

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

As stress fractures represent one of the most common and potentially serious overuse injuries in the military environment, the causative factors and the mechanisms by which they interact must be clearly understood. It is only through this understanding that clear guidelines for prevention can be established and followed (McBryde, 1985; Hulkko & Orava, 1987; Matheson *et al.*, 1987; Jones *et al.*, 1989; Sterling *et al.*, 1992; Beck *et al.*, 2000; Jones *et al.*, 2002; Shaffer *et al.*, 2006; Trone *et al.*, 2007).

Since the first few citations of case studies of soldiers incurring stress fractures in the 19th and early 20th centuries (Bernstein *et al.*, 1946; Belkin, 1980; McBryde, 1985; Markey, 1987; Jones *et al.*, 1989), potential intrinsic and extrinsic risk factors for stress fractures have been researched. Presently, the only physical requirement for enlistment and acceptance into voluntarily military service in the SANDF, is to pass a basic medical examination to ensure that the recruit is physically healthy. No additional biomechanical factors are evaluated, nor is a minimum level of physical fitness a requirement for acceptance. Thus it is imperative that research be conducted to determine whether or not intrinsic factors affect the development of stress fractures during BT (Jones and Knapik, 1999; Kaufmann *et al.*, 2000; Bemben *et al.*, 2004; Shaffer *et al.*, 2006) and how extrinsic factors, such as PT regime, affect the final outcome of both fitness

levels and stress fracture development (Jones & Knapik, 1999; Kaufmann *et al.*, 2000; Popovich *et al.*, 2000; Rosendal *et al.*, 2003; Rauh *et al.*, 2006; Shaffer *et al.*, 2006).

Based on conflicting literature, the question, “Will the incidence of stress fractures increase in military recruits who have intrinsic risk factors, as highlighted in the current literature, during BT?” was posed by the author. It was hypothesized that the incidence of stress fractures would increase in military recruits with intrinsic risk factors, as highlighted in the current literature, during BT. Additionally, a sub-hypothesis was formulated from the main hypothesis, that by following clear guidelines, as laid out in the literature on how to prevent stress fracture development it would assist in explaining the low incidence of stress fracture occurrence. In an attempt to answer the research question and prove or disprove the above-mentioned hypothesis and sub-hypothesis the following primary and secondary objectives were set:

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

The approach undertaken to achieve the above-mentioned objectives was to identify and measure the intrinsic risk factors for the development of stress fractures, based on already existing literature, and follow the BT cohort over the 12 weeks BT period during which injury occurrence was monitored and recorded. Additionally, a new 12-week PT Programme was developed and implemented.

The Pre-test and Post-test biokinetic and bone density measurements were done on the prospective EG (who all underwent BT). The standardised fitness test results were also compared to a CG who had undergone BT in the year prior to this cohort. This was done to evaluate the efficacy of the PT Programme in relation to the previously used PT Programme. The limitation of the findings of this study, was that it could only be generalised to the people from the same sample group.

Over the 12-week BT period, a zero incidence of stress fractures was reported amongst the cohort of 183. This made it impossible to compare stress fracture cases to non-stress fracture cases and determine if the stress fracture cases had a greater risk for a particular intrinsic risk factor. The next step taken by the investigator was to determine if the group, as a whole, was at risk for each specific risk factor and establish if this was not possibly the cause for the zero stress fracture incidence. The following findings, with regard to the intrinsic risk factors investigated, were found:

- **Sex** - Although female sex of the participant is the most commonly identified intrinsic demographic 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.*, 1993; Goldberg & Pecora, 1994; Bennell *et al.*, 1996; Bijur *et al.*, 1997; MacLeod *et al.*, 1999; Beck *et al.*, 2000; Bell *et al.*, 2000; Shaffer *et al.*, 2006) and 45.4% of this cohort comprised of females, this did not place this cohort at risk for stress fractures. This is possibly due to the initial fitness levels and normal BMD of female participants (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.*, 1993; Goldberg & Pecora, 1994;

