CHAPTER 4

RESULTS AND DISCUSSION

The primary goal of this study, set before the study commenced, was to determine the incidence of stress fractures, during 12 weeks of BT. This was done by analysing and monitoring the changes in the military recruits' intrinsic risk factors, if any, from when they reported, to when they completed their training. The study aimed to achieve this goal through the following objectives:

4.1 PRIMARY OBJECTIVES

The objectives of this investigation are:

- To determine the incidence of stress fractures during 12 weeks of BT;
- To compare the results of risk indicators obtained from the group of participants who suffered stress fractures during their 12 weeks of BT, with the rest of the original group (controls) who didn't suffer from any stress fractures.

4.2 SECONDARY OBJECTIVE

- To determine whether 12 weeks of BT results in any changes in physical markers, whilst following a progressive, scientifically designed PT programme.

Due to the uniqueness of both military recruits and military training, generalisation of this investigation's findings to other population groups, should only be done with the utmost caution. The results are based on data collected. The sample sizes changed according to the number of participants who were tested with a particular test. All analyses are based on participants where all the data was available.

The Bone Density measurements were only taken for 70 randomly selected female participants from the cohort therefore the results of these variables reflects this sample. For the physical fitness results and discussion, the cohort is referred to as the EG and their results were compared to the CG. The CG consisted of 198 participants, who had undergone BT in the SAMHS, in Lohatla, in the year prior to the cohort's BT. Analysis for this group (CG) also only included the number of cases with complete data.

All results that showed statistically significant tendencies were significant at the 95% level of confidance, unless otherwise specified. One must remember that all statistically significant differences necessarily imply clinical differences in results.

4.3 STRESS FRACTURES INCIDENCE DURING BT

All participants were followed, for the occurrence of stress fractures, from the first day of BT until the last day of training or separation from BT. Upon the completion of the training or separation, the participant's medical records were reviewed in order to collect information on the number of visits to the sickbay, injury occurrence, site, onset, diagnosis, treatment and the number of light duty days given (if any).

The diagnosis of stress fractures was based on criteria used on the clinical presentation of localised pain of gradual and harmful onset, without prior acute trauma, aggravated by repetitive weight-bearing activities and relieved with rest; and then followed by a radiograph and/or Bone Scan, at a site consistent with the clinical presentation, which confirmed the presence of a stress fracture (Bennell & Brukner, 1997; Rauh *et al.,* 2006). This was diagnosed by the medical officer of the sickbay and recorded in the recruit's medical record.

Upon reviewing the medical records it was found that after following the cohort prospectively for the duration of 12 weeks of BT, not one recruit was diagnosed with a stress fracture (although a total of 719 visits to the sickbay were recorded over this period). Furthermore, the researcher reviewed the medical records of all participants for a six month period after the completion of BT, to ensure that the delayed confirmation of stress fracture diagnosis was controlled for (Jones *et al.,* 2002). This review also found no incidence of stress fractures.

This is in contrast to several other studies that specifically looked at the stress fracture incidence during a recruits' initial-entry, which starts with BT. Researchers showed that the stress fracture incidence reported was sex specific, with the incidence rate, during BT, ranging from 0.9% to 5.2% in males, and 3.4% to 21.0% in females (Reinker & Ozbourne, 1979; Kowal, 1980; Brudvig *et al.,* 1983; Jones *et al.,* 1993a; Jones *et al.,* 1999).

Possible reasons for this lack of stress fracture occurrence include, insufficient cohort size, lack of risk factors within the cohort and the new, gradually progressive, scientifically designed PT Programme used during BT.

4.3.1 Cohort size

Although a prospective cohort is the preferred design as it permits the ongoing collection of predetermined data sets over a specific period of time, it has the risk of no incidences occurring in the specific period of time (Snyder *et al.,* 2006). The study started with 185 participants, 100 male and 85 female. After the 12 weeks of BT, 2 female participants dropped out of the study, having resigned from the South African National Defence Force. In 2 local studies, Gordon *et al.* (1986c) reported a stress fracture incidence of 4.12% amongst the 947 recruits studied whilst Jordaan and Swellnus (1994) reported a 1.2% incidence rate amongst 1151 recruits during the nine weeks of BT in 1989. A case series study done on 250 female cohort of Infantry BT participants, in the South African context, found 19 stress fractures had developed in the 12-week period (Wood & Krüger, 2007).

The method used in the diagnosis of a stress fracture plays a vital role in the final incidence rate of the various studies. When Bone Scans are used to classify stress fractures, the incidence rate appears to be over inflated, as opposed to a radiographic diagnosis, where a lower incidence rate is reported. This is due to its poor sensitivity (Milgrom *et al.,* 1994, Berger *et al.,* 2007). In the current study, despite the use of Bone Scans as a diagnosis tool, no incidences of stress fractures were reported. The different sensitivity and specificity of Bone Scans and radiographs, in detecting stress fractures, is relevant to both clinicians as well as to researchers. In addition, the delayed confirmation of stress fracture diagnoses by radiographs, must be factored into both clinical and research protocols (Jones *et al.,* 2002). Regardless of the diagnosis method used, it is clear that stress fractures are a common problem within the military environment (Lappe *et al.,* 2001; Jones *et al.,* 2002; Rosental *et al.,* 2003; Välimäki *et al.,* 2005; Rauh *et al.,* 2006; Shaffer *et al.,* 2006).

4.3.2 Risk

To begin with, the cohort used may not have possessed the intrinsic risk factors as highlighted in the literature, or may not have been exposed to the extrinsic risk factors identified in previous studies, thus reducing the risk for developing stress fractures (Brukner *et al.,* 1999; Jones *et al.,* 2002; Rosental *et al.,* 2003; Välimäki *et al.,* 2005; Rauh *et al.,* 2006; Shaffer *et al.,* 2006). This will be investigated in detail under 4.4 and 4.5.

4.3.3 Scientifically designed progressive PT Programme

The gradually progressive, scientifically designed PT Programme used during BT (Appendix: Copy Disk- B), may have contributed to no stress fractures being developed. As all training exercises involve the maintenance of a balance between the risk of fracture, inherent in exposure to loading, and the beneficial effect that loading has (stimulating bone cells to produce a more robust architecture)(Brukner *et al.,* 1999; Ducher *et al.,* 2006), the PT Programme designed was, possibly, a safer exercise regime for the BT population.

4.4 RISK FACTORS RESULTS

4.4.1 Intrinsic risk factors

Intrinsic risk factors are characteristics of the individual sport or exercise participant. This includes demographic characteristics, anatomic factors, bone characteristics, physical fitness and health risk behaviors (Jones *et al.,* 2002).

4.4.1.1 Demographic characteristics

Demographic characteristics that have been reported in the literature include age, sex and race (Proztman & Griffis, 1977; Reinker & Ozbourne, 1979; Kowal, 1980; Brudvig *et al.,* 1983; Lloyd *et al.,* 1986; Barrow & Saha, 1988; Gardner *et al.*, 1988; Zahger *et al.,* 1988; Brunet *et al.,* 1990; Myburgh *et al.,* 1990; Friedl *et al.,* 1992; Jones *et al.,* 1993b; Goldberg & Pecora, 1994; Bennell *et al.,* 1996; Bijur *et al.,* 1997; MacLeod *et al.,* 1999; Shaffer *et al.,* 1999b; Beck *et al.,* 2000; Bell *et al.,* 2000; Kelly *et al.;* 2000; Lappe *et al.*, 2001; Jones *et al.,* 2002; Shaffer *et al.,* 2006).

4.4.1.1.1 Chronological Age

The ages of the cohort used in this study ranged from 18 to 22 years (see Table 4.1), with 74.3% of the participants, falling in the category between 19 and 21 years of age.

Table 4.1: Chronological age of the participants in years

		Frequency	Percent	Valid Percent	Cumulative Percent
Age	18	17	9.2	9.2	9.8
	19	40	21.9	21.9	31.1
	20	57	31.1	31.1	62.3
	21	39	21.3	21.3	83.6
	22	30	16.4	16.4	100.0
	Total	183	100.0	100.0	

Studies in military recruits have had conflicting results as to whether recruits in their late twenties and early thirties are at an increased risk for stress fractures compared to their younger counterparts (Brudvig *et al.,* 1983; Gardner *et al.*, 1988; Milgrom *et al.*, 1994). The military studies reviewed indicated that older age, specifically men over the age of 21 years, may heighten the risk of stress fractures (Brudvig *et al.,* 1983; Gardner *et al.,* 1988; Milgrom *et al.*, 1994).

Based on the above, it appears that the age of this cohort was not a factor that would have placed them at an increased risk for the development of stress fractures.

4.4.1.1.2 Sex

The cohort studied, consisted of 54.6% male participants and 45.4% female participants as indicated in Table 4.2.

Table 4.2: Sex of the participants

		Frequency	Percent	Valid Percent	Cumulative Percent
Sex	Male	100	54.6	54.6	54.6
	Female	83	45.4	45.4	100.0
	Total	183	100.0	100.0	

Amongst demographic factors, female sex is the most commonly identified intrinsic risk factor for stress fractures (Proztman & Griffis, 1977; Reinker & Ozbourne, 1979; Kowal, 1980; Brudvig *et al.,* 1983; Lloyd *et al.*, 1986; Barrow & Saha, 1988; Zahger *et al.*, 1988; Brunet *et al.*, 1990; Myburgh *et al.*, 1990; Friedl *et al.*, 1992; Jones *et al.,* 1993a; Goldberg & Pecora, 1994; Bennell *et al.*, 1996; Bijur *et al.*, 1997; MacLeod *et al.*, 1999; Beck *et al.,* 2000; Bell *et al.,* 2000; Jones *et al.*, 2002; Shaffer *et al.*, 2006).

Contrary to studies that have shown that women, performing the same, prescribed physical activities as men during BT, incur stress fractures at incidences 2–10 times higher than those for men (Proztman & Griffis, 1977; Reinker & Ozbourne, 1979; Kowal, 1980; Brudvig *et al.,* 1983; Jones *et al.*, 1993a; Bijur *et al.*, 1997; MacLeod *et al.*, 1999; Armstrong *et al.*, 2004), this cohort did not experience any stress fractures, even though 45.4% of the cohort were females who trained with their male counterparts.

This study possibly reinforces the findings by Bell *et al.*(2000) who reported that although the crude injury rates indicated that women were at a higher risk of injury than men, when the injury rates were adjusted for fitness, no significant sex difference existed. Thus, much of the sex related injury relationship appears to be explained by physical fitness, in particular, aerobic fitness, as opposed to the sex *per se*. There appears to be no significant difference between the fitness levels of the female and male counterparts (see section 4.4.1.4).

Additionally, other studies examining risk factors have suggested that this higher incidence of stress fractures in young women may be secondary to decreased BMD associated with eating disorders and irregular menses (Black, 1982; Myburgh *et al.;* 1990; Milgrom *et al.,* 1991). The female participants of this cohort who had BMD tested, showed that their BMD was within the limits as prescribed by the World Health Organisation (WHO) (1994). It therefore appears that this cohort sex did not place this cohort at risk for stress fractures.

4.4.1.1.3 Race

Several military studies have examined race as a potential risk factor for stress fractures (Brudvig *et al.,* 1983; Barrow & Saha, 1988; Gardner *et al.,* 1988; Jones *et al.,* 1989; Friedl *et al.*, 1992; Milgrom *et al.,* 1994; Shaffer *et al.*, 1999b; Kelly *et al.,* 2000; Lappe *et al.,* 2001; Shaffer *et al.*, 2006). This cohort was predominantly African (93.5%) as shown in Table 4.3.

Table 4.3: Race of the participants

		Male	**Female**	**Total**	**Cumulative %**
Race	African	94	77	171	93,5%
	Mixed	1	4	5	2.7%
	Indian	1	1	2	1.1%
	Caucasian	4	1	5	2.7%
	Total	100	83	183	100

These military studies suggest that the risk for stress fractures is greater for both male and female Caucasians than for other racial groups, including Afro-Americans, Hispanics and Ethiopians (Brukner *et al.,* 1999). Although the latter are officially classified as Caucasian. The literature strongly suggests that Africans and Hispanics are less likely to develop stress fractures and it has been surmised that higher bone density, larger bones as well as different biomechanical features, such as foot type and lower limb alignment, or anthropometrical features, such as the amount of lean body mass may have a protective effect (Giladi *et al.,* 1991; Bennell & Brukner, 1999; Kelly *et al.,* 2000; Shaffer *et al.,* 2006).

The current study cannot support findings on higher or lower stress fracture incidence regarding race as there were no stress fractures reported. However, with this cohort being 93.5% African, the above-mentioned studies possibly explain why no stress fractures developed and the racial composition of the cohort providing protection against stress fracture development.

4.4.1.2 Anatomical factors

This study evaluated three biomechanical parameters: foot morphology, the Q angle and leg length. These biomechanical factors are surmised to alter the biomechanics of a movement and in this way, create stress-concentration areas in bone or promote muscle fatigue, possibly predisposing the individual to the development of a stress fracture (Hall, 2003). The complete descriptive analysis is presented in Appendix Copy Disk- D as complete statistical output.

4.4.1.2.1 Foot morphology

The medical officer categorised each foot as being flat, normal or high arched based on his observation of the imprint formed. The results in Table 4.4 and 4.5 indicate that the male participants, mostly, had neutral left and right foot types (75%). This tendency was echoed in the female participants where 77.1% had neutral left and right foot types.

Studies have shown that the risk for stress fractures is greater for military recruits who have a high foot arch than for those with a low foot arch (Giladi *et al.,* 1985; Simkin *et al.,* 1989; Brosh & Arcan, 1994; Kaufmann *et al.,* 1999).

Table 4.4: Classification of foot type (left)

Sex			Frequency	%	Valid %	Cumulative %
Male	Valid	Flat	22	22.0	22.0	22.0
		Neutral	75	75.0	75.0	97.0
		High	3	3.0	3.0	100.0
		Total	100	100.0	100.0	
Female	Valid	Flat	18	21.7	21.7	21.7
		Neutral	64	77.1	77.1	98.8
		High	1	1.2	1.2	100.0
		Total	83	100.0	100.0	

Table 4.5: Classification of foot type (right)

Sex			Frequency	%	Valid %	Cumulative %
Male	Valid	Flat	20	20.0	20.0	20.0
		Neutral	75	75.0	75.0	95.0
		High	5	5.0	5.0	100.0
		Total	100	100.0	100.0	
Female	Valid	Flat	18	21.7	21.7	21.7
		Neutral	64	77.1	77.1	98.8
		High	1	1.2	1.2	100.0
		Total	83	100.0	100.0	

The current study found that only 4% of male recruits and 1.2% of female recruits had high-arched feet. With the majority having neutral to flat feet. This is in line with the cohort been 93.5% African as this racial group typically have neutral to flat feet compared to other racial counterparts (Wunderlich & Cavanagh, 2001). it can be concluded that foot morphology was not a risk factor for this cohort due to the high incidence of a neutral foot.

4.4.1.2.2 Quadriceps angle (Q angle) and leg-length

The mean range for both the male and female Q angle was 9.76° to 11.9°. Additionally, no statistically significant differences were found in the male and female participants' Q angle of both the right and left leg between Pre and Post test measurements (see Figure 4.1). A relationship has been found to exist between the Q angle, a measure of knee alignment, and the incidence of stress fractures. Cowan *et al.* (1996) showed a cumulative incidence of stress fractures 4.3 times higher in recruits whose Q angle was greater than 15° compared to that of male recruits with Q angles of 10° or less. It therefore appears that if the Q angle is a risk factor for stress fracture development it has to be greater than 15°. This cohort was thus not at risk as their mean Q angles were not greater than 15°.

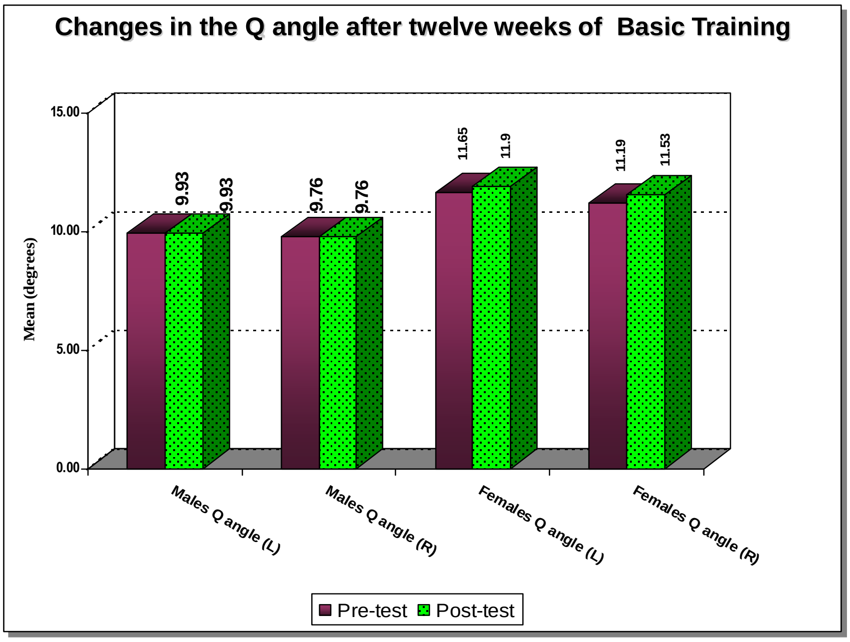

Figure 4.1: Changes in the Q angle after 12 weeks of BT.

The mean leg-length of the participants in the current study is shown in Figure 4.2.

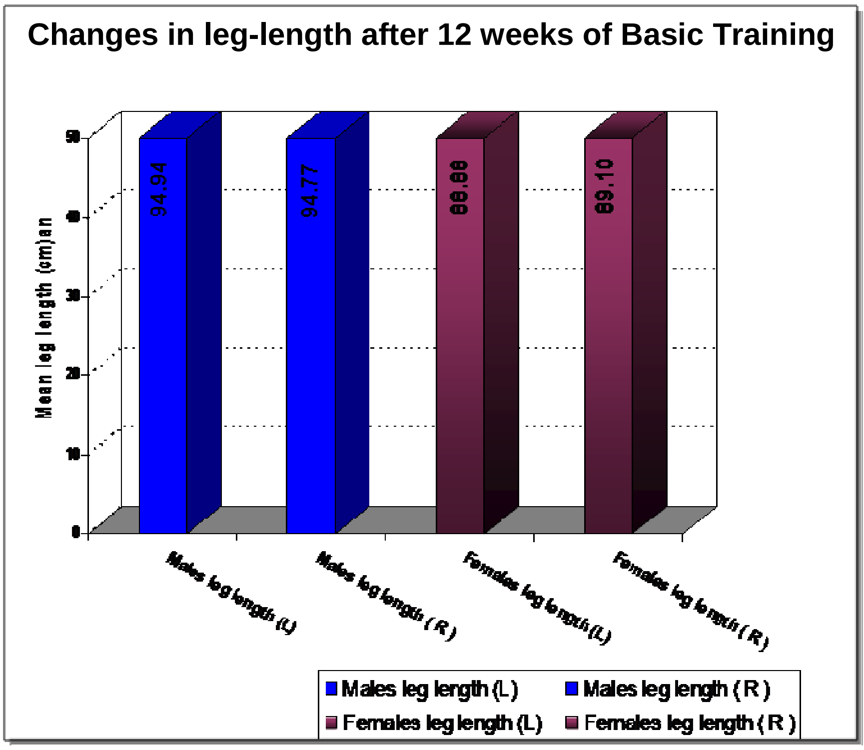

Figure 4.2: Changes in leg-length after 12 weeks of BT

A leg-length discrepancy has theoretically, been postulated as being a potential risk factor for stress fractures because of the resulting skeletal realignment and asymmetries in loading, body tortion and muscle contraction (Ammann & Rizzoli, 2003).The majority of studies assessing the association between differences in right and left leg-length and the risk of stress fractures do suggest an association with a leg-length difference of more than 0.5 cm (Friberg, 1982; Brunet *et al.,* 1990; Bennell *et al.,* 1996).

The current study found that although only 24% of males and 12.04% of the females had a leg-length discrepancy of less than 0.5 cm, there were no incidences of stress fractures reported. The incidence of leg-length discrepancy is reported in percentage of occurrence in Table 4.6. The findings in this study concur with those reported by Cowan *et al.* (1996) who found no difference in stress fracture incidence amongst 294 Army trainees with measured leg-length discrepancies and trainees without them.

Table 4.6: Leg-length discrepancy expressed in percentage of occurrence

Sex	Discrepancy(%) >2.00cm	Discrepancy(%) 1.01-2.00cm	Discrepancy(%) 0.5-1.00cm	Discrepancy(%) 0.00-0.49cm
Male (n=100)	3.00	20.00	53.00	24.00
Female (n= 83)	0.12	20.48	66.27	12.04

4.4.1.3 Bone characteristics

Bone strength is related to both bone density as well as bone geometry (Brukner *et al.,* 1999; Ducher *et al.,* 2006). A number of researchers have examined military and civilian bone characteristics (geometry or density) and the occurrence of stress fractures (Margulies *et al.,* 1986; Milgrom *et al.,* 1988; Milgrom *et al.,* 1989; Pouilles *et al.,* 1989; Carbon *et al.,* 1990; Giladi *et al.,* 1991; Grimston *et al.,* 1991; Beck *et al.,* 1996; Beck *et al.,* 2000; Jones *et al.,* 2002).

Due to the high cost factor and the high incidence of stress fractures amongst South African female military BT trainees, reported by Wood and Krüger (2007), only female participants underwent DEXA scans. The results therefore only reflect these results.

The current study investigated the bone density of 70 randomly selected female participants from the 83 female participants in the sample. One of the 70 participants terminated her employment before any bone density tests could be completed, thus Pre-test measurements were completed on 69 female participants. Furthermore, another member terminated her employment before the end of BT. Complete bone density data are thus available for 68 female participants.

The complete descriptive analysis is presented in Appendix Copy Disk-E as complete statistical output. Mean scores on all relevant measurements were transferred to the figures and tables in the following sections for easier interpretation.

4.4.1.3.1 Bone density

BMD measurements are used to diagnose osteoporosis, assess future fracture risks, and monitor treatment. DEXA is a planar measurement where BMC is measured (g) and then related to the scanned region area (cm^2) to provide the BMD (g/cm^2). BMD is calculated as follows (Phillips & Phillipov, 2006):

$$BMD = \frac{BMC\ (g)}{Area\ (cm^2)}$$

The measurements taken in this study were compared to the reference data for the LUNAR DPX (Lunar Corporation, 1993).

The following measurements were taken and reported:

- **Absolute BMD** (g/cm^2): was calculated by comparing the X-ray attenuation measurements for the participants, to measurements of the LUNAR DPX calibration standard. This allowed a comparison between the Pre-test and Post-test measurements to be made (Nielsen, 2000).
- **T-score**: represented the number of Standard Deviations (SD) that the absolute BMD found to be above or below the mean value for a healthy, same sex, young adult counterpart (20–35 years-when peak bone mass occurs). This score assisted in defining bone status as being normal (≥–1 and ≤+1), osteopaenia (between –1.0 and –2.5) or osteoporosis (<–2.5) as outlined according to the World Health Organisation (WHO) (1994) represented in Figure 4.3. One SD approximates to 10% of total BMD,

thus a T-score of –1 implies that BMD was about 10% less than the mean of a young, healthy, same sex counterpart (Kanis *et al.,* 2000).

- **Z-score**: this represented the number of SDs the absolute BMD found to be above or below the mean value for a healthy, age and sex matched counterpart (Kanis *et al.,* 2000), in other words, the relative BMD status with respect to an age and sex matched counterpart. This measurement assesses whether there was an underlining cause of an abnormal BMD measurement (over and above the effects of aging and sex) (Kanis *et al.,* 2000). The Z-score is not used to confirm a diagnosis of osteoporosis because a favorable BMD measurement (compared to the average BMD measurement for the patient's age group) does not mean the individual is not at risk for osteoporosis (Nielsen, 2000).

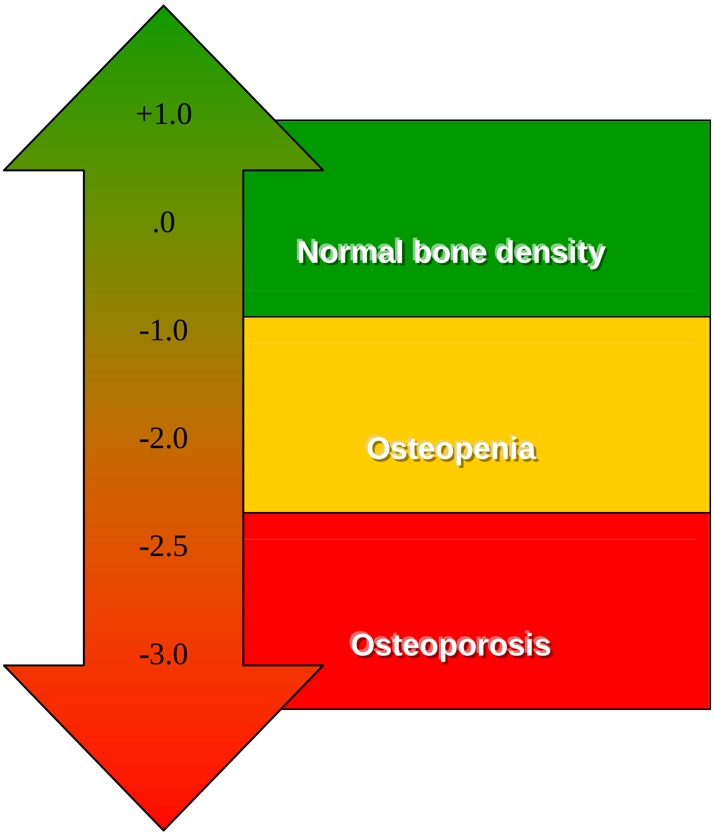

Figure 4.3: Bone density classification according to the WHO guidelines (World Health Organisation, 1994, Kanis *et al.,* 2000).

A complete bone density test was done which included assessing the BMD at the following measurement sites:

- **Total body:** value represented the mean of all the body regions combined, namely: the head, arms, legs, trunk, ribs, pelvis and spine (Bemben *et al.,* 2004).
- **Anterior-Posterior (AP) Spine**: value represented the average of vertebrae L1–L4 (Casez *et al.,* 1995; Cline *et al.,* 1998; Bemben *et al.,* 2004; Välimäki *et al.,* 2005).
- **Left femur**: These measurements include those for the neck, trochanter and Ward's triangle (Cline *et al.,* 1998; Beck *et al.,* 2000; Bemben *et al.,* 2004). The latter is defined as an area of diminished density in the trabecular pattern of the neck of the femur evident by X-ray as well as by direct inspection of the area (Stedman's Medical Dictionary, 2000).

BMD predicts future risk of fractures however; this is complicated by the effects of individuals' sex, age and previous facture history (Kanis *et al.,* 2000, Phillipov *et al.*, 2001). For each SD decrease in femur and neck BMD, the relative risk of hip and vertebral fracture increases by 2.6 and 1.8 respectively. Additionally, the relative risk of vertebral and hip fracture increases 2.3 and 1.6 times respectively for each SD decrease in spine BMD. The best estimate of fracture risk, at any particular site, is given by a BMD measurement of the site measured (Phillipov *et al.*, 2001).

In general, the risk for bone fracture doubles with every SD below normal. Thus, a person with a BMD of 1 SD below normal (T-score of -1) has twice the risk for bone fracture than a person with a normal BMD. A person with a T-score of -2 has four times the risk for bone fracture than a person with a normal BMD (Kanis *et al.,* 2000, Phillips & Phillipov, 2006).

Table 4.7 shows that for all measurement sites, at least 80% of all participants had normal bone density measurements for both the Pre-test and Post-test. It was only in the Pre-test and Post-test measurements for L2, where 79.71% and 77.61% of the participants were respectively classified as having normal bone density, while 76.12% of the participants were classified as having normal bone density L1 measurements. These findings are similar to those observed by Casez *et al.* (1995) and Välimäki *et al. (*2005).

Table 4.7: Bone status of participant T-scores according to the WHO guidelines

Measurement site	**Normal**		**Osteopaenia**		**Osteoporosis**	
	(≥–1 and ≤+1)		**(–1.01 and –2.49)**		**(<–2.5)**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
	%	**%**	**%**	**%**	**%**	**%**
T-score total body	94.20	95.52	2.90	4.48	2.90	0.00
T-score: total hip	97.10	97.01	2.90	2.99	0.00	0.00
Neck	89.86	92.54	10.14	7.46	0.00	0.00
Ward's	92.75	92.54	7.25	7.46	0.00	0.00
Trochanter	84.06	85.07	14.49	13.43	1.45	1.49
T-score: L1	81.16	76.12	17.39	19.40	1.45	4.48
T-score: L2	79.71	77.61	17.39	20.90	2.90	1.49
T-score: L3	88.41	89.55	11.59	8.96	0.00	1.49
T-score: L4	82.61	82.09	14.49	13.43	2.90	4.48
T-score: L1-L2	84.06	82.09	15.94	16.42	0.00	1.49
T-score: L1-L3	88.41	85.07	11.59	13.43	0.00	1.49

Measurement site	**Normal**		**Osteopaenia**		**Osteoporosis**	
	(≥–1 and ≤+1)		**(–1.01 and –2.49)**		**(<–2.5)**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
	%	**%**	**%**	**%**	**%**	**%**
T-score: L1-L4	86.96	86.57	13.04	11.94	0.00	1.49
T-score: L2-L3	88.41	86.57	11.59	11.94	0.00	1.49
T-score: L2-L4	86.96	85.07	10.14	11.94	2.90	2.99
T-score: L3-L4	85.51	85.07	11.59	11.94	2.90	2.99

Additionally, the cohort was 92.8% African with only 1.2% Caucasian. According to Shaffer *et al.* (2006: 111)"…*lower rates or apparent protective factors against stress fractures among black women, may be related to their higher bone density."* This is supported by work by Bennell & Brukner (1997) and Kelly *et al.* (2000).

