A PROSPECTIVE COHORT STUDY OF THE CORRELATION BETWEEN CHEST CIRCUMFERENCE AND SPIROMETRY MEASUREMENTS OVER A 19-WEEK INTENSE TRAINING PROGRAMME

University of Pretoria

By

Mrs Tanya Chantelle de Sousa Camacho

A dissertation submitted in fulfilment of the requirements for the degree

MA (Human Movement Science)

in the Department of Sport and Leisure Studies at the

UNIVERSITY OF PRETORIA

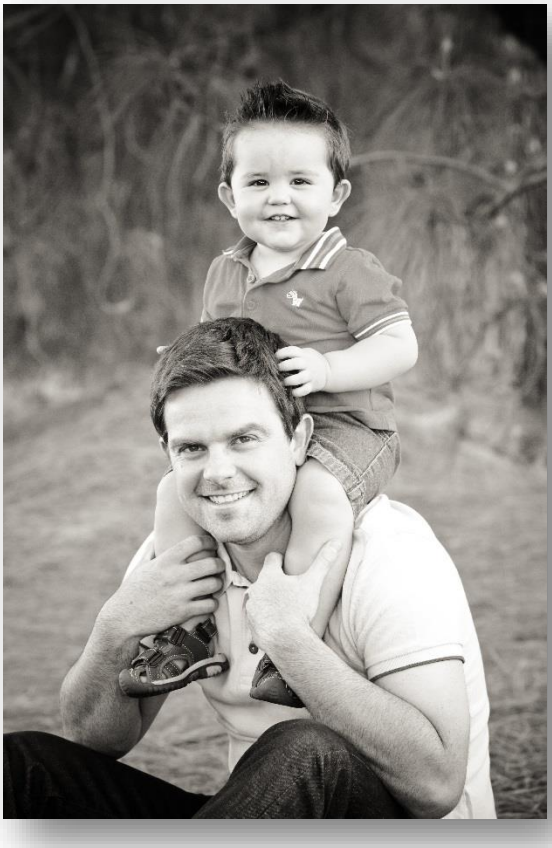
FACULTY OF HUMANITIES

Supervisor: Dr Paola Wood

April 2014

DEDICATION

I dedicate this study to my loving husband, Leandro Camacho, and my adorable son, Gabriel Camacho.



"The Love of a Family is Life's Greatest Blessing" - Unknown

ACKNOWLEDGEMENTS

I would like to thank and express my sincere gratitude to the following people and institutions for their role in assisting me to successfully complete this study:

Dr Paola Wood (Department of Physiology – Division Biokinetics and Sports Science, University of Pretoria) for her guidance, support, motivation and enduring patience.

Dr Lizelle Fletcher (Department of Statistics, University of Pretoria) for the statistical analysis. Your assistance and guidance are greatly appreciated.

Lt. Col. Etresia Terreblanche (South African Defence Force) for acting as the liaison with the SANDF and helping create the opportunity to conduct this study.

The **participants** of the study – without them this study would not have been possible.

Jill Bishop (Independent language practitioner) for the language editing.

Prof PE Kruger (Director of the Institute for Sports Research, University of Pretoria) for allowing me to use the ISR's equipment required for the data collection and for his support and guidance.

The **staff** of the Biokinetics Division of the ISR, for their support and motivation.

My parents, for their never-ending love and support.

My husband and son, Leandro and Gabriel, for their unconditional love, support and understanding. Thank you for always believing in me. You two are the light and love of my life.

My **late grandfather**, **Senhor Americo Teles**, for encouraging me to do my Master's degree and always believing in my abilities and potential. You have played an integral part of who I am today. I love you and miss you very much.

Lastly, to **GOD**, for blessing me with these wonderful people and giving me the ability to do this study. HE is my inner strength and guide.

ABSTRACT

TITLE:	A prospective cohort study of the correlation between chest circumference and spirometry measurements over a 19-week intense training programme
CANDIDATE:	Mrs Tanya Chantelle de Sousa Camacho
SUPERVISOR:	Dr P.S. Wood
DEGREE:	MA (HMS)

Objective: Pulmonary disease is a common cause of morbidity and mortality; however a large number of individuals remain undiagnosed. Reasons for this include the inconsistent use of spirometry and the inability to produce acceptable and reproducible results. Chest circumference measurements have been positively correlated with pulmonary function in healthy individuals and those with pulmonary pathologies, thus potentially offering an additional method for assessing pulmonary function. Regular participation in endurance activities appears to increase VO_2 max and the strength of the respiratory muscles. Thus, the aim of the study was to determine whether a strong, significant correlation between chest circumference measurements and spirometry measures existed in a young healthy active population, and whether this relationship remained consistent with changes in physical fitness.

Methods: A total of 235 military recruits (136 male; 99 female; 18–28 years old) were recruited in the study. In weeks 1, 12 and 19 of the Basic Military Training (BMT) programme, each participant voluntarily participated in a testing session which included anthropometric measurements (height, weight and chest circumference), spirometry tests and the multistage shuttle run test. Overall 26 participants complied with all spirometry inclusion criteria and completed all measures in all three testing sessions. Parametric descriptive and inferential statistics were used. Alpha was set at 0.05.

Results: The correlational analysis showed weak and non-significant correlations ($r<0.4$) between chest circumference measurements and spirometry measures over

the 19 weeks of BMT, except for a moderate, positive and significant correlation between FVC and ICC in the male sample ($r=0.522$; $p<0.05$) in week 12. Strong, positive and statistically significant correlations between FVC and VO_2 max were observed in weeks 1, 12 and 19 ($r=0.682$, $p<0.01$; $r=0.616$, $p<0.01$ and $r=0.697$; $p<0.01$, respectively) and between FEV_1 and VO_2 max in week 1 and week 19 ($r=0.628$; $p<0.01$ and $r=0.658$; $p<0.01$, respectively). A moderate, positive and statistically significant correlation between FEV_1 and VO_2 max in week 12 ($r=0.554$; $p<0.01$) was noted. There were no statistically significant changes in chest circumference measures over time ($p=0.401$). Statistically significant changes in FVC between week 1 and week 12, week 1 and week 19 and week 12 and week 19 ($p=0.021$; $p<0.001$ and $p=0.025$, respectively) were observed, as well as in FEV_1 between week 1 and week 12 and week 1 and week 19 ($p=0.027$ and $p<0.001$). There were no statistically significant changes in FEV_1/FVC between all testing sessions. Changes in VO_2 max were statistically significant between week 1 and week 12 and week 1 and week 19 ($p\leq0.001$ and $p\leq0.001$, respectively). When controlled for by gender, the overall changes in FVC, FEV_1 and relative VO_2 max remained statistically significant ($p=0.001$; $p=0.002$ & $p<0.001$, respectively) and FEV_1/FVC remained statistically non-significant ($p=0.806$).

Conclusion: This study did not find a statistically significant correlation between chest circumference measurements and pulmonary function, despite the statistically significant increase in the VO_2 max; thus the hypothesis that chest circumference measurements could be used as a measurement of pulmonary function in a young healthy active population was not supported. Future research should be aimed at exploring this relationship using a larger sample.

Keywords: pulmonary disease; pulmonary function testing; forced vital capacity; forced expiratory volume in one second; chest circumference measurements; maximal oxygen consumption; physical fitness; basic military training.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BMT	Basic Military Training
CD	Compact Disk
CO_2	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disease
DLCO	Diffusing Capacity of the Lung for Carbon Monoxide
ECC	Expiration Chest Circumference
FEF_{25-75}	Forced Expiratory Flow at 25 – 75 % of Forced Vital Capacity
FEV_1	Forced Expiratory Volume in one second
FEV_1/FVC	Ratio between Forced Expiratory Volume in one second and Forced Vital Capacity; represented as a percentage
FIV_1	Forced Inspiratory Volume in one second
FIVC	Forced Inspiratory Vital Capacity
FVC	Forced Vital Capacity
ICC	Inspiration Chest Circumference
ICC-ECC	Difference between Inspiration Chest Circumference and Expiration Chest Circumference
IS	Idiopathic Scoliosis
O_2	Oxygen
PEFR	Peak Expiratory Flow Rate
PT	Physical Training
RM	Respiratory Muscles
SANDF	South African National Defence Force
SPA	Severe Persistent Asthma
TLC	Total Lung Capacity
US	United States
VO_2 max	Maximal Oxygen Consumption

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION AND MOTIVATION FOR THE STUDY

Pulmonary diseases, such as chronic obstructive pulmonary disease (COPD) and asthma, are common causes of morbidity and mortality (Miravitlles, De le Roza, Morera, Montemayor, Gobartt, Martin & Alvarez-Sala, 2006; Joo, Au & Lee, 2009; Arne, Lisspers, Stöulberg, Baman, Hedenström, Janson & Emtner, 2010; Lubiński & Gólczewski, 2010). Obstructive pulmonary diseases are expected to be the third leading cause of morbidity and mortality in 2020 (Lubiński & Gólczewski, 2010). Despite campaigns against tobacco smoking, the prevalence of the disease is still on the rise, presenting society with an economic burden (Miravitlles *et al.,* 2006). The cost of a severe case of COPD may be as much as seven times higher than that of a mild case (Miravitlles *et al.,* 2006). Therefore the best strategy to reduce costs is early diagnosis of the disease, with appropriate management in the early stages.

A large portion of patients, however, remain undiagnosed, preventing them from receiving the appropriate treatment such as smoking cessation counselling and regular follow-ups (Miravitlles *et al.,* 2006). Possible reasons for this include a lack of knowledge of pulmonary disease and its associated symptoms and risks, the inconsistent use of spirometry in primary care settings and the inability to produce results that satisfy the full criteria for acceptability and reproducibility (Lee, Bartle & Weiss, 2006; Miravitlles *et al.,* 2006; White, Wong, Fleming & Gray, 2007; Schermer, Crockett, Poels, Van Dijke, Akkermans, Vlek & Pieters, 2009). Arne *et al.* (2010) mentioned that 70% of COPD patients lacked spirometry results confirming their diagnosis. Achieving spirometry results of a high standard requires the

comprehensive training of staff, reliable equipment and standardised procedures (Miller, Hankinson, Brusasco, Burgos, Casaburi, Cotes, Carpo, Enright, Van der Griten, Gustafsson, Jensen, Johnson, MacIntyre, McKay, Navajas, Pedersen, Pellegrino, Viegi, & Wanger, 2005b; Pierce, 2005; Schermer *et al.,* 2009).

Spirometry is a well-known and widely used pulmonary function test that offers an objective measure of pulmonary function (Wu, Zang, Gang & Love, 2009; Meo, 2010; Shiner & Steier, 2013). It is valuable in describing the effects of obstruction or restriction on pulmonary function as well as in the early diagnosis of pulmonary pathologies (Booker, 2008). Spirometry is also used to monitor the therapeutic efficiency of various treatment methods and the course of the disease (Meo, 2010). However, instrument accuracy and attention to quality execution are vital in order to produce valid and reliable tests (Juroszek, 2006; Booker, 2008 & Arne *et al.,* 2010). Ehrlich, White, Myers, Thompson, Churchyard, Barnes & De Villiers (2000) stated that in South African mines pulmonary function tests are not regarded as essential in benefit examinations under the Occupational Diseases in Mines and Works Act, as many such examinations are carried out at provincial facilities or by practitioners who do not have pulmonary function testing capacity.

A simple test like chest circumference measurements may potentially offer practitioners and technicians with an additional method for assessing pulmonary function, especially for conditions that affect the expansion of the lungs and thoracic cage. It is a relatively easy method to perform and does not require a high level of expertise or costly technical equipment. Numerous studies have shown that a significant correlation exists between inspiration-and-expiration chest circumference and spirometry measures in both healthy individuals and those with pulmonary disorders or postural deviations (Stamm & Docter, 1965; Brokan, Glynn, Bachman, Bassé & Weiss, 1981; Hawes & Brooks 2001; Cimbiz, Vahdeltin, & Hallaceli, 2004; Lopes, Fanelli-Galvani, Prisco, Gonçalves, Jacob, Cabral, Martins & Carvalho, 2007; Chambers, Heshka, Huffaker, Xiong, Wang, Eden, Gallagher & Pi-Sunyer, 2008; Wu *et al.,* 2009).