- World Health Organization, 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).
- **Age** - The ages of the participants ranged from 18 to 22 years with 74.3% falling into the category between 19 and 21 years of age. Reviewed studies have indicated that older age may heighten the risk of stress fracture development (Brudvig *et al.*, 1983; Gardner *et al.*, 1988; Shaffer *et al.*, 1999). Due to the cohorts relatively young age it appears that the age did not place them at an increased risk for the development of stress fractures.
 - **Race** - The race of the cohort may have provided protection against stress fractures as 93.5% of the participants were African and only 2.7% were Caucasian which has been identified as being a risk factor in both athletes as well as in military personnel (Brudvig *et al.*, 1983; Barrow & Saha, 1988; Gardner *et al.*, 1988; Friedl *et al.*, 1992; Shaffer *et al.*, 1999; Shaffer *et al.*, 2006).
 - **Foot morphology** - The risk for stress fractures is greater for in military recruits who have a high-foot arch than in those with a low foot-arch. Only 4% of the male and 1.2% of female participants were classified as having high arched feet. This small incidence, even if it is a risk factor, may not result in the development of stress fractures (Giladi *et al.*, 1985; Simkin *et al.*, 1989; Brosh & Arcan, 1994; Kaufmann *et al.*, 1999).
 - **Q angle** - The mean range for both the male and female Q angle was 9.76° to 11.9°. This cohort was therefore not at risk, as their mean Quadriceps angles were not greater than 15°. Recruits with a Q angle greater than 15° have a relative risk of stress fractures that is 5.4 times that of individuals who have a angle less than 15° (Montgomery *et al.*, 1989; Cowan *et al.*, 1996).

- **Leg length discrepancy** - A leg length discrepancy within the 1-2cm range was found in 20.00% of the male and 20.48% of female participants. This was not a sufficient risk to result in stress fracture development.
- **Bone density** - A risk for stress fracture development exists in the Total Body Density T-score measurement of >-2.5 . Only 2 of the 68 female participants that underwent the DEXA test fell into this category with 80% having normal bone density measurements for both the Pre-test and Post-test. Additionally, the cohort was 92.8% African, which may have offered a protective factor against stress fractures (Shaffer *et al.*, 2006) and 7.3% of these female participants had suffered a fracture in their past (Phillips & Phillipov, 2006). Therefore, the BMD of the cohort tested was not at risk for the development of stress fractures. No statistically significant difference was found in both the Total Body T-score and Z-score measurements after 12 weeks of BT; however a statistically significant increase was measured in the T and Z-score of the left femur area.
- **Physical fitness** - As this cohort did not suffer any stress fractures, the contribution of physical fitness to the development of stress fractures is difficult to make. However, it does appear that the findings do not support that muscle strength and endurance, as measured by the sit-up test, is a risk factor for the development of stress fractures. The reason for this is that this cohort had lower isotonic, isometric and isokinetic strengths than other cohorts, who did report a relatively high stress fracture incidence (Jones *et al.*, 1993; Beck *et al.*, 2000; Bell *et al.*, 2000).
- The efficacy of the PT Programme followed for the BT period was found to be superior to the previous programme used by the group who had undergone BT the year prior to this cohort, at the same training unit. This is supported by significant improvements shown in both the male and female participants in aerobic fitness as measured by the 2.4km run and