The above studies support the findings that only two participants having a total body density T-score measurement of >-2.5. This is a very small number to classify the group as a risk for fracture development based on BMD measurements.

An increased fracture risk is not only associated with low bone density, but also with a previous history of fracture (Phillips & Phillipov, 2006). In the fifth week of BT, all 83 female participants were requested to complete a questionnaire regarding previous history of fractures. The complete, descriptive analysis is presented in Appendix Copy Disk – F (Tables 1 to 6) as complete statistical output. A small percentage (3.6%) of the female sample indicated that they had a history of osteoporosis in their family. Therefore, 96.4% of the female cohort reported no history of osteoporosis. None have been treated for low BMD.

The results in Table 4.8 indicate that 7.3% of these female participants had suffered a fracture in their past.

Table 4.8: History of fracture

		Frequency	%	Valid %	Cumulative %
Valid	Yes	6	7.2	7.3	7.3
	No	76	91.6	92.7	100.0
	Total	82	98.8	100.0	
Missing	System	1	1.2		
Total		83	100.0		

Additionally, in order 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 2 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).

Other factors affecting DEXA BMD values include significant weight change and absolute body size (Nielsen, 2000; Tothill, 2005). The BMD was thus analysed with statistically controlling for body weight (Pouilles *et al.,* 1989). Additionally, the absolute, as well as the relative measurements, were analysed for changes between Pre and Post test measurements.

According to Phillopov *et al.,* (2001) significant changes in serial BMD values are associated with changes greater than 0.055 and 0.045 g/cm^2 at the spine and hip respectively (ie 4–7% depending on the baseline BMD value) (Phillips & Phillipov, 2006).

4.4.1.3.2 Changes in BMD after 12 weeks of BT

BMD may be measured within a volume of bone (g/cm^3), termed volumetric density, or within a known area of bone (g/cm^2), termed areal density (Chinappen-Horsley *et al.,* 2007). The LUNAR DPX used in this study, measured areal density thus, when interpreting the BMD results, it is important that the site area be considered (Phillopov *et al.,* 2001, Phillips & Phillipov, 2006).

The changes in total BMD were only clinically and statistically significant at the head site, with a mean increase of 0.067g/cm^2. Increases in BMD and area at this site may be attributed to consumption of both calcium (800-1200 mg) (Välimäki *et al.,* 1994; Lappe *et al.,* 2008) and Vitamin D daily as most of their BT occurred outdoors under the African sun (Chapuy *et al.,* 1992; Dawson-Hughes *et al.,* 1997; Lappe *et al.,* 2008). However, this is speculation as these two markers where not tested for and could possibly be an area for future research.

The pelvis site total BMD measurement showed a clinically significant mean increase of 0.141g/cm^2 whilst the pelvis area, showed a significant decrease of 5.44 cm^2. Both the head and the pelvic site BMD measurement changes were larger than that prescribed by Phillopov *et al.* (2001).

A reason for the BMD change in the pelvis was not being statistically significant (p= 0.311), may be attributed to the small base size and the SD (1.12 for the pelvis measurement), which was far greater than the other sites. The increase in BMD and the simultaneous decrease in area, may be explained by the timing of the bone remodeling process. Remodelling refers to the process via which fatigue, damaged bone is replaced by new bone. Remodelling occurs in cycles, which involve breakdown of bone by osteoclasts and the laying down of new bone matrix by osteoblasts. Through a coupled process, over time, filling in of the resorped areas may be incomplete. It occurs at many simultaneous sites, throughout the body, where bone is experiencing growth, mechanical stress, micro fractures or breaks. Remodelling occurs on the surface of trabeculae bone of the pelvis (Martini *et al.,* 2001).

The total remodelling process takes about four to eight months. As the participants were subjected to intense, weight-bearing exercise and the Post-test was carried out only three months after the based-line values were measured, the participants may have been going through the reabsorption phase of the remodelling process, characterised by the osteoclasts digging out a cavity, called a resorption pit, in spongy bone, or burrowing a tunnel in compact bone, which may have affected the area (Martini *et al.,* 2001).

What is vital to understand is that the positioning of the participant for the Post-test DEXA scan needed to be identical to the Pre-test. Failure of this may have resulted in the area measured been different to the Pre-test and thus influencing both the BMD and the area measurements. Although great care was taken to replicate the testing by utilising the same radiographers and the same DEXA machine, the chance of error still exists (Phillopov *et al.,* 2001, Phillips & Phillipov, 2006). Therefore, T-scores and Z-scores are a more reliable measure as they are calculated independent of area (Phillips & Phillipov, 2006).

Additionally, the leg area also showed statistically significant increases in the mean scores measured, without a statistically significant change in BMD. This may be attributed to the intense weight-bearing exercises followed by the participants during the 12 weeks of BT - which may have stimulated modelling in the overload zone, in this case the legs, resulting in the accretion of bone (Duncan & Turner, 1995; Martini *et al.,* 2001). Exercise has been recognised as, usually, having a beneficial effect on bone density because of the mechanical loading forces on the skeleton (Snow, 1996; Stewart *et al.,* 2005). Figure 4.4 reflects the changes in the total body area measurements that occurred during BT.

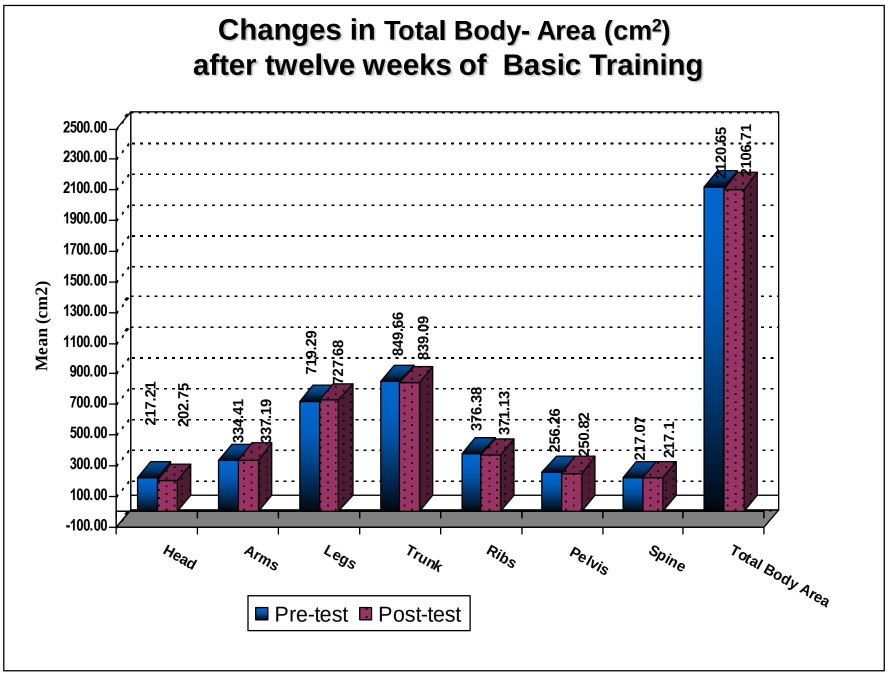

Figure 4.4: Changes in Total Body - Area (cm^2) after 12 weeks of BT in female participants

The changes in AP Spine BMD were only clinically significant at the T12 site, showing a mean increase of 0.4.46g/cm^2 and a clinical and statistical decrease in T12 site area measurement (Phillopov *et al.,*2001). Statistically significant differences were found on all but two of the AP Spine Area (cm^2) measurements. No significant differences were found at L1 and L1-L2 measurements. All the other measurements showed a statistically significant increase from Pre- to Post-test measurements as shown in Figure 4.5. These changes may also be attributed to the reasons cited above.

The changes in left femur BMD were also only clinically significant at one site, with the femur neck showing a mean increase of 0.147g/cm^2 (Phillopov *et al.,* 2001). The Ward's triangle and Trochanter areas showed statistically significant differences in area measurements of the Left Femur (see Figure 4.6).

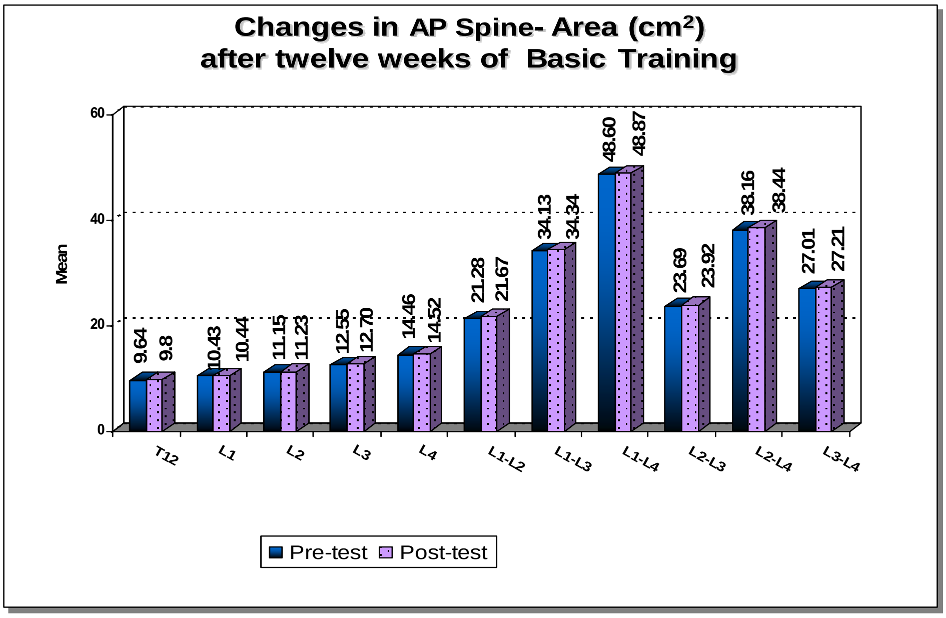

Figure 4.5: Changes in AP Spine - Area (cm^2) after 12 weeks of BT in female participants

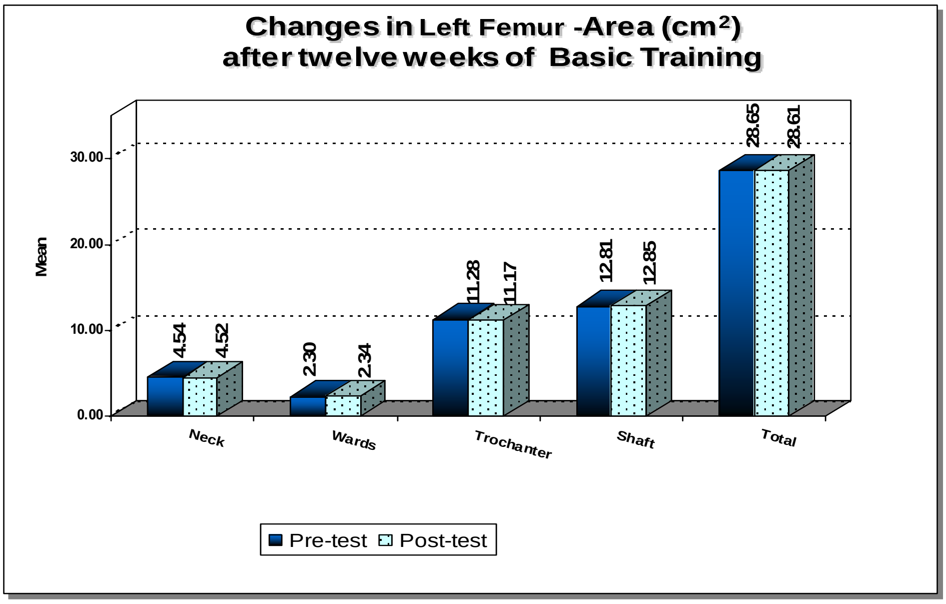

Figure 4.6: Changes in Left Femur - Area (cm^2) after 12 weeks of BT in female participants

The Ward's area measurement of the Pre-test (x=2.30) was significantly lower than the Post-test (x=2.34). The Pre-test of the Trochanter area showed a significantly higher score (x=11.28) than the Post-test (x=11.17). The same reasons sited for the increase in BMD and area for the total body and AP Spine, can be used to explain the increases observed in the femur, neck and Ward's triangle, whilst the decrease could be attributed to the timing involved in the bone remodeling process (Martini *et al.,* 2001).

4.4.1.3.3 Changes in BD T-scores and Z-scores after 12 weeks of BT

The results in Figure 4.7 indicate that no statistically significant difference was found in both the Total Body T-score and Z-score measurements as the changes were smaller than that prescribed by Phillopov *et al.* (2001).

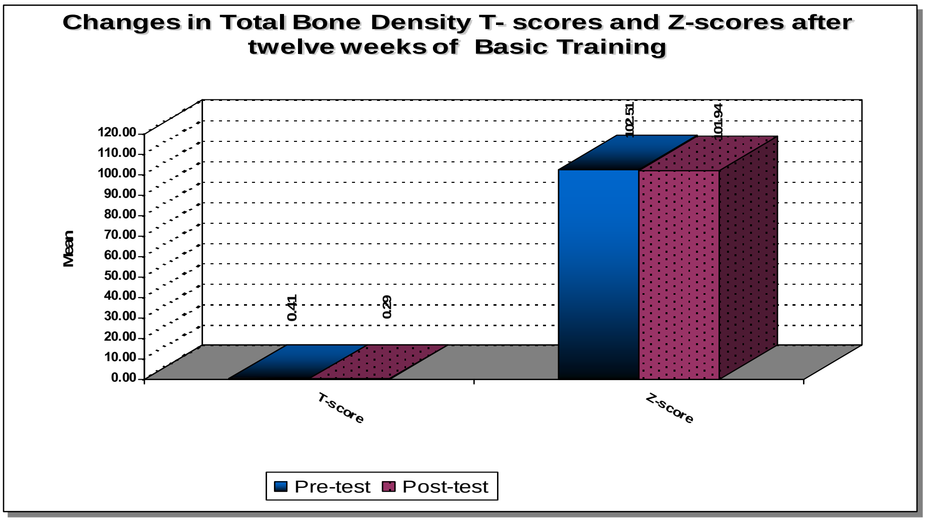

Figure 4.7: Changes in Total Bone Density T-scores and Z-scores after 12 weeks of BT in female participants

The Pre- and Post-test measurements did not change significantly. These findings echo those found by Bemben *et al.* (2004) who compared total body BMD changes in gymnasts and cross-country athletes following six months of training and competition. Only one statistically significant difference was found on the AP Spine T-scores (see Figure 4.8). A statistically significant decline in the L1 scores was observed. None of the other scores showed statistically significant changes.

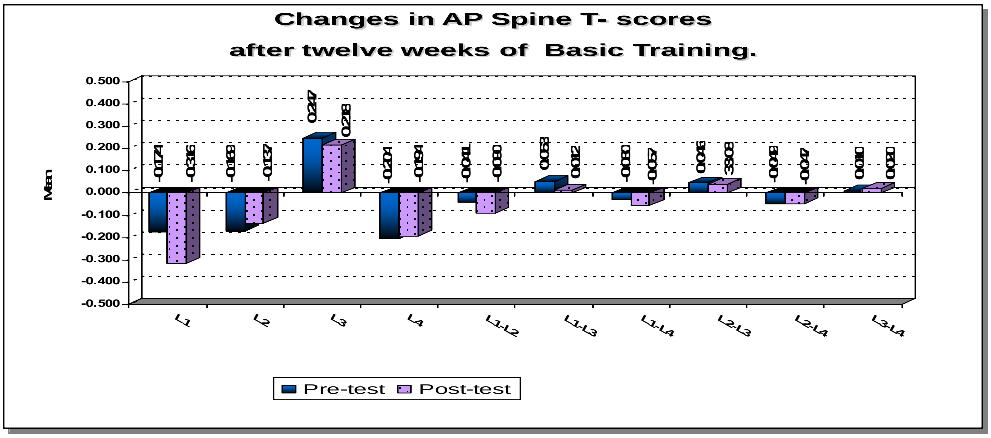

Figure 4.8: Changes in AP Spine T-scores after 12 weeks of BT in female participants

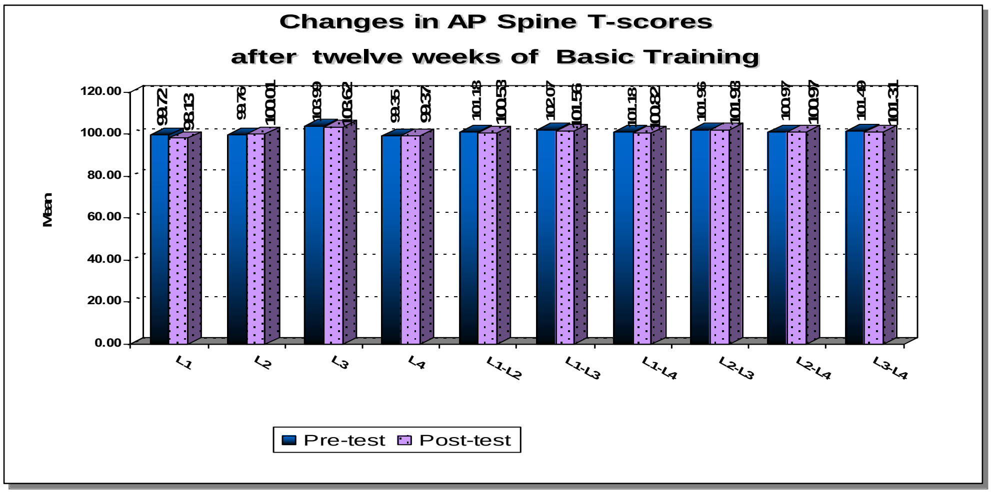

Figure 4.9: Changes in AP Spine Z - scores after 12 weeks of BT in female participants

Only one statistically significant difference was found in the AP-Spine Z-scores as shown in Figure 4.9. Once again, the significant change occurred in the L1 measurement, with Pre-test scores (x=99.72) significantly higher than Post-test scores (x=98.13).

Figure 4.10 reflects the results of the Left-Femur T-scores. Only one statistically significant difference was found at the 5% level of significance. The Left-Femur T-score showed a significant increase from Pre-test (x=0.674) to Post-test (x=0.718).

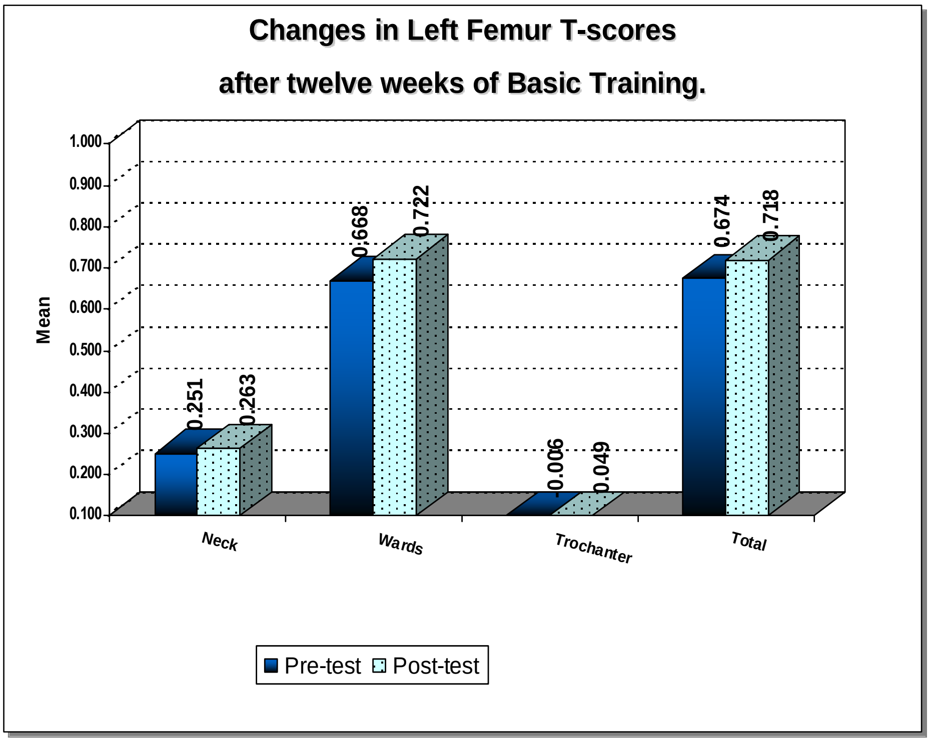

Figure 4.10: Changes in Left Femur T - scores after 12 weeks of BT in female participants.

Only one statistically significant difference was found in the Left-Femur Z-scores, namely in the total Z-score (See Figure 4.11). The Post-test score (x=109.15) was significantly higher than the Pre-test score (x=108.43) as shown in Figure 4.11. This difference was significant at the 5% level of significance.

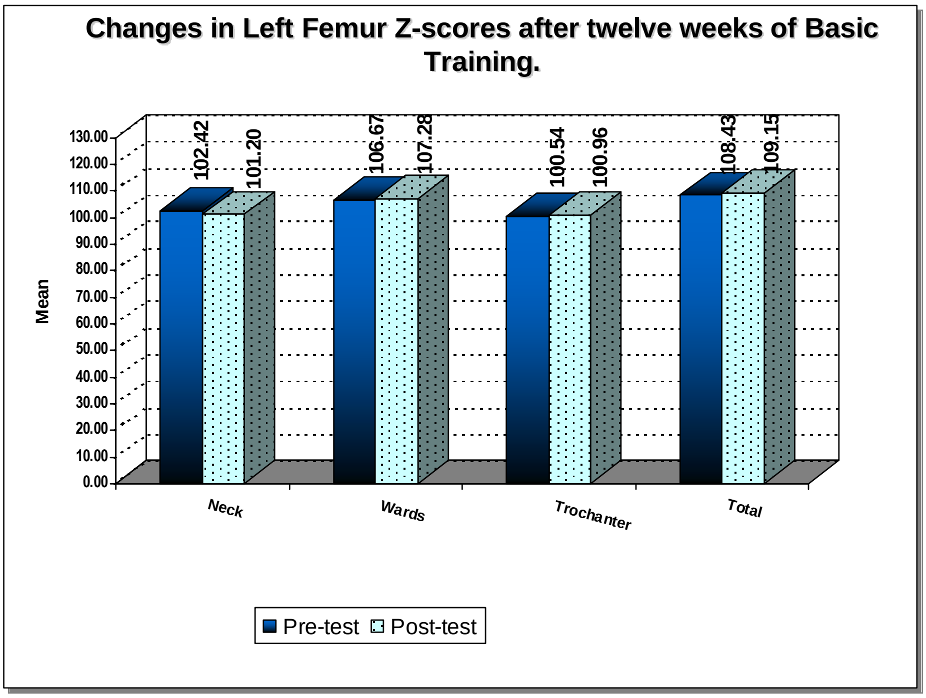

Figure 4.11: Changes in Left Femur Z - scores after 12 weeks of BT in female participants

4.4.1.3.4 Changes in BMC after 12 weeks of BT

The total BMC measurements showed a significant decrease. Figure 4.12 shows the 12 statistically significant changes, on the 5% level of significance, which occurred in the BMC measurements taken. The left arm, left trunk, left total bone, total trunk as well as the left femur's Ward's' triangle, neck and total femur mineral content mean scores showed a statistically significant decrease from Pre-test to Post-test. This supports other studies that also showed significant decreases in BMC, at some of these sites, after BT (Casez *et al.,* 1995; Armstrong *et al.,* 2004).

The head, left leg, right leg, total legs and L1's BMC mean scores showed a statistically significant increase from Pre- to Post-test. These findings support studies by Pouilles *et al.* (1989) and Marguiles *et al.* (1986). The former study reported that BMD was significantly lower amongst 41 stress fracture participants than amongst 48 recruits from the same units, matched for chronological age, height, and weight and that mean BMC increased significantly during 12 weeks of military training amongst 35 uninjured recruits (Pouilles *et al.,* 1989). Marguiles *et al.* (1986) found that mean BMC increased significantly during fourteen weeks of BT for both the 105 persons, whose training was interrupted by stress fractures and other conditions, and the 144 persons who completed training. Tibial bone width did, however, not increase.

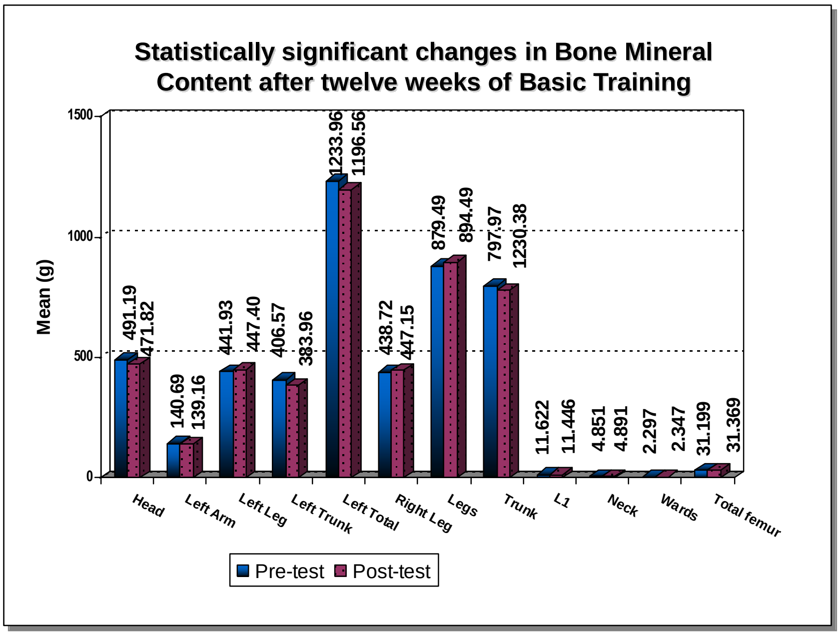

Figure 4.12: Statistically significant changes in BMC after 12 weeks of BT in female participants

The mean BMC of participants in these studies with stress fractures was lower before training than that of persons who completed the training, but not significantly so.

4.4.1.3.5 Bone geometry

This study did not measure skeletal ratios, cross-sectional bone area or cross-sectional moments of inertia, thus, no conclusions can be made regarding the risk of the female participants to stress fracture development, based on results from this study. However, what must be noted is that this is definitely an area for future research, especially as new technology emerges and one can now accurately and precisely calculate skeletal ratios from DEXA total body scan images:

> "…*the LPC method is easy to use and relatively rapid. This new phenotype will be useful for osteoporosis research for individuals or large-scale epidemiological or genetic studies*" (Chinappen-Horsley *et al.,* 2007: 113).

A bone's strength is greatly determined by its geometry and is directly proportional to the bone's cross-sectional area, when either tension or compression loads are applied to it. This implies that a larger bone is more resistant to fracture, as the internal forces are distributed over a larger surface area therefore resulting in lower stresses (Hayes & Gerhart, 1985; Ammann & Rizzoli, 2003).

The amount of load the bone can withstand before failing, is directly proportional to the cross-sectional area of the bone (Brukner *et al.,* 1999). Bones that have a larger cross-sectional area, and in which bone tissue is distributed further away from the neural axis, will be stronger when subjected to a load and will be less likely to fracture (Buckwalter *et al.,* 1995; Hall, 2003; Greene *et al.,* 2005). The strength in bending of the long bone shaft, to bending and torsional stresses should be proportional to its section modulus and inversely related to its length.

> "*In military recruits who are subjected to intense, unaccustomed physical activity, the presence of smaller and weaker bones may lead to a higher rate of bone microdamage. If there is inadequate time for adaptive cortical remodeling to occur, a stress fracture could result***"** (Brukner *et al.,* 1999:53-54).

4.4.1.4 Physical fitness

Two methodologies were utilised to assess the relationships between lack of prior physical activity and/or poor physical conditioning, with the incidence of stress fractures. The first was through the use of questionnaires where the participants reported on past and current levels of activity (Gardner *et al.*, 1988; Montgomery *et al.*, 1989; Cline *et al.,* 1998). The second method was comprised of various aerobic fitness tests which, indirectly measured the fitness component (Jones *et al.,* 1993a; Bijur *et al.,* 1997; Beck *et al.,* 2000; Bell *et al.*, 2000; Knapik *et al.*, 2001; Jones *et al.*, 2002; Rauh *et al.*, 2005; Rauh *et al.,* 2006; Shaffer *et al.*, 2006).

This study utilized both methods. All participants completed a Health and Physical Activity questionnaire, which provided a detailed history of sport participation as well as health and medical history information (Appendix B) (Lee & Nieman, 2007). Additionally, the participants' physical fitness was assessed through a standardised physical fitness test.

The physical fitness tests, used by militaries around the world, differ from country to country and between service corps; however, they are all comprised of a combination of muscle endurance and aerobic fitness tests, such as 2.4 km run, maximal amount of push-ups and sit-ups in two minutes, shuttle runs and a 4 km walk (Gordon *et al.*, 1986a; Gordon *et al.*, 1986b; Shaffer *et al.*, 1999a; Beck *et al.*, 2000; Bell *et al.*, 2000; Rosendal *et al.*, 2003; Knapik *et al.*, 2005; Dyrstad *et al.,* 2006).

Results of the standard fitness test were analysed. This was done to determine whether statistically significant differences occurred, over time for all fitness components done within the EG that was tested during this study, as well as in the CG which consisted of participants who completed their BT a year prior to the EG, at the same unit as the EG. The CG utilised the same BT programme, but did not follow the new PT Programme, as did the EG, instead, they utilised the pre-existing PT Programme.