Despite the significant correlation between these variables, studies investigating predictive equations for spirometry have excluded chest circumference as a variable because the reproducibility of the measurements were inadequate (Schrader,

Quanjer, Borsboom & Wise, 1984; Wu *et al.,* 2009). However, a study conducted by Cimbiz *et al.* (2004) revealed no statistical significance between inter- and intra-measurements of chest circumference ($p>0.05$), and mentioned that measuring dynamic chest circumference with a measuring tape is an effective, reliable and useful test for determining thoracic excursion (i.e. the difference between chest circumference at the end of forced inspiration and chest circumference at the end of forced expiration). When researching the reliability of the cloth tape measure technique, Bockenhauer, Cheng, Julliard and Weedan (2007) showed that using a tape measure to assess thoracic excursion is highly reliable in men (intra-class correlation coefficient 0.81-0.91), resulting in inspiration chest circumferences of significant reliability. Moreover, Bockenhauer *et al.* (2007) stated that this method of measurement can be useful in clinical settings where the accurate measurement of thoracic excursion is required for patient diagnosis, disease classification and interval assessment. Conditions such as asthma, COPD, ankylosing spondylitis and thoracic scoliosis all require the accurate assessment of thoracic excursion (Bockenhauer *et al.,* 2007). Furthermore, Malaguti, Rondelli, De Souza, Domingues and Dal Corso (2009) observed good reliability of intra-observer (intra-class correlation coefficient 0.84-0.95, $p<0.001$) and inter-observer (intra-class correlation coefficient 0.69-0.89, $p=0.004$) chest circumference measurements (performed at the axillary, xiphisternal and abdominal levels) when they were repeated on the same day. Additionally, a fair–good reliability was observed with intra-observer chest circumference measurements (intra-class correlation coefficient 0.64-0.84, $p<0.001$) when repeated on different days (Malaguti *et al.,* 2009).

Despite the literature supporting the significant correlation between chest circumference measurements and spirometry measures, and the reliable use of a tape measure to assess thoracic excursion, few researchers have assessed the relationship between the difference between these two measures and spirometry. Furthermore, the literature supports that pulmonary function is influenced by adaptations associated with participation in regular physical activity and improvements in cardiorespiratory fitness (Hagberg, Yerg, & Seals, 1988; Chen & Kuo, 1989; Janssens, Pache & Nicod, 1999; Rasmussen, Lambrechtsen, Siersted, Hansen & Hansen, 2000; Jakes, Day, Patel, Khaw, Oakes, Luben, Welch, Bingham & Wareham, 2002; Pelkonen, Notkola, Lakka, Tukiainen, Kivinen & Nissinen, 2003;

Garcia-Aymerich, Serra, Gómez, Farrero, Balcell, Rodriguez, De Batlle, Gimeno, Donaire-Gonzalez, Orozco-Levi, Sauleda, Gea, Rodriguez-Roisin, Roca, Agusti, Antó & PAC-COPD Study Group, 2009; Suzuki, Aoyama, Shindo & Ishiyama, 2011) thereby possibly affecting the relationship between chest circumference measurements and spirometry measures as an individual's physical fitness changes over time.

Thus investigating the correlation between chest circumference measurements and spirometry measures over a 19-week intense training programme was warranted. The study assisted with determining whether a strong correlation between these variables existed and whether the correlation remained consistent with changes in physical fitness over time. Moreover, it facilitated with determining whether the use of chest circumference measurements could be considered as an inexpensive alternative for diagnosing and therapeutic monitoring of pulmonary disease. This is especially useful in disadvantaged communities that lack funds to acquire equipment and the expertise to assess patients presenting with the risks and symptoms of pulmonary disease. Anthropometric measures, such as height and weight, are popular variables used in spirometry predictive equations, because of their statistically significant correlation to spirometry measures (Gulsvik, Tosteson, Bakke, Humerfelt, Weiss & Speizer, 2001; Cotes, Chinn & Miller, 2006; Ostrowski & Barud, 2006; Wu *et al.,* 2009). The validation of a strong correlation between chest circumference measurements and spirometry measures may reinforce the use of chest circumference measurements in future spirometry predictive equations.

1.2 THE RESEARCH QUESTION

For this study, the following research question was used:

'Does a significant correlation between chest circumference measurements and spirometry measurements exist, and does this relationship remain consistent with changes to an individual's physical fitness?'

1.3 THE RESEARCH AIM

The aim of the study was to determine whether there was a strong ($r>0.6$) and statistically significant ($p\leq0.05$) correlation between:

- Inspiration chest circumference (ICC) and various spirometry measurements (namely, force vital capacity (FVC), forced expiratory volume in 1 second (FEV_1) and FEV_1/FVC percentage) at the commencement and for the duration of a 19-week intense training programme;
- Expiration chest circumference (ECC) and various spirometry measurements (FVC, FEV_1 and FEV_1/FVC) at the commencement and for the duration of a 19-week intense training programme;
- The difference between inspiration chest circumference and expiration chest circumference (ICC-ECC) and various spirometry measurements (FVC, FEV_1 and FEV_1/FVC) at the commencement and for the duration of a 19-week intense training programme;
- Spirometry measures (FVC, FEV_1 and FEV_1/FVC) and maximal oxygen uptake (VO_2 max) at the commencement and for the duration of a 19-week intense training programme.

Additionally, the study aimed to:

- Determine whether there was a statistically significant ($p\leq0.05$) change between the measured variables (i.e. ICC, ECC, ICC-ECC, FVC, FEV_1, FEV_1/FVC and VO_2 max) over the 19-week intense training programme.

The research was aimed at helping to validate the use of various inexpensive chest circumference measurements as a measurement of pulmonary function in a young healthy active population.

1.4 HYPOTHESES AND OBJECTIVES

It was hypothesised that there would be a statistically significant correlation ($p \leq 0.05$) between:

a) Chest circumference measurements (ICC, ECC and ICC-ECC) and spirometry measures (FVC, FEV_1, FEV_1/FVC) when assessed at weeks 1, 12 and 19 of the intense training programme; and
b) Spirometry measures (FVC, FEV_1 and FEV_1/FVC) and relative VO_2 max when assessed at weeks 1, 12 and 19 of the intense training programme.

Additionally, this study hypothesised that there would be a statistically significant ($p \leq 0.05$) change in the measured variables (i.e. ICC, ECC, ICC-ECC, FVC, FEV_1, FEV_1/FVC and VO_2 max) over the 19-week intense training programme

1.5 RESEARCH APPROACH

The research approach used in biokinetics and spirometry studies can be quantitative or qualitative in nature (Thomas & Nelson, 2001; Brink, Van der Walt & Van Rensburg, 2012).

The qualitative paradigm concentrates on investigating subjective data, in particular the perceptions of the people involved. The intention is to illuminate these perceptions and thus gain greater insight and knowledge. The quantitative paradigm concentrates on what can be measured. It involves collecting and analysing objective (often numerical) data that can be organised into statistics (Thomas & Nelson, 2001; Brink *et al.,* 2012). This study used a quantitative research approach.

1.6 RESEARCH DESIGN

A quantitative, prospective correlational research design was used (Thomas & Nelson, 2001; Brink *et al.,* 2012).

In prospective correlational studies a population is selected and observed over time to determine outcomes (Brink *et al.,* 2012). The purpose of correlational studies is to examine the relationship between certain performance variables, traits or attitudes and behaviour. It is a descriptive research technique that may only establish whether or not an association between two or more variables exists. It cannot assume a cause-and-effect relationship (Thomas & Nelson, 2001). In this study the participants were observed in weeks 1, 12 and 19 of the Basic Military Training (BMT) programme, at the South African National Defence Force (SANDF) military base in Lephalale, Limpopo. This study examined whether a significant correlation between chest circumference measurements and spirometry measurements existed and whether this relationship remained consistent with changes to the participants' physical fitness.

Since the data was gathered from participants before the intervention and compared with their own data gathered again after 12 and 19 weeks of training, the sample was, therefore, the self-control (Thomas & Nelson, 2001).

1.7 RESEARCH PROCEDURE AND STRATEGY

The following research procedure and strategy was followed:

1. Identification of the research question, research approach and research design
2. Compilation of the research proposal
3. Presentation of the research proposal to the research committee of the Department of Sport and Leisure Studies
4. Submission of the research proposal to the Post-Graduate Committee of the University of Pretoria for approval (Approved) (Appendix A)

5. Submission of the research proposal to the Ethics Committee of the Faculty of Humanities, University of Pretoria, for approval (Approved) (Appendix A)
6. Submission of the research protocol to the Ethics Committee of the SANDF for approval (Approved) (Appendix A)
7. Commencement of data collection
    a. Setting: SANDF Military Base in Lephalale, Limpopo
    b. Participant selection
        i. 235 SANDF recruits volunteered (136 male and 99 female)
    c. Measurements
        i. Pre-testing session – included a pre-study orientation, a screening session and completion of the indemnity form
        ii. Testing Session – included anthropometric measurements, spirometry testing and a multistage shuttle run
        iii. Testing was conducted in week 1, week 12 and week 19
8. BMT programme
9. Data analysis
    a. The data collected was captured by the researcher and analysed by the Department of Statistics at the University of Pretoria
10. Results and discussion
11. Research conclusion

The pulmonary system comprises several anatomical structures that all play a key role in the mechanics and functioning thereof (Shiner & Steier, 2013). Biological and anthropometrical factors – along with others – also play an influential role in the functioning of the pulmonary system (Rossiter & Wiell, 1973; Lapp, Amandus, Hall, & Morgan, 1974; Brokan *et al.,* 1981; Donnelly, Yang, Peat & Woolcook, 1991; Hunter, Reid, Pauli & Scott, 1996; Gulsvik *et al.,* 2001; Cimbiz *et al.,* 2004; Ebomoyi & Iyawe, 2005; Whittaker, Sutton & Beardsmore, 2005; Cotes *et al.,* 2006; Ostrowski & Barud, 2006; Lopes *et al.,* 2007; Watsford, Murphy & Pine, 2007; Chambers *et al.,* 2008; Harms & Rosenkranz, 2008; Chlif, Keochkerian, Choquet, Vaidie & Ahmaidi, 2009; Wu *et al.,* 2009; Lim, Kwon, Yoon, Kim, Choi, Park, Yoon, Chang, Lee, Lee, Kim & Jang, 2011). Currently, the most popular technique being used to test pulmonary

function is known as spirometry (Pierce, 2005; Derom, Van Weel, Lilstro, Buffels, Schermer, Lammers, Wouters & Decramer, 2008; Miller *et al.,* 2005b).

Chapter 2 provides a description of the anatomical structures of the pulmonary system and the role they play in the mechanics of breathing. Existing knowledge of the factors that influence this system – both dependently and independently – is discussed. Furthermore, the use and the value of spirometry are investigated along with the alternative technique (i.e. chest circumference measurements) which, according to the literature, has potential as a preliminary measure of pulmonary function. The influence of cardiorespiratory fitness on pulmonary function is also examined.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

The pulmonary system is made up of a number of anatomical structures that all work together to perform a variety of functions. Several factors, both internal and external, influence the efficiency and efficacy of the pulmonary system (ACSM, 2006b; Cotes *et al.,* 2006; Saladin, 2010; Shiner & Steier, 2013). Spirometry – a method of assessment of pulmonary function – is a popular technique used in most clinical environments (Pierce, 2005; Derom *et al.,* 2008; Miller *et al.,* 2005b). In the literature, a complementary method, namely chest circumference measurements – measured during pulmonary inspiration and expiration – has proved to be significantly related to spirometry measures (Brokan *et al.,* 1981; Cimbiz *et al.,* 2004; Chambers *et al.,* 2008; Wu *et al.,* 2009). This chapter discusses the anatomy and mechanics of the pulmonary system and examines the different factors that influence this system. Additionally, the validity and reliability of spirometry and chest circumference measurements are discussed. The influence of an individual's cardiorespiratory fitness on the pulmonary system is also reviewed.

2.2. ANATOMY OF THE PULMONARY SYSTEM

The pulmonary system fulfils a number of functions and is made up of various organs and anatomical structures (Figure 2.1). These organs and structures all play an important role in at least one of the three fundamental functions of the pulmonary system, namely ventilation, diffusion and perfusion (Shiner & Steier, 2013). The anatomy of the pulmonary system supports the instrumental function of oxygen (O_2)

uptake and carbon dioxide (CO_2) elimination which is essential for cellular activity (ACSM, 2006b; Shiner & Steier, 2013).