- 4km walk, and muscular endurance and strength, as measured by the sit-up and push-up test.
- **Flexibility** - The mean hip external rotation was not an intrinsic risk factor as it was below the documented risk of 65° (Giladi *et al.*, 1987; Giladi *et al.*, 1991). The male and female participants of this cohort had a mean ankle dorsiflexion of $17.14^{\circ} \pm 3.65$ (L) / $18.25^{\circ} \pm 4.14$ (R) and $15.21^{\circ} \pm 3.18$ (L) / $16.40^{\circ} \pm 3.53$ (R) respectively. Although the cohort had a limited ankle dorsiflexion, no stress fractures were reported.
 - The 12-week BT period found that the male participants' plantarflexion and hip external rotation decreased, whilst an improvement was observed in their dorsiflexion. Female participants showed a significant deterioration in left ankle dorsiflexion and hip external rotation whilst their plantarflexion had a significant increase. The decrease in dorsiflexion may be attributed to a shortening of the Achilles tendon, which may be the result of wearing the combat boot during all activities except for PT (Jones & Knapik, 1999). Further study by measuring ankle dorsiflexion with the knee at 0° flexion in the South African context is recommended.
 - **Body composition and stature**- The male participants were found to be shorter than their counterparts in other militaries around the world, whilst the female participants were of similar height and mass. Due to the 0% incidence of stress fractures this study failed to prove an association between stress fractures and various parameters of body size, including BMI as in other studies (Taimela *et al.*, 1990; Finestone *et al.*, 1991; Giladi *et al.*, 1991; Winfield *et al.*, 1997; Cline *et al.*, 1998; Rauh *et al.*, 2006; Shaffer *et al.*, 2006). Additionally, there was no acute weight loss which has been found to be a significant risk factor for stress fracture injuries in both male and female recruits (Armstrong *et al.*, 2004).
 - The 12 weeks of BT resulted in significant improvements in body composition as measured manually using the Yuhasz (1974) method on

- all participants, and in the 68 females who underwent DEXA testing. The male participants experienced increases in lean body mass and mesomorph component and decreases in %BF as well as in the ectomorph and endomorph component. The female participants also experienced these significant changes, except they did not have any change in lean body mass. The anthropometric changes during training were positive, although favourable changes were more prominent in the male recruits. Some changes, specifically in female participants, although still positive, were of a lesser magnitude than has been shown to be possible during a training programme of similar length.
- **Menstrual disturbances** - 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). Only 3.6% of the females reported having experienced their last period earlier than a year before the commencement of BT, thus female participants of this cohort were not a great risk with regards to their menstrual disturbances. Further research should be carried out with calcium turnover within the blood being evaluated (Drinkwater *et al.*, 1984; Rutherford, 1993; Micklesfield *et al.*, 1995; Tomten *et al.*, 1998). Akin to already published literature, the majority of participants (80.5%) indicated that they experienced changes in their menstrual cycle during BT.
 - **Lifestyle behaviours** - Lifestyle behaviours evaluated in this study included smoking, history of previous injury, level of previous physical activity and the use of female contraception. Further research should be done on alcohol as a potential risk factor.
 - **Smoking** - Only 14.1% of the cohort reported to be smokers with a mere 7.7% indicating that they smoked more than 20 cigarettes per day. This is lower than the reported prevalence of smoking amongst the South African

population and other military BT studies (Altarac *et al.*, 2000; Popovich *et al.*, 2000; van Walbeek, 2000; Trent *et al.*, 2007). The low incidence of smoking therefore did not place this cohort at risk for stress fracture development (Friedl *et al.*, 1992; Altarac *et al.*, 2000; Moroz *et al.*, 2006). 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.

- **Female contraception** - Only 13.3% of the participants indicated that they were using birth control or hormonal pills. Due to the low incidence of female contraception usage by this cohort as well as to no stress fractures being reported during BT, this study supports the work of those that have failed to prove 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 in stress fracture cases to the non-stress fracture cases within the South African military environment.
- **Medical history of previous injury** - The majority of participants indicated that they had no history of previous injuries (93.5%). A history of stress fractures was reported by only 3.8% of the cohort, however this should be interpreted with caution as confusion may have existed with regards to stress fractures and trauma fractures. This was also too small a sample to result in adequate risk. Individuals with a medical history of stress fracture development have a relatively greater risk of developing stress fractures, however, this may be confounded by other factors such as adequacy to recover and levels of past physical activity (Kuusela, 1984; Milgrom *et al.*, 1985; Giladi *et al.*, 1986; Shaffer *et al.*, 1999). This should

therefore guide future research and make it focused on the severity and type of injury as well as making it specific to the sex of the individual.