The results were split for male and female participants, due to different norms used for the two sexes. Complete statistical results are presented in Appendix Copy Disk - G.

Questions regarding level of physical activity prior to entering the service and the frequency of the activity, have provided important clues about the effect of past activity on current risk of PT related injuries and stress fractures (Jones *et al.,* 1999). The majority of recent studies tend to suggest that physical fitness or prior physical activity, may be a predictor of stress fracture risk in individuals undergoing BT (Jones *et al.,* 1993a; Bijur *et al.,* 1997; Windfield *et al.,* 1997; Bell *et al.,* 2000; Välimäki *et al.,* 2005; Shaffer *et al.,* 2006).

4.4.1.4.1 Physical activity levels based on the Health and Physical Activity questionnaire

Participants completed a questionnaire which provided a detailed history of sport participation as well as health and medical history information (Appendix B). As shown by Table 4.9, the majority of participants (74.3%) indicated that they were active in sports. Several military studies have examined the association between previous levels of physical activity and risk of stress fracture during military training (Gardner *et al.,* 1988; Montgomery *et al.,* 1989; Jones *et al.,* 1999; Shaffer *et al.,* 1999a).

Table 4.9: Activity levels of the participants

		Frequency	%	Valid %	Cumulative %
Valid	Yes	136	74.3	74.3	74.3
	No	47	25.7	25.7	100.0
	Total	183	100.0	100.0	

The complete results of this analysis are presented in Appendix Copy Disk,- H, tables 19-22. The majority of participants (84%) indicated that they did participate in sport. The types of sports are listed in Table 4.10 and include soccer (49.3%), followed by netball (15.1%) and running (13.2%).

Table 4.10: Kind of sport the participants participated in

Sport type	Frequency	%	Valid %	Cumulative %
Soccer	75	40.8	49.3	49.3
Rugby	4	2.2	2.6	52.0
Running	20	10.9	13.2	65.1
Netball	23	12.5	15.1	80.3
Karate	6	3.3	3.9	84.2
Cricket	2	1.1	1.3	85.5
Boxing	1	.5	.7	86.2
Tennis	1	.5	.7	86.8
Basketball	3	1.6	2.0	88.8
Volleyball	5	2.7	3.3	92.1
Softball	2	1.1	1.3	93.4
Walking	1	.5	.7	94.1
Dance	1	.5	.7	94.7
Javelin	1	.5	.7	95.4
Gym	2	1.1	1.3	96.7
Hockey	2	1.1	1.3	98.0
Body building	2	1.1	1.3	99.3
Snooker	1	.5	.7	100.0
Total	152	82.6	100.0	
Missing from system	32	17.4		
Total	184	100.0		

The level of participation was mostly recorded at 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 31.8%, reporting high intensity of participation.

Some military studies have reported a relationship between self-reported, previous physical activity levels and a rate of stress fracture development during BT, while others have failed to corroborate a relationship (Gardner *et al.*, 1988; Montgomery *et al,* 1989; Winfield *et al.*, 1997; Cline *et al.,* 1998; Shaffer *et al.*, 1999a). The aim was thus to compare the self-reported, previous physical activities to the rate of stress fractures in this study's cohort, but, due to no stress fractures being reported, this was not possible.

Several prospective studies of US Army recruits and US Marine Corps recruits, have reported that a sedentary lifestyle behaviour prior to entering the military, is associated with higher risk of injury during the initial BT (Gardner *et al.,* 1988; Jones *et al.,* 1993a; Jones *et al.,* 1993b). Before the start of training, 3010 Marine recruits completed a survey on past health and health behaviours, rating their previous physical activity level in five categories from inactive to very active. The study documented a significant trend of higher cumulative incidence of radiographically confirmed stress fractures amongst those recruits with successively lower levels of previous activity (Gardner *et al.,* 1988).

Another study of Marine recruits also showed higher rates of stress fractures among those least physically activity prior to BT (Shaffer *et al.,* 1999b). Marine recruits who reported never or only occasionally sweating, experienced significantly more stress fractures, along with those with fewer months of running before entering BT. A survey of 449 Navy Special Warfare trainees (Montgomery *et al.,* 1989) and a study of Finnish Army recruits reported similar findings (Taimela *et al.,* 1990).

Conversely, a military study found no relation between the duration of training or the amount of running prior to BT, and stress fracture risk (Swissa *et al.,* 1989). The level of previous physical activity should be investigated further in a cohort, where the level of physical activity prior to the start of BT is compared in stress fracture cases versus that of the non-stress fracture cases.

4.4.1.4.2 Aerobic physical fitness

The aerobic physical fitness of this cohort was indirectly measured by the 2.4 km run and 4 km walk in the standard fitness test (DOD policy on Physical Training, DOD Instruction: SG no 00006/2000). The most consistently documented risk factor for injuries in US Army studies is low cardio-respiratory endurance, measured by running performance. Both men and women indicated trends of increasing risk of injury for groups with increasingly low running times (Jones *et al.,* 1993a; Bijur *et al.,* 1997; Shaffer *et al.*, 1999b; Beck *et al.*, 2000; Bell *et al.*, 2000; Jones *et al.*, 2002; Rosendal *et al.*, 2003; Knapik *et al.*, 2005; Rauh *et al.*, 2005; Rauh *et al.,* 2006; Shaffer *et al.,* 2006). Stress fractures were included amongst the injuries documented, however, the link between poor aerobic fitness and stress fracture development, was unclear, as the above-mentioned studies showed a clear association whilst others did not (Swissa *et al.,* 1989; Giladi *et al.,* 1991; Hoffman *et al.,* 1999; Brukner *et al.,* 1999).

Although data are conflicting, low levels of aerobic fitness, before BT, have been consistently identified as a risk factor amongst women (Jones *et al.,* 1993a; Winfield *et al.,* 1997; Bell *et al.,* 2000; Shaffer *et al.,* 2006). As the baseline fitness is a modifiable factor, this is an area in which much attention should be paid. Shaffer *et al.* (2006) suggest that objective measures such as run time, previous aerobic or high activity levels, are consistent in predicting stress fractures during military training for both male and female soldiers.

As this cohort did not suffer any stress fractures, the contribution of aerobic fitness to the development of stress fractures cannot be made. Additionally, the SANDF's standard fitness test utilizes the 2.4 km run and the 4 km walk as its test for aerobic fitness, but Army's around the world utilize different measures, making comparisons difficult. The American Physical Fitness Test (APFT) executed by the American Military utilises a 1- and 2- mile run as the test of aerobic fitness (Popovich *et al.*, 2000; Sonna *et al.,* 2001; Knapik *et al.,* 2002; Armstrong *et al.,* 2004; Knapik *et al.,* 2005; Rauh *et al.*, 2005; Knapik *et al.,* 2006; Rauh *et al.,* 2006; Smith & Petersen, 2007), whilst the Norwegian Military makes use of a 3 km run (Heir & Eide, 1997; Dyrstad *et al.,* 2006). The only armies found to use the 2.4 km run are the British and New Zealand Armies (Daniels *et al.,* 1979; Daniels *et al.,* 1982; Stacey *et al.,* 1982; Harwood *et al.,* 1999). What makes using the latter difficult for comparisons, is that BT in the British Army is six weeks in duration, whilst recruits in New Zealand follow a 10 week BT Programme, compared to the 12-week programme followed by the SANDF. Additionally, none of these studies documented the incidence of stress fractures or related them to aerobic fitness as a risk factor.

Regardless of the measurement used to assess aerobic fitness, the changes, if any, in aerobic fitness could be assessed, and the effect of the new PT programme was ascertained, by comparing the results of the EG to those of the CG.

The 2.4 km running test was executed as the first component of the battery test, whilst the last component of the battery test was the 4 km walk test. Both these tests measured the time taken to complete the specified distance and were a measure of cardiorespiratory fitness (Daniels *et al.,* 1982; Stacey *et al.,* 1982; Harwood *et al.,* 1999). The standardised fitness test was done in the first week of BT (measurement A), the mid-evaluation took place in the 5th week (measurement B) whilst the last fitness test, was done in the last week of BT (measurement C).

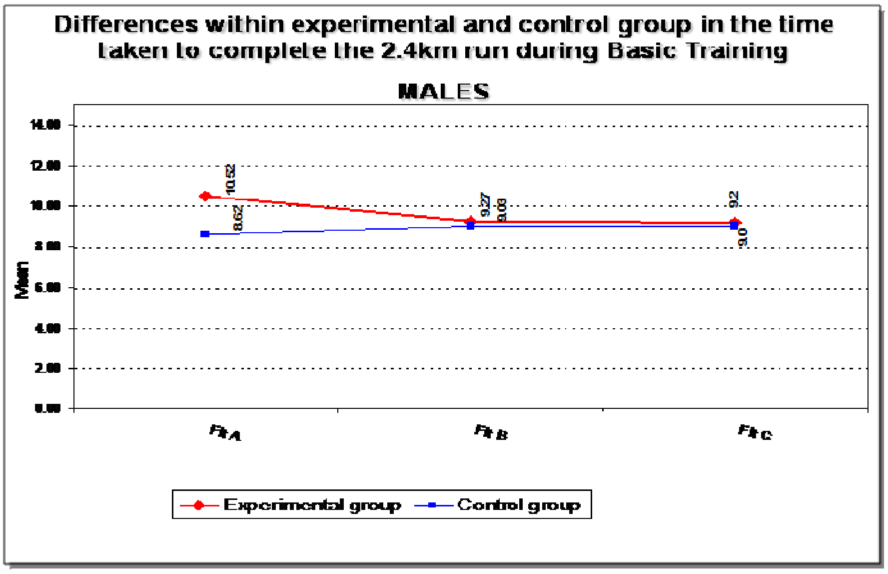

Figure 4.13: Differences (within males) in the EG and CGs in the time taken to complete the 2.4 km run

Figure 4.13 reflects the results for males on the total time taken to complete the 2.4 km run over the 3 measurements taken, i.e., measurements A, B and C. The results show that there were statistically significant differences between the Pre- and (two) Post-test measurements for the male participants in the EG and CG. The EG showed a statistically significant decline in total time taken to complete the 2.4 km run from the Pre- to the Post-tests. Even though the CG showed a significant difference in total time taken to complete the 2.4 km run, it did not show a significant decline, but rather an increase over time. The EG also had a much higher time at the first measurement (A), but at the last Post-test measurement (C), the two groups' times were similar. Thus, the male participants in the EG were not as fit as those in the CG at the start of BT. However the EG improved sufficiently to be as fit as the CG by the end of 12 weeks of BT.

The results of the total time taken by the female participants to complete the 2.4km run are reflected in Figure 4.14. There were statistically significant differences between the Pre- and (two) Post-test measurements for both the EG and CG also exhibited in the males groups. The EG showed a statistically significant decline in total time taken from the Pre- to the Post-tests.

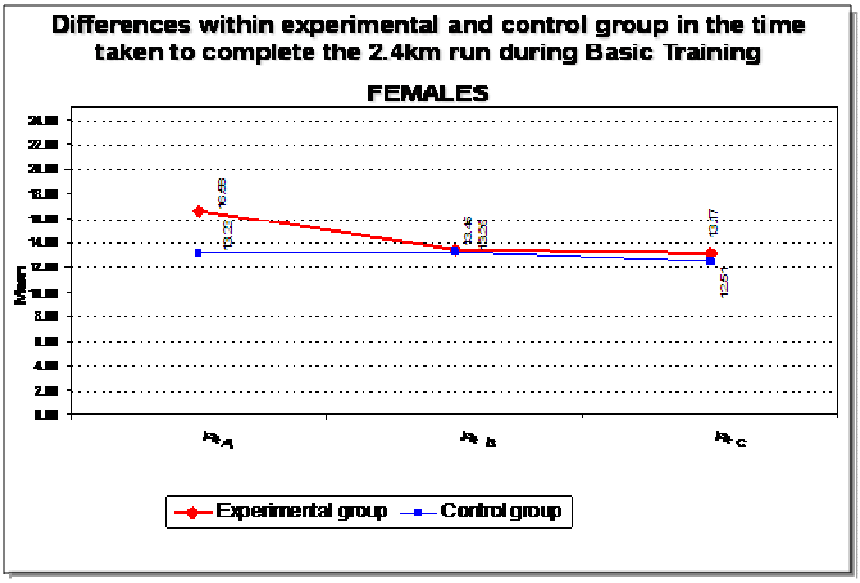

Figure 4.14: Differences (within females) in the EG and CG in the time taken to complete the 2.4 km run

Even though the CG showed a significant difference in scores, it did not show a steady decline in the total time measured, but rather, an initial increase in time in the first Post-test (B) with another decline, during the last Post-test (C). The EG also had a much higher score at the first measurement (A), but at the last Post-test measurement (C), the two groups' times on the 2.4 km run, were not significantly different. This response is then very similar to the profile of the males.

The results in Figures 4.15 and 4.16 reflect the results for the time taken to complete the 4 km walk by sex. Statistically significant differences were found in mean time scores for both the EG and CG's. In both the male and female groups, the time taken to complete the 4 km walk decreased significantly over time, reflecting an improvement in cardiovascular fitness (Heyward, 2002). The EG did, however, have the biggest decrease and thus showed a greater improvement than the CG. This supports the findings in the 2.4 km run and appears as if the PT Programme followed by this study's cohort, was a better training stimulus that yielded greater improvements in aerobic fitness, than did the PT programme followed by the CG.

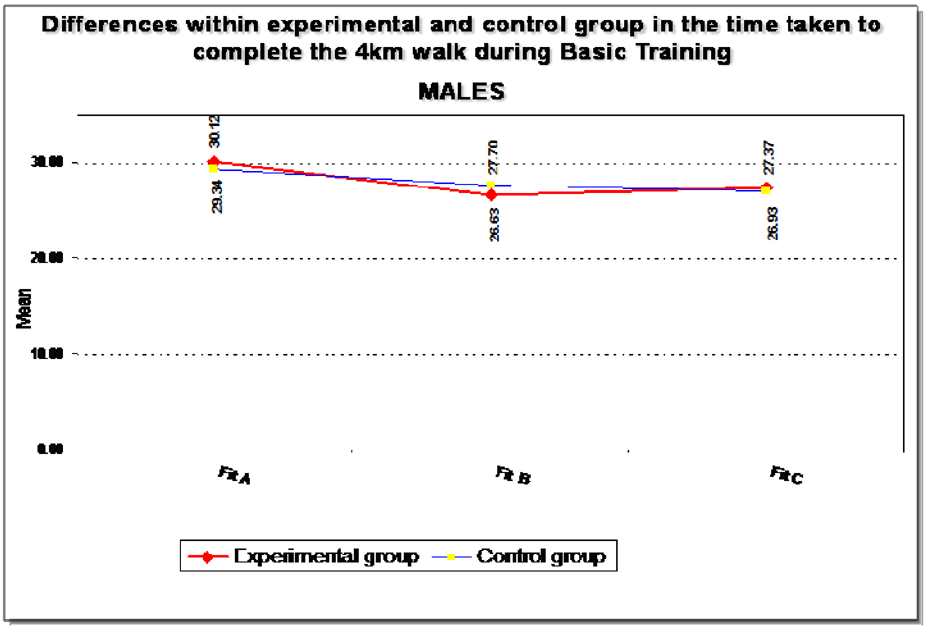

Figure 4.15 Differences (within males) in the EG and CG in the time taken to complete the 4km walk

In order to determine whether statistically significant differences existed between the EG and CG, at each of the 2.4 km run and 4 km walk, measurements at each of the testing phases (Pre-test A, Post-test B and Post-test C), t-tests for independent samples were used.

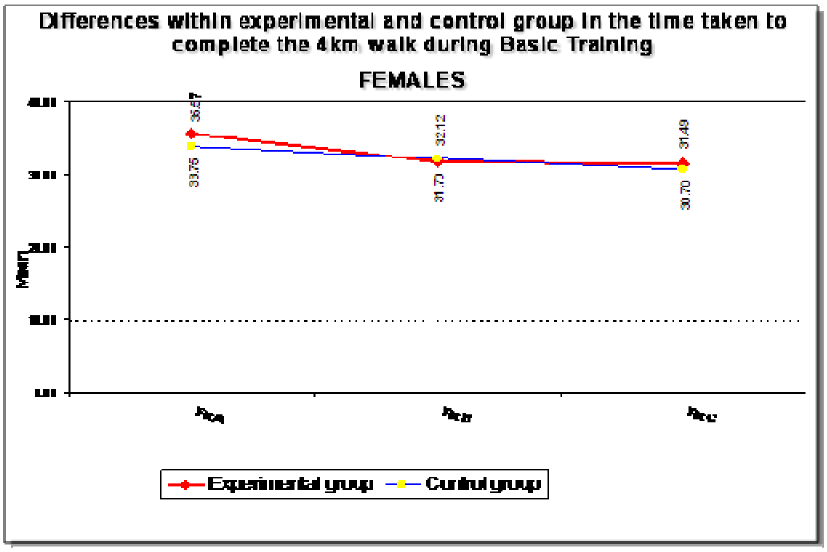

Figure 4.16: Differences (within females) in the EG and CG in the time taken to complete the 4 km walk

The results in Figure 4.17 reflect the differences between the male EG and CG for the time taken to complete the 2.4 km run and 4 km walk at the three measurement dates.

Statistically significant differences, between the mean scores of the male participants in the EG and CG, were found in the time taken to complete the 2.4 km, run during the first fitness test (measurement A). The time taken to complete the 4 km walk showed no significant difference. The EG took significantly longer to complete the 2.4 km run than the CG, thus indicating that the male participants in the CG were more fit cardiovascularly than those in the EG (Heyward, 2002).

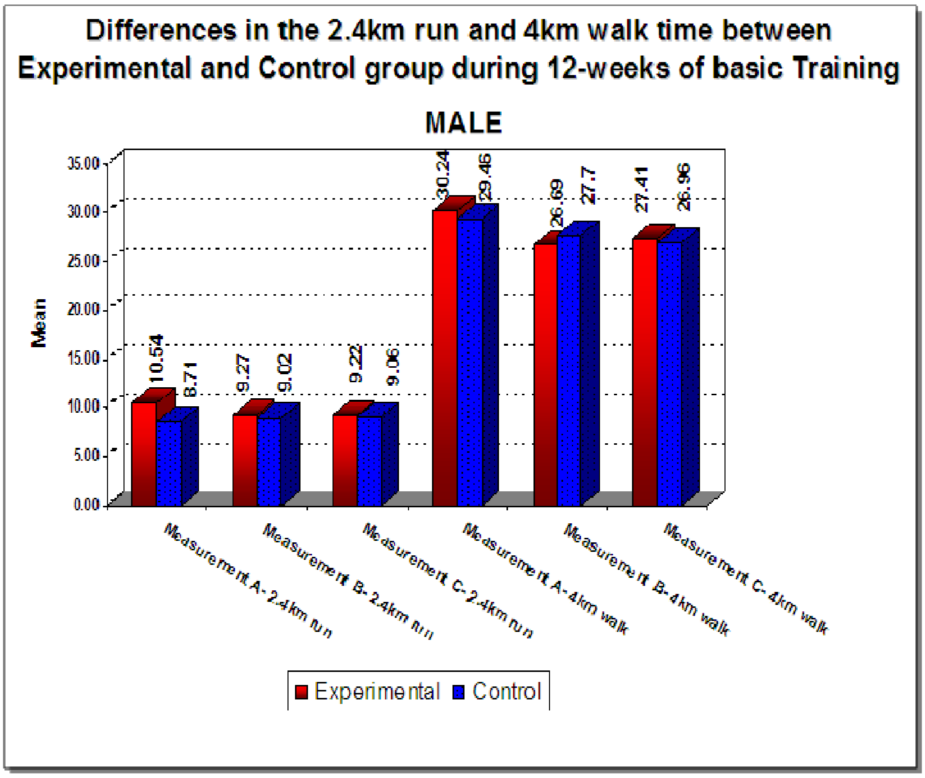

Figure 4.17: Differences in the time taken to complete the 2.4 km run and the 4 km walk between male participants of the EG and CG

During the Post-test (measurement B) the EG still had significantly higher 2.4 km run times than the CG. The differences in mean scores were, however, slightly less than during the Pre-test.

The 4km walk time of the EG was significantly better than that of the CG at the first Post-test. These results imply that the EG’s performance improved to such an extent, that they were performing better than the CG at the first Post-test.

The differences between the male EG and CG during the second Post-test (C), found no statistically significant difference in the 2.4km run time and the 4km walk time. The EG thus caught up with the CG during the first Post-test (B) and their performance, on these two tests, remained similar thereafter during Post-test (C).

This reflects a 12.5% improvement in running time for the 2.4 km test for the male participants in the EG, compared to the slight decrease shown by the CG (-0.4%) during the 12 weeks of BT. The changes in aerobic fitness were not as marked in the 4 km walk, however, the 9.4% improvement observed in the EG was still greater than the 8.5% shown in the CG. It could, therefore, be deduced that the PT Programme followed by the EG, elicited a better aerobic fitness change in the male participants, compared to the PT programme followed by the CG, as both groups followed the same BT programme. Alternatively, various studies have indicated that greater improvements in aerobic fitness would be expected of groups with lower initial aerobic fitness. As the EG had a lower initial aerobic fitness, this could explain the findings (Pollack *et al.;* 1969; Daniels *et al.,* 1979; Shvartz & Reibold, 1990; Legg & Duggan, 1996; Dyrstad *et al.,* 2006).

The results in Figure 4.18 reflect the differences between the female participants in the EG and CG for the time taken to complete the 2.4 km run and 4 km walk at the three measurement dates.

The EG took significantly longer to complete the 2.4 km run than the CG did at the Pre-test (measurement A). In measurement C, the 2.4 km run time of the EG was significantly poorer than that of the CGs. Since there was no difference in performance during the first Post-test (B), there seems to have been a slight decline in the EG’s performance during the last Post-test (C). On the 4km walk, the EG still performed poorer than the CG during the last Post-test, even though within the group itself, there was improvement on this test.

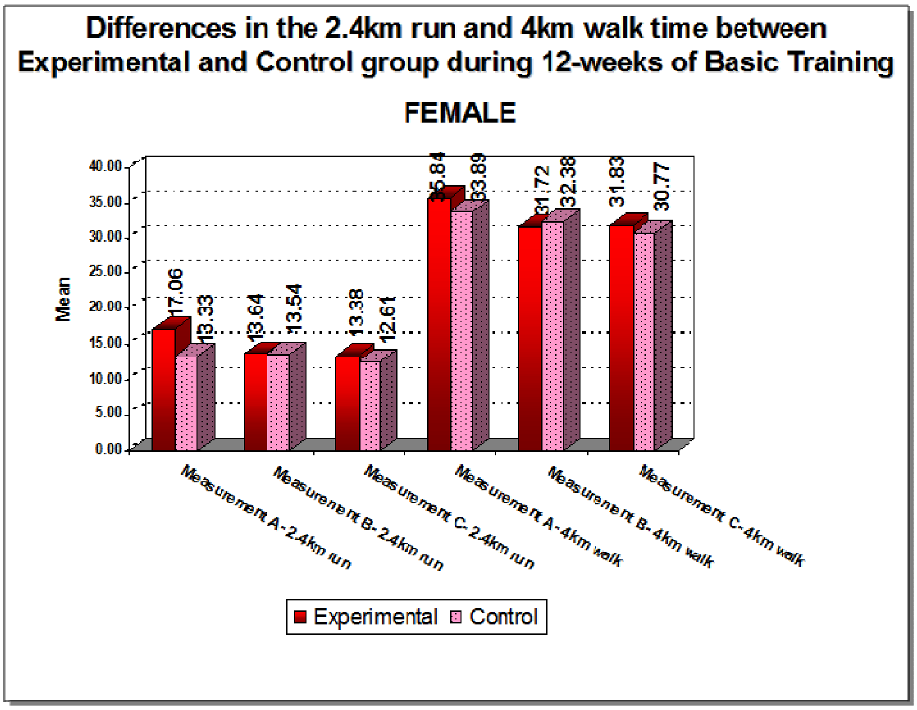

Figure 4.18: Differences between females in the EG and CG in the time taken to complete the 2.4 km run and the 4 km walk

This reflects that the female participants in the EG, although having started off with a poorer cardiovascular fitness level than that of the the CG, showed a 21.6% improvement in running time for the 2.4 km test, compared to the 5.4% improvement shown by the CG. The EG experienced a 20.0% improvement within the first five weeks of BT. The slight decline in the EG's performance, during the last Post-test, in the time taken to complete the 2.4km run, may be due to lack of motivation, as the participants were completing this test purely for research purposes and they were cognisant of the fact that their performance would not influence their results in BT. This was not the case for the CG, whose last Post-test contributed to their final mark for BT.

As with the 2.4 km run, the changes in aerobic fitness were marked in the 4 km walk, especially by the female participants in the EG, within the first five weeks of

BT. Although the EG still performed poorer than the CG did during the last Post-test on the 4 km walk, the EG showed an 11.2% improvement on this test within the group itself, compared to the 9.2% shown by the CG.

Once again, the improvements seen could be attributed to the new PT Programme, as suggested improvements were greater in the EG, because they had a lower initial aerobic fitness (Pollack *et al.;* 1969; Daniels *et al.,* 1979; Shvartz & Reibold, 1990; Legg & Duggan, 1996; Dyrstad *et al.,* 2006).

The initial fitness aerobic level of the male participants in both the EG and CG, (10.54 ± 1.06min and 8.71 ± 1.25 min, respectively) is slightly lower than that reported by Harwood *et al.* (1999) - 9.4 ± 0.94 min. Harwood *et al.* (1999) reported a 9% improvement after 13 weeks of military training compared to the 12.5% and -0.4% found in the EG and CG respectively, after 12 weeks. The female participants' initial fitness aerobic level in both the EG and CG, 17.07 ± 2.01 min and 13.33 ± 2.26 min respectively, is far lower than that reported by Harwood *et al.* (1999) - 11.8 ± 1.10 min. The female participants, in this British cohort, showed an 11% improvement after 13 weeks of military training compared to the 21.6% and 5.4% found after 12 weeks in the EG and CG respectively. Once again these changes may be attributed to the new PT Programme or/and the lower initial level of aerobic fitness (Pollack *et al.;* 1969; Daniels *et al.,* 1979; Shvartz & Reibold, 1990; Legg & Duggan, 1996; Dyrstad *et al.,* 2006).

4.4.1.4.3 Muscular strength and endurance

The participant's muscle strength and muscle endurance was indirectly measured by sit-up and push-up tests in the standard fitness test (DOD policy on Physical Training, DOD Instruction: SG no 00006/2000). Isometric strength was determined by the handgrip strength test and isokinetic strength was measured by knee extension/flexion and ankle plantar/dorsiflexion isokinetic testing (Cybex

340: Extremity Testing and Rehabilitation System User's Manual, 1988; Heyward, 2002).

The effect of muscle strength and endurance on injury rates and risks has been well documented. However, the effect of muscle strength and endurance on injury rates and stress fracture risk in military and athletic populations has not been the participant of intensive study (Jones & Knapik*,* 1999; Jones *et al.,* 2002).

Lower muscle strength and endurance have been documented as likely contributors to stress fractures in military recruits (Giladi *et al.,* 1991; Grimston *et al.,* 1991; Almeida *et al.,* 1997; Burr, 1997; Beck *et al.,* 2000; Jones *et al.,* 2002; Armstrong *et al.,* 2004). Muscle fatigue, with the resulting increased bone strain, may contribute to stress fracture injury after daily strenuous exercise (Beck *et al.,* 2000; Jones *et al.,* 2002; Armstrong *et al.,* 2004).

Sit-up and push-up test

As this cohort did not suffer any stress fractures, the contribution of muscle strength and endurance to the development of stress fractures cannot be fully assessed. However, the effect of the new PT Programme can be assessed by comparing the results of the EG to those of the CG.

Figure 4.19 reflects the amount of push-ups that males completed in the allocated 2 minutes. The initial amounts performed by the EG (31.45 ± 8.87 push-ups) and the CG (39.16 ± 12.81 push-ups) are in line with findings reported by Bell *et al.* (2000) - who performed a mean 32.4 ± 12.4 push-ups, Popovich *et al.* (2000) - who completed 36.9 ± 13.6 push-ups and Jones *et al.* (1993a) who performed 31.0 ± 9.3 push-ups. Popovich *et al.* (2000) reportedly had a 3.1% stress fracture rate in a cohort of 1357 male participants, whilst Jones *et al.* (1993a) had a 2.4% stress fracture incidence in their 124 strong cohort. This study suggests that muscle strength and endurance, as measured by push-ups, is not a risk factor for the development of stress fractures in male participants, however this would have to be investigated further in a study where stress fracture incidences are reported

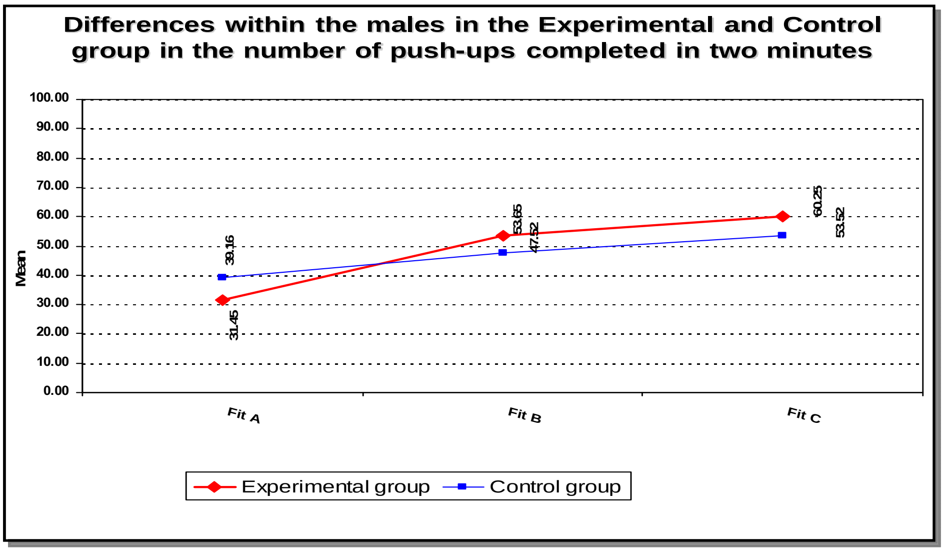

Figure 4.19: Differences (within males) in the EG and CG in the number of push-ups completed in two minutes

The results reflect that both the groups showed statistically significant increases in the amount of push-ups they could do over time. The EG had a lower score than the CG at the Pre-test measurement, but the EG (60.06 ± 11.07 push-ups) could do more push-ups than the CG (53.56 ± 11.33 push-ups) by the third measurement (C) at the end of the 12 weeks of BT.