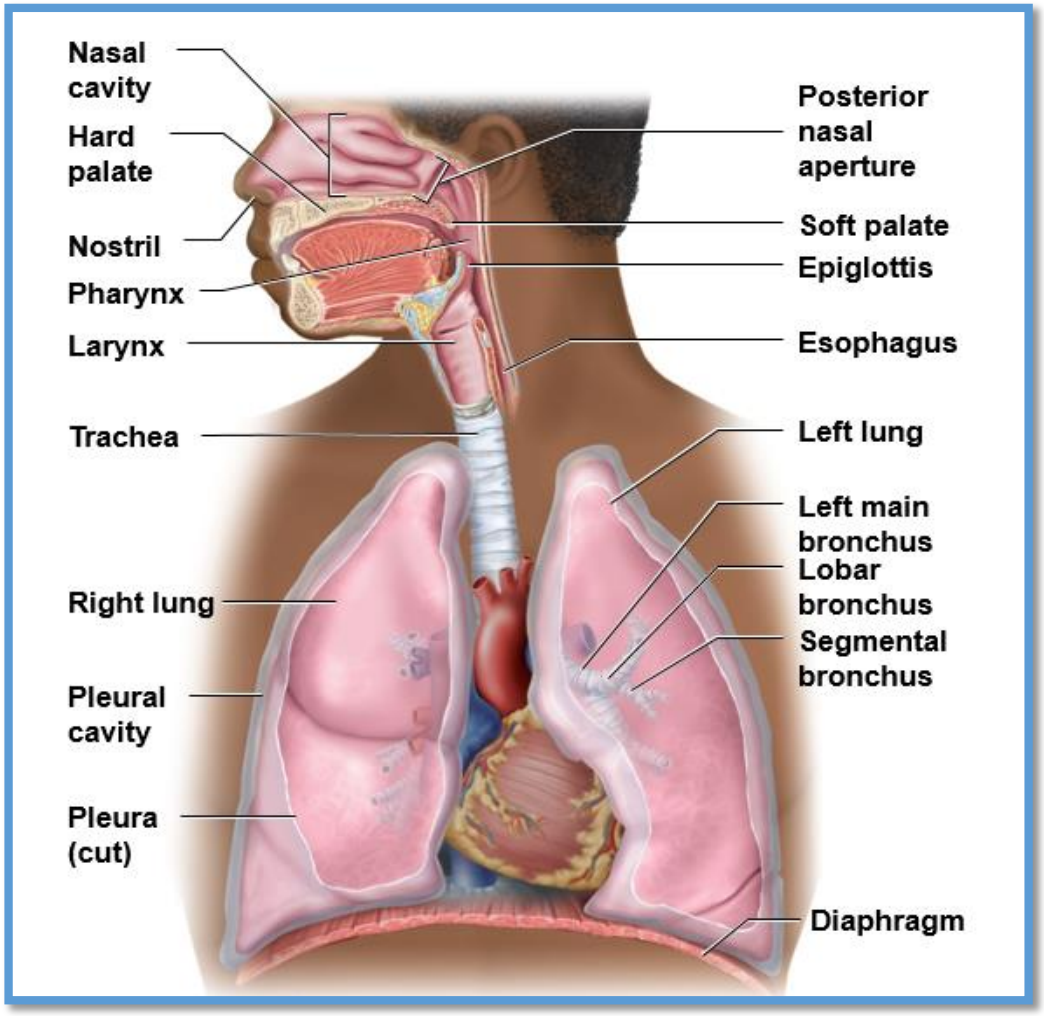


Figure 2.1 Organs of the pulmonary system (Saladin, 2010:865)

The structural components of the pulmonary system are the framework for the corresponding functions of the system (ACSM, 2006b). Table 2.1. presents the structural components of the system and their corresponding functions.

Table 2.1. Structural components of the pulmonary system and their corresponding functions (ACSM, 2006b:14)

Structural Components	**Function**
Respiratory centre Peripheral chemoreceptors Afferent and efferent nerves	Control of breathing
Upper respiratory tract Conducting airways Respiratory bronchioles	Distribution of ventilation
Chest wall, respiratory muscles and pleura	Respiratory pump
Pulmonary arteries, capillaries and veins	Distribution of blood
Functional respiratory unit	Gas exchange
Mucociliary escalator Alveolar macrophages	Bronchial clearance
Lymphatic drainage	Lung clearance and defence

The pulmonary system begins with the upper respiratory tract which is followed by the lower respiratory tract (Seeley, Stephens & Tate, 2006; Shiner & Steier, 2013). The upper respiratory tract comprises the nose, paranasal sinuses, mouth, pharynx and larynx (ACSM, 2006b; Seeley *et al.,* 2006; Saladin, 2010; Shiner & Steier, 2013). The upper respiratory tract may also be referred to as the conducting zone of the system, as it acts as a conduction pathway for the movement of air into the lower respiratory tract (ACSM, 2006b; Saladin, 2010) (Figure 2.2). The function of these structures is to warm, purify and humidify the air from the external environment before it reaches the structures essential for gaseous exchange (ACSM, 2006b; Cotes *et al.,* 2006; Shiner & Steier, 2013).

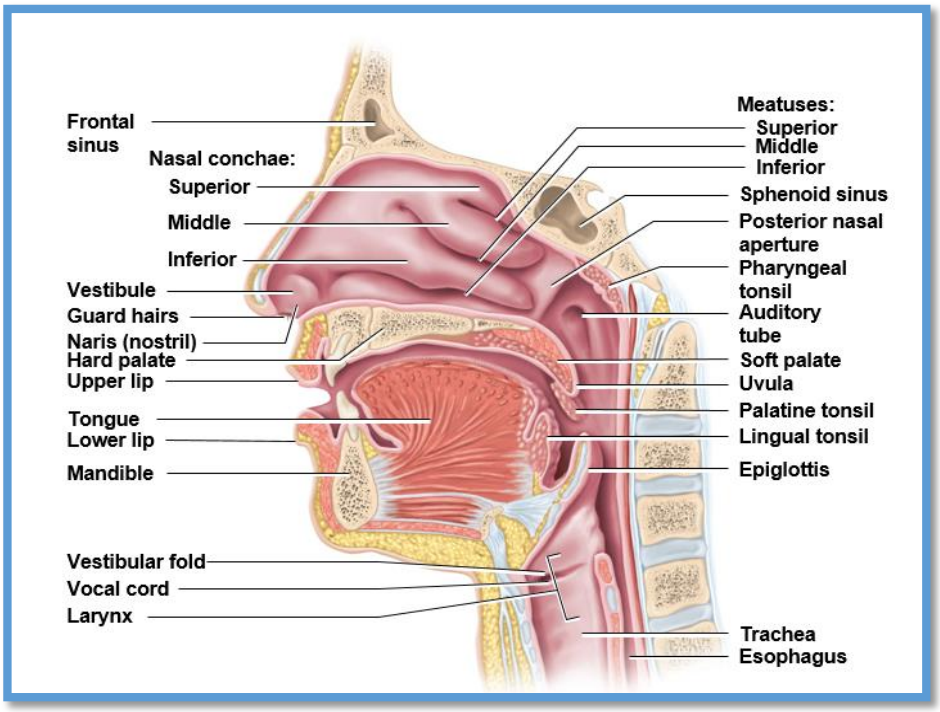


Figure 2.2 Upper respiratory tract: internal anatomy (Saladin, 2010: 866)

The lower respiratory tract includes the trachea, bronchi, bronchioles and alveoli (ACSM, 2006b; Seeley *et al.,* 2006) (Figure 2.3). There are approximately 23 generations of airways: the first 16 are conducting airways, and the last seven are respiratory airways ending in approximately 300 million alveoli, which form the gaseous exchange surface (ACSM, 2006b). The respiratory zone is where gaseous exchange occurs (ACSM, 2006b; Saladin, 2010). Once the O_2 passes through the basal membrane of the lung, the capillaries, arteries, veins and blood containing haemoglobin play an important role in gaseous exchange and gas transport (Shiner & Steier, 2013). Similarly, the tissue surrounding the lungs, which includes the pleura, chest and neuromuscular system, forms the respiratory pump which is vital for pulmonary function (Shiner & Steier, 2013).

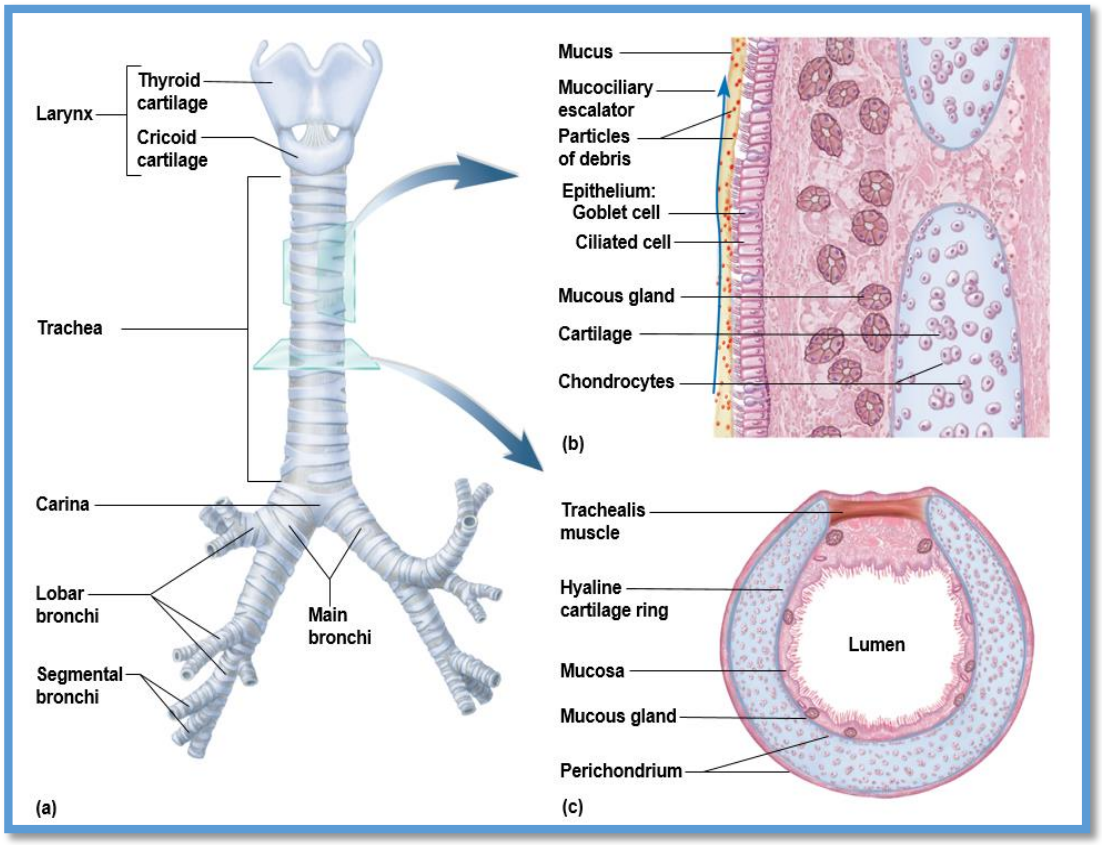


Figure 2.3 Lower respiratory tract. a) anterior view; b) longitudinal section of the trachea; c) cross-section of the trachea (Saladin, 2010:870)

The function of the respiratory pump is regulated by the brain stem and the central nervous system through several afferent and efferent nerves and feedback mechanisms (i.e. chemo- and baroreceptors) (Shiner & Steier, 2013).

The respective weights of the left and right lung, in a healthy young adult male, are approximately 500g and 600g (Cotes *et al.,* 2006). The left lung is smaller than the right lung because the heart extends out into the left thoracic space (Cotes *et al.,* 2006).

2.2.1 CHEST WALL AND RESPIRATORY MUSCLES

The chest wall and respiratory muscles play an essential role in the pulmonary system, as the respiratory pump (Shiner & Steier, 2013).

The structures of the pulmonary system are enclosed by the thoracic cage (Cotes *et al.,* 2006; Saladin, 2010; Shiner & Steier, 2013). The skeletal structures involved are the thoracic vertebrae, the sternum, the ribs, the scapulas and the clavicles (Saladin, 2010; Shiner & Steier, 2013) (Figure 2.4). These structures provide the lungs with stability and protection (Saladin, 2010; Shiner & Steier, 2013). The thoracic cage has a broad base and a narrower superior apex which allows enough space for the expansion of the lungs while breathing and moving (Saladin, 2010; Shiner & Steier, 2013).