- Intrinsic factors as potential risk factors for the development of stress fractures cannot be viewed completely separately from potential extrinsic risk factors. The following comments, with regard to the extrinsic risk factors investigated, may be made:
- **Types of physical activity** - Military studies indicate that different units and different types of training may place military personnel at different degrees of risk (Kuusela, 1984; Goldberg & Pecora, 1994; Shaffer *et al.*, 1999). This cohort completed 12 weeks of BT, which was critical to operational readiness and similar in content to the BT conducted by other militaries around the world (Kuusela, 1984; Shaffer *et al.*, 1999; Williams *et al.*, 1999; Kaufman *et al.*, 2000; Jones *et al.*, 2002; Knapik *et al.*, 2003; Rosendal *et al.*, 2003; Knapik *et al.*, 2005).
- **PT** - During BT, 48 periods of 40 minutes of PT were completed (DOD policy on Physical Training, DOD Instruction: SG no 00006/2000). A new cyclic-progressive PT Programme for BT was developed by the author and implemented (Appendix Copy Disk- B and C).
- Care was taken to implement the following scientifically proven programme guidelines into the new cyclic-progressive PT Programme in order to reduce the risk of injury, to allow sufficient periods of recovery, to gradually increase the duration, frequency and intensity of the initial training events, to reduce repetitive weight-bearing activities, including a variety of exercises in the PT Programme using of running shoes, rather than combat boots and to eliminate marching and running on concrete (Proztman, 1979; Reinker & Ozburne, 1979; Belkin, 1980; Scully & Besterman, 1982; Greaney *et al.*, 1983; Gordon *et al.*, 1986; Hulkko & Orava, 1987; Matheson *et al.*, 1987; Jones *et al.*, 1989; Ha *et al.*, 1991; McArdle *et al.*, 1991; Heir & Eide, 1997; Rudzki & Cunningham, 1999;

- Popovich *et al.*, 2000; Kaufmann *et al.*, 2000; Rosendal *et al.*, 2003; Armstrong *et al.*, 2004; Knapik *et al.*, 2004; Shaffer & Uhl, 2006).
- Additionally, a large strength and aerobic component was included in the PT Programme, to obtain maximal improvement in the fitness components evaluated by the Standardised Fitness Test over the 12-week BT period (Daniels *et al.*, 1979; Cilliers & Gordon, 1983; Fleck & Kramer, 1997; Jones *et al.*, 1993; Knapik *et al.*, 2005; Heyward, 2006; Wood & Krüger, 2007). In conclusion, a 12-week PT programme for both male and female participants had a positive beneficial effect on body composition, aerobic fitness and strength. As measured by the Standardised Physical Fitness test, the PT Programme was found to be achieving the desired aim, except for no improvement in anaerobic capacity, and yielded greater improvements in physical fitness when compared to the previous programme followed.
 - **Equipment** - This study did not include the analysis of the impact of equipment. The preventative steps taken included allowing the participants to wear military issued trainers, rather than combat boots, during the PT periods and the PT periods were conducted on grassed sport fields. Additionally, drilling, parade rehearsal and execution was done on a smooth, flat parade ground hereby reducing the amount of training and time spent on hilly, rocky terrain -. This type of terrain is associated with a higher incidence of stress fracture development (Devas & Sweetnam, 1956; Zahger *et al.*, 1988; Brunet *et al.*, 1990; Brukner *et al.*, 1999; Jones *et al.*, 2002).

5.1 RECOMMENDATIONS AND FUTURE RESEARCH

5.1.1 Study design

The prospective cohort design is considered a 'strong' design as it enables accurate comparisons to be made between the injured and the uninjured groups. These comparisons then lead to true assessment of the incidences and risks which may then lead to casual inferences been drawn. The limiting factor of this type of design, is that in order to have enough statistical power, particularly for detection of small differences, sample sizes have to be large. Thus, it is recommended that future studies include a larger size cohort utilizing BT groups from different corps and units in the South African military environment.