The initial number of push-ups performed by the female participants (see Figure 4.20) in the EG (31.30 ± 10.34 push-ups) and the CG (41.58 ± 13.01 push-ups) is far greater than that reported by Bell *et al.* (2000), with a mean 10.9 ± 7.4 push-ups and Jones *et al.* (1993a) who only performed 12.4 ± 9.9 push-ups. Jones *et al.* (1993a) reported a 12.3% stress fracture rate. However the findings were similar to the 28.8 ± 9.5 push-ups and 33.7 ± 11.6 push-ups reported by Knapik *et al.* (2004).

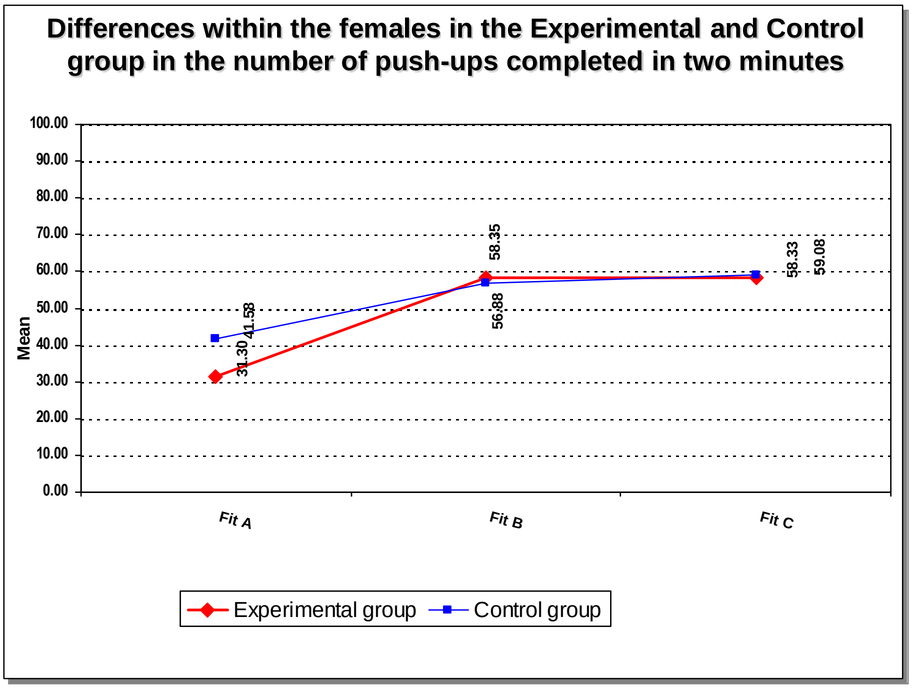

Figure 4.20: Differences (within females) in the EG and CG in the number of push-ups completed in two minutes

Unfortunately, they did not indicate if any stress fractures occurred. From the above, it would appear that the female participants of this cohort may have had a much lower risk for the development of stress fractures, due to their initial muscle strength and endurance as measured by the push-up test. This is in line with Bell *et al.* (2000: 144) who argued that ”…*gender, after controlling for fitness, is not significantly associated with training-related injury, while fitness, a covariate of gender, is.* “

When observing the changes that took place over the 12 weeks of BT, the trend for the female participants was similar to the males participants, where both the EG and CG showed statistically significant increases in the amount of push-ups they could do over time (see Figure 4.21). The EG had a lower score than the CG at the Pre-test measurement, but the EG (56.32 ± 13.69 push-ups) caught up to the CG (59.47 ± 14.05 push-ups) by the end of BT.

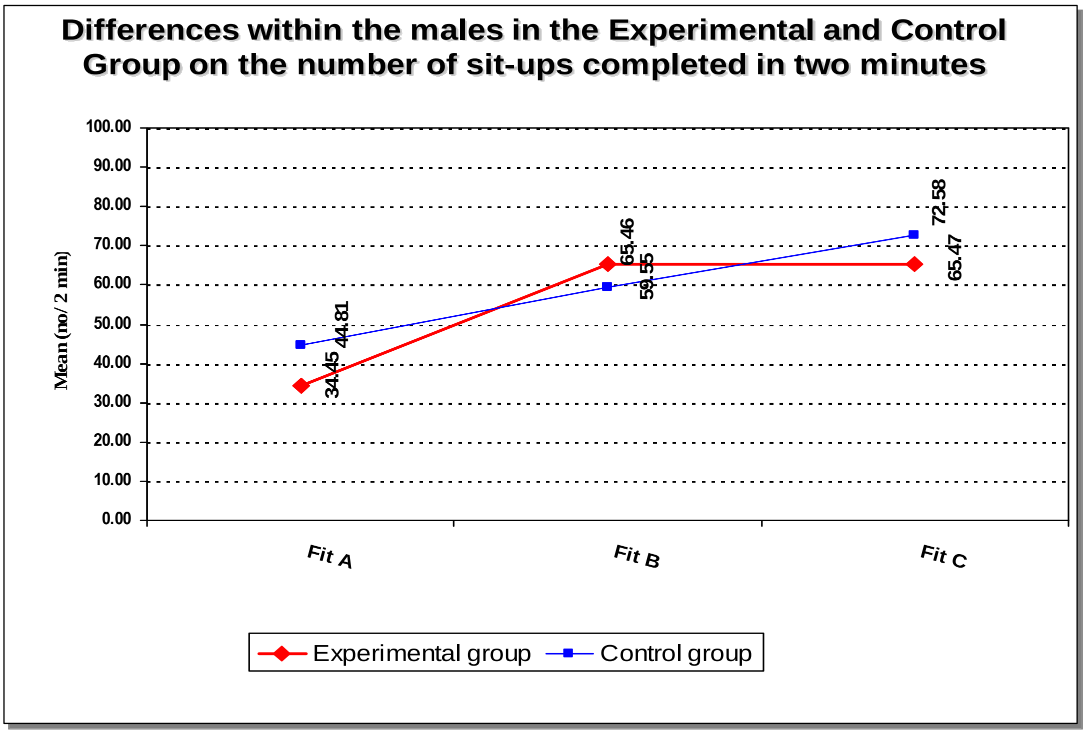

Figure 4.21: Differences (within males) in the EG and CG on the number of sit-ups completed in 2 minutes

The results in Figure 4.21 reflect the number of sit-ups the males completed in the allocated 2 minutes. At the Pre-test the male participants of this study's cohort completed 34.45 ± 10.07 sit-ups, which is lower than that of male participants from the American Army who performed 43.7 ± 11.6 sit-ups (Bell *et al.,* 2000). Beck *et al.* (2000) reported a 6.4% stress fracture incidence in their male cohort. Those that developed stress fractures, completed 51.8 ±10.8 sit-ups on entry into BT and those that did not develop any stress fractures having completed significantly more (57.2 ± 13.3 sit-ups). Additionally, Jones *et al.* (1993a) reported a 2.4% stress fracture incidence and they too completed more sit-ups (54.5 ± 13.8 sit-ups) than the present cohort. The findings in this study do not support that muscle strength and endurance, as measured by the sit-up test, are a risk factor for the development of stress fractures in male participants as no stress fracture incidence was reported amongst the male participants in the EG.

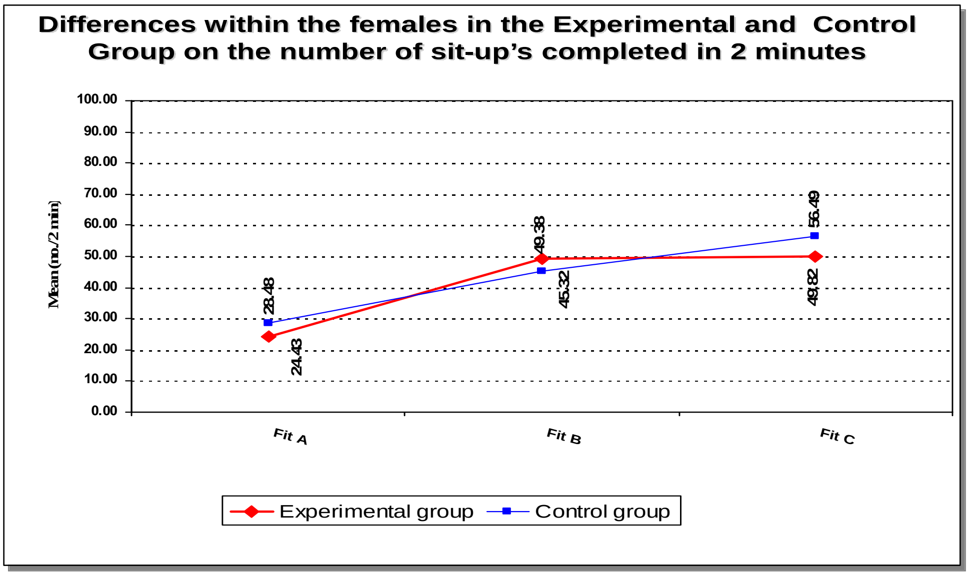

Figure 4.22: Differences (within females) in the EG and CG on the number of sit-ups completed in 2 minutes

Male participants in both the EG and the CG showed statistically significant increases in the number of sit-ups that they could do, when comparing the Pre-test with the consecutive 2 Post-tests. The CG, however, showed a steady increase, while the EG seemed to reach their peak sooner, with Post-test (B) and (C) having similar scores.

The results of the female participants are presented in Figure 4.22. At the Pre-test, this study's female cohort completed 24.43 ± 10.09 sit-ups, which is lower than those completed by the female participants from the American Army - 30.9 ± 13.9 sit-ups (Bell *et al.,* 2000). Beck *et al.* (2000) reported a 5.3% stress fracture incidence in their female cohort. Those that developed stress fractures, completed 32.7 ± 6.64 sit-ups on entry into BT and those that did not develop any stress fractures, completed slightly more (35.0 ± 6.45 sit-ups). Additionally, Jones *et al.* (1993a) reported a staggering 12.3% stress fracture incidence and they too completed more sit-ups (37.9 ± 11.9 sit-ups) than the present cohort. Similarly to the male participants, the findings do not support that muscle strength and endurance, as measured by the sit-up test, are a risk factor for the development of stress fractures in female participants.

The female participants in both groups showed a statistically significant increase in the number of sit-ups they could complete over time. This increase was greatest between Post-tests (A) and (B) whist the CG showed a steady increase peaking at Post-test (C).

The improvements in muscle endurance and muscle strength as measured by sit-up and push-up tests, are similar to the findings of other researchers who documented similar changes in these two parameters during BT (Bell *et al.,* 2000; Popovich *et al.,* 2000; Sonna *et al.,* 2001; Knapik *et al.,* 2002; Armstrong *et al.,* 2004; Evans *et al.,* 2005; Knapik *et al.,* 2005; Dyrstad *et al.,* 2006; Knapik *et al.,* 2006).

T-tests for independent samples were used to determine whether statistically significant differences existed between the EG and CG, for sit-up and push-up measurements, at each of the testing phases (Pre-test A, Post-test B and Post-test C). The complete statistical results can be found in Appendix Copy Disk - G.

The results in Figure 4.23 reflect the changes in sit-ups and push-ups performed by the male participants. The EG completed significantly less push-ups than the CG with the same tendency found for sit-ups - the EG performed significantly poorer than the CG at the Pre-test. Statistically significant differences between the mean scores of the EG and CG were found in both the push-up and sit-up test during the first Post-test. Since there were significant differences during the Pre-test (A), these results imply that the EG's performance improved to such an extent that they were performing better than the CG at the first Post-test.

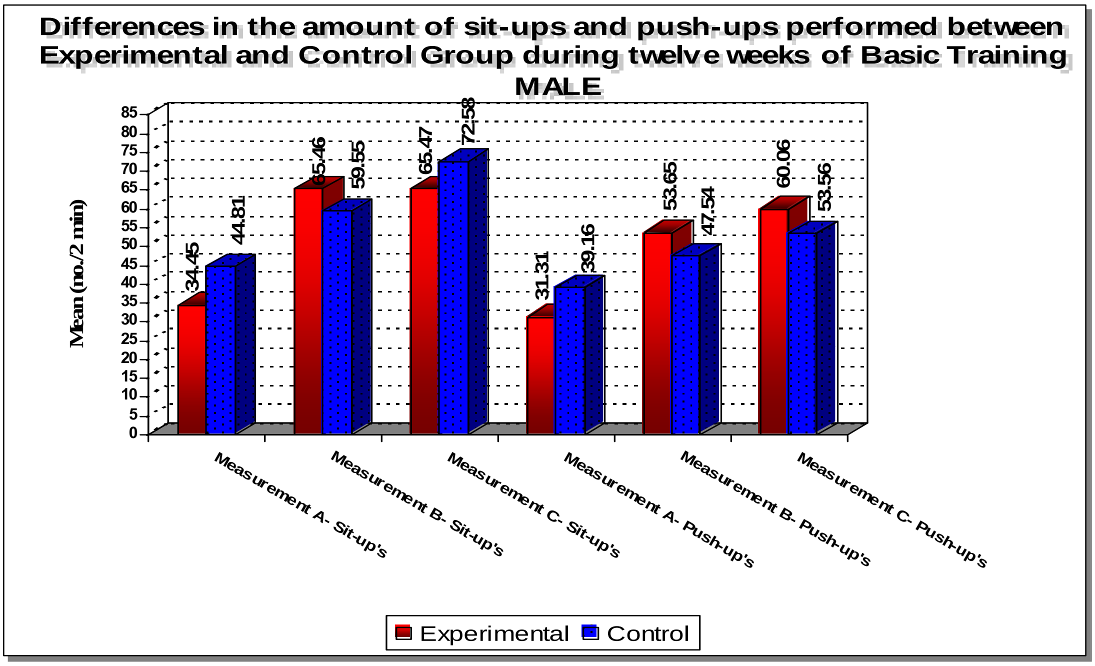

Figure 4.23: Differences in the amount of sit-ups and push-ups performed by male participants in the EG and CG

During the last measurement (C), statistically significant differences between the mean scores of the EG and CG were found for both the sit-up and push-up tests. In both cases, the EG performed better than the CG.

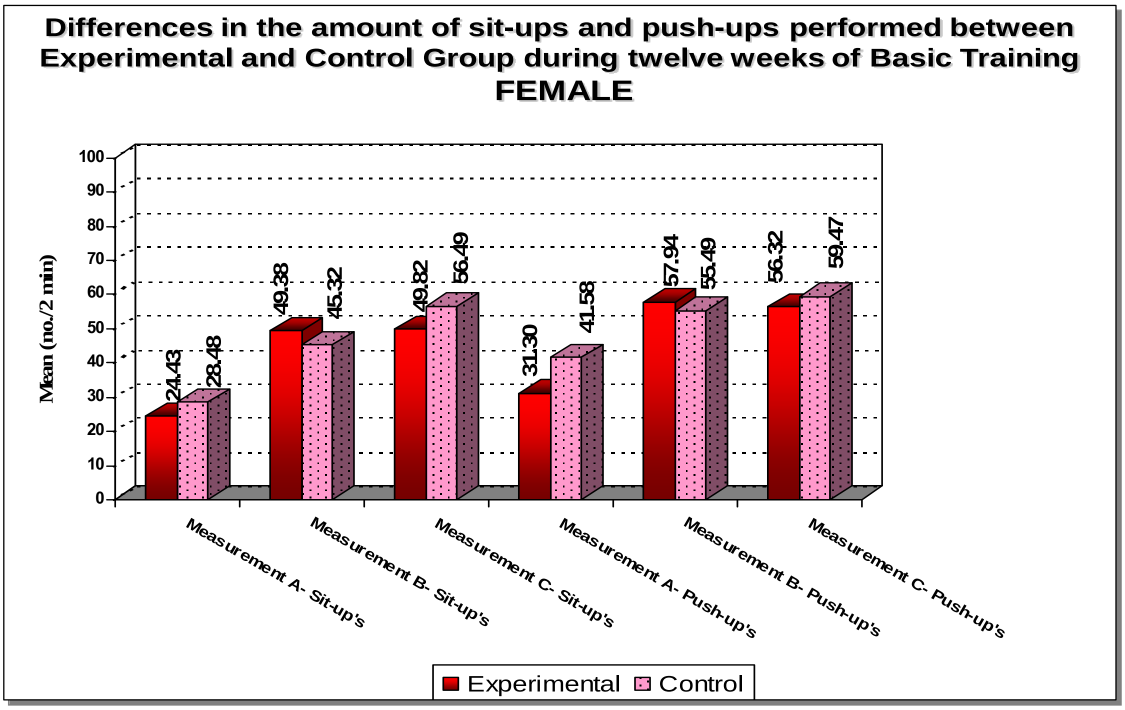

Figure 4.24: Differences in the amount of sit-ups and push-ups performed by female participants in the EG and CG

The results in Figure 4.24 reflect that, similar to the male results, the EG also did significantly less push-ups and sit-ups than the CG at the Pre-test scoring. During Post-test B, no statistically significant differences between the mean scores of the EG and CG were found. The results imply that the EG improved their performance on this test to such an extent, that their mean scores moved from being below the CGs to being above them during the first Post-test. The CG performed significantly more sit-ups than the EG during the last Post-test (C). This showed that although the EG showed a sharp increase in sit-up performed after five weeks of BT, the group then reached a plateau and did not improve further whereas the CG, showed a steady and significant increase throughout the 12 weeks. The number of push-ups performed did, however, not differ significantly. The performance of the two groups, in terms of push-ups, thus remained the same from the previous Post-test. The EG's performance improved to reach the same level as the CG's, and then remained the same.

Handgrip strength test

Both male and female participants showed a statistically significant decrease in their isometric left handgrip strength as measured with the handgrip dynamometer (see Figure 4.25 and 4.26). The complete statistical results can be found in Appendix Copy Disk - D.

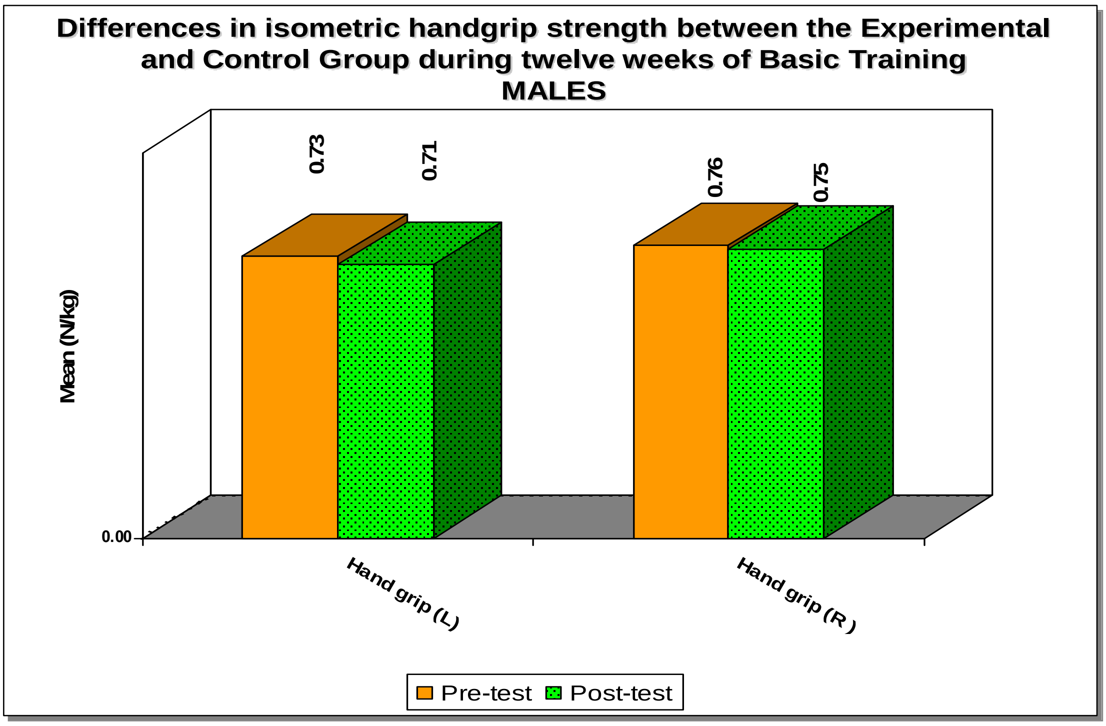

Figure 4.25: Differences in isometric handgrip strength between the EG and CG in male participants during 12 weeks of BT

There was no significant increase or decrease in the isometric right handgrip strength. These findings are in contrast to those reported by Brock & Legg (1997) and Teves *et al.* (1985) who showed a 10.5% and 15.8% increase in handgrip strength respectively. The findings are, however, similar to those found by Marcinik *et al.* (1985) and Legg & Duggan (1996) who also reported decreases in isometric handgrip strength. Both authors attributed these changes to insufficient emphasis being placed on muscle strength and endurance training, and that the emphasis was rather placed on running exercises during BT.

In this study, much of the military training centered on weight bearing PT, such as marching or running, which are lower limb exercises. Upper body strength and endurance formed part of the PT Programme but very little isolated, lower arm training was done.

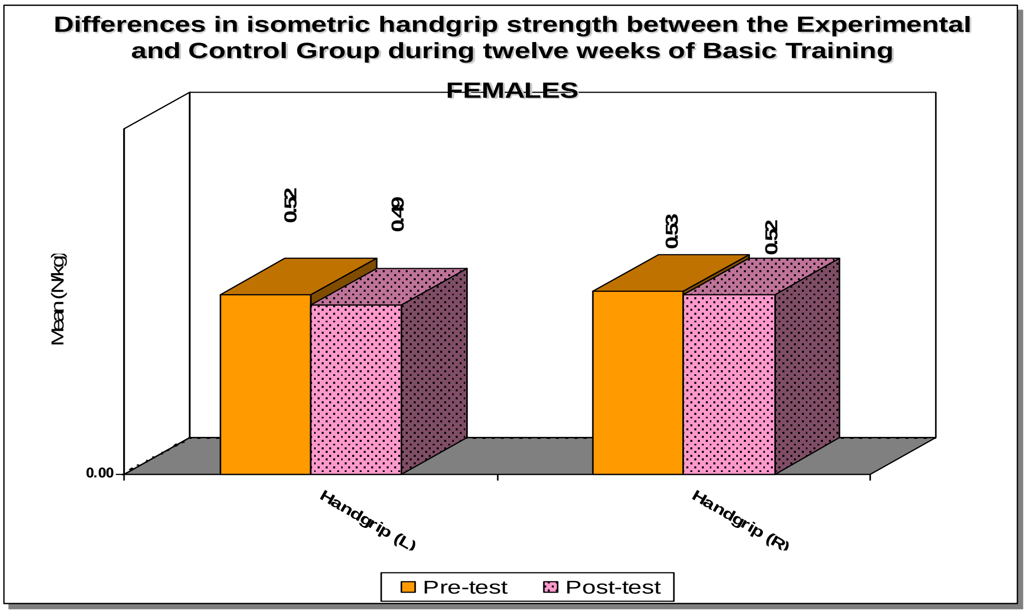

Figure 4.26: Differences in isometric handgrip strength of female participants between the EG and CG during 12 weeks of BT

The only exception may have been the weapon training, which demands high rates of manual handling of ammunition equipment and involves a fair amount of lower arm exercise (Legg & Patton, 1987). As only 5% (n=5) and 1.67% (n=2) of the male and female cohorts, respectively, were right handed, this may explain why the strength in their right hands did not show as much of a decrease as in their left, as their right hands were used for the weapon handling activities.

Isokinetic strength

The concept of isokinetic exercise was developed by James Perrine and introduced in the scientific literature in 1976 by Hislop and Perrine (1967) and Thistle *et al.* (1976) (Perrin, 1993). Isokinetic testing is performed on devices at a fixed speed with variable resistance that is totally accommodative to the individual throughout the range of motion (Brukner & Khan, 1996).

Participants in this cohort underwent both knee extension and flexion isokinetic testing at 60º, and ankle plantar and ankle dorsiflexion testing at 30º. The cohort mean results can be compared to the recommended norms available in the literature, and the results can then be analysed to determine if the participants' isokinetic strength was below the recommended norm thus, possibly, placing the participants at risk for the development of stress fractures (Perrin, 1993).

Figures 4.27 and 4.28 reflect the male participants' results for both their knee and ankle isokinetic evaluation. As the male participants had a 1.4 kg increase in their mean body mass, both the relative, as well as the absolute values, were considered. The values represent the results of their mean relative and absolute peak torque obtained at 60˚/s over five repetitions. The complete statistical results can be found in Appendix Copy Disk - D.

As outlined in Table 4.11, the male participants' initial absolute and relative isokinetic quadriceps and hamstring strength was below that prescribed for college track athletes by Appen and Duncan (1986) and Worrel *et al.* (1991).

Table 4.11: Isokinetic strength changes that occurred in the male participants during 12 weeks of BT

Isokinetic movement	**Pre-test**				**Post-test**			
	Males			**Norms**	**Males**			**Norms**
	n	**Mean (SD)**			***n***	**Mean (SD)**		
Knee extension (abs)(60º/sec)(Nm)	*100*	L	170.07 (34.82)	202.64 *(Appen & Duncan, 1986)*	*100*	L	173.77 (32.12)	202.64
		R	164.28 (38.73)			R	169.09 (30.88)	
Knee flexion (abs)(60º/sec) (Nm)	*100*	L	106.34 (24.09) *	129.2	*100*	L	120.31 (23.25) *	129.2
		R	103.51 (25.70)			R	123.72 (24.29) *	
Knee extension (rel)(60º/sec) (Nm)	*100*	L	2.75 (0.46)	2.95 *(Worrell et al., 1991)*	*100*	L	2.75 (0.40)	2.95
		R	2.66 (0.53)			R	2.68 (0.43)	
Knee flexion (rel)(60º/sec) (Nm)	*100*	L	1.72 (0.33)	1.83	*100*	L	1.90 (0.33) *	1.83
		R	1.68 (0.37)			R	1.96 (0.379) *	
Knee flexor/extensor ratio (60º/sec)(%)	*100*	L	64.27 (15.73)	60% (Perrin, 1993)	*100*	L	69.90 (10.22) *	60%
		R	64.72 (14.71)			R	73.84 (11.29) *	
Ankle plantarflexion (abs)(60º/sec) (Nm)	*100*	L	68.47 (17.28)	79.29 *(Berg et al., 1985)*	*100*	L	72.51 (17.40)	79.29
		R	68.21 (17.86)			R	77.92 (18.28)	
Ankle dorsiflexion (abs)(60º/sec) (Nm)	*100*	L	28.63 (5.02)	22.8	*100*	L	27.45 (5.14)	22.8
		R	28.52 (5.07)			R	28.27 (5.58)	
Ankle plantarflexion (rel)(60º/sec) (Nm)	*100*	L	1.11 (0.27)	No norms	*100*	L	1.13 (0.31)	No norm
		R	1.11 (0.29)			R	1.22 (0.35)	
Ankle dorsiflexion (rel)(60º/sec) (Nm)	*100*	L	0.46 (0.06)	No norms	*100*	L	0.44 (0.08)	No norm
		R	0.46 (0.07)			R	0.45 (0.08)	

Values are mean differences between Pre-test and Post-test and prescribed isokinetic norms

* Significant change from the Pre-test to the Post-test at the end of 12 weeks of BT p≤0.05.

When compared to the isokinetic knee extension (221± 40 – right / 208 ±40 -left) and flexion (119 ± 29 – right / 114 ± 27 -left) absolute findings reported by Gordon *et al.* (1986b) on 93 BT recruits, these participants have weaker quadricep strength and similar hamstring strength. Even when measured up to a more recent (2006) study, comparing 2 different units of 'elite' soldiers extensor strength (211± 35/ 241±55 – right / 212 ±24/ 212 ±37 -left) and flexor isokinetic strength (105± 24/ 124 ±31 – right /107 ± 20/ 114 ± 29 - left) in the British military the male participants of this cohort have relatively weaker quadriceps and hamstring strength (Simpson *et al.,* 2006).

During the 12 weeks of BT the male participants' relative and absolute knee extensors peak torque showed no statistically significant changes from Pre-test to Post-test. This supports the findings by Gordon *et al.* (1986b). However, the male participants did show a relative and absolute statistically significant increase in knee flexor peak torque. This is in contrast to Gordon *et al.* (1986b), who showed no significant change with BT. This change may be attributed to the PT Programme eliciting adequate training stimulus as well as to the relatively low initial isokinetic strength (Daniels *et al.,* 1979; Perrin, 1993).