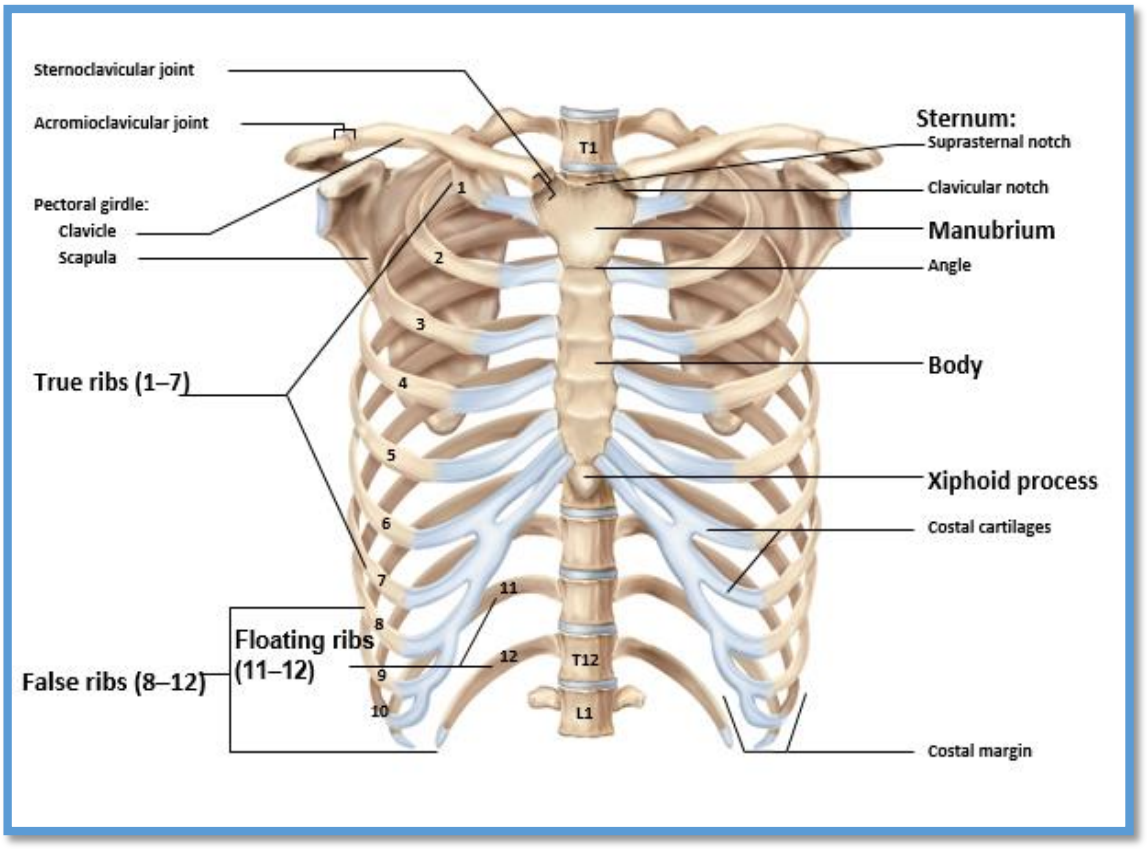


Figure 2.4 The thoracic cage (Saladin, 2010:265)

The respiratory muscles are the only skeletal muscles in the body considered to be vital for life (ACSM, 2006b). They can be largely distinguished by their function, which is either inspiratory or expiratory (Shiner & Steier, 2013). The primary muscles involved with respiration are the diaphragm, external intercostal, internal intercostal and innermost intercostal muscles (Seeley *et al.,* 2006; Saladin, 2010; Shiner & Steier, 2013) (Figures 2.5 & 2.6). These muscles enclose the thoracic cavity (Seeley *et al.,* 2006). The diaphragm bulges upwards against the base of the lungs and forms a muscular dome between the thoracic and abdominal cavities (Saladin, 2010). The external, internal and innermost intercostal muscles are situated between the ribs (Saladin, 2010). Other muscles in the neck, shoulder, chest and abdomen also assist with respiration, especially during exercise and forced breathing manoeuvres (Saladin, 2010; Shiner & Steier, 2013).

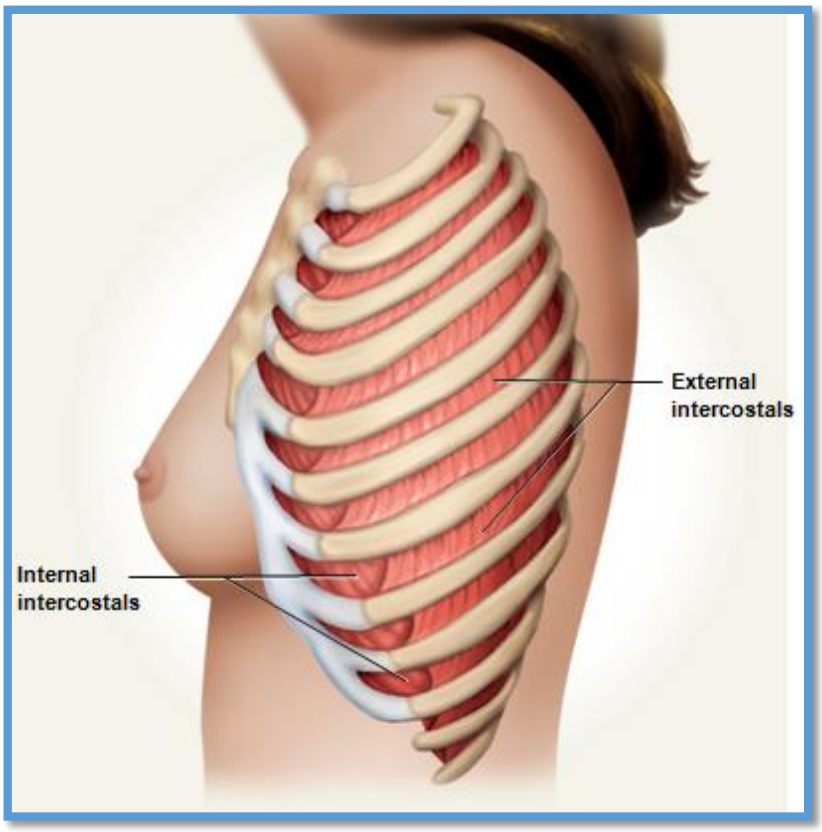


Figure 2.5 Primary muscles of respiration: intercostals (Saladin, 2010: 340)

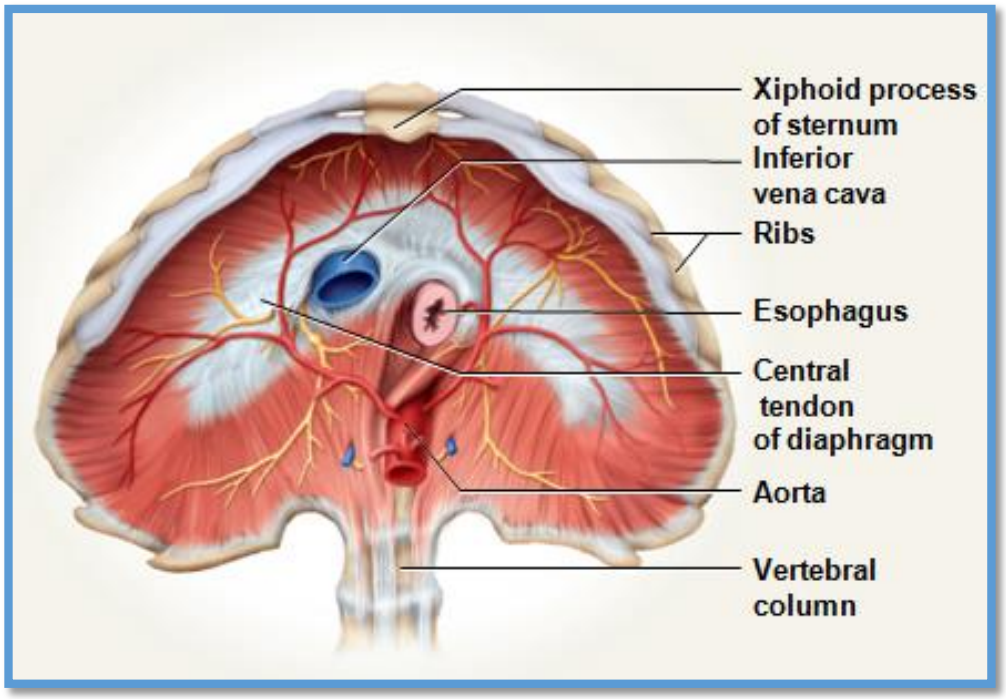


Figure 2.6 Primary muscles of respiration: diaphragm (Saladin, 2010:340)

2.2.2 THE RESPIRATORY PUMP AND THE MECHANICS OF BREATHING

Respiration can be divided into two sub-divisions: (1) pulmonary respiration and (2) cellular respiration (Powers & Howley, 2004; Saladin, 2010). Pulmonary respiration refers to ventilation of the lungs (i.e. breathing) and gaseous exchange of O_2 and CO_2 in the lungs. Cellular respiration refers to the consumption of O_2 and the production of CO_2 by the tissues (Powers & Howley, 2004; Saladin, 2010). Pulmonary ventilation consists of rhythmic cycles of pulmonary inspiration and expiration (Saladin, 2010). One complete inspiration and expiration is referred to a respiratory cycle (Saladin, 2010). During rest, when breathing is effortless and automatic, respiration is referred to as ‘quiet respiration’; and during vigorous activity (e.g. during exercise) – when breathing is deep, rapid and forceful – breathing is referred to as ‘forced respiration’ (Cotes *et al.,* 2006; Saladin, 2010).

The respiratory pump plays an important role during respiration. It is responsible for moving the air in and out of the lungs during each respiratory cycle (Cotes *et al.,* 2006; Shiner & Steier, 2013). It consists of the chest wall (intercostal muscles, spine, ribs and sternum), the respiratory muscles and the pleural space. These components are responsible for the processes of inspiration and expiration (ACSM, 2006b). The amount of air flowing in and out of the lungs is greatly dependent on the pressure gradient differences between the air pressure within the lungs and the air pressure outside the body (Powers & Howley, 2004; Cotes *et al.,* 2006; Seeley *et al.,* 2006; Saladin, 2010; Shiner & Steier, 2013). Contractions of the respiratory muscles cause pressure differences between the anatomical compartments (Cotes *et al.,* 2006; Saladin, 2010; Shiner & Steier, 2013). Inspiration occurs when the air pressure within the lungs is lower than the atmospheric pressure. Conversely, expiration occurs when the air pressure within the lungs is higher than the atmospheric pressure (Powers & Howley, 2004; Cotes *et al.,* 2006; Seeley *et al.,* 2006).

2.2.2.1 Inspiration

During inspiration the respiratory muscles are responsible for the expansion of the thoracic cage (Cotes *et al.,* 2006; Saladin, 2010). The lungs are unable to ventilate themselves independently as they only contain smooth muscle (in the walls of the bronchi and bronchioles), which influences the speed of airflow by changing the diameter of the airway (Saladin, 2010). These muscles do not play a role in the expansion and recoil of the lungs during respiration (Saladin, 2010).

The expansion of the thoracic cage during inspiration takes place as a result of an upward and outward movement of the ribs and a downward movement of the diaphragm (Cotes *et al.,* 2006). The contraction of the intercostal muscles and the diaphragm are responsible for these movements (Cotes *et al.,* 2006). During inspiration the diaphragm contracts and flattens, which forces the abdominal contents downward and forward as well as lifting the ribs outward (Powers & Howley, 2004; Seeley *et al.,* 2006; Saladin, 2010). The intercostal muscles act as synergists to the diaphragm and are primarily responsible for stiffening the thoracic cage during respiration and preventing the thoracic cage from caving inward while the diaphragm

flattens (Saladin, 2010). While the external intercostal muscles pull the remaining ribs upwards, the scalene muscles stabilise the first two ribs (Saladin, 2010). The ribs are anchored at both ends via the vertebral column on the proximal end and via costal cartilage of the sternum on the distal end (Cotes *et al.,* 2006; Saladin, 2010). This causes the ribs to swing upward like the handles on a bucket and thrust the sternum forward during inspiration (Cotes *et al.,* 2006; Seeley *et al.,* 2006; Saladin, 2010). This action increases the anteroposterior and transverse diameters of the chest (Cotes *et al.,* 2006; Seeley *et al.,* 2006; Saladin, 2010).

During forced inspiration other muscles, namely the erector spinae, pectoralis major, pectoralis minor and serratus anterior, assist in increasing the volume of the thoracic cage (Saladin, 2010). The pleura that surround the lungs also play a role in inspiration (ACSM, 2006b; Cotes *et al.,* 2006; Shiner & Steier, 2013). The space between the visceral and parietal pleura is called the pleural space (ACSM, 2006b). During rest, a negative pressure is produced when the chest wall and lung tissue pull against each other across the pleural space (ACSM, 2006b). A greater negative pressure is produced in the pleural space during inspiration, as both the visceral and parietal pleuras expand outward (ACSM, 2006b; Cotes *et al.,* 2006).

2.2.2.2 Expiration

During quiet respiration, expiration occurs passively, meaning that no muscular effort is required (ACSM, 2006b; Cotes *et al.,* 2006; Seeley *et al.,* 2006). The relaxation of the inspiratory muscles, the elastic recoil of the lung tissue and gravity are responsible for returning the ribs to their natural position and compressing the alveolar gas (ACSM, 2006b; Cotes *et al.,* 2006; Seeley *et al.,* 2006). These two actions increase the intra-pleural pressure in comparison to the atmospheric pressure, resulting in a reverse in the direction of air flow (Cotes *et al.,* 2006). During forced respiration, such as during exercise and hyperventilation, expiration is assisted by the respiratory muscles (ACSM, 2006b; Cotes *et al.,* 2006; Seeley *et al.,* 2006). The major muscles involved with forced expiration are the intercostal and abdominal muscles (rectus abdominis, external and internal oblique and transverse abdominis) (ACSM, 2006b; Cotes *et al.,* 2006; Seeley *et al.,* 2006). The contraction

of the rectus abdominis and the internal and external obliques increases the intra-abdominal pressure, which forces the diaphragm upwards and pulls the ribs downward and inward (Cotes *et al.,* 2006). This results in the compression of the lungs and the expulsion of the air within the lungs (ACSM, 2006b; Cotes *et al.,* 2006). The lumbar and pelvic muscles may also contribute towards increasing the thoracic pressure during forced expiration (Powers & Howley, 2004; Saladin, 2010). Figure 2.7 shows the muscles and mechanics involved during inspiration and forced expiration.

