992: 624). This test was used to determine whether statistically significant differences existed between measurements obtained during the Pre-test and two consecutive Post-tests during the fitness tests.

The methodology used and procedures followed were outlined in this chapter. The cohort comprised of 183 South African BT trainees where prospectively followed over a 12-week BT period and tested at the beginning and end of the 12 weeks. A mid-course fitness evaluation was also included in the results and only 68 female participants underwent DEXA testing due to financial constraints. The following chapter provides the results measured and attempts to explain and discuss these results.