The hamstring muscle group has been shown to produce about 60% of torque values generated by the quadriceps muscle, at 60º/sec isokinetic test velocity, and this is accepted to be the ideal ratio (Perrin, 1993). The males in this study had statistically significant increases, from the Pre-test to the Post-test, in their knee flexor-extensor ratios. This was true for both left and right sides.

Upon entering into BT, male participants' isokinetic dorsiflexion strength was greater than that reported by 69 male Cadet officer trainees entering the Belgian Royal Military Academy, for six weeks of BT (21.24 ± 4.72 – right / 21.44 ± 5.29 - left). However, the Belgian cadets had a far greater plantar flexor isokinetic strength (83.42 ± 25.05 – right / 87.56 ± 26.19 - left) (Mahieu *et al.,* 2006).

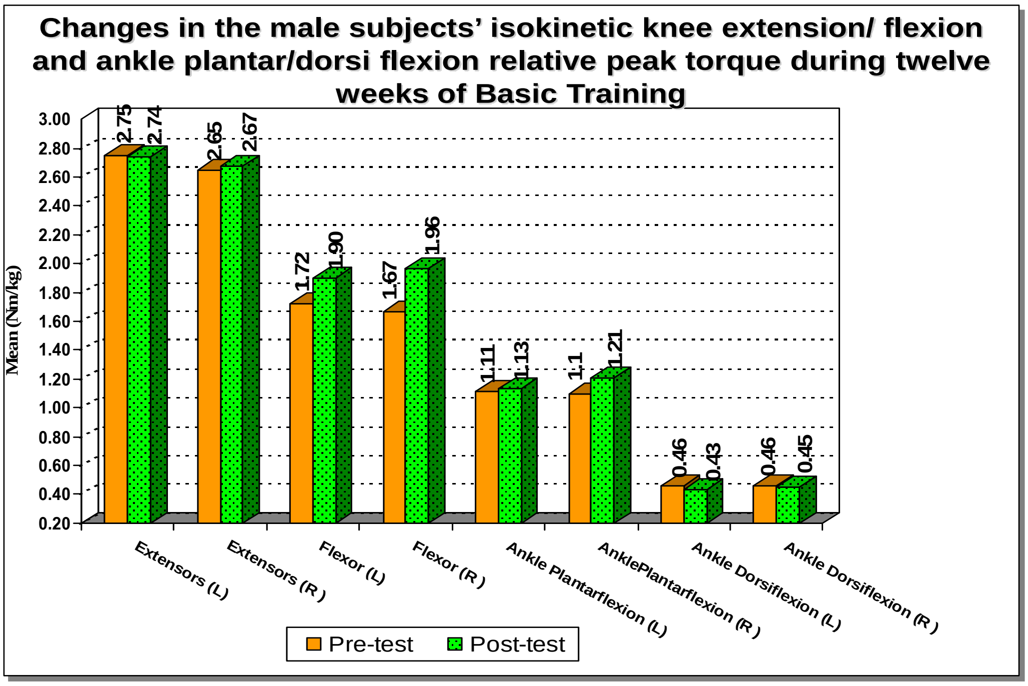

Figure 4.27: Changes in male participants' isokinetic knee extension/ flexion and ankle plantar/dorsi flexion relative peak torque during 12 weeks of BT

The ankle isokinetic evaluation found that the male participants showed a statistically significant increase in relative and absolute right plantarflexion, whilst a statistically significant decrease from Pre-test to Post-test was observed in their left relative and absolute ankle dorsiflexion values.

These changes may be attributed to the high amount of running activities and calf strengthening exercises included in the PT Programme, however, little emphasis was placed on specific exercises to develop tibialis anterior, extensor ditorum longus, and peroneous tertius muscle strength. This should be considered when revising the PT Programme.

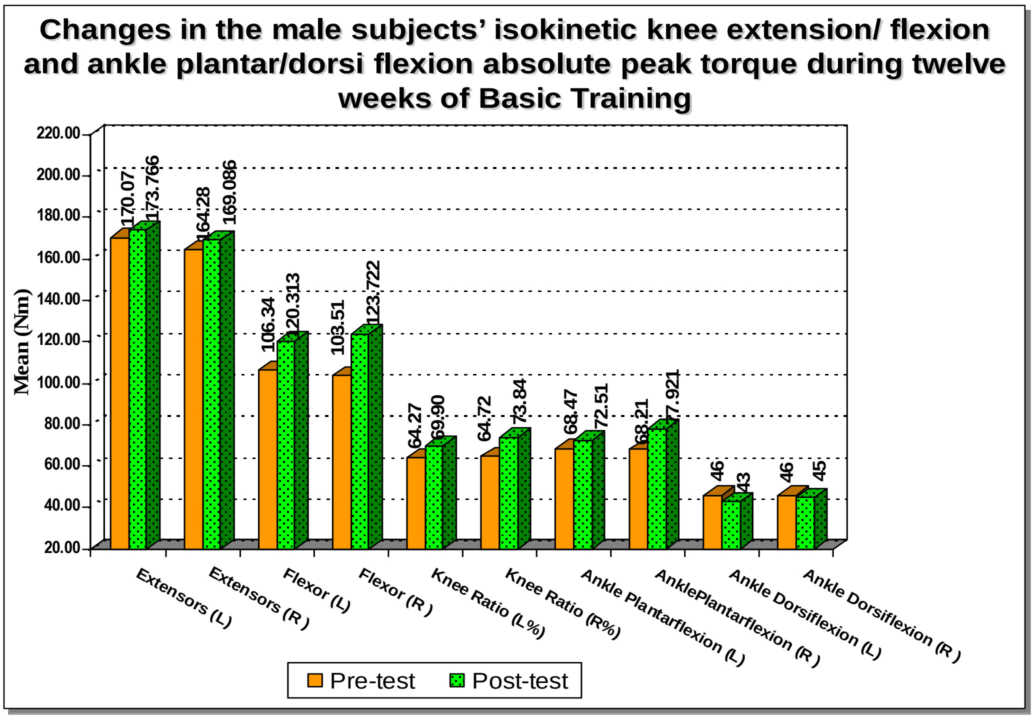

Figure 4.28: Changes in male participants' isokinetic knee extension/ flexion and ankle plantar/dorsi flexion absolute peak torque during 12 weeks of BT

Considerably less literature is available on the isokinetic strength of female military recruits, thereby rendering it difficult to compare the female participants in this cohort's initial isokinetic strength. Table 4.11 and Figures 4.29 and 4.30 reflect the female participants' results for both their knee and ankle isokinetic evaluations. Unlike the male participants, the female participants did not have a significant change in body mass during the 12 weeks of BT. Therefore, relative isokinetic changes will be reflected in the absolute values.

As outlined in Table 4.12, the female participants' initial absolute isokinetic quadriceps and hamstring strength was slightly below that reported by Fillyaw *et al.* (1986) for female university soccer players. However, this cohort's female absolute flexor strength was greater than the Fillyaw *et al.* (1986) group. When their relative extensor and flexor isokinetic strength was compared to females ages 15 to 34 years, this cohort favoured well (Highgenboten *et al.,* 1988).

Table 4.12: Isokinetic strength changes that occurred in female participants during 12 weeks of BT

Isokinetic movement	**Pre-test**				**Post-test**			
	Females			**Norms**	**Females**			**Norms**
	N	**Mean (SD)**			***n***	**Mean (SD)**		
Knee extension (abs)(60º/sec)(Nm)	*83*	L	111.61 (22.72)	118.32 (Fillyaw *et al.* , 1986)	*83*	L	105.88 (26.72)	118.32
		R	106.20 (23.66)			R	107.95 (19.96)	
Knee flexion (abs)(60º/sec) (Nm)	*83*	L	67.39 (12.82)	63.51	*83*	L	71.05 (14.13)*	63.51
		R	66.23 (17.01)			R	73.76 (13.01)*	
Knee extension (rel)(60º/sec) (Nm)	*83*	L	1.87 (0.36)	1.26 (Highgenboten *et al.,* 1988)	*83*	L	1.78 (0.44)*	2.19
		R	1.79 (0.39)			R	1.81 (0.30)	
Knee flexion (rel)(60º/sec) (Nm)	*83*	L	1.14 (0.24)	0.87	*83*	L	1.19 (0.22)*	0.87
		R	1.12 (0.28)			R	1.24 (0.22)*	
Knee flexor/extensor ratio (60º/sec)(%)	*83*	L	61.34 (10.64)	60% (Perrin, 1993)	*83*	L	68.16 (14.57)*	60%
		R	63.13 (11.81)			R	69.87 (14.75)*	
Ankle plantarflexion (abs)(60º/sec) (Nm)	*83*	L	47.45(12.88)	*79.29 (Berg et al., 1985)*	*83*	L	49.66 (12.12)	79.29
		R	44.28 (11.31)			R	52.92 (12.92)	
Ankle dorsiflexion (abs)(60º/sec) (Nm)	*83*	L	19.96 (4.17)	31.01	*83*	L	19.65 (5.44)	31.01
		R	19.11 (3.71)			R	20.23 (5.26)*	
Ankle plantarflexion (rel)(60º/sec) (Nm)	*83*	L	0.80 (0.22)	No norms	*83*	L	0.83 (0.21)	No norms
		R	0.75 (0.20)			R	0.89 (0.21)*	
Ankle dorsiflexion (rel)(60º/sec) (Nm)	*83*	L	0.34 (0.08)	No norms	*83*	L	0.33 (0.08)	No norms
		R	0.32 (0.07)			R	0.34 (0.08)*	

Values are mean differences between Pre-test and Post-test and prescribed isokinetic norms

* Significant change from the Pre-test to the Post-test at the end of 12 weeks of BT. p≤0.05.

The female participants showed more statistically significant changes than the male participants during 12 weeks of BT. Left leg mean relative knee extensor peak torques showed a statistically significant decrease from Pre-test to Post-test, whilst knee flexor values, on both legs, showed statistically significant increases from the Pre-test to the Post-test. The decrease in left extensor strength is difficult to explain and should be researched further, by including a lower limb strength test in the Standardised PT test as, currently, only upper body and trunk muscular endurance is assessed with the push-up and sit-up tests (DOD Policy on Physical Training, 2000).

The knee flexor-extensor ratio showed statistically significant increases. This difference was statistically significant for the left and right sides.

The results of the knee flexor-extensor ratio are, however, similar to those observed in the male participants. One possible area of concern is that the female cohort showed a large increase in flexor strength accompanied by no or a slight decrease in knee extensor strength. This resulted in the knee flexor-extensor ratio going from around the desired 60% to almost 70%, possibly predisposing the cohort to thigh injuries (Perrin, 1993). It therefore appears that the PT Programme produced an insufficient training stimulus for knee extensor strength development in the female cohort and should be revised by including more strength training knee extensor exercises.

Upon entering into BT the female participants’ isokinetic dorsiflexion and plantarflexion strength was far less than that reported on twenty-year old female college basketball players (Berg *et al.,* 1985). Additionally, it was also less than the plantarflexion (59.5 ± 12.7-left / 64.8 ± 11.7- right) and dorsiflexion (30.2 ± 5.6- left / 32.4 ± 4.7- right) in another study of female college basketball players (Payne *et al.,* 1997).

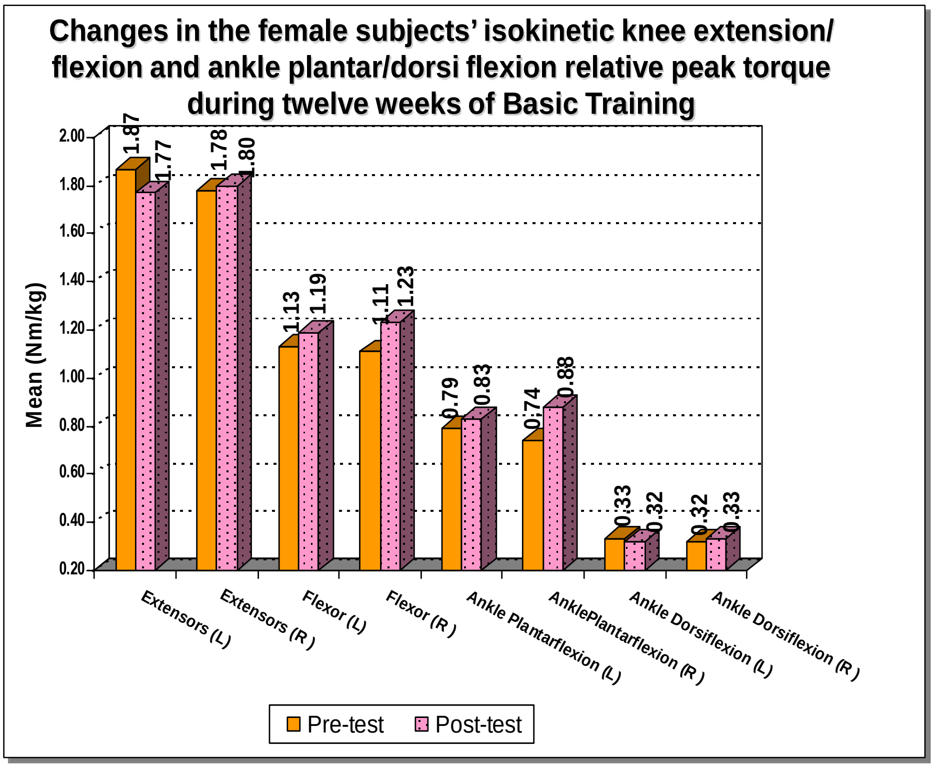

Figure 4.29: Changes in female participants' isokinetic knee extension/ flexion and ankle plantar/dorsi flexion relative peak torque during 12 weeks of BT

The ankle isokinetic evaluation found that the female participants showed a statistically significant increase in relative right plantarflexion, (the same as the male participants), however, the female participants experienced a statistically significant increase in the mean peak torque of their right limb with ankle dorsiflexion from Pre-test to Post-test.

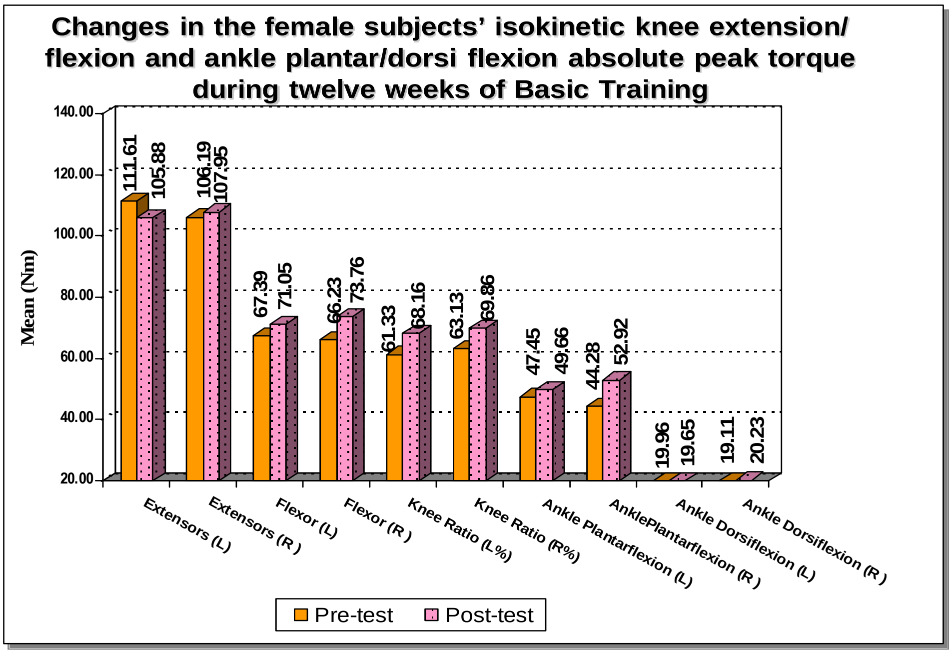

Figure 4.30: Changes in female participants' isokinetic knee extension/ flexion and ankle plantar/dorsi flexion absolute peak torque during 12 weeks of BT

The PT Programme included exercises designed to improve muscle strength (Appendix Copy Disk - B). The PT programme was progressive in nature, thus the strength training stimulus continued to increase over the 12 weeks of BT. This was achieved by including exercises from week five using wooden poles. In a military set-up, strength training is often difficult to execute as the strength training facilities are limited and the number of training recruits, to undergo the strength training simultaneously are large (Jones *et al.,* 1993b; Knapik *et al.,* 2005). The pole used in PT provided a cost-effective method of strength training which elicited a sufficient strength training response. It was based on the free-weight principle and may have contributed to the increase in strength (Daniels *et al.,* 1979; Fleck & Kramer, 1997; Heyward, 2002).

4.4.1.4.4 Anaerobic physical fitness

Anaerobic capacity refers to the total amount of energy that can be released by anaerobic pathways during intensive exercise to exhaustion; this is therefore applicable to a range of exercises that extend from about 60 seconds to 10 minutes (Hahn*,* 1992). Anaerobic fitness was measured by the 10 x 22m shuttle run test, a component of the SANDF standardized fitness test (DOD Policy on Physical Training, 2000).

10 x 22m Shuttle Run test

The results in Figure 4.31 reflect that there were statistically significant differences between Pre-test and Post-test shuttle run time scores, in males, in both the EG and CG. The CG, however, seemed to show a steady decline, while the EG, showed a slight increase toward the last Post-test score (C).

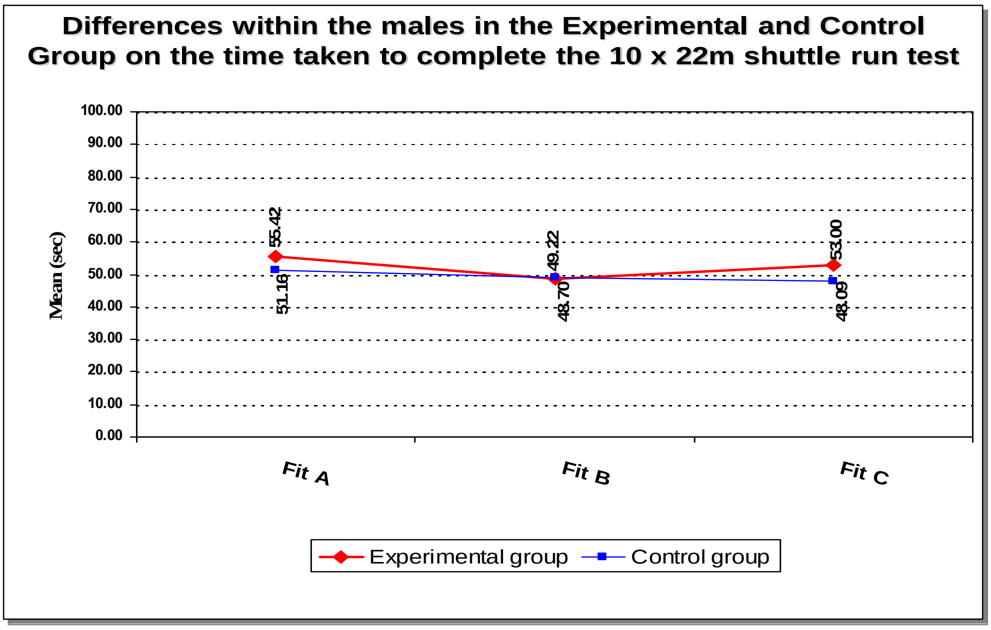

Figure 4.31: Differences (within males) in the EG and CG on the time taken to complete the 10 x 22m shuttle run test

The females showed a similar profile in their shuttle run times (see Figure 4.32). There were statistically significant differences between the times taken to complete the shuttle run test for the Pre-test and Post-test for both the EG and CG. The CG, however, seemed to show a steady decline, while the EG, showed a slight increase towards the last Post-test score (C).

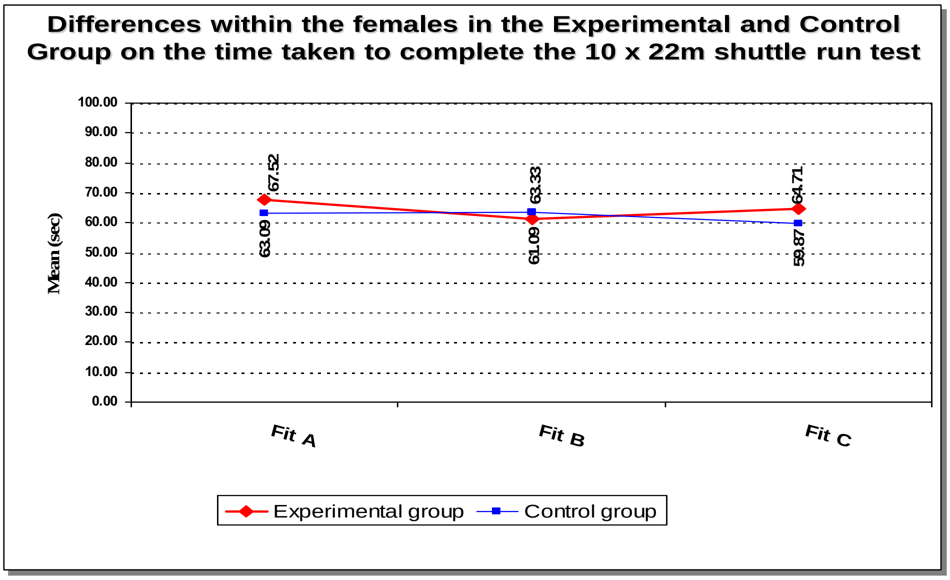

Figure 4.32: Differences (within females) in the EG and CG on the time taken to complete the 10 x 22m shuttle run test

The results in Figures 4.33 and 4.34 reflect the differences between the male and female EG and CGs, respectively, for the time taken to complete the 10 x 22m shuttle run test at the three measurement dates. Statistically significant differences between the mean scores of the EG and CG were found, with the CG performing better than the EG in the Pre-test. Although no statistically significant difference was shown by the male and female EG in the first Post-test (measurement B), the results imply that the EG improved its performance in the shuttle run test to such an extent, that its mean scores moved, from being below the CGs' to being above them during the first Pre-test. Both the male and female participants in the EG then showed a significant decrease in anaerobic fitness, with deterioration in time taken to complete the shuttle run test. This was not seen in the CG.

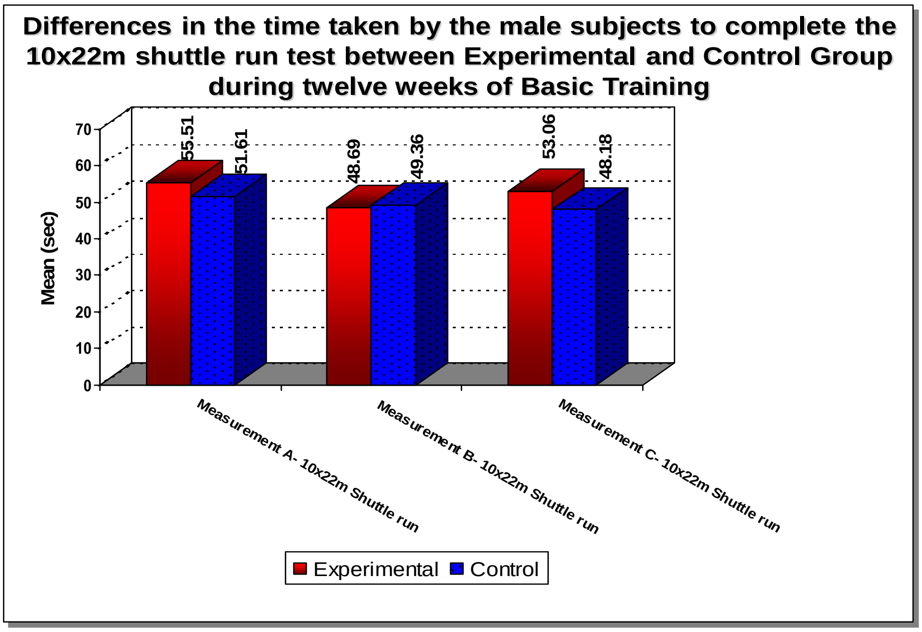

Figure 4.33: Differences in time taken by male participants to complete the 10 x 22m shuttle run test between the EG and CG 12 weeks of BT

The decline shown by the EG may be attributed to a lack of motivation, as the participants were completing this test purely for research purposes and they were cognisant of the fact that their performance would not influence their results in BT. This was not the case for the CG, whose last Post-test contributed to their final mark for BT. Additionally, the PT Programme followed by the EG may not have provided sufficient stimulus to elicit an improvement in the anaerobic component and should, therefore, be altered to include more anaerobic training.

The shuttle run test, as prescribed by the DOD Policy on PT (2000), is not a standardised test (as used by other studies) rendering comparison of results not possible. The majority of military studies utilising a shuttle run test use the multi-stage shuttle run test as prescribed by Léger *et al.*(1988) (Harwood *et al.,* 1999; Williams *et al.,* 1999; Rosendal *et al.,* 2003; Williams, 2005).

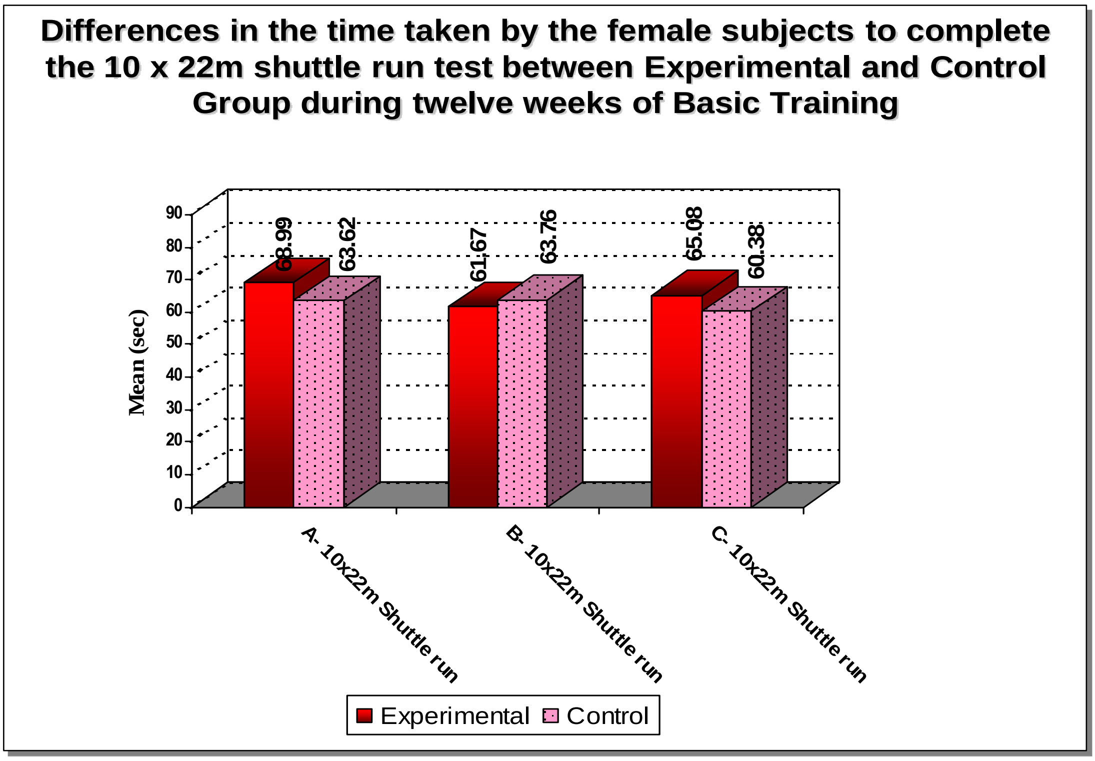

Figure 4.34: Differences in time taken by female participants to complete the 10 x 22m shuttle run test between EG and CG during 12 weeks of BT

4.4.1.4.5 Fitness test results

Points are allocated to each BT recruit according to their performance level (time achieved and number of repetitions achieved) per component. A BT recruit passes a component if 600 points are achieved. Recruits, under the age of 34 years, pass the battery test if they achieve a minimum of 3000 points the sum total of points achieved for all the components (DOD policy on Physical Training, DOD Instruction: SG no 00006/2000). A Chi-square analysis was used to determine whether there were statistically significant relationships between group membership (ie CG or EG) and pass or fail rates.

The complete statistical results for each fitness test are presented in Appendix Copy Disk - G. Only the results of the total tests were included in this analysis. The results of the Chi-square analysis indicated that there was a relationship between group membership and whether participants passed or failed the fitness test in total (see Table 4.13). However this relationhip was not strong enough to be statistically significant.

Table 4.13: Relationship between group membership and pass rate at the Pre-test (Measurement A)

Relationship between group membership and pass rate at the Pre-test (Measurement A)					
			Total Pass/Fail		Total
			Pass	Fail	
GROUP	Experimental	Count	37	146	183
		% within GROUP	20.2%	79.8%	100.0%
		% within fitness test A: Total Pass/Fail	24.2%	**68.5%**	50.0%
		% of Total	10.1%	39.9%	50.0%
	Control	Count	116	67	183
		% within GROUP	63.4%	36.6%	100.0%
		% within fitness test A: Total Pass/Fail	75.8%	**31.5%**	50.0%
		% of Total	31.7%	18.3%	50.0%
Total		Count	153	213	366
		% within GROUP	41.8%	58.2%	100.0%
		% within fitness test A: Total Pass/Fail	100.0%	100.0%	100.0%
		% of Total	41.8%	58.2%	100.0%

Relationship between group membership and pass rate at the Pre-test (Measurement A)					
Chi-square Tests					
	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	**70.091(b)**	**1**	**0.000**		
Continuity Correction(a)	68.328	1	0.000		
Likelihood Ratio	72.842	1	0.000		
Fisher's Exact Test				0.000	0.000
Linear-by-Linear Association	69.900	1	0.000		
N of Valid Cases	366				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 76.50.