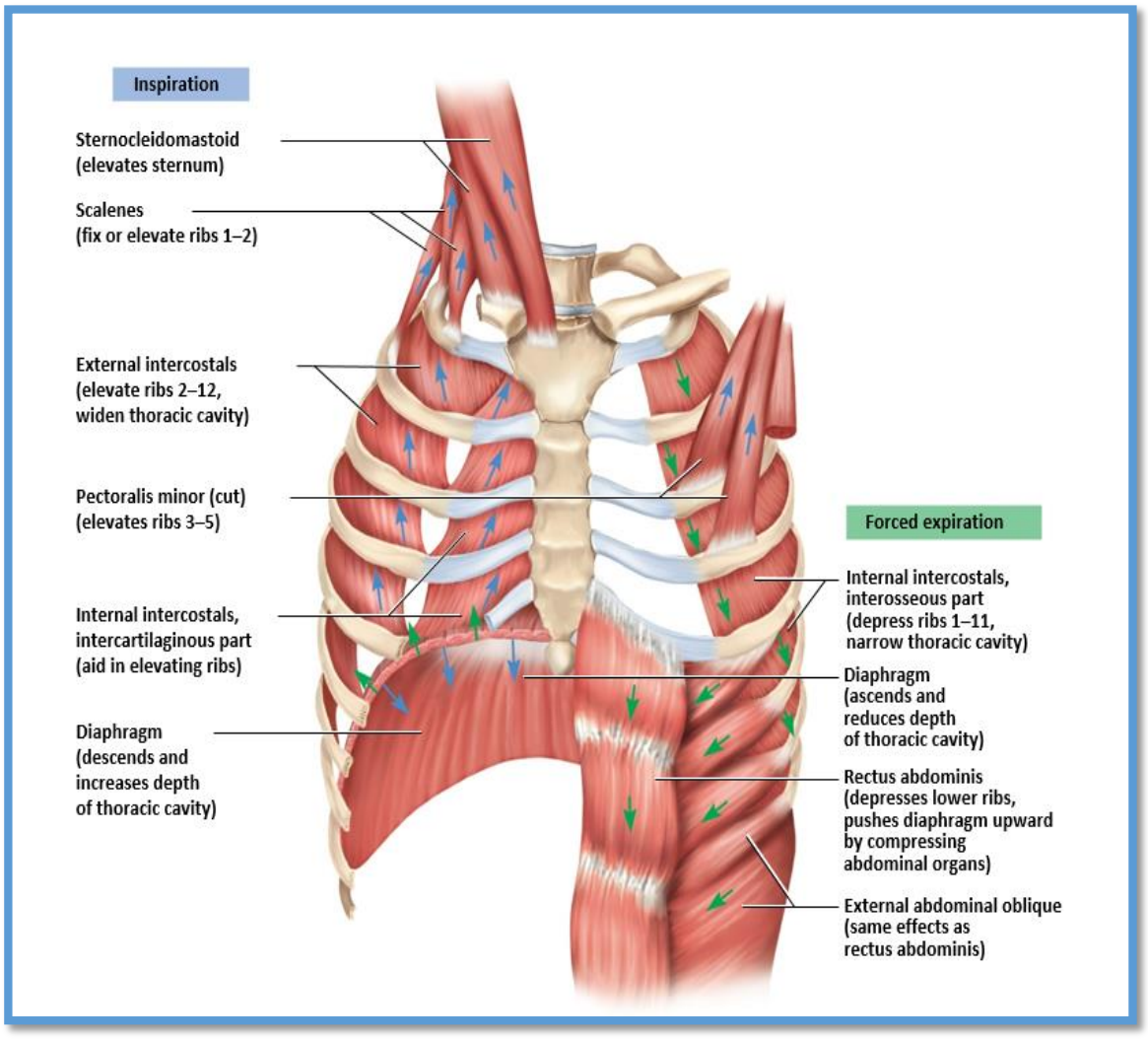


Figure 2.7 The muscles and mechanics of respiration: inspiration and forced expiration (Saladin, 2010: 876)

2.3. FACTORS INFLUENCING PULMONARY FUNCTION

Pulmonary function is influenced by many biological factors such as age, sex and race, as well as by anthropometrical incidences like height, weight and body size (Rossiter & Wiell, 1973; Lapp *et al.,* 1974; Brokan *et al.,* 1981; Donnelly *et al.,* 1991; Hunter *et al.,* 1996; Gulsvik *et al.,* 2001; Cimbiz *et al.,* 2004; Ebomoyi & Iyawe, 2005; Whittaker *et al.,* 2005; Cotes *et al.,* 2006; Ostrowski & Barud, 2006; Lopes *et al.,* 2007; Watsford *et al.,* 2007; Chambers *et al.,* 2008; Harms & Rosenkranz, 2008; Chlif *et al.,* 2009; Wu *et al.,* 2009; Lim *et al.,* 2011). Other factors such as pulmonary mechanics, muscle strength and endurance, functional capacity, airflow limitations, hormones and smoking have also been shown to potentially affect pulmonary function (Hagberg *et al.,* 1988; Xu, Dockery, Ware, Speizer & Ferris, 1992; Burchfiel, Marcus, Curb, MacLean, Vollmer, Johnson, Fong, Rodriguez, Kamal, Masaki & Buist, 1995; Gold, Wang, Wypij, Speizer, Ware & Dockery, 1996; Rasmussen *et al.,* 2000; Scanlon, Connett, Waller, Altose, Bailey, Buist & Lung Health Study Research Group, 2000; Anthonisen, Connett & Murray, 2002; Jakes *et al.,* 2002; Cheng, Macera, Addy, Sy, Weilnad & Blour, 2003; Pelkonen *et al.,* 2003; Cotes *et al.,* 2006; Ostrowski & Barud, 2006; Garcia-Aymerich *et al.,* 2009; Watsford *et al.,* 2007; Radovanovic, Aleksandrovic, Stojiljkovic, Ignjatovic, Popovic & Marinkovic, 2009; Hirayama, Lee & Hiramatsu, 2010; Kroff & Terblanche, 2010; Suzuki *et al.,* 2011). Researchers have studied these factors either independently or in combination.

2.3.1. BIOLOGICAL FACTORS

2.3.1.1. Pulmonary function and age

Age is the most commonly used predictor for calculating pulmonary function prediction values (Cotes *et al.,* 2006; Wu *et al.,* 2009). Pulmonary function is considered to be dynamic, with growth in childhood and adolescence, a plateau during young adulthood, and a decline in later adulthood (Gulsvik *et al.,* 2001; Jackson, Kubzansky, Cohen, Weiss & Wright, 2004; Cotes *et al.,* 2006; Ostrowski & Barud, 2006; Wu *et al.,* 2009). In healthy participants, pulmonary function increases

with growth and reaches its peak at approximately 20–25 years of age and declines thereafter (Santana, Zoico, Turcato, Tosoni, Bissoli, Olivieri, Bosello & Zamboni, 2001; Cotes *et al.,* 2006; Ostrowski & Barud, 2006; Wu *et al.,* 2009).

More specifically, Gulsvik *et al.* (2001) established that the peak value of FEV_1 appears at an earlier age than FVC and that the peak values for FVC, FEV_1 and forces inspiratory vital capacity (FIVC) occur at approximately the same age in men and women, while the peak forced inspiratory volume in one second (FIV_1) occurs at an earlier period in women than in men. Moreover, when researching the pulmonary function changes in healthy never-smoking males and females from adolescence to old age, Kohansal, Martinez-Camblor, Agustí, Buist, Mannino and Soriano (2009) observed that females had a longer FEV_1 plateau phase than males and that their yearly rate of FEV_1 decline with age was slight but not significantly lower than in healthy never-smoking males (17.6 vs 19.6 ml/year, respectively; p=0.266). There is a plateau phase of peak pulmonary function from 18–35 years of age and thereafter an accelerating decrease of pulmonary function with age (Gulsvik *et al.,* 2001; Ostrowski & Barud, 2006).

The main causes for the decline in pulmonary function are deterioration in lung tissue, decrease in respiratory muscle strength and stiffening of the thoracic cage (Cotes *et al.,* 2006). These changes reduce the elastic recoil pressure of the lung, the lung volumes an individual is able to achieve and the ventilatory capacity of the lungs (Cotes *et al.,* 2006). The decrease in the physiological capacity of the lungs has also proven to affect the performance of everyday tasks and more specifically the capacity of the respiratory system (Watsford *et al.,* 2007). Interestingly, Suzuki *et al.* (2011) noticed that pulmonary function continued to decrease with age despite the physical fitness levels of the individuals, and concluded that exercise does not inhibit the age-associated decline of pulmonary function in healthy individuals.

2.3.1.2. Pulmonary function and sex differences

Sex differences exist in pulmonary structure and in pulmonary function (Harms & Rosenkranz, 2008). They are one of the most important predictors of pulmonary function (Ostrowski & Barud, 2006). Young men have larger lungs than women,

allowing for greater extension of all its component parts, including the alveoli, the aveolar sacs and the air passages from the respiratory bronchioles to the trachea (Cotes *et al.,* 2006; Harms & Rosenkranz, 2008). Consequently, men have lower airway resistance than women and therefore larger FEV_1 values (Cotes *et al.,* 2006; Harms & Rosenkranz, 2008). The size of the lungs also influences compliancy: the lungs of young men are usually more compliant than the lungs of young women (Cotes *et al.,* 2006). The differences in lung compliance reflect the respective respiratory muscles' strength in men and women (Cotes *et al.,* 2006). Men are more muscular than women (Cotes *et al.,* 2006). Moreover, young adult women have proven to have lower resting lung diffusing capacities, smaller lung volumes and lower maximal expiratory flow rates, even when corrected for height and age, relative to men (Cotes *et al.,* 2006; Harms & Rosenkranz, 2008). In addition to the differences in lung size and respiratory muscle strength, these gender differences can be explained, in part, by fewer total number of alveoli (smaller surface area) and smaller airway diameter relative to lung size in women (lower maximum flow rates) (Harms & Rosenkranz, 2008). These differences may influence airway responsiveness, ventilation and gaseous exchange during exercise (Harms & Rosenkranz, 2008).

Furthermore, the increase in blood progesterone levels in women during the luteal phase of the menstrual cycle has proven to influence gaseous exchange and ventilation of the lungs (Cotes *et al.,* 2006; Harms & Rosenkranz, 2008). Increased levels of progesterone result in more blood being present in the lung capillaries, therefore increasing the transfer factor of gases. Progesterone also increases the ventilation and tidal volume at rest and during exercise (Cotes *et al.,* 2006). Additionally, Harms and Rosenkranz (2008) state that increased progesterone levels are believed to contribute to expiratory flow limitations during exercise, resulting in women experiencing greater respiratory muscle fatigue than men during heavy exercise. As men and women get older, the lung function of men deteriorates to a greater extent than that of women (Cotes *et al.,* 2006). The intrinsic changes in the lungs with ageing, as mentioned in section 2.3.1.1, occur more quickly in men than in women. These changes are accelerated by exposure to tobacco smoke and atmospheric pollutants, to which men are generally more exposed to than women (Cotes *et al.,* 2006).

2.3.1.3. Pulmonary function and race differences

Race differences in pulmonary function have been recognised in both adults and children (Whittaker *et al.,* 2005). The influence of race differences on pulmonary function were first observed in the 1960s (Cotes *et al.,* 2006). The magnitude and the extent of these differences were then later explored during the International Biological Programme (Cotes *et al.,* 2006). Studies conducted during this period showed that the lung and chest size relative to height in Asian Indians, sub-Saharan Africans and Australian Aboriginals are smaller than those of Europeans and would therefore influence pulmonary function (Cotes *et al.*, 2006). A study conducted by Donnelly *et al.* (1991) showed that the mean total lung capacity (TLC) and FVC in Caucasians were 5–10% higher than in Chinese and 17–20% higher than in Indians. Moreover, the Caucasian group had higher fat-free mass, wider chests and greater inspiratory and expiratory muscle pressures than the other races (Donnelly *et al.,* 1991). These findings suggest that the Caucasian group has greater lung volumes than the Chinese and Indian groups because they have physically larger chest cavities and more alveoli (Donnelly *et al.,* 1991). The chest dimensions, together with height and race, explained 90% of the variation in FVC and 86% of the variation in TLC (Donnelly *et al.,* 1991).

Chest size has also proven to be an important determinant of lung volume in Africans (Rossiter & Wiell, 1973; Donnelly *et al.,* 1991; Ebomoyi & Iyawe, 2005). Research has shown that Africans have a lower thoracic diameter than Caucasians, resulting in lower TLC and FVC values (Donnelly *et al.,* 1991; Ebomoyi & Iyawe, 2005). More specifically, the FVC and FEV_1 of Africans is approximately 12% lower than that of Caucasians of the same age and height (Lapp *et al*., 1974). Furthermore, a study by Rossiter and Weill (1973) showed that Caucasians had a 13% larger chest volume than Africans, which accounted for the differences in TLC, FVC, FEV_1, forced expiratory flow rate and alveolar volume between Africans and Caucasians.