5.1.2 Intrinsic risk factors

This study was the first to attempt to investigate the intrinsic risk factors, which have been highlighted in the literature, with regard to stress fracture development in the South African military. Due to no stress fractures being reported in this study, conclusive evidence could not be given with regards to the risk associated with various intrinsic risk factors for the development of stress fractures. Therefore, future research is needed in this area of study, within the South African military setting, where there are stress fracture incidences so that the stress fracture cases can be compared to the non-stress fracture cases. The research should be aimed at addressing these types of training injuries especially with regards to possible physical inclusion and exclusion guidelines for military selection.

Additionally, a limiting factor in this study was that the BMD was only done on a limited number of females. Future research should also include DEXA testing on male recruits to ascertain whether changes, which may be incurred with BT, are comparable to that observed in the female participants.

5.1.3 Extrinsic risk factors

Little and outdated research is available with regards to extrinsic risk factors for the development of stress fractures within the South African setting, with the only research having been done on the PT Programme (Gordon *et al.*, 1986). Future research should definitely look at the role of other potential extrinsic risk factors such as surface and equipment in the South African environment. This advocated research should include a more detailed history of physical activity. This should be compared to initial fitness levels as well as include a one or two mile test as a measure of aerobic capacity as these are the tests utilised by the American military, which forms part of the majority of the research published. This would allow for comparisons to be drawn on changes as well as on initial fitness levels.

This study provided important data regarding the physical changes that occurred in the male and female BT participants, as well as determining whether the training stimulus, provided by the PT Programme, was sufficient to result in improvements in physical fitness. Based on the latter, the following adaptations to the PT Programme and research, in assessing the efficacy of these changes, are recommended:

- A more gradual increase in strength and cardiovascular activities to ensure that the greatest improvement in physical fitness is observed at the end of the 12-week BT period, as compared to the peak observed at the fifth week.
- A greater muscle strength component, especially for the female recruits, to result in an increase in lean body mass, not observed in the female participants.
- To include more anaerobic activity to ensure an improvement in this component.

- To include isolated lower arm training in order to possibly prevent the decrease in handgrip strength observed in the left arm of this cohort.
- To include more hip stretches as well as gastrocnemius and soleus muscle stretches especially in the male participants.

5.2 RESEARCH LIMITATIONS

Several limitations exist when conducting research within the military. These include:

- Military studies have to follow the rules and habits of the military, often resulting in logistical problems which, in turn, often result in no proper randomization, no true control group and difficulties in exact quantification of exercise (Casez *et al.*, 1995).
- When BT recruits have a medical problem, they are seen by a number of different medical care providers in the clinic during the study period and although they are guided by policy, each may have different criteria for assigning restricted duty.
- Due to the large groups studied in the military set-up, multiple variables are often examined which makes it difficult to determine which interventions are most effective.
- Large groups need to undergo the training simultaneously, thus the exercises presented in PT need to be simple, clear and be able to be completed within a small personal space.
- No individual training weights are available, thus exercises need to be designed based on resistance offered by own body weight and progressed to the use of solid timber wooden poles (2.1m in length by 25cm in diameter).

- Most BT trainees have no previous experience in formal exercise activities, thus exercises need to be simple and be easily corrected by the PT instructor.
- Due to financial constraints the Bone Mineral Density (BMD) dual-energy X-ray absorptiometry measurements will only be completed on a limited number (n=70) of female subjects.
- BMD was measured however calcium and Vitamin D daily intake which may influence BMD was not, and could possibly be an area for future research.

Based on the results of this study it is imperative that this study be replicated in other military units within the SANDF to determine if the extrinsic factors such as terrain possibly play a larger role than what has already been suggested by other authors (Brukner *et al.*, 1999; Rosental *et al.*, 2003; Välimäki *et al.*, 2005; Rauh *et al.*, 2005; Rauh *et al.*, 2006; Shaffer *et al.*, 2006) and to further investigate the potential protective properties of a cyclic progressive PT programme. Having concluded this it should be replicated in militaries in other countries around the world to further investigate the possible role ethnicity plays in the development of stress fractures.