The cross tabulation shows that the majority of participants who failed the total fitness tests during the Pre-test were in the EG (68.5%). This is supported in the previous sections, where the results of the EG are statistically poorer (p.0.005) than the CG in the Pre-test. The individual test results thus showed that the group who failed consisted mostly of participants in the EG.

Chi-square analyses of the first Post-test (measurement B) indicate that the majority of participants who failed were in the CG (73.3%) (Table 4.14). The same profile was found in the 2.4 km run, push-up and sit-up tests. However, on the shuttle run and 4 km walk tests, there were no significant relationships (Appendix Copy Disk - G).

Table 4.14: Relationship between group membership and pass rate at the first Post-test (Measurement B)

Relationship between group membership and pass rate at the first Post-test (Measurement B)

			Total Pass/Fail		
			Pass	Fail	Total
GROUP	Experimental	Count	151	8	159
		% within GROUP	95.0%	5.0%	100.0%
		% within fitness test B: Total Pass/Fail	50.0%	**26.7%**	47.9%
		% of Total	45.5%	2.4%	47.9%
	Control	Count	151	22	173
		% within GROUP	87.3%	12.7%	100.0%
		% within fitness test B: Total Pass/Fail	50.0%	**73.3%**	52.1%
		% of Total	45.5%	6.6%	52.1%
Total		Count	302	30	332
		% within GROUP	91.0%	9.0%	100.0%
		% within fitness test B: Total Pass/Fail	100.0%	100.0%	100.0%
		% of Total	91.0%	9.0%	100.0%

Chi-square tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	**5.954(b)**	**1**	**0.015**		
Continuity Correction(a)	5.055	1	0.025		
Likelihood Ratio	6.203	1	0.013		
Fisher's Exact Test				0.020	0.011
Linear-by-Linear Association	5.936	1	0.015		
N of Valid Cases	332				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 14.37.

Table 4.15: Relationship between group membership and pass rate at the last Post-test (measurement C)

Relationship between group membership and pass rate at the last Post-test (Measurement C)

			Total Pass/Fail		Total
			Pass	Fail	
GROUP	Experimental	Count	161	13	174
		% within GROUP	92.5%	7.5%	100.0%
		% within fitness test C: Total Pass/Fail	48.5%	68.4%	49.6%
		% of Total	45.9%	3.7%	49.6%
	Control	Count	171	6	177
		% within GROUP	96.6%	3.4%	100.0%
		% within fitness test C: Total Pass/Fail	51.5%	31.6%	50.4%
		% of Total	48.7%	1.7%	50.4%
Total		Count	332	19	351
		% within GROUP	94.6%	5.4%	100.0%
		% within fitness test C: Total Pass/Fail	100.0%	100.0%	100.0%
		% of Total	94.6%	5.4%	100.0%

Chi-square tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	**2.855(b)**	**1**	**0.091**		
Continuity Correction(a)	2.113	1	0.146		
Likelihood Ratio	2.916	1	0.088		
Fisher's Exact Test				0.103	0.072
Linear-by-Linear Association	2.847	1	0.092		
N of Valid Cases	351				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 9.42.

The results of the Chi-square analysis in Table 4.15 shows that there was no statistically significant relationship between the total fitness scores at the last Post-test (measurement C) and the group membership of participants.

It appears that as participants grew fitter, their group membership seemed to not be a determinant in whether they would pass or fail anymore. The results of the individual tests indicated no significant relationships for the 2.4 km run, push-up and sit-ups tests. However, on the shuttle run and 4 km walk tests, there were significant relationships, with the EG, once again, making up the biggest part of the failing group.

4.4.1.4.6 Flexibility

Flexibility of muscles and joints may directly influence stress fracture risk by way of altering the forces applied to bone. Numerous variables have been assessed but the range of hip external rotation and of ankle dorsiflexion, have been associated, albeit inconsistently, with stress fracture development (Hughes, 1985; Giladi *et al.,* 1987; Giladi *et al.,* 1991; Milgrom *et al.,* 1994; Brukner *et al.,* 1999).

Recruits with external rotation of the hip greater than 65°, experienced an incidence of stress fracture 1.8 times higher than that of recruits with lower degrees of rotation (95% CI: 1.3, 2.5) (Giladi *et al.,* 1987; Giladi *et al.,* 1991). Conversely, Milgrom *et al.* (2004) failed to relate this measurement to stress fracture risk. The male and female participants of this cohort had a mean hip external rotation of 25.57º(L) / 23.40º(R) and 26.19º(L) / 24.78º(R) respectively-is below the recommended 45º-50º average ROM value for healthy adults (Heyward, 2002). The complete statistical results for each fitness test are presented in Appendix Copy Disk - D.

Limited hip external rotation has been linked to the risk of developing stress fractures; unfortunately, this could not be assessed in this study due to the lack of stress fracture incidence. It therefore appears that the hip external rotation of this cohort, was not an intrinsic risk factor, as it was below the documented risk of 65º (Giladi *et al.,* 1987; Giladi *et al.,* 1991). These findings thus support work done by Milgrom *et al.* (2004).

Hughes (1985) found that restricted ankle-joint dorsiflexion (ROM = ≈10º) was related to an increased risk of metatarsal stress fractures. The recruits who had a reduced range were 4.6 times more likely to develop a metatarsal stress fracture. The male and female participants of this cohort had a mean ankle dorsiflexion of 17.14º ± 3.65 (L)/18.25º ± 4.14 (R) and 15.21º ± 3.18(L)/ 16.40º ± 3.53(R), respectively.

According to Heyward (2002), the average ankle dorsiflexion ROM value for healthy adults is 20º. Therefore, the cohorts' mean values were slightly below the norm. Kaufman *et al.* (1999) reported that their 407 male Navy SEAL trainees had a mean ankle dorsiflexion of 20.5º ± 5.5, which was higher than the dorsiflexion results measured in the male participants of this study (17.14 ± (L) 18.25± (R)). Kaufman *et al.* (1999) classified >18.5° dorsiflexion as tight and 18.5°–23.0° dorsiflexion, with the knee bent at 90º , as a normal range. They did not suggest either ranges to be associated with a greater risk for the development of stress fractures (Kaufmann *et al.,* 1999).

The methodology used to assess the ankle dorsiflexion, with knee at 90º flexion meant that the gastrocnemius muscle was relaxed. DiGiovanni *et al.* (2002) found that isolated gastrocnemius contracture, as measured by dorsiflexion, with knee at 0º flexion, assisted in the development of forefoot and/or midfoot pathology in otherwise healthy people. These findings are, however, not supported by Kaufmann *et al.* (1999). As the did not have limited dorsiflexion this study cannot exclude limited ankle dorsiflexion as a possible risk factor in the development of stress fractures. The male cohort did, however, show a significant 43.40 %(L) and 38.52 %(R) improvement in their dosiflexion during the 12 weeks of BT possibly offering some form of protection. Further study by measuring ankle dorsiflexion, with the knee at 0º flexion, in the South African context is recommended.

All the flexibility measurements for male participants showed a statistically significant change from Pre-test to Post-test. The plantarflexion, both right and left, as well as the hip external rotation (right and left) showed statistically significant decreases in scores from the Pre-test to the Post-test. Both the right and left dorsiflexion scores showed a statistically significant increase in scores from the Pre-test to the Post-test (see Figure 4.35).

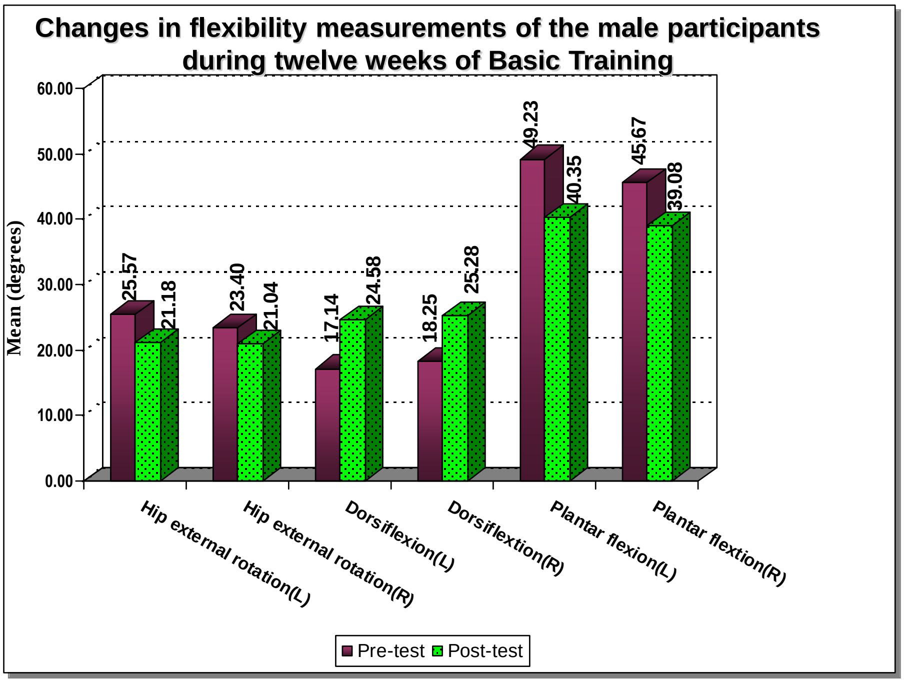

Figure 4.35: Changes in flexibility measurements of male participants during 12 weeks of BT (ankle plantarflexion, dorsiflexion and hip external rotation)

In female participants, not all flexibility measurements showed a statistically significant change in scores (see Figure 4.36). Hip external rotation scores on the right and left hand side, showed significant decreases, as was the case in the male participants. The ankle dorsiflexion of the right ankle showed no statistically significant changes, whilst the left decreased significantly. This is in contrast to the male findings which found ankle dorsiflexion increased significantly over the 12-week period. Where plantarflexion scores for males decreased significantly (see Figure 4.35), these scores seemed to have increased significantly for females both on the right and left hand side.

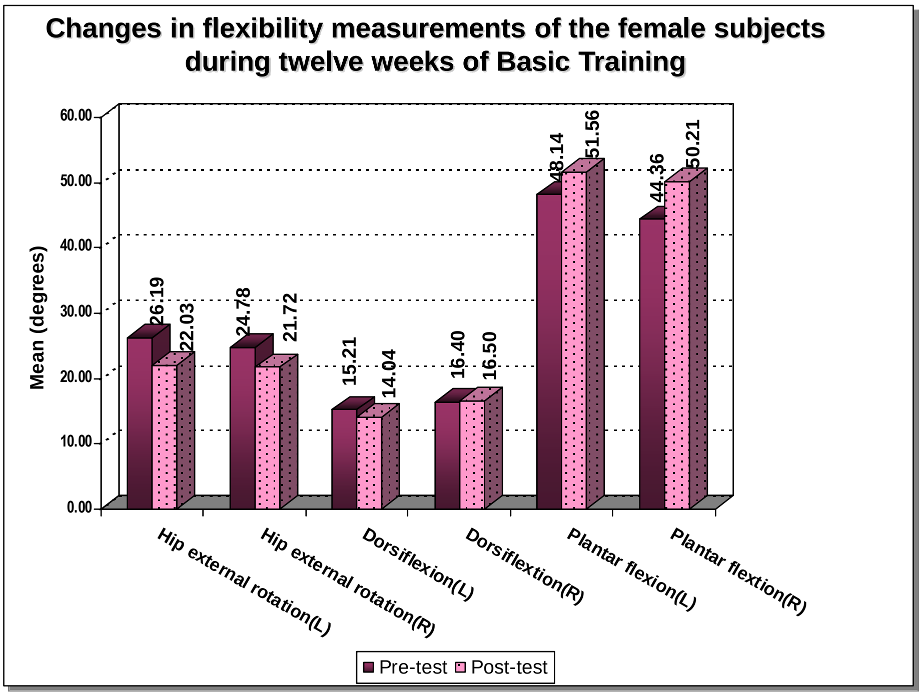

Figure 4.36: Changes in flexibility measurements of female participants during 12 weeks of BT (ankle plantarflexion, dorsiflexion and hip external rotation)

Although studies have reported prospective flexibility measures of toe touching ability to have increased during BT, there appears to be no clinical relevance

(Jones *et al.,* 1999; Kaufman *et al.,* 2000; Pope *et al.* 2000; Popovich *et al.,* 2000). Studies have found that lower extremity stretching before training does not offer a protective effect from stress fractures or reactions (Pope *et al.,* 2000; Shaffer & Uhl, 2006). Additionally, studies involving stretching concluded that pre-exercise stretching did not reduce the incidence of muscle soreness or lower extremity injuries, including stress fractures, in young active adults involved in running and marching (Yeung & Yeung, 2001; Herbert & Gabriel, 2002).

The PT Programme followed by this cohort, allowed for stretching at the end of each session. However, reasons for the difference in responses by the male and female participants, are not clear. Possibly, the vast improvement shown by the female participants in ankle plantarflexion may be attributed to the improvement in soleus strength, which assists in the plantarflexion, (see Figure 4.30). The male participants also had a smaller, but yet still significant, improvement in ankle plantarflexion strength (see Figure 4.28). Regardless of the reasons, this raises questions about the efficacy and the necessity of pre and post-exercise stretching for the prevention of lower extremity injuries, including stress fractures.

4.4.1.5 Body size and composition

Theoretically, body size and soft-tissue composition could affect stress fracture risk directly, by influencing the forces applied to the bones and, indirectly, by influencing bone density or menstrual function. Various potential risk factors related to body size and composition, have been investigated including: height, weight, skinfold thickness, Body-Mass Index (BMI), total and regional lean mass and fat mass, limb and segment lengths, body girths and widths (Brukner *et al.,* 1999).

Simple anthropometric techniques have usually been used as measurement tools, however, DEXA is being used with more frequency, despite its cost, due to its high accuracy rate dual-energy (Brukner *et al.,* 1999). In this study all participants were evaluated according to the Yuhasz (1974) method, with 70 female participants also underwent DEXA testing. The body composition results of the latter, will be discussed separately at the end of this section.

At the start of BT the anthropometric measurements showed the males participants to be taller and heavier than female participants (Table 4.16). This is similar to that reported by other military studies around the world (Jones *et al.,* 1993a; Legg & Duggan, 1996; Brock & Legg, 1997; Bell *et al.,* 2000; Lappe *et al.,* 2001; Knapik *et al.,* 2005).

Table 4.16: Means and standard deviations of selected anthropometric characteristics at the start of BT

Anthropometric Characteristics	**Pre-test**				**Post-test**			
	Males		**Females**		**Males**		**Females**	
	n	**Mean (SD)**	***N***	**Mean (SD)**	***N***	**Mean (SD)**	***n***	**Mean (SD)**
Height-cm	100	171.36 (5.86)	83	159.26(5.49)	100	171.36 (5.86)	83	159.26(5.49)
Mass-kg	100	61.78 (6.89)	83	60.22 (8.99)	100	63.18 (6.61)	83	60.04 (7.48)
Waist-Hip Ratio	100	0.78(0.04)	83	0.72(0.05)	100	0.76(0.08)	83	0.77(0.06)
Body Mass Index (kg.m^2)	100	21.43(2.16)	83	23.40(3.04)	100	22.42(2.47)	83	22.52(2.34)
Body Fat-%	100	8.72 (2.93)	83	17.33 (4.47)	100	8.15 (1.52)	83	14.92 (3.15)
Lean Mass-kg	100	56.29(5.52)	83	49.48 (5.46)	100	57.95 (6.00)	83	50.11 (5.37)
Fat Mass-kg	100	5.49 (2.39)	83	10.74 (4.27)	100	5.29 (2.29)	83	9.92 (4.76)
Endomorph component	100	2.79 (1.16)	83	5.87 (1.64)	100	2.60 (0.77)	83	5.37 (1.26)
Mesomorph component	100	3.95 (1.06)	83	3.65 (1.09)	100	4.76 (1.02)	83	4.73 (1.16)
Ectomorph component	100	3.42 (1.14)	83	1.48 (1.43)	100	3.15 (1.06)	83	1.46 (1.13)

The South African male participants were comparatively shorter (171.4 ± 5.9 cm) than research conducted on British male recruits (176.0 ± 0.08 cm), Norwegian male recruits (180.7 ± 6.4 cm) and American male recruits (175.2 ± 4.8 cm; 175.1 ± 7.3 cm) (Jones *et al.,* 1993b; Legg & Duggan, 1996; Bell *et al.,* 2000; Dyrstad *et al.,* 2006). Earlier studies conducted by Gordon *et al.* (1986a) and Jordaan and Schwellnus (1994), in the South African military, reported their recruits to be taller than the cohort studied here, documenting a mean height of 177.0 ± 6.5 cm and 178.6 ± 6.9 cm respectively. This difference may be attributed to the predominantly Caucasian sample used by Gordon *et al.,* (1986a) and Jordaan and Schwellnus (1994) compared to the current study, where the cohort was predominantly African (Steyn *et al.,* 2000).

The South African female participants were found to be of similar height and mass to other female recruits around the globe. Brock and Legg (1997) reported their British female recruits being 1.65m ± 7.1 cm tall and having a mass of 60.0 ± 7.9 kg, whilst the American female recruits were 163.3m ± 6.58 cm and 163.3m ± 6.7 cm tall and had a mass of 58.7 ± 5.76 kg and 57.8 ± 6.8 kg (Jones *et al.,* 1993a; Rauh *et al.,* 2006).

Jones *et al* (1993a) reported a stress fracture incidence of 2.3% (n=124) and 12.3% (n=186) in their male and female participants respectively, during BT. The male participants were a mean 4.14cm taller and 11.82kg heavier, whilst their female participants were 4cm taller and 1.5kg lighter than the participants of the current study. Rauh *et al.* (2006) had a 6.8% stress fracture incidence in their female recruits. Although both Jones *et al.* (1993a) and Beck *et al.* (1996) showed a risk association between stress fracture and shorter stature, this study supports the findings of studies that failed to conclude an association between stress fractures and various parameters of body size, due to the 0% incidence of stress fractures (Finestone *et al.,* 1991; Giladi *et al.,* 1991; Taimela *et al.,* 1990; Winfield *et al.,* 1997; Cline *et al.,* 1998; Shaffer *et al.,* 2006).

BMI9kg.m^2) has been both directly and inversely associated with stress fracture rates (Beck *et al.,* 1996; Zanker & Cooke, 2004). The male participants' BMI (21.43 ± 2.16) was similar to the 22.0 ± 2.1 reported by Williams (2005), the 24.3 ± 4.85 by Jones *et al.* (1993a) and the 24.8 ± 3.0 reported by Sonna *et al.* (2001). All the participants in these studies fell within the "normal" range of 18.5-24.9, as prescribed by the American College of Sport Medicine (2006). Due to the lack of stress fracture incidence in this study, it would appear that these finding do not support this inverse association as the male participants had a slightly lower BMI than Jones *at al*. (1993a) who reported a stress fracture incidence of 2.3%.

The female participants' BMI (23.40 ± 3.04) was also within the 'normal' range (American College of Sport Medicine, 2006) and similar to the 23.1 ± 3.1 reported by Sonna *et al.* (2001), the 21.7 ± 2.0 by, Rauh *et al.* (2006)and the 21.5 ± 1.9 reported by Shaffer *et al.* (2006). Rauh *et al.* (2006) reported a 6.8% stress fracture incidence and Shaffer *et al.* (2006), a 5.3% stress fracture incidence. Similar to the findings of Rauh *et al.* (2006), this study fails to support the inverse association of stress fracture incidence and BMI.

The percentage of body fat in the male (8.72 ± 2.93) and female participants (17.33 ± 4.47) was low in comparison to Irazusta *et al.* (2006), who reported 15.20 ± 5.02 and 22.50 ± 6.11 and also employed the Yuhasz's (1974) method. During the 12 weeks of BT, significant changes to most of the anthropometric measures occurred from Pre-test to Post-test (Figure 4.37). The male participants' mass (2.3%), biceps circumference (5.1%), calf circumference (2.3%) and lean body mass (2.9%) measurements showed significantly higher Post-test scores than Pre-test scores. All the changes were statistically significant at the 5% level of significance.

These findings are in support of the majority of research done on monitoring the changes in anthropometric measures during BT in militaries around the world. Adult artillery recruits, in the British Military, showed a 2.6% increase in body weight over a three month BT programme, compared to the 2.3% increase shown in the current study (Legg & Duggan, 1996). Williams (2005) also supported these findings by reporting a 1.3% and 2.9% increase in mass and a 2.7% and 4.1% increase in fat free mass in the British Army regular and Reserve Army personnel, respectively, after 12 weeks of BT. The current study showed a 2.9% increase in Lean Body Mass. Gordon *et al.* (1986a) reported a 0.7% increase in body weight and a 1.7% increase in lean body mass in the South African Defence Force after ten weeks of BT. Contrary to the above findings, Williams *et al.* (1999) reported a 1.6% loss in body mass over 10 weeks of BT with a 1.2% increase in Lean Body Mass, whilst Nindl *et al.* (2000) showed a decrease in body mass after a 62 day U.S. Army Ranger Course. BT recruits in the New Zealand military showed no change in body mass over a ten week period (Stacy *et al.,* 1982).

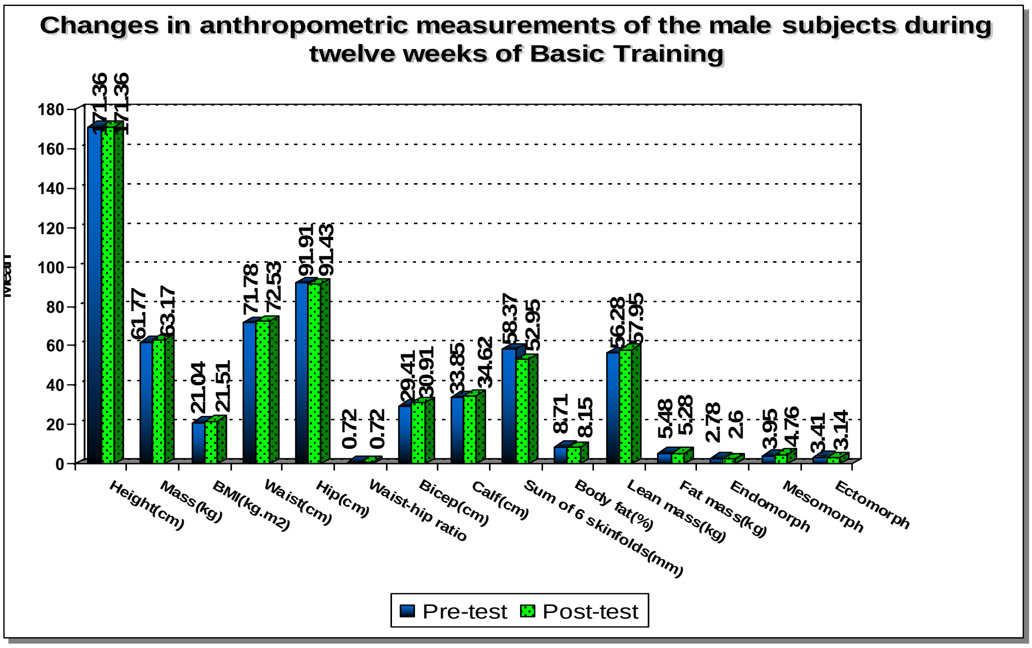

Figure 4.37: Changes in anthropometric measurements of male participants during 12 weeks of BT

The increase in FFM of 2.9% in the present study, is a positive training adaptation. This positive change may be attributed to the progressive resistance training that was included in the PT Programme. Increases in FFM of 4.1% and 1.2% for males have been reported by Sharp *et al.* (1993) and Williams *et al.* (1999), respectively, resulting from adaptations due to training programmes for BT.

The sum of skin folds (9.3) and %BF (6.5%)scores showed a statistically significant decrease in scores from Pre-test to Post-test.

These findings support work done by other researchers (Stacy *et al.,* 1982; Gordon *et al.,* 1986a; Williams *et al.,* 1999; Williams, 2005). Stacy *et al.* (1982) reported a 2.2% decrease in % BF, which is lower that the 6.5% reported by this study. This difference may be attributed to the shorter ten week BT programme followed by the New Zealand recruits or to the three-skinfold measurement technique used to measure %BF. This skinfold measurement technique may be responsible for the smaller difference observed by Gordon *et al.* (1986a), where a 4.4% decrease in %BF was observed over 12 weeks of BT with the sum of 4 skinfolds being used to calculate %BF. Williams *et al.* (1999) and Williams (2005) reported a staggering 21.7% and 10.2% decrease, respectively, after 12 weeks of BT. This sharp decrease may be attributed to the large scheduled PT time (71 periods of 40 minutes = 2,840 minutes in total; and 90 periods of 40 minutes = 3,600 minutes in total, respectively) compared to the lesser scheduled PT time for the current study (60 periods of 40 minutes = 2,400 minutes in total).

The reported percentage decrease in the sum of the 6 skinfolds is directly linked to the %BF, as this is used to calculate the %BF (MacDougall *et al.,* 1991). The male participants' fat mass, hip circumference and BMI did not change significantly from Pre- to Post-test. This supports the work by Williams (2005) who also found no significant change in BMI in regular British Army personnel (p 0.420).

Amongst the female participants, fewer statistically significant changes occurred. The mass, lean body mass, waist circumference, hip circumference and waist-hip ratio did not change significantly (Figure 4.38). This is in contrast to Brock and Legg (1997) who described a 1% increase in body mass after six weeks of BT in the British Army. Increased body mass was also observed in US female recruits after seven weeks of BT (Knapik *et al.,* 1980; Patton *et al.,* 1980).

Conversely, Williams *et al.* (1996) reported a 2.1% decrease in body mass and a 3.4% increase in Fat Free Mass (FFM) after 12 weeks of BT. The FFM increase compared favourably to the 2.3% reported by Brock and Legg (1997) and to the 1.3% increase experienced by this cohort. Surprisingly large increases in Fat Free Mass of 5.9% and 6.1% have been reported in US female BT recruits by Knapik *et al.* (1980) and Patton *et al.* (1980), respectively.

As with the male participants, significant increases in the bicep circumference (2.8%) and calf circumference (3.3%) were observed. The increases in these variables show a positive training adaptation, which may be attributed to the progressive resistance training that, was included in the PT Programme. It appears as if the training adaptation was not as successful as in the male participants, in resulting in the expected increase in lean body mass.

The sum of skin folds (16.3%) and % BF (13.9%) decreased significantly from Pre-test to Post-test. All these differences were significant at the 5% level of significance. These findings are similar to those in the male participants.

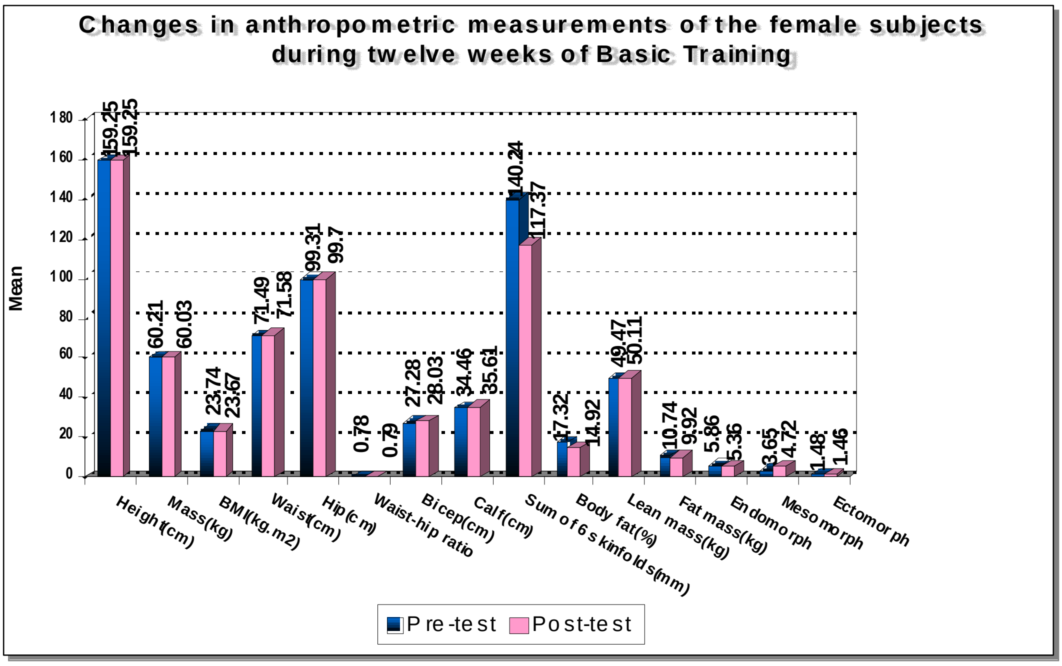

Figure 4.38: Changes in anthropometric measurements of female participants during 12 weeks of BT

The favourable change in %BF is less than the 16.8% decrease observed by Williams *et al.* (1996) in British female recruits over 12 weeks of BT, but compares well to the reported 3.3% decrease reported by Brock and Legg (1997).The comparatively small difference observed by Brock and Legg (1997) may be explained by the shorter six-week period of BT completed by these recruits. Decreased %BF was also observed for females after 7 weeks of US BT (Knapik *et al.* 1980 and Patton *et al.* 1980).