Despite these findings, a study conducted by Whittaker *et al.* (2005), investigating whether race differences in lung function could be explained by chest size, concluded that the influence of chest dimensions of pulmonary function was

insignificant despite BMI being smaller in Asians than in Caucasians (Whittaker *et al.,* 2005). Furthermore, Lapp *et al.* (1974) observed that when the difference in lung size was controlled for by matching African and Caucasian participants of the same TLC, no significant differences in flow rates were observed.

A recent plea for an international workshop to review aspects of race and ethnicity in relation to pulmonary function has been made, despite past studies observing the influence of racial differences on pulmonary function (Quanjer, 2013). In the past ethnicity was based on race, but recently the description has changed due to the strong influence of geographical, social, economic and dietary factors (Cotes *et al.,* 2006). This has made the use of the race factor on pulmonary function less simple than it originally appeared (Cotes *et al.,* 2006).

2.3.2. ANTHROPOMETRICAL FACTORS

The pulmonary system's capacity to transfer O_2 from the atmosphere to the blood is directly proportional and related to an individual's body size and composition (Cotes *et al.,* 2006). Therefore, a larger, leaner or more athletic individual is likely to have a greater TLC, transfer factor, cardiac stroke volume and quantity of skeletal muscle than a smaller or fatter individual with a lower muscle mass (Cotes *et al.,* 2006).

2.3.2.1. Pulmonary function and stature

Stature (standing height) is one of the most commonly used predictors of pulmonary function and contributes significantly to the prediction of FVC, FEV_1 and forced expiratory flow 25-75% ($FEF_{25–75}$) (Gulsvik *et al.,* 2001; Ostrowski & Barud, 2006; Wu *et al.,* 2009). Stature can be represented as the sum of leg length and sitting height (Cotes *et al.,* 2006). Standing height is considered to be inversely related to pulmonary function and linearly related to lung size (Cotes *et al.,* 2006; Lim *et al.,* 2001). Thus a taller individual is expected to have a greater pulmonary function, due

to his or her larger thoracic cage and bigger lungs, than a shorter individual (Cotes *et al.,* 2006).

2.3.2.2. Pulmonary function, body fat and muscle mass

Pulmonary function is also influenced by changes in body fat and muscle mass. The distribution of body fat directly influences pulmonary function when it accumulates in the trunk region (Santana *et al.,* 2001; Cotes *et al.,* 2006; Chambers *et al.,* 2008; Chlif *et al.,* 2009; Lim *et al.,* 2011). In healthy individuals, the central pattern of fat distribution is negatively related to pulmonary function (Santana *et al.,* 2001). Fat accumulated in the mediastinum, around the heart, in the pleural space and above the diaphragm reduces the space that is generally available for alveolar air (Cotes *et al.,* 2006). Similarly, fat accumulated in the abdominal region (specifically intra-abdominal fat) reduces the functional residual capacity and expiratory reserve volume, both directly by its presence in the thorax and indirectly by raising the diaphragm (Cotes *et al.,* 2006; Chambers *et al.,* 2008; Chlif *et al.,* 2009). This ultimately affects the chest wall mechanics during respiration (Chlif *et al.,* 2009). Generally, middle-aged men with a 'beer belly' (i.e. increased intra-abdominal fat), can have limited vital capacities (Cotes *et al.,* 2006). Furthermore, obesity is known to affect the thorax, diaphragm and abdominal muscles, thereby influencing pulmonary function (Wu *et al.,* 2009). Conversely, whilst high levels of body fat in the trunk region reduce static lung volumes, reductions in body fat will enhance them (Cotes *et al.,* 2006; Lim *et al.,* 2001). It was discovered that after adjusting for an individual's age, fat mass in the trunk region was inversely related to pulmonary function in both sexes (Lim *et al.,* 2011). An increase of muscle mass in the trunk and lower extremities in men, and a reduction in fat mass in the trunk region and upper body in both men and women, have proven to assist in maintaining pulmonary function in the elderly population (Lim *et al.,* 2011).

2.3.2.3. Pulmonary function and chest circumference

Chest circumference is another anthropometric factor that influences pulmonary function (Cotes *et al.,* 2006). Chest circumference is predominantly used for the measurement of chest expansion, which is the chest circumference from complete expiration to full inspiration (Cimbiz *et al.,* 2004; Cotes *et al.,* 2006). It has occasionally been used in predictive equations for spirometry due to its positive correlation to pulmonary function in healthy individuals (Brokan *et al.,* 1981; Cimbiz *et al.,* 2004; Wu *et al.,* 2009). Hunter *et al.* (1996) presented some preliminary results regarding the possible association of chest size with pulmonary function and its associated respiratory signs and symptoms. Cimbiz *et al.* (2004) showed that the chest expansion of men who smoked was significantly lower than that of men who did not smoke, even though their chest size and shape were similar. Furthermore, Lopes *et al.* (2007) showed that there is a significant difference in the chest expansion of children with severe persistent asthma (SPA) compared to children without asthma ($p<0.01$). The children with SPA had limited chest expansion, possibly due to the postural adaptations and muscle shortening of both respiratory and non-respiratory muscles associated with the disease (Lopes *et al.,* 2007).

Although chest circumference measurements may theoretically be a good predictor of pulmonary function because of its association with chest dimension, it has occasionally been excluded from predictive equations for spirometry because the reproducibility of the measurements is poor (Schrader *et al.,* 1984; Wu *et al.,* 2009).

2.3.3. OTHER FACTORS INFLUENCING PULMONARY FUNCTION

Research has revealed that physical activity, respiratory muscle strength and endurance, as well as some lifestyle-related factors such as smoking and diet, can influence pulmonary function (Hagberg *et al.,* 1988; Xu *et al.,* 1992; LoRusso, Belman, Elashoff & Koerner, 1993; Burchfiel *et al.,* 1995; Gold *et al.,* 1996; Rasmussen *et al.,* 2000; Scanlon *et al.,* 2000; Anthonisen *et al.,* 2002; Jakes *et al.,* 2002; Cheng *et al.,* 2003; Pelkonen *et al.,* 2003; Cotes *et al.,* 2006; Ostrowski &

Barud, 2006; Garcia-Aymerich *et al.,* 2009; Watsford *et al.,* 2007; Radovanovic *et al.,* 2009; Hirayama *et al.,* 2010; Kroff & Terblanche, 2010; Suzuki *et al.,* 2011).

2.3.3.1. Pulmonary function, physical activity and cardiorespiratory fitness

Participation in regular physical activity has proved to have a positive influence on pulmonary function (Hagberg *et al.,* 1988; Rasmussen *et al.,* 2000; Jakes *et al.,* 2002; Pelkonen *et al.,* 2003; Garcia-Aymerich *et al.,* 2009; Hirayama *et al.,* 2010; Suzuki *et al.,* 2011). In a 25-year follow-up study conducted by Pelkonen *et al.* (2003), the decline in pulmonary function was slower in individuals that participated in regular physical activity. More specifically, it was predicted that climbing more stairs and participating in more vigorous leisure-time activities slowed down the rate of annual percentage decline in FEV_1 ($p<0.004$ and $p<0.002$, respectively) (Jakes *et al.,* 2002). In particular, FEV_1 has been identified as a significant risk factor for cardiovascular disease, stroke, lung cancer and all-cause mortality (Jakes *et al.,* 2002). Thus poor pulmonary function plays an essential role in the prediction and cause of mortality (Jakes *et al.,* 2002). One possible reason for this association is that FEV_1 is a marker of other determinants of mortality risk, such as obesity and physical inactivity (Jakes *et al.,* 2002). In patients with COPD, significant correlation coefficients for the relationships between VO_2 max and measures of pulmonary function, namely maximal voluntary ventilation, FVC, FEV_1 and diffusing capacity of the lung for carbon monoxide (DLCO), have been reported (LoRusso *et al.,* 1993). The functional status – in terms of DLCO, maximal expiratory pressure, six-minute walking distance, maximal oxygen uptake and systemic inflammation – has shown to be better in COPD patients who participate in regular physical activity (Garcia-Aymerich *et al.,* 2009).

Hirayama *et al.* (2010) proposed an inverse association between participation in life-long physical activity and the risk of COPD and breathlessness. The pulmonary function of older adults who remained physically active proved to be better than those who remained physically inactive (Hirayama *et al.,* 2010). More specifically, the decline in pulmonary function and volumes associated with ageing appears to be

slower in older athletes who participated in prolonged strenuous endurance training (Hagberg *et al.,* 1988).

Scientific studies investigating the relationship between VO_2 max and measures of pulmonary function, especially in patients with pulmonary pathologies, have noted that there is a strong and significant correlation between these measures (McGavin, Gupta & McHardy, 1979; Fisher, Cawley & Holgate, 1990; Ganju, Fuladi, Tayade & Ganju, 2011). Fatemi, Shakerian, Ghanbarzade, Habibi and Moghaddam (2012) mentioned that pulmonary function may limit VO_2 max in conditions with airway obstruction, increased breathing resistance or inhalation of high-density gas mixtures. Furthermore, FEV_1 has proven to be a valuable measure of airway obstruction and closely related to VO_2 max, especially in patients with COPD (Babb, Long & Rodarte, 1997; Fatemi *et al.,* 2012). Babb *et al.* (1997) stated that despite patients with mild COPD being able to achieve similar maximal heart rates and ventilatory reserve as age-matched normal patients, they had lower VO_2 max levels which were in proportion to their reduced FEV_1.

Rasmussen *et al.* (2000) stated that individuals with greater cardiorespiratory fitness have higher ventilator thresholds. This may be due to the larger respiratory manoeuvres induced by exercise, causing increased range of motion of the rib cage and hence larger ventilator capacities (Rasmussen *et al.,* 2000). Furthermore, improvements in cardiorespiratory fitness in asthmatic patients have been associated with fewer respiratory symptoms and the consumption of medication (Rasmussen *et al.,* 2000). Moreover, individuals with elevated levels of cardiorespiratory fitness seem to have a lower risk of developing asthma (Rasmussen *et al.,* 2000). Radovanovic *et al.* (2009) studied the impact of a waterpolo training programme on cardiorespiratory endurance in pre-adolescent boys. The values of absolute VO_2 peak, FEV_1 and FVC were significantly higher in participants involved with the waterpolo training (Radovanovic *et al.,* 2009). They speculated that the improvements in FEV_1 and FVC were due to the improvement in cardiorespiratory fitness of these participants (Radovanovic *et al.,* 2009).

Despite this, there is also an opposing view in the literature regarding the relationship between cardiorespiratory fitness and pulmonary function. It has been stated that there is inconclusive data regarding the change in pulmonary function in

high-level aerobic performers, and more specifically in military recruits (Cochet, Lucero, Zacher & Morris, 2013; Degens, Rittweger, Parviainen, Timonen, Suominen, Heinonen & Korhonen, 2013).

Regular participation in endurance training results in significant adaptations within the cardiovascular, musculoskeletal and haematological systems (McKenzie, 2012; Cochet *et al.,* 2013). However, McKenzie (2012) and Degens *et al.* (2013) both stated that the structural and functional properties of the lungs and airways do not change in response to repetitive physical activity. Furthermore, Suzuki *et al.* (2011) discovered that when comparing three different levels of VO_2 max (i.e. high, normal & low) with pulmonary function, not all pulmonary function measures were associated to VO_2 max in healthy male and female volunteers.

Although participation in whole-body endurance activities has proved to increase the strength of the respiratory muscles (Cotes *et al.,* 2006; Kroff & Terblanche, 2010) and thus increase the function of the respiratory pump in moving the air in and out of the lungs (Cotes *et al.,* 2006; Shiner & Steier, 2013), Lanza, De Camargo, Archija, Selman, Malaguti and Dal Corso (2013) stated that lung volumes obtained in spirometry tests are related not only to the strength of the respiratory muscles, but also to the elastic recoil, compliance and resistance of the lungs and airways. Interestingly, Cotes *et al.* (2006) stated that the usefulness of chest dimensions for describing the pulmonary function of children appears to be less meaningful in adults.

According to McKenzie (2012) there are four factors associated with limitations in pulmonary function in healthy individuals, namely:

1. arterial hypoxemia;
2. expiratory flow limitations;
3. vocal cord dysfunction; and
4. respiratory muscle fatigue.

The demands of ventilation and gaseous exchange during exercise exceed the capacity of the pulmonary system (McKenzie, 2012). Additionally, the pulmonary system's inability to increase its diffusion capacity with training may contribute to the often-observed exercise-induced hypoxemia in athletes (Degens *et al.,* 2013).

Studies comparing athletes to untrained individuals provide little evidence that high demands on the pulmonary system during exercise change underlying values of pulmonary function tests (McKenzie, 2012).