Acute weight loss was found to be a significant risk factor for stress fracture injuries in both male and female recruits (Armstrong *et al.,* 2004). In a study of 2591 Israeli soldiers, those with stress fractures weighed less than controls (Givon *et al.,* 2000). It, therefore, seems as if this cohorts' change in body mass over the 12 weeks of BT was not a risk factor for the development of stress fractures as no weight loss was observed. Contrarily, the male participants showed a significant increase in body mass, whilst the female participants remained constant throughout the BT period.

The male participants' pre-test somatotype was 2.8 - 4.0 - 3.4, following 12 weeks of BT the post-test somatotype was 2.6 – 4.8 – 3.1. This showed a favourable adaptation in all three categories with the endomorph component decreasing significantly ($p \leq 0.05$) by 6.8%, the mesomorph component increasing significantly ($p \leq 0.05$) by 20.5% and the ectomorph component decreasing significantly ($p \leq 0.05$) by 8.9%.

The somatotype changes in the male participants in the present study respresent a positive training adaptation which may be attributed to the progressive resistance and cardiorespriratory training components included in the PT Programme. Additionally, the decrease observed in the endomorph components may be attributed to the decrease observed in the %BF (MacDougall *et al.,* 1991). Whilst the decrease in the ectomorph components may be explained by the large increase in the mesomorph component and significant increases in bicep and calf circumferences (MacDougall *et al.,* 1991).

The female participants' pre-test somatotype was 5.9 – 3.7 – 1.5, whist the post-test revealed a 5.4 – 4.7 – 1.5 somatotype. This showed some favourable adaptation with the endomorph component decreasing significantly ($p \leq 0.05$) by 8.5%, the mesomorph component increasing significantly ($p \leq 0.05$) by 29.3% and the ectomorph component showing no change ($p = 0.7$).

The changes observed in the female participants are similar to those in the male participants, however, no decrease was observed in the ectomorph component, which may be explained by the small increase in lean body mass and the small decrease observed in fat mass.

Figure 4.39 shows the changes that occurred in the cohorts' somatotype over the 12 weeks of BT. Both the male and female participants showed a statistically significant increase from Pre-test to Post-test in their Y-axis value, whilst the female participants showed a statistically significant decrease and the male participants experienced no significant changes in their X-axis value.

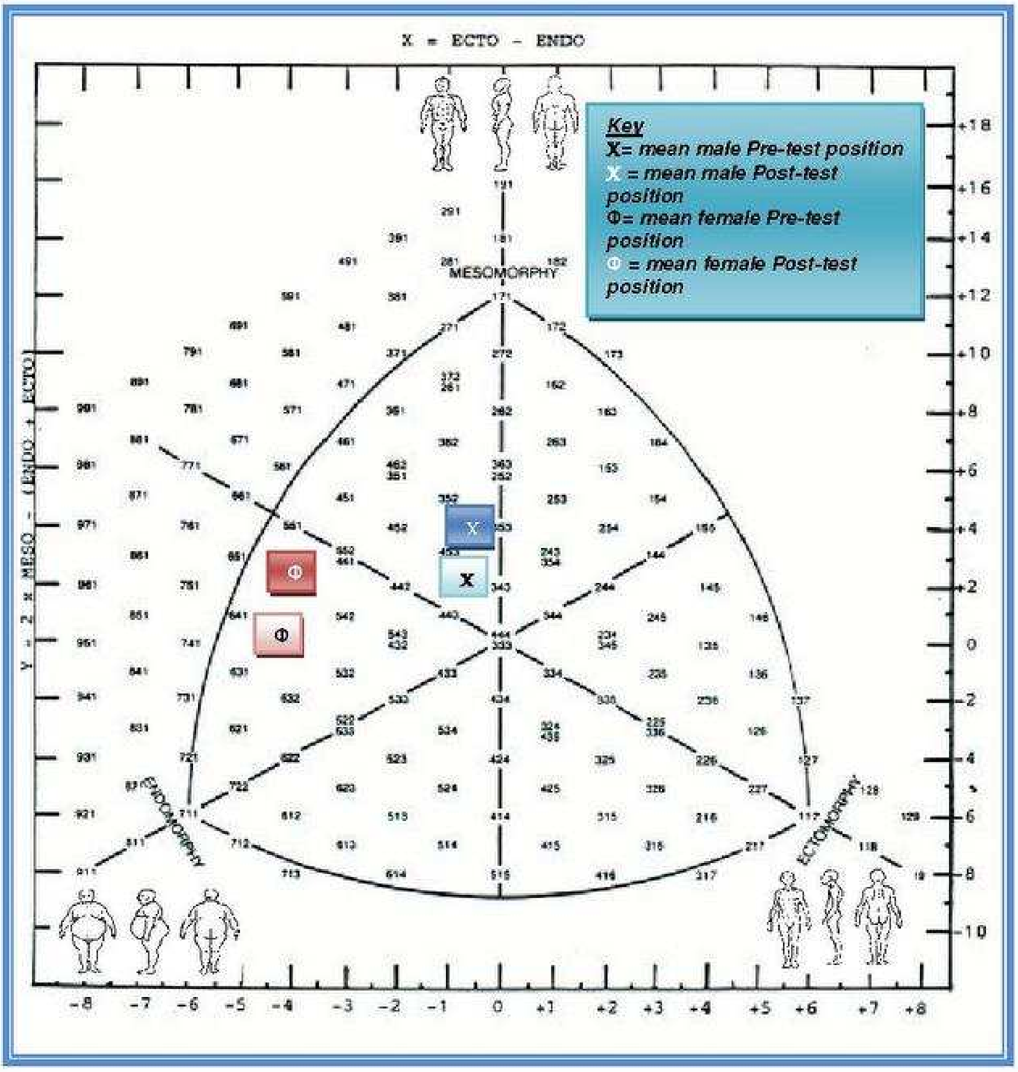

Figure 4.39: Dimensional representation of the somatotype changes in the male and female participants during 12 weeks of BT (Adapted from Carter, 2002)

In summary, the anthropometric changes during training were positive, although favourable changes were more prominent in the male recruits. Some changes, specifically in the female participants, although still positive, were of a lesser magnitude than has been shown to be possible during a training programme of similar length.

4.4.1.5.1 Dual-energy X-ray absorptometry assessed changes in body size and composition

DEXA has been shown to provide accurate estimates on BMC and BMD (Ellis & Shypailo, 1998). DEXA is highly precise and is used as a valid technique for body composition assessment in healthy young participants (Mazess *et al.,* 1990; Snead *et al.,* 1993; Kohrt, 1998; Pietrobelli *et al.,* 1998; Ellis & Shypailo, 1998; Prior *et al.,* 1997; Houtkooper *et al.,* 2000; Taylor *et al.,* 2002). Even though values may differ, based on the DEXA instrumentation, these differences are small (Tothill *et al.,* 1994; Kistorp & Svendsen, 1997; Ellis & Shypailo, 1998; Schoeller *et al.,* 2005).

In this study, DEXA measurements were done primarily to ascertain the BMD and BMC of the 70 female participants which were originaly selected, and the 68 who completed the BT, as discussed in Chapter 3. DEXA also provides a measure of total-body bone mineral mass, bone-free lean tissue, and fat mass thereby yielding a three-compartment model of body composition (Kohrt, 1998; Mattila *et al.,* 2007). Few studies have used DEXA to measure body composition on military recruits and only Knapik *et al.* (2001) included female recruits in their study (Knapik *et al.,* 2001; Lintsi *et al.,* 2004; Mattila *et al.,* 2007). The results are presented in kilograms for total body mass, grams for LBM and fat mass, and as percentage for BF. The DEXA assessed changes of regional body composition, of the female participants over 12 weeks of BT, are outlined in Table 4.17.

Table 4.17: Dual-energy X-ray absorptiometry assessed changes of regional body composition, of the female participants over 12 weeks of BT

Body Region	**Total Soft Tissue Mass (g)**		**Percent Tissue Fat (%)**		**Fat Mass(g)**		**Lean Mass(g)**	
	Difference	% △	Difference	% △	Difference	% △	Difference	% △
Total body	843.16	1.49	-4.11	-11.03*	-2224.58	-10.31*	3067.60	8.74*
Left side	153.75	0.54	-4.04	-10.85*	-1186.68	-10.93*	1340.46	7.59*
Right side	689.42	2.45*	-4.16	-11.17*	-1037.77	-9.68*	1727.24	9.90*
Trunk	-4.66	-0.02	-6.12	-16.53*	-1630.70	-17.02*	1626.08	10.38*
Left	-19.61	-0.16	-6.10	-16.49*	-816.12	-17.11*	796.54	10.20*
Right	23.60	0.19	-6.12	-16.53*	-814.72	-16.94*	829.48	10.55*
Legs	755.33	3.45*	-2.11	-4.99*	-222.81	-2.36	978.24	7.87
Left	302.29	2.73*	-2.09	-4.95*	254.92	5.34	440.46	7.00
Right	457.05	4.23*	-2.13	-5.04*	-36.55	-0.79	1335.06	21.76
Arms	156.08	2.76	-5.34	-17.44*	-290.53	-16.20*	446.67	11.56*
Left	6.36	0.22	-5.35	-17.48*	-168.44	-18.20*	175.05	8.83*
Right	149.67	5.45*	-5.35	-17.46*	-122.19	-14.07*	271.88	14.47*

Values are mean differences between Pre-test and Post-test and % change that was observed in 68 female participants.

* Significant change from the Pre-test to the Post-test at the end of 12 weeks of BT. p≤0.05.

The DEXA assessed total body mass, as reflected in Figure 4.40, did not increase significantly from Pre-test (59.14kg) to Post-test (59.96kg). Knapik *et al.* (2001) did not report changes in body mass as their major purpose of their investigation was to "…*examine associations between injuries and physical fitness with special attention to physiological measures of aerobic capacity, body composition, and muscle strength."* (Knapik *et al.,* 2001: 947). However, their female BT recruits were a mean 3.1kg heavier than those measured by DEXA in this study.

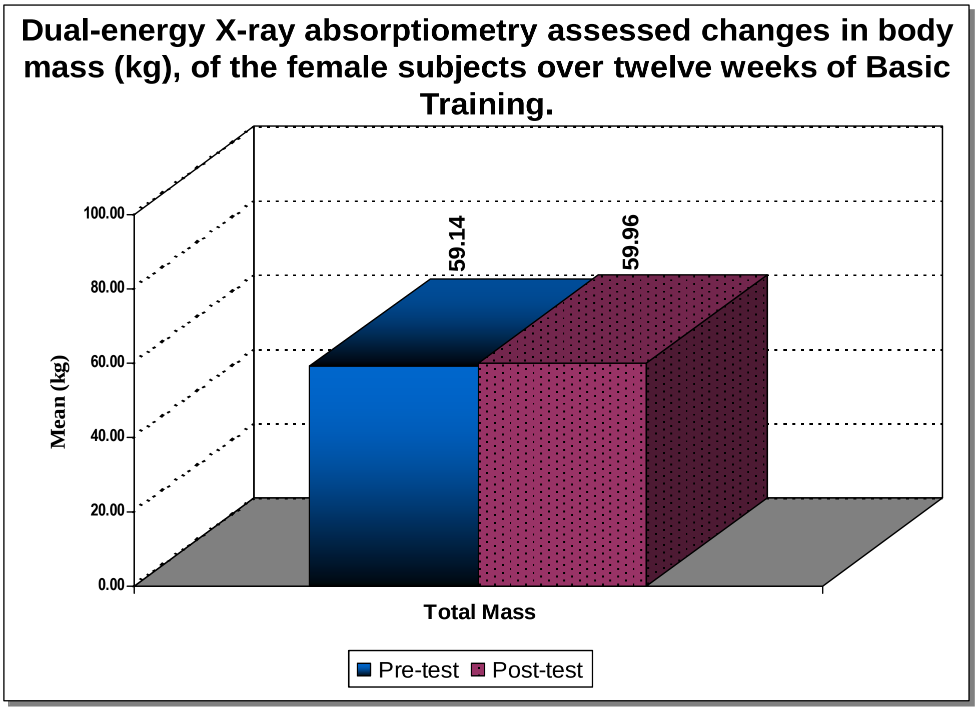

Figure 4.40: Dual-energy X-ray absorptiometry assessed changes in body mass (kg), of female participants over 12 weeks of BT.

The slight increase in total body mass supports findings by other researchers who used more traditional methods of assessing body mass and who also reported an increase in body mass (Knapik *et al.,* 1980; Patton *et al.,* 1980; Brock & Legg, 1997).

Changes in the whole body and regional total soft tissue mass over the 12 weeks of BT are given in Figure 4.41 and outlined in Table 4.16. Total soft tissue mass is the mass of the whole body's body tissue excluding the bone, teeth, nails, hair and cartilage mass (Stedman's Medical Dictionary, 2000).

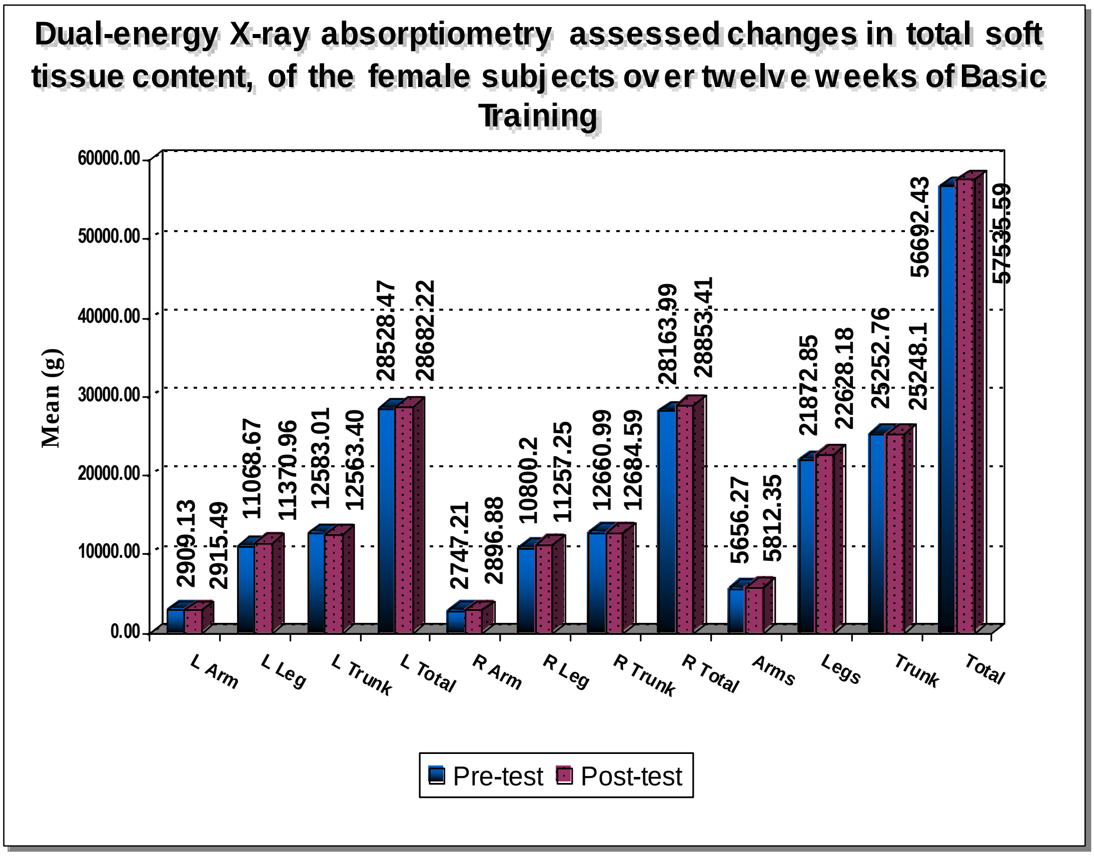

Figure 4.41: Dual-energy X-ray absorptiometry assessed changes in total soft tissue content, of female participants over 12 weeks of BT (arm, leg, trunk and total body region)

Significant increases, at the 5% level of significance, were observed in the left leg (302.29g: 2.73%), right leg (457.05g: 4.23%) and total leg (755.33g: 3.45%) measurements as well as in the right arm (149.67g: 5.45%) and total right tissue (689.42g: 2.45%), measurements. The total arm measurements (156.08g: 2.76%), as well as the total soft tissue measurements (843.16g: 1.49%) did not increase significantly. The increase observed in the leg area is similar to the significant increase (0.8g: 3.8%) reported by Nindl *et al.* (2000) in 31 civilian women after six months of periodised PT.

Soft-tissue composition of the total body and major sub-regions were measured with DEXA. Figure 4.41 reflects the changes that took place in the percent fat of the tissues in the different body regions. The results of the T-test indicate that statistically significant differences were found between Pre- and Post-test measurements for all measurements taken. All these differences were significant at the 5% level of significance. There was a favourable change in all the body regions in tissue percent fat, as the Post-test scores were significantly lower than Pre-test scores.

Due to conflicting data on associations between injuries and body composition as estimated by BMI or skinfolds, Knapik *et al.* (2001) tried to clarify the relationship by assessing body composition with DEXA (Macera *et al.,* 1989; Jones *et al.,* 1992; Jones *et al.,* 1993b; Heir & Eide, 1997). Unfortunately, Knapik *et al.* (2001) did not distinguish the type of injury and did not specify if the injuries reported included stress fractures, among their male and female BT cohort. They did, however, suggest that "…*body fat measured with DEXA demonstrated only a weak association with injury."* (Knapik *et al.,* 2001: 950).

According to Sonna *et al.* (2001), the mean percent body fat by DEXA (±SD) of 85 female Army recruits at the start of an eight-week BT course, was 27.9 ± 6.1, which was much lower than the 37.71 ± 7.39 measured in the 68 female recruits assessed by DEXA in this study. Unfortunately, Sonna *et al.* (2001) did not report the changes that occurred in percent body fat after their eight-week BT course. Although no studies have reported DEXA assessed changes in tissue percent fat in female military recruits, the findings support studies that have shown that intensive military training is effective in reducing total body fat as measured by two-compartment models, namely skinfold thickness measurement and bioimpedance (Knapik *et al.,* 1980; Patton *et al.,* 1980; Williams *et al.,* 1996; Brock & Legg, 1997).

Additionally, Nindl *et al.* (2000) reported a 2.7% decrease in total body adiposity compared to the 11.3% decrease observed in this study. This study showed that, before training, the legs had the greatest relative adiposity (11.51%), followed by the arms (11.40%) and trunk (10.09%) whilst in the Nindl *et al.* (2000) study, before training, the arms had the greatest relative adiposity (40.0%), followed by the legs (34.4%) and trunk (33.8%). After 12 weeks of BT, the female participants' difference was greater when comparing their relative leg adiposity (13.30%) to that of the trunk (10.24%) and the arms (8.38%).

Changes in % BF, fat tissue content and lean mass are shown in Figure 4.42, 4.43 and Figure 4.44. The left, right and total leg fat tissue content measurements where the only three measurements that did not show a statistically significant decrease from Pre-test to Post-test. The other regions experienced statistically significant soft tissue fat decreases during 12 weeks of BT. The trunk region experienced the largest decrease in fat tissue content showing a 17.02% decrease followed by the arm region with 16.20%. The leg region showed a non-significant increase in fat tissue content. These findings can be compared to the female, non-military, older participants in a Nindl *et al.* (2000) six month study that reported that their participants' arms exhibited the largest loss (30.8%), followed by the trunk (11.6%) and no changes in the leg region.

Nindl *et al.* (2000) highlighted the fact that few studies are available in the literature that document concomitant upper body, lower body and truncal changes in soft tissue fat and lean mass after longitudinal training. Their study thus shows the importance of considering regional body composition changes rather that whole body changes alone.

The progressive training programme followed by this cohort included both aerobic and resistance exercises, performed five days per week, that were efficacious in reducing the total body adiposity and regional adiposity of the truncal and arm regions – with the Nindl *et al.* (2000) training programme – however, very little mobilization of the fat stores was observed in the leg region.

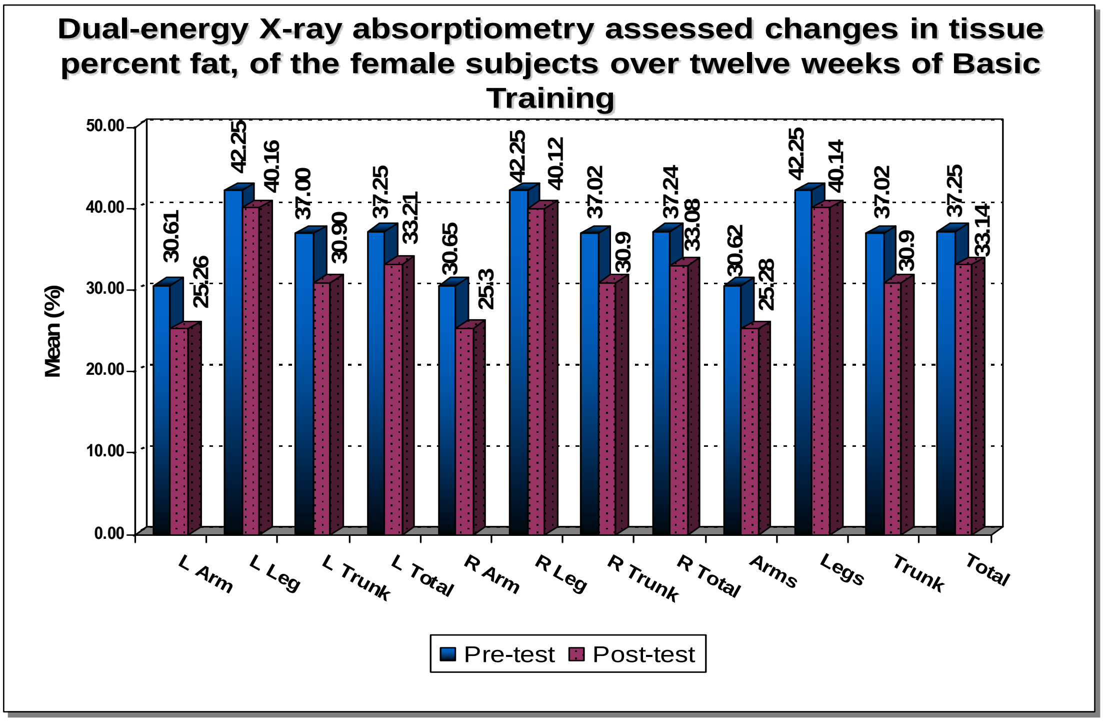

Figure 4.42: Dual-energy X-ray absorptiometry assessed changes in tissue percent fat, of female participants over 12 weeks of BT (arm, leg, trunk and total body region)

A prominent resistance of thigh fat to mobilization and utilization has been reported in the literature (Smith *et al.,* 1979; Rognum *et al.,* 1982; Nindl *et al.,* 2000). Reasons for this resistance have included lipoprotein lipase activity, local blood flow, receptor agonist-to-antagonist ratio, sympathetic nervous stimulation, tissue morphology and lipolytic responsiveness to endocrine stimuli (Smith *et al.,* 1979; Rognum *et al.,* 1982; Leibel *et al.*, 1989; Nindl *et al.,* 2000). The fat mobilization, for this study, was the same as Nindl *et al.* (2000): arm>trunk>legs compared to that documented for males: namely: trunk>arms>legs (Friedl *et al.,* 1993; Nindl *et al.,* 1996).

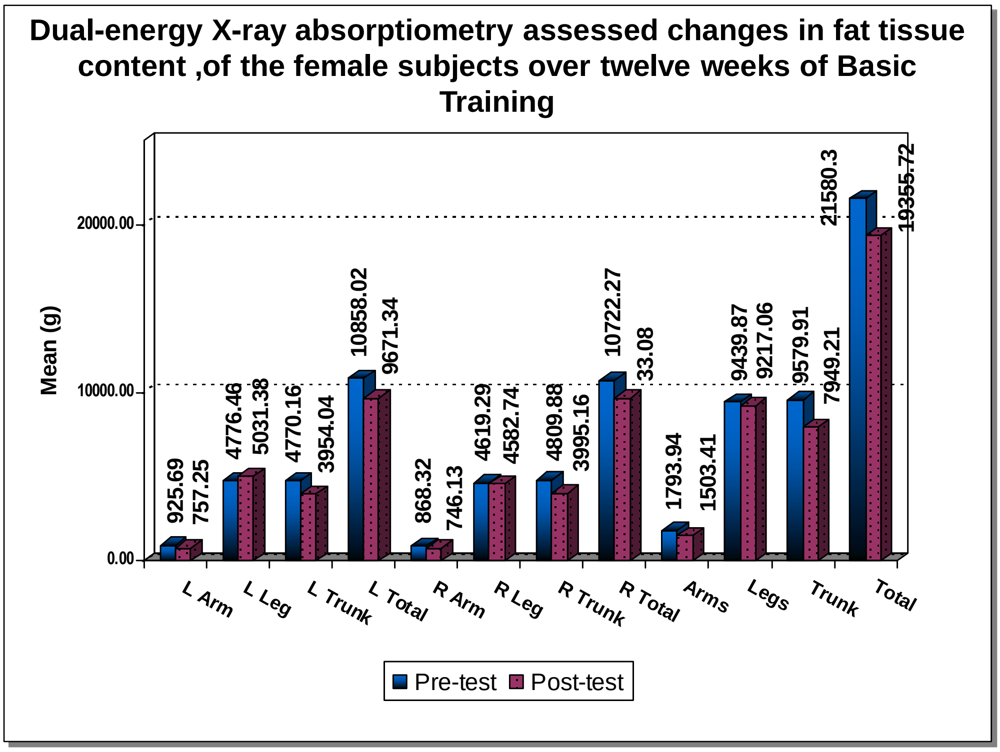

Figure 4.43: Dual-energy X-ray absorptiometry assessed changes in fat tissue content, of female participants over 12 weeks of BT (arm, leg, trunk and total body region)

An overall 8.74% increase in whole body soft tissue lean mass reflects the positive change that was evident in soft tissue lean mass of all the body regions. All but one of the soft tissue lean mass measurements showed statistically significant increases, which were significant at the 5% level of significance, whilst although the soft tissue lean mass of the right leg showed an increase, this change was not significant. Nindl *et al.* (2000) reported smaller, yet significant, gains in soft tissue lean mass - 3.8% between weeks 0 and 14, 1.8% between weeks 14 and 24, and an overall increase of 0.7kg or 5.5% after six months of periodised training.

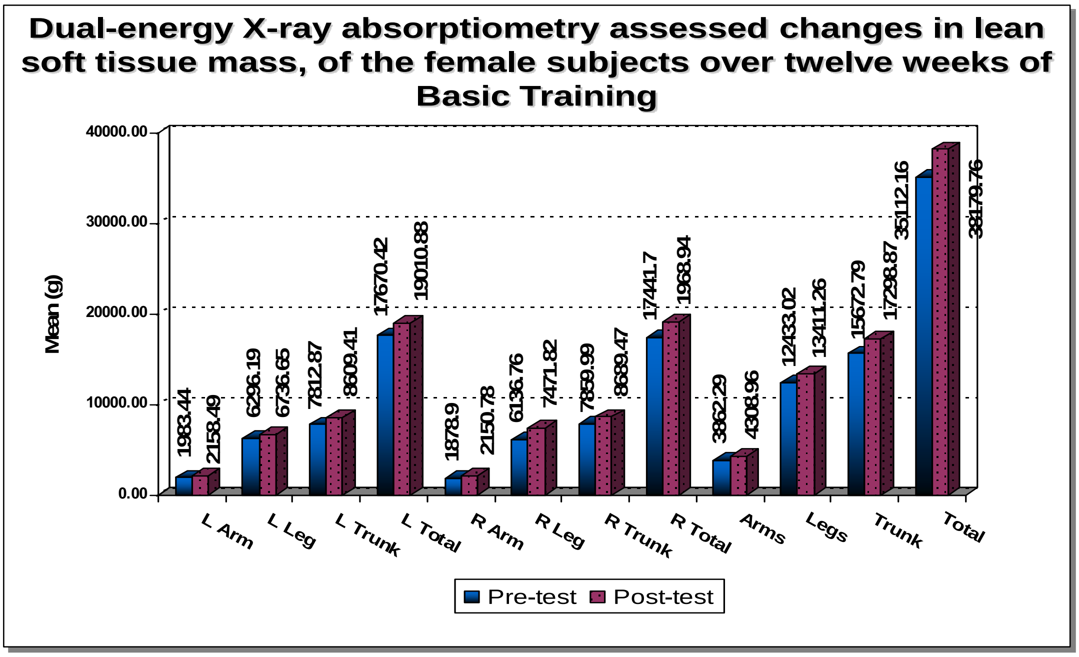

Figure 4.44: Dual-energy X-ray absorptiometry assessed changes in lean soft tissue mass, of female participants over 12 weeks of BT (arm, leg, trunk and total body region).

As the Knapik *et al.* (2001) study is the only known study to have assessed body composition by means of DEXA on military female recruits, it is not possible to directly compare the results. However, the gains shown in this study, support the increases reported (2.3%-6.1%) by other studies on female military recruits during BT, who used the skinfold method to assess lean body mass (Knapik *et al.,* 1980; Patton *et al.,* 1980; Williams *et al.,*1996; Brock & Legg, 1997).

4.4.1.6 Resting blood pressure

This study found that both the male and female participants showed a statistically significant decrease in Systolic and Diastolic resting blood pressure measurements (Figure 4.45). These changes were also significant at the 5% level of significance. A decrease in Systolic Blood Pressure (SBP) (pre - 126.2 ± 3.3 mmHg, post - 111.3 ± 3.5 mmHg) and Diastolic Blood Pressure (DBP) (pre -

76.7± 3.2 mmHg, post - 66.9 ± 2.7 mmHg) was also reported by Jouanin *et al.* (2004) in military recruits following a five week, physically and psychologically challenging, Ranger course.

This is in contrast to the findings by Clarkson *et al.* (1999) who reported that after ten-weeks of BT, 35 British male recruits' Supine Systolic (pre - 119 ± 12 mmHg, post - 120 ± 10 mmHg) and Diastolic Blood Pressure (pre - 72 ± 12 mmHg, post - 73 ± 10 mmHg) remained unchanged.

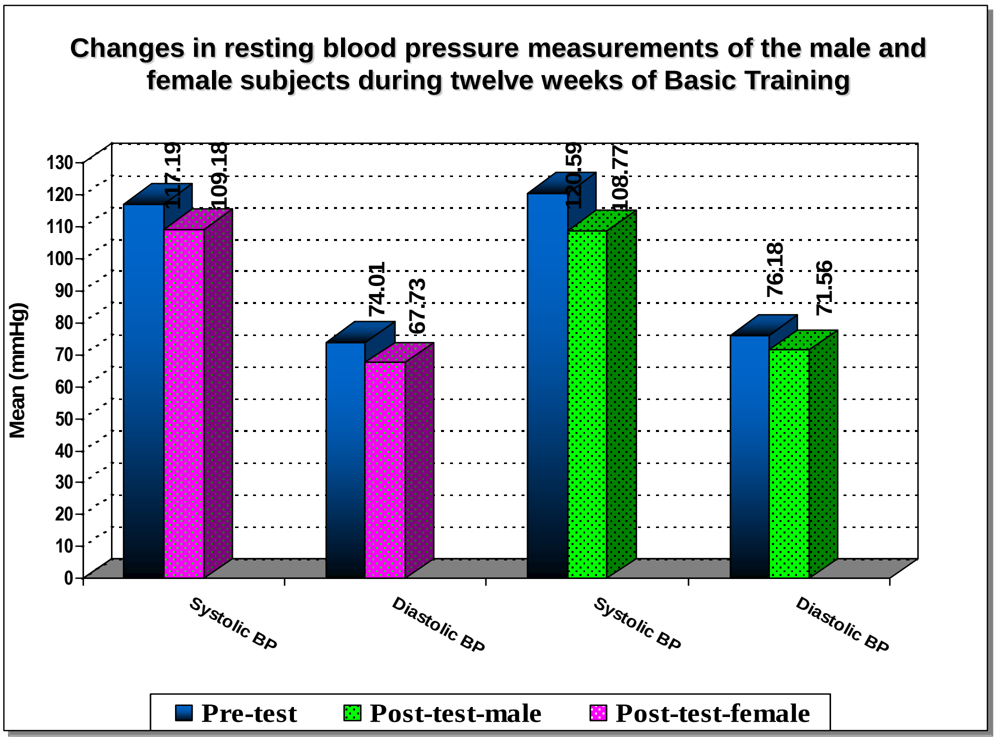

Figure 4.45: Changes in resting blood pressure measurements of male and female participants during 12 weeks of BT

4.4.1.7 Menstrual disturbances

4.4.1.7.1 Sexual hormones

Researchers have reported that stress fractures may be more frequent in female athletes with menstrual disturbances and that menstrual disturbances may also predispose female recruits to stress fractures (Nattiv *et al.,* 1997; Brukner *et al.,* 1999). For this reason, all 83 female participants were requested to complete a questionnaire which provided detailed insight into their menstrual history prior to BT, as well as identifying any changes which may have occurred during the initial part of BT (in the fifth week) (Appendix C).

This questionnaire was developed by the author and included questions pertaining to the onset of menarche, regularity of menstrual cycle, incidence of changes and nature of change in menstrual cycle, as well as the use of female contraception. The questionnaire was repeated at the end of the 12-week BT period. On reviewing literature, it was found that most studies assessing menstrual history and menstrual changes, within the military environment, had the investigators developing their own questionnaires (Winfield *et al.,* 1997; Cline *et al.,* 1998; Lappe *et al.,* 2001; Schneider *et al.,* 2003; Bemben *et al.,* 2004; Armstrong *et al.,* 2004; Rauh *et al.*, 2005; Rauh *et al.,* 2006; Shaffer *et al.,* 2006).

The complete results of this analysis can be found in Appendix Copy Disk - F.

4.4.1.7.2 Menstrual history

The complete results of this section of the menstrual history questionnaire can be found in Tables 7 - 19 in Appendix Copy Disk - F. Table 4.18 below, portrays the regularity of participants' menstrual cycle. The results indicated that most of the participants (70.7%) perceived their menstrual cycles to be very regular. A further 19.5% perceived it to be somewhat regular, with only 9.8% indicating that it was very irregular. The last may be extrapolated to having less than 10 menses per year, which has been linked to an increased risk of stress fracture development.

Table 4.18: Regularity of menstrual cycle

Menstrual cycle regularity	Frequency	%	Valid %	Cumulative %
Very regular (within 3 days)	58	69.9	70.7	70.7
Somewhat irregular (4-10 day variation)	16	19.3	19.5	90.2
Very irregular (variation > 10 days)	8	9.6	9.8	100.0
Total	82	98.8	100.0	
Missing System	1	1.2		
Total	83	100.0		

In a study of 101 female Marines, the incidence of stress fractures in those with fewer than 10 periods per year, was 37.5% compared to 6.7% in those with 10 to 13 periods per year (Winfield *et al.,* 1997). Similar results, that suggest a history of amenorrhea is a risk factor for stress fractures, support these findings (Friedl *et al.,* 1992, Rauh *et al.*, 2005; Rauh *et al.,* 2006; Shaffer *et al.,* 2006). Shaffer *et al.* (2006) did, however, suggest that only the women who reported no menses during the whole year before commencing with BT, had a greater likelihood of stress fractures than the women who reported 10 - 12 menses.

Only 3.6% reported having experienced their last period earlier than a year before the commencement of BT. They also found that, female recruits who reported secondary amenorrhea during the year before training, were at higher risk for pelvic or femoral stress fractures. It suggests that prolonged lack of menses may be a better predictor of stress fracture incidence during a structured military training programme (Rauh *et al.,* 2006). Conversely, Kelly *et al.* (2000) found no association between secondary amenorrhea and pelvic stress fractures in navy recruits. Cline *et al.* (1998) also found that the menstrual patterns did not differ in a study of 49 female soldiers with stress fractures, compared to the 78 soldiers, with no orthopaedic injuries, although the number of soldiers with menstrual disturbances was relatively low.

The cause for the above may be attributed to lowered estrogen levels, resulting in lower bone density, accelerated bone remodeling or negative calcium balance, or the interaction of these variables. Further research should be conducted where calcium turnover within the blood is evaluated (Drinkwater *et al.,* 1984; Rutherford, 1993; Micklesfield *et al.,* 1995; Tomten *et al.,* 1998). As no stress fracture incidence was reported in this cohort, this study cannot support the above research conversely nor can it support findings by Cline *et al.* (1998).

During the Post-test completed at the end of the twelfth week of training, slightly more participants (15.7%) indicated that their menstrual cycle was very irregular (Appendix Copy Disk - F Table 16). This is similar to findings in both military populations and military cohorts who participate in an intense PT programme (Sanborn *et al.,* 1987; Cokkinades *et al.,* 1990; Cline *et al.,* 1998; Schneider *et al.,* 2003; Bemben *et al.,* 2004).

Similar to that in already published literature, the majority of participants (80.5%) indicated that they experienced changes in their menstrual cycles during BT. The nature of these changes is depicted in Table 4.19.

More than half (61.2%) indicated that their cycle became shorter, with a third (34.4%) indicating that they had developed oligomenorrhea (they could not be considered as having amenorrhea, as menstruation did not stop for six months or more) (Stedman's Medical Dictionary, 2000). Only 12.2% of participants indicated that they were without a menstrual cycle for three months or more, but the exact length of time was not recorded.

Table 4.19: Nature of changes in menstrual period during BT

Nature of change		Frequency	%	Valid %	Cumulative %
Longer		3	3.6	4.5	4.5
Shorter		41	49.4	61.2	65.7
Absent		23	27.7	34.3	100.0
Total		67	80.7	100.0	
Missing	System	16	19.3		
Total		83	100.0		

Although the use of contraceptive pills has been recorded and discussed as a lifestyle behaviour, it is fitting that it be discussed under this section. Very few of the participants (13.3%) indicated that they were using birth control or hormonal pills. This is compared to similarly aged (18.5±0.17) United States Naval Trainees reporting for BT, where 26.92% reported using female contraception (Armstrong *et al.,* 2004). Of the 824 women completing Marine Corps BT at Parris Island in 1999, Rauh *et al.* (2006) reported that 33.25% were making use of contraceptive medication. Due to the low incidence of contraction usage by this cohort, as well as no stress fractures having been reported during BT, it appears as if this study supports the work of those that have failed to associate a protective effect between birth control hormone use and the incidence of stress fractures (Bennell *et al.,* 1996; Cline *et al.,* 1998; Rauh *et al.,* 2006; Shaffer *et al.,* 2006). However, this should be investigated further in a cohort where the use of female contraception and the type of female contraception used is compared to stress fracture cases and non-stress fracture cases.

4.4.1.7.3 Chronological age at menarche onset

All the participants indicated that they had a menstrual cycle. Table 4.20 indicates that 68.3% of the participants had their first menstrual period by the age of 14. All the participants had their first menstrual cycle by the age of 19 years. All but 3 participants had their last period within the year of being tested. Rauh *et al.* (2006) reported that 96.35% of their cohort reached age of menache before the age of 16 years. It appears that this study's cohort reached age of menache later than those reported on the United States Military by Lappe *et al. (*2001) (12.6 ±1.6) and Shaffer *et al.* (2006) (12.9 ±1.4).

Table 4.20: Chronological age of menarche onset in female cohort undergoing 12 weeks of BT

Age (years)	***Frequency***	***%***	***Valid %***	***Cumulative %***
11	5	6.0	6.1	6.1
12	6	7.2	7.3	13.4
13	21	25.3	25.6	39.0
14	24	28.9	29.3	68.3
15	15	18.1	18.3	86.6
16	7	8.4	8.5	95.1
17	1	1.2	1.2	96.3
18	2	2.4	2.4	98.8
19	1	1.2	1.2	100.0
Total	82	98.8	100.0	
Missing on the system	1	1.2		
Total	83	100.0		

The relationship between chronological age at menarche onset and risk of stress fracture is unclear. Some authors have found that athletes with stress fractures have a later chronological age of menarche onset (Carbon *et al.,* 1990; Bennell *et al.,* 1996), while others have found no difference (Myburgh *et al.,* 1990; Armstrong *et al.,* 2004).

An association between delayed onset of menarche and stress fractures may be explained by a lower rate of bone mineral accretion during adolescence and a resultant decrease in peak bone mass (Brukner *et al.,* 1999). A later onset of menarche has also been found in association with menstrual disturbance, decreased body fat or bodyweight, lowered energy intake, and excessive pre-menarcheal training (Frisch *et al.,* 1981; Moisan *et al.,* 1990). All of these could feasibly influence stress fracture risk (Brukner *et al.,* 1999). As with the use of female contraception, this should be investigated further in a cohort where the onset of menarche is compared in stress fracture cases with the onset of menarche in non-stress fracture cases.

4.4.1.8 Health risk behaviours

Questionnaires have been used to study associations of injury risks with lifestyle behaviours and habits among military populations (Heir & Eide, 1997; Jones *et al.,* 1999; Popovich *et al.,* 1999; Lappe *et al.,* 2001). These lifestyle behaviours and habits include smoking, alcohol, history of previous injury, level of previous physical activity and the use of female contraception. The latter two have already been discussed under section 4.4.1.4.1 and 4.4.1.5.1.1, respectively. The others will be discussed in the section below.

4.4.1.8.1 Smoking

Tobacco smoking is a behavioural health risk factor reported to be associated with higher risks of injury amongst military recruits. The complete results of this section of the physical activity and medical history questionnaire, can be found in Tables 17 and 18 in Appendix Copy Disk - H.

Smoking was not a common habit of this population (14.1%), when compared to the 42% of men and 40% of women reporting for BT at Fort Jackson in South Carolina, USA (Altarac *et al.,* 2000). Of the 14.1% that reported to be smokers, only 7.7% indicated that they smoked more than 20 cigarettes per day. Trent *et al.* (2007) studied the pre-military tobacco use of 15,689 male Marine Corps recruits (mean age - 19.5years) and found that 41% were smokers.

When this cohorts' smoking percentage is compared to data available on the prevalence of smoking in South Africa, it is still below the reported 33.6% in 1993, 24.0% in 1998, 27.1% in 2000 and 8.4% (female) and 31.1% (male) in South Africans in 2003 (van Walbeek, 2000). Possible reasons for this could be that 93.5% of this cohort was African and according to van Walbeek (2000) smoking prevalence amongst Africans is much lower, decreasing from 28.1% in 1993 to 22.7% in 1998. Thus smoking prevalence amongst Africans is relatively low and is decreasing at a significant rate. Additionally, smoking prevalence amongst young adults (people aged 16 - 24) is significantly lower than the national average and also shows encouraging decreasing trends (van Walbeek, 2000).

Both current and past histories of smoking have been found to increase the risk of stress fractures, training-related injuries and osteoporotic hip fractures in military female recruits, with the relative risk increasing with increasing packs per day and increased years of smoking (Lappe *et al.,* 2001). These findings were supported by other military studies (Williams *et al.,* 1982; Friedl *et al.,* 1992; Jones *et al.,* 1993b; Grisso *et al.,* 1994; Reynolds *et al.,* 1994; Cummings *et al.,* 1995; Altarac *et al.,* 2000). Since both osteoporotic hip fractures and stress fractures are fragility fractures - they occur during activities which most participants complete without fracturing - it is plausible that smoking might also increase the risk of stress fractures (Lappe *et al.,* 2001). This aspect should be investigated further in a cohort where prevalence of smoking is compared in stress fracture cases to those in non-stress fracture cases.

4.4.1.8.2 Alcohol

A shortcoming of this study was that drinking habits were not included in the Medical History Questionnaire. Long-term excessive alcohol intake has been associated with low bone mass and fragility fractures (Johnell *et al.,* 1982; Felson *et al.,* 1988; Hemenway *et al.,* 1988; Diamond *et al.,* 1989; Seeman, 1996; Lappe *et al.,* 2001). It is also well established that alcohol abuse confers a high risk for fragility fractures, although this risk is said to be more pronounced in men than in women (Johnell *et al.,* 1982; Hemenway *et al.,* 1988; Seeman, 1996). In female recruits on BT, excessive alcohol intake was associated with stress fractures even when controlled for smoking (although the relative risk was much less than the unadjusted risk) (Lappe *et al.,* 2001). Alcoholism has been associated with a number of factors known to increase the risk for osteoporotic fractures, namely: liver disease, poor nutrition, malabsorption, parathyroid dysfunction, hypogonadism, vitamin D deficiency, sub-optimal nutrition and increased cortisol output (Carter *et al.,* 1981). Additional, a study investigating the direct effect of ethanol on bone formation found that excessive alcohol consumption decreases bone formation and leads to defective mineralization (Diamond *et al.,* 1989).

In the current study it was decided that nutritional habits, including alcohol consumption would be excluded. It should however be investigated further within the South African military context, especially considering that in Africa, beer consumption in 15-year-olds rose six-fold between 1961 and 1981 (Oxorio, 1992). Authors have emphasized the enormous ill-health cost and suffering and the likelihood of alcohol consumption rising further, especially among urban dwellers (Seftel, 1985; Walker, 2002).

4.4.1.8.3 Medical history of previous injury

The complete statistical results of the medical history can be found in Appendix Copy Disk - H, Tables 3 -18. None of the participants indicated that they had a history of cholesterol, anemia, high blood pressure, gout or low bone density. The latter was far less than the 9.8% reported by Kelly *et al.* (2000) in their cohort of 86 female recruits entering into BT. One participant indicated that he suffered from Diabetes Mellitus and two participants indicated that they suffered from fatigue. Only 9.8% of participants reported the prevalence of allergies. Popovich *et al.* (2000) also used a Health and Physical Activity Questionnaire, however, did not report on any findings, except for their smoking history reported under 4.4.1.8.1.

The participants were also asked to recall their weight history and reason, if any, for a change in weight. The majority (80.9%) of participants reported that they maintained their weight. Reported reasons for a change in weight included increased food intake, smoking cessation, stopping exercise, increasing exercise volume, stress and the festive holiday period.

A small percentage (7.6%) reported suffering from muscle cramps and the treatment listed included, heat balm, anti-inflammatory medication, drinking water and the local application of ice packs.

The majority of participants indicated that they had no history of previous injuries (93.5%). The incidence and the area of incidence are outlined in Table 4.21. The cohort also reported that the majority (79.9%) had not made use of over-the-counter medicine as well as other prescription medicines (94.4%). Of the 21.1% who had made use of over the counter medicine, most indicated that they had used laxatives.

As studies of risk factors for injury among athletes have shown prior injury to be related to subsequent injury, this is important to document and should be investigated further in a cohort with a stress fracture incidence (Milgrom *et al.,* 1985; Giladi *et al.,* 1986; Macera *et al.,* 1989; Ross & Woodward, 1994; Shaffer *et al.,* 1999b; Rauh *et al.,* 2000; Rauh *et al.,* 2006; Shaffer *et al.,* 2006).

Table 4.21: Previous history of the incidence and area of injury prior to the start of BT

Incidence & area of injury	Frequency	%	Valid %	Cumulative %
None	172	**93.5**	93.5	93.5
Ankle	2	**1.1**	1.1	94.6
Knee	6	**3.3**	3.3	97.8
Arm	1	**0.5**	0.5	98.4
Back	2	**1.1**	1.1	99.5
Neck	1	**0.5**	0.5	100.0
Total	184	100.0	100.0	

This is crucial, especially as other studies have shown no association between lower-extremity injury and stress fractures or non-stress fracture overuse injury during BT (Rauh *et al.,* 2006; Shaffer *et al.,* 2006). Authors speculate that the difference in findings may be related to the severity of the previous injury, differing types of injuries as well as to the difference in how male and female recruits, entering BT, report prior injuries (Rauh *et al.,* 2006; Shaffer *et al.,* 2006). This should guide future research to focusing on the severity and type of injury as well as to making it specific to the sex of the individual.

4.4.2 Extrinsic risk factors

The primary focus of this study was to explore the role of intrinsic factors as potential risk factors for the development of stress fractures. However, intrinsic factors cannot be viewed completely separately from extrinsic risk factors regarding their potential impact on risk of injury and their applicability to prevention. Few studies have examined these extrinsic risk factors which include aspects such as type of physical activity, PT, training surfaces and footwear

(Brukner *et al.,* 1999; Rosental *et al.,* 2003; Välimäki *et al.,* 2005; Rauh *et al.*, 2005; Rauh *et al.,* 2006; Shaffer *et al.,* 2006).

This study was able to explore the type of physical activity and PT (including the type of physical activity and the amount and duration of the PT). It did not investigate the intensity of the PT nor did it assess the role of equipment as a risk for stress fracture development.

4.4.2.1 Type of physical activity

As military service is done on a voluntary basis in South Africa, unlike some countries like Norway, Italy, Greece and Israel where military service is compulsory, the cohort studied was made up of young men and women who wanted to be part of the SANDF (Jordaan & Schwellnus, 1994; Dyrstad *et al.,* 2006). The type of physical activity this cohort followed was what was included in the BT Programme (Copy Disk Appendix: A).

This was characterised by military activities such as drilling (48 periods), regimental aspects (21 periods), general military aspects (53 periods), musketry (58 periods), signal training (8 periods), shooting (26 periods), field crafts (32 periods), mine awareness (8 periods), map reading (36 periods), buddy aid (38 periods), parade rehearsal and execution (55 periods), water orientation (52 periods) and PT (48 periods). These are all critical to operational readiness and similar in content to the BT conducted by other militaries around the world (Kuusela, 1984; Shaffer *et al.,* 1999a; Williams *et al.,* 1999; Kaufman *et al.,* 2000; Jones *et al.,* 2002; Knapik *et al.,* 2003; Rosendal *et al.,* 2003; Knapik *et al.,* 2005).

One factor that was different to other BT programmes reviewed, was the vast amount of time allocated for water orientation for this cohort. These 52 periods were dedicated to teaching the participants how to swim. Swimming was not included in the SANDF in the 1980’s; however, it became a priority in 2002, after a number of reported drownings in peacekeeping missions abroad (The Portfolio Committee on Defence, 2005). During the six-weeks of British BT only two periods of BT, are dedicated to swimming (Brock & Legg, 1997) whilst Williams (2005) reported nine periods of swimming activity during the 12 weeks of British BT.

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)(Table 4.22).

Table 4.22: Mean energy expenditure for male and female participants during 12 weeks of BT

	Mean weight	**Daily BMR**	**Light activity factor**	**kJ used during PT**	**Total kJ used during BT**
Description		**kJ/day**	**excl. exercise**	**4 x p/w**	**daily activities +PT**
Males	62.5kg	6832.5	1.5	1350	20 084.5
Females	60.3kg	5910	x 1.5	1350	18 700.7
Mean	61.4kg	6371.3	x 1.5	1350	19 392.7

This was determined by taking weight, age and sex into consideration. The daily kilojoules used by men and women were calculated as 6832.5 kJ/day and 5910 kJ/day respectively. Therefore, the mean 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 spent on the training programme with basic exercises were 45 minutes, 4 times per week. Thus, 1350kJ were used for PT, four times per week. The average amount of kJ used for BT, per day, were calculated by averaging three hours of exercise per day, resulting in 8485.7kJ used per day.

It is, however, important to understand that the duration and intensity, as well as the activity can differ between countries, within countries, between corps and within corps and between units. This places military personnel at different degrees of risk (Kuusela, 1984; Shaffer *et al.,* 1999a). A shortfall in military studies, outside of the United States, is that research may be reported on, provided that the anonymity of the study participants and the units/ bases involved is insured. This makes it difficult to ascertain the corps as most literature will only provide the level of military training, namely BT, Officers training, Special Forces training. etc. As BT differs between units and between corps, comparisons are difficult.

Public perception exists that the youth of today are less physically fit and fatter than in previous years (Sharp *et al.*, 2002). This perception is supported by a 5% slower running time, over a two-mile distance, for basic trainees in the United States military, over the period 1988-1997 (Knapik, 2000). This decrease in youth physical fitness renders the military's task of recruiting and training physically capable soldiers complicated, especially when one considers that lower levels of physical fitness have also been shown to increase the prevalence of training injuries and reduce the likelihood of successfully completing BT (Knapik, 2000; Sharp *et al.,* 2002). It is, therefore, important that the BT programme and the PT Programme within, complement each other to result in the best possible outcome.

4.4.2.2 PT

Physical fitness is a critical element of soldiering with military historians having repeatedly emphasized its importance, necessary for soldiers to perform their main function (Nye, 1986; Dubik & Fullerton, 1987; DOD policy on Physical Training, DOD Instruction: SG no 00006/2000; Knapik *et al.,* 2005; Dyrstad *et al.,* 2006). The physical fitness standards required, at the end of BT in the SANDF, includes measures of cardiovascular endurance, muscular strength and endurance as well as anaerobic fitness. The efficacy of the training in improving this physical fitness is therefore a crucial aspect of BT (Williams *et al.,* 1999; DOD policy on Physical Training, DOD Instruction: SG no 00006/2000).

The new cyclic-progressive PT Programme for BT, followed by the cohort, with its accompanying manual can be seen in Appendix Copy Disk - B and C. The cohort completed 48 periods of PT consisting of 40 minutes each, over the 12-week period (DOD policy on Physical Training, DOD Instruction: SG no 00006/2000). This differs to the PT programme reported by Knapik *et al.* (2005) who, over a nine-week period, completed 45 periods of PT (60 minutes each) and was almost half the 90 periods allocated to the regular recruits on 12 weeks of British BT (Williams, 2005). The PT programme followed by the SANDF in the 1980's, included 50 PT periods of 40 minutes each over a 10-week period.

The new PT programme was implemented, for the first time, for the period of this study. The efficacy of the Programme on fitness parameters, was determined by comparing the measured changes in fitness of one group, to the changes in fitness measured in another group who completed BT, at the same unit the previous year (as discussed under 4.4.1.4). When compared to the CG that had followed the traditional PT Programme, it was found that this new PT programme yielded superior changes in the cardiovascular component, muscle strength and endurance component but not in the anaerobic component. Additionally it appeared that the greatest improvements in these components were achieved by week five during the first Post-test measurements.

As many studies have shown an association between PT and a high rate of injury and stress fractures, care was taken to implement as many scientifically proven programme guidelines into the new cyclic-progressive PT Programme (Black, 1982; Scully & Besterman, 1982; Milgrom *et al.,* 1985; Milgrom *et al.,* 1988; Giladi *et al.,* 1991; Jones *et al.,* 1994; Almeida *et al.,* 1999; Jones & Knapik, 1999; Beck *et al.,* 2000; Trank *et al.,* 2001; Knapik *et al.,* 2004).

These guidelines included:

- Allowing sufficient periods of recovery from weight-bearing stress during the early weeks of following the PT Programme. This was done by including a progressive build-up, from walking to jogging, as the cardiovascular activity prescribed (Scully & Besterman, 1982; Popovich *et al.*, 2000).
- Gradually increasing the duration, frequency and intensity of the initial training events thereby accommodating the potentially unfit incoming recruits (Heir & Eide, 1997; Rudzki & Cunningham, 1999; Kaufmann *et al.,* 2000; Rosendal *et al.,* 2003; Armstrong *et al.,* 2004; Knapik *et al.,* 2004). By following the exercise principle of overload, the PT Programme emphasized the gradual introduction of the exercises (Knapik *et al.,* 2004). This approach, to start slowly and progressively build up training to avoid injury, is common practice in the athletic world, however as a result of a void in this literature, it is not yet clear whether progressive exercise actually prevents stress reactions and fractures within the SANDF (Shaffer & Uhl, 2006).
- Reducing repetitive weight-bearing activities such as running and marching, as they are the most frequently reported causes of stress fractures (Belkin, 1980; Hulkko & Orava, 1987; Matheson *et al.,* 1987; Jones *et al.,* 1989; Ha *et al.,* 1991). This was very difficult to do due to the limited resources available to conduct aerobic activities. This aspect was rather incorporated into the above-mentioned guideline, by gradually increasing the repetitive weight-bearing activity.

- Eliminating marching and running on concrete (Reinker & Ozburne, 1979; Greaney *et al.,* 1983). This was achieved by conducting the PT periods on grassed sport fields.
- Using running shoes rather than combat boots (Proztman, 1979; Greaney *et al.,* 1983). The participants wore military issued trainers during the PT periods. This differed to the field uniform used two decades ago by the SADF, which included long trousers, long sleeve shirts, metal helmets, web-belts and combat boots (Gordon *et al.,* 1986c).
- Offering a variety of exercises in the PT Programme. There are no studies indicating that a greater variety will reduce injury, however, 'cross training' (different exercises on different days) is often recommended for this purpose (McArdle *et al.,* 1991; Knapik *et al.,* 2004).

As the PT Programme was not only designed to avoid injury, but to obtain maximal improvement in the fitness components evaluated by the Standardised Fitness Test over the 12-week BT period, care was taken to implement as many scientifically proven programme guidelines, in this regard, into the new cyclic-progressive PT Programme. These guidelines included:

- A larger strength component based on a study in the SANDF by Wood and Krűger (2007) on the training of PT Instructors in the SANDF. This was achieved by including 'Pole PT' exercises from the fifth week. Due to the limited strength training facilities and the large number of training recruits undergoing PT training simultaneously pole PT provided a cost-effective and manageable method of strength training which was based on the principle of free-weight training (Daniels *et al.,* 1979; Fleck & Kramer, 1997; Jones *et al.,* 1993b; Knapik *et al.,* 2005; Heyward, 2002).
- A larger aerobic component based on a study during BT in the SANDF by Cilliers and Gordon, (1983). This was achieved by gradually progressing from walking to jogging in the first seven weeks and then introducing

interval training from the seventh week. The duration of the latter was also gradually increased and only performed twice a week and not on consecutive days.

4.4.2.3 Surface and Equipment

Although this study did not include the analysis of the impact of exercise equipment such as footwear, orthotic inserts and training surface, preventative steps were taken in this area (Brukner *et al.,* 1999; Jones *et al.,* 2002).

Firstly, the participants wore military issued trainers during the PT periods, rather than combat boots, unlike in the SANDF recruits in the Gordon *et al.* (1986c) study. Secondly, the PT periods were conducted on grassed sport fields whilst drilling, parade rehearsal and execution were done on a smooth, flat parade ground. Hilly, rocky terrain has been associated with a higher incidence of stress fractures as compared to flatter, smoother terrain (Devas & Sweetnam, 1956; Zahger *et al.,* 1988; Brunet *et al.,* 1990).

4.5 STUDY DESIGN

The prospective cohort design's greatest strength was that each individual's risk profile was established before the stress fracture had occurred. These participants' intrinsic risk factors, which were analysed, showed that this particular cohort was not at great risk for the development of stress fractures.

The extrinsic risk factors, although not analysed, were to a certain extent controlled for, as all possible, logistical, preventative actions were taken to reduce the risk of the extrinsic factors. Combined, this seemed to have reduced the risk for the development of stress fractures in this cohort as no stress fractures were reported.

Both the primary and secondary objectives of this study were outlined and met. However the zero incidences of stress fractures in this particular cohort resulted that the emphasis of the discussion was placed on the effect that the PT programme had on the measurements taken rather than the comparison of these measurements between stress fracture cases and non stress fracture cases. The last chapter provides conclusions, discusses the limitations of this study and offers recommendations for both future research and adaptations to the PT programme which should be made and then investigated.