Granted that active duty military recruits, with their greater emphasis on regular physical fitness, are supposed to have above-normal pulmonary function test values when compared to non-active duty military recruits, Cochet *et al.* (2013) observed that there is no significant difference in pulmonary function tests in active duty versus non-active duty recruits of the same age range. Moreover, Cochet *et al.* (2013) concluded that the pulmonary function test values of active duty military recruits should not be assumed by virtue of their active duty status.

2.3.3.2. Pulmonary function and respiratory muscle strength and endurance

Significant differences in respiratory muscle (RM) strength and endurance between athletes and sedentary individuals have been observed (Kroff & Terblanche, 2010). This may be due to athletes having increased muscle quantity and greater RM strength and endurance, particularly athletes participating in whole-body endurance training such as middle-distance runners, swimmers and cyclists (Cotes *et al.,* 2006; Kroff & Terblanche, 2010). In some instances anatomical features, like a long trunk length in a swimmer, may pose a respiratory advantage (Cotes *et al.,* 2006; Kroff & Terblanche, 2010). Watsford *et al*. (2007) studied the effects of ageing on respiratory muscle function and performance in older adults. The study revealed that the expiratory muscle strength in males were significantly related to walking performance ($p=0.04$) and that, in both males and females, inspiratory muscle strength contributed significantly to walking performance (Watsford *et al.,* 2007). Furthermore, Cheng *et al.* (2003) showed that physical activity enhances inspiratory muscle strength.

2.3.3.3. Pulmonary function and smoking

Cigarette smoking is associated with a decline in pulmonary function (Xu *et al.,* 1992; Burchfiel *et al.,* 1995; Gold *et al.,* 1996; Scanlon *et al.,* 2000; Anthonisen *et al.,* 2002;

Cotes *et al.,* 2006). The inhalation of tobacco smoke causes an immediate increase in airway resistance, which results in reduced FEV_1 and maximal expiratory flow (Cotes *et al.,* 2006). Moreover, continued cigarette smoking causes a decline in FEV_1 (Xu *et al.,* 1992; Burchfiel *et al.,* 1995; Anthonisen *et al.,* 2002; Shiner & Steier, 2013). Xu *et al.* (1992) stated that the accelerated loss of FEV_1 among smokers is linearly dependent on the number of cigarettes smoked per day. The estimated increase in rate of loss in smokers was 12.6 ml/year per pack of cigarettes smoked per day for males and 7.2 ml/year per pack of cigarettes smoked per day for females (Xu *et al.,* 1992). Furthermore, in a study by Burchfiel *et al.* (1995), Japanese-American males who continued to smoke experienced greater rates of decline in FEV_1 in comparison with males who never smoked (-33 ml/year versus -22 ml/year, respectively; p=0.0001). Anthonisen *et al.* (2002), who examined the pulmonary function of participants 11 years after they entered the Lung Health Study, observed a decline in FEV_1 of 66.1 ml/year in males who continued smoking and 54.2 ml/year in females who continued smoking. Moreover, 38% of continuing smokers had an FEV_1 less than 60% of the predicted normal value, in comparison with 10% of those who quit smoking (Anthonisen *et al.,* 2002).

In adolescent boys and girls, a dose–response relation between smoking and lower levels of both FEV_1/FVC and $FEF_{25–75}$ of FVC was observed (Gold *et al.,* 1996). Each pack of cigarettes smoked per day was associated with a 3.2% decrease in $FEF_{25–75}$ for girls (p=0.01) and a 3.5% decrease in $FEF_{25–75}$ for boys (p=0.007) (Gold *et al.,* 1996). Tobacco smoking, particularly heavy smoking, long duration of smoking and smoking of high-tar cigarettes, are all factors contributing to the development of COPD (Scanlon *et al.,* 2000). Table 2.2. summarises the average effects of smoking on pulmonary function indices in comparison with non-smokers of the same age.

Table 2.2. Average effect of smoking 20 cigarettes per day on pulmonary function indices in comparison with non-smokers of the same age (Cotes *et al.*, 2006: 511)

		Males		Females	
		Non-sm	**Sm**	**Non-sm**	**Sm**
Number of subjects		139	91	97	84
FEV_1	L	3.80	3.42	2.65	2.45
VC	L	5.11	4.80	3.07	2.91
FEV_1/VC	%	77	74	87	84
$FEF_{25-75\%}$	1 s^{-1}	3.86	3.12	3.43	3.01

Non-sm: non-smoking; Sm: smoking

For each index, being a smoker significantly impaired the pulmonary function ($p<0.05$).

The prevalence and smoking behaviour of military recruits appears to be unique to the military population. A study by Schei and Sogaard (1994) showed that military service had a negative influence on the smoking behaviour of Norwegian army recruits. The study reported that amongst the recruits who smoked, 55.7% increased their smoking during military service, and 7.8% of the recruits who were non-smokers had started to smoke (Schei & Sogaard, 1994). These changes in smoking behaviour were linked with having a best friend who smoked, with dissatisfaction with the military service, and with frequent alcohol consumption. Ninety percent of the recruits lived in dormitories where cigarette smoking occurred regularly (Schei & Sogaard, 1994). Similarly, Klesges, Sherrill-Mittleman, Ebbert, Talcott, & DeBon (2010) reported that after a one-year follow-up of military service, most cigarette smokers had either maintained or increased their tobacco use. Understanding the detrimental effects smoking has on health, the United States (US) military enforces

mandatory tobacco abstinence during BMT. This has been reported to have had a positive, though small, effect on smoking after BMT, with the overall smoking prevalence for US military male recruits decreasing from 12.7% from the second day of BMT to 9.8% 90 days after BMT (Williams, Hermesch, Gackstetter, Lando & Fiedler, 1996). The SANDF does not enforce tobacco abstinence during BMT.

2.3.3.4. Pulmonary function and diet

The relationship between diet and pulmonary function has also received attention (Ostrowski & Barud, 2006). Positive associations between pulmonary function and a number of antioxidant vitamins, namely vitamin C, vitamin E and β-carotene, have been observed (Ostrowski & Barud, 2006). Vitamin C has proven to decrease the effect of respiratory infections in children, military recruits and athletes participating in heavy physical exercise (Hemilä, 1996).

2.4. MEASURES OF PULMONARY FUNCTION

Studies of pulmonary function started as early as 280 BC. It began with Erasistratus (280 BC) and Galen (129–201 BC) discovering the role of the diaphragm, the intercostal and accessory muscles as a muscles of respiration (Cotes *et al.,* 2006). Studies, discoveries and debates continued for many years thereafter about the anatomy, physiology and mechanics of lungs and heart. However, around 1667 different techniques to assess pulmonary function became available and created an interest in further research (Cotes *et al.,* 2006). The assessment techniques used to assess pulmonary function became more refined and practical as the physiology and mechanics of the pulmonary system became better known (Cotes *et al.,* 2006). Currently there are a number of techniques that can be used to assess pulmonary function, namely spirometry, gas dilution techniques, body plethysmography, gas diffusion tests, inhalation challenge tests and exercise stress tests (Shiner & Steier, 2013). These tests are performed to determine lung volume, the rate at which air moves in and out of the lungs and the efficiency of gaseous exchange between O_2

and CO_2. Additionally, these tests are performed to determine pulmonary disease diagnosis, prognosis and severity, as well as treatment efficiency (Shiner & Steier, 2013). Spirometry is a well-known and widely used pulmonary function test that offers an objective measure of pulmonary function (Wu *et al.,* 2009; Meo, 2010; Shiner & Steier, 2013).

Since spirometry is the assessment technique used in this study, it is discussed in further detail.

2.4.1. SPIROMETRY

2.4.1.1. What is spirometry?

Spirometry is considered to be the most widely used and uniquely useful non-invasive pulmonary function test (Pierce, 2005; Derom *et al.,* 2008; Miller *et al.,* 2005b). It is a medical test that measures the volume or flow of air an individual inhales or exhales as a function of time (Seeley *et al.,* 2006; Miller *et al.,* 2005b; Shiner & Steier, 2013). It is mainly used to evaluate patients with a diagnosed pulmonary disease or who present with a medical history, physical examination or respiratory symptoms that warrant an assessment of basic pulmonary function (Pierce, 2005; ACSM, 2006a; Derom *et al.,* 2008). A spirometer is the device used to assess pulmonary function (Seeley *et al.,* 2006). It is a volitional test of flow and volumes, and is therefore directly dependent on the motivation of the patient and the experience of the staff conducting the test (Miller, Carpo, Hankinson, Brusasco, Burgos, Casaburi, Coates, Enright, van der Grinten, Gustafsson, Jensen, Johnson, MacIntyre, McKay, Navajas, Pedersen, Pellegrino, Viegi, & Wanger, 2005a; Shiner & Steier, 2013). It requires the patient to breathe forcefully into a device that measures the mechanical properties of the pulmonary system (Powers & Howley, 2004). The device measures the respired lung volumes and capacities during forced expiration and inspiration (Powers & Howley, 2004; Pierce, 2005). It quantifies how effectively and quickly the lungs can be emptied and filled (Pierce, 2005). The results obtained from spirometry tests are therefore dependent on technical as well as personal

factors (Miller *et al.,* 2005b). Figure 2.8 illustrates the steps that should be followed to decrease the variability of the results and to improve the accuracy of the measurements (Miller *et al.,* 2005b).

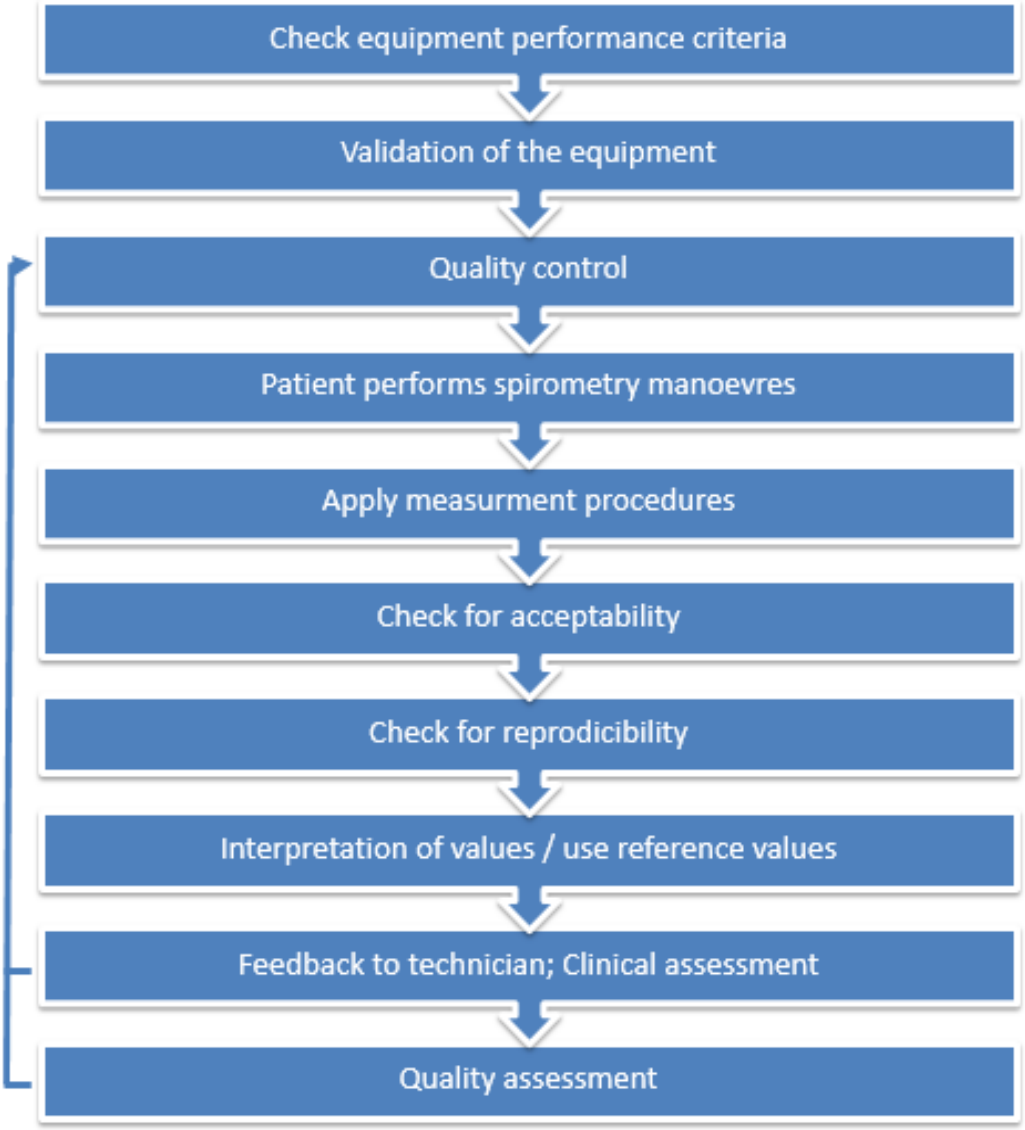


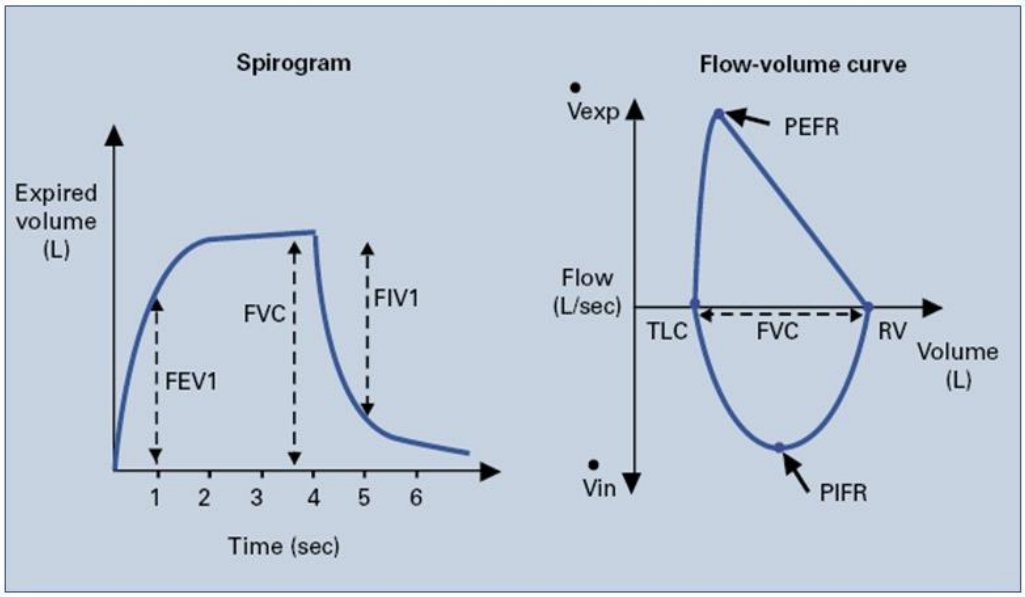
Figure 2.8 Standardisation steps for spirometry (Miller *et al*., 2005b:321)

2.4.1.2. Measurements of spirometry

The most commonly recorded spirometry measurements are FVC, FEV_1 and FEV_1/FVC (Pierce, 2005; Miller *et al.,* 2005b). FVC is the maximum amount of air that is expired forcefully and as completely as possible after a full inspiration (Miller

et al., 2005b; Shiner & Steier, 2013). FEV_1 is the expired volume of air during the first second of an FVC manoeuvre (Miller *et al.,* 2005b; Shiner & Steier, 2013). This measurement declines with age and is associated with both the diagnosis and prognosis of asthma and COPD (Shiner & Steier, 2013).

In addition to the above-mentioned measurements, maximal inspiratory measures – e.g. FIV_1 and FIVC – and measures of forced maximal flow during forced expiration and inspiration – e.g. peak expiratory flow rate (PEFR) – can also be recorded (Pierce, 2005). Furthermore, spirometry values obtained during a test can also be represented on a flow-volume curve (Pierce, 2005). A flow-volume curve presents the practitioner with information of diagnostic value (Pierce, 2005; Shiner & Steier, 2013) (Figure 2.9 & Figure 2.10).



FEV1 = forced expiratory volume in 1 second
FIV1 = forced inspiratory volume in 1 second
FVC = forced vital capacity
PEFR = peak expiratory flow rate
IRV = inspiratory residual volume
Vt = tidal volume

FVC = forced vital capacity
TLC = total lung capacity
RV = residual volume
PIFR = peak inspiratory flow rate
ERV = expiratory residual volume

Figure 2.9 Normal spirogram and flow-volume curve showing the measurements made (Pierce, 2005:536)

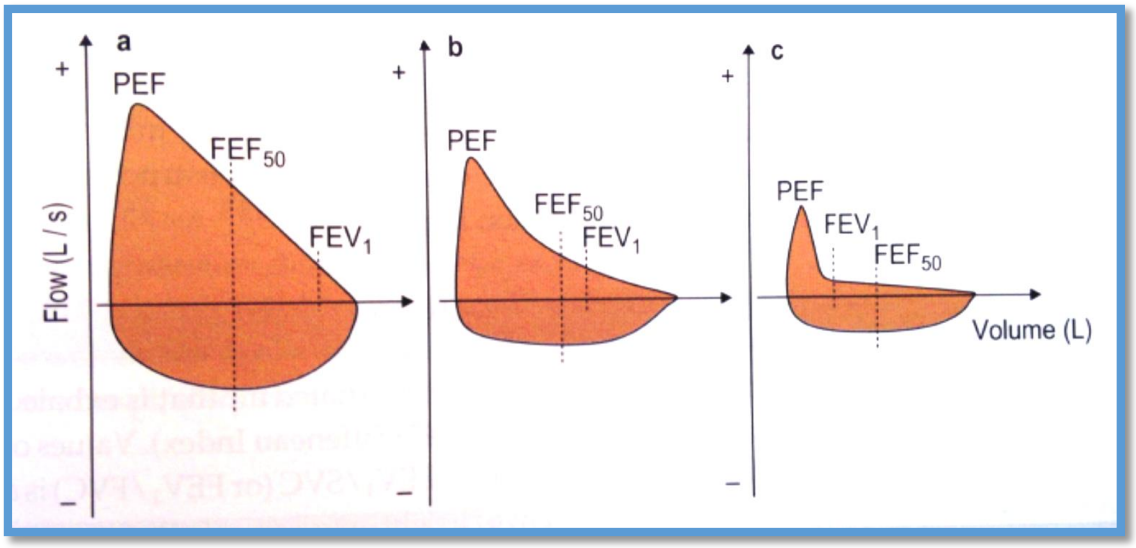


Figure 2.10 Flow-volume curves: a. normal subject; b. patient with moderate airway obstruction; c. patient with severe chronic airflow obstruction (Shiner & Steier, 2013: 45)

Maximum flows (e.g. PEFR) and dynamic pulmonary volumes (e.g. FEV_1, FVC) are compared with reference values obtained from a normal population using comparable test protocols and carefully calibrated equipment (Pierce, 2005).

A pulmonary defect can be suspected when any of the spirometry values measured (i.e. FEV_1, FVC, PEFR or FEV_1/FVC) are outside the required reference range (Pierce, 2005). An obstructive pulmonary defect (i.e. asthma, emphysema and chronic bronchitis) is signified by a decrease of FEV_1 in relation to the FVC, resulting in a low FEV_1/FVC percentage (<70%) and an increased airway resistance (Pierce, 2005; ACSM, 2006b; Shiner & Steier, 2013). The primary physiological limitation of obstructive pulmonary diseases is increased airway resistance (ACSM, 2006b). This is a result of the reduced cross-sectional airway diameter, attributed to the structural or dynamic changes of the diseases (ACSM, 2006b). Intra-thoracic or extra-thoracic narrowing of the airway leads to diminished FEV_1 and decreased FEV_1/FVC ratio (Shiner & Steier, 2013). A restrictive pulmonary defect can be assumed when a decrease in vital capacity is present and the percentage ratio (FEV_1/FVC) remains normal or high (>80%) with the presence of a normal flow–volume curve (Pierce, 2005; ACSM, 2006b; Shiner & Steier, 2013). Pulmonary causes of restriction may be recognised by a relatively high PEFR, which is attributed to changed compliance of

the lung, a measure of elasticity, with fast retraction following full inflation (Shiner & Steier, 2013). Restrictive defects may be due to interstitial lung disease, respiratory muscle weakness and thoracic cage deformities (Pierce, 2005; ACSM, 2006b). Table 2.3. represents the severity classifications for spirometric abnormalities based on FEV_1.

Table 2.3. Severity of spirometric abnormality based on the FEV_1 (Pellegrino, Viegi, Brusasco, Crapo, Burgos, Casaburi, Coates, Van der Grinten, Gustafsson, Hankinson, Jensen, Johnson, MacIntyre, McKay, Miller, Navajas, Pedersen & Wanger, 2005: 957)

Degree of severity	**FEV_1 % predicted**
Mild	>70%
Moderate	60–69%
Moderately severe	50–59%
Severe	35–49%
Very severe	< 35%

2.4.1.3. Indications for spirometry

Typically spirometry is routinely used by doctors, nurses and physical therapists (ACSM, 2006a). It provides these practitioners with a better understanding of functional changes in the lungs and is a good indicator of respiratory ability and function (Ebomoyi & Iyawe, 2005). Spirometry is characteristically performed in a number of settings and for a number of reasons. It may be performed in hospital-based pulmonary function laboratories or clinics, in primary care settings (e.g. general medical clinics), and in community-based service settings (Derom *et al.* 2008). Some clinical indications of spirometry are presented in Table 2.4.

Table 2.4. Clinical indications for spirometry (Pierce, 2005: 536–537; Miller *et al.*, 2005b:320; Shiner & Steier, 2013: 38)

Clinical indications for spirometry

Diagnostic	To assess symptoms, signs or abnormal laboratory tests To screen individuals at risk of having pulmonary disease To measure the effect of disease on pulmonary function To differentiate between obstructive versus restrictive pulmonary defects To identify upper airway obstruction To identify diseases associated with weakness of respiratory muscles To assess pre-operative risk To assess prognosis To assess health status before beginning strenuous physical activity programmes To assess pulmonary complications of non-pulmonary disease (e.g. heart failure)
Monitoring	To assess therapeutic intervention and treatment effects To describe the course of diseases that affect lung function To monitor the natural history and progression of respiratory, systemic and/or neuromuscular disease To monitor people exposed to injurious agents To monitor adverse reactions to drugs with known pulmonary toxicity To monitor rehabilitation effects
Disability/ impairment evaluations	To assess patients as part of a rehabilitation programme To assess individuals for legal reasons To assess risks as part of an insurance evaluation
Public health	Clinical research Epidemiological surveys Derivation of reference equations

2.4.1.4. Reproducibility and acceptability criteria

To ensure that spirometry results are valid and reproducible, the tests must fulfil the within- and between-manoeuvre acceptability criteria (Miller *et al.,* 2005b; Booker, 2008). Tables 2.5. and 2.6. describe the acceptability criteria for spirometry stipulated in *Series ATS/ERS Task Force: Standardisation of Lung Function Testing, Number 2: Standardisation of Spirometry* by Miller *et al.,* 2005b.

Table 2.5. Acceptability criteria – within-manoeuvre criteria (Miller *et al.,* 2005b:325)

ACCEPTABILITY CRITERIA
<u>Within-manoeuvre criteria</u> Individual spirometry tests are 'acceptable' if: ○ They are free from artefacts: 1. cough during the first second of exhalation 2. glottis closure (i.e. Valsalva manoeuvre) that influences the measurement 3. early termination or cut-off of the test 4. effort that is not maximal throughout the test 5. leak at the mouth 6. obstructed mouthpiece (e.g. tongue or teeth obstructing the front of mouthpiece) 7. evidence of an extra breath taken during the manoeuvre ○ They have good starts: ▪ extrapolated volume< 5% of FVC or 0.15L, whichever was greater ○ They show satisfactory exhalation: ▪ duration of ≥6s or a plateau in the volume-time curve; or ▪ if the participant could not or should not continue to exhale

Table 2.6. Acceptability criteria – between-manoeuvre criteria (Miller *et al.,* 2005b:325)

ACCEPTABILITY CRITERIA

Between-manoeuvre criteria
• After three acceptable spirometry tests have been obtained, the following must be applied to the tests:
  ○ The two largest values of FVC must be within 0.150L of each other.
  ○ The two largest values of FEV_1 must be within 0.150L of each other.
• If both of these criteria are met, then the test session may be concluded.
• If both of these criteria are not met, then the testing must continue until:
  ○ both of the criteria are met with the analysis of additional spirograms; or
  ○ a total of eight tests has been performed; or
  ○ the participant cannot or should not continue
• Saved, as a minimum, the three satisfactory manoeuvres
Manoeuvres with early termination or Valsalva manoeuvre may be used for selecting the largest FVC and FEV_1.

2.4.1.5. The value of spirometry and its associated limitations

Spirometry has been reported as being a valuable and indispensable tool for the assessment of pulmonary function, especially for the diagnosis and severity of COPD (White *et al.,* 2007; Derom *et al.,* 2008; Schermer *et al.,* 2009). The number of patients diagnosed with asthma and COPD is on the rise and many symptomatic cases of asthma or COPD in the community remain undiagnosed, thus reinforcing the importance of and need for spirometry tests in various settings (Derom *et al.,* 2008). Both the American Thoracic Society and the European Respiratory Society enforce the use of spirometry in all patients with a family history of COPD, a history of exposure to cigarette smoke and/or environmental pollutants, or the presence of a chronic cough, sputum production or shortness of breath (Miller *et al.,* 2005b; Lee *et al.,* 2006; White *et al.,* 2007).

It has been indicated that primary care spirometry increases the rates of diagnosis for COPD and may also lead to improvements in its treatment. Despite this, spirometry is being inconsistently used in the diagnosis of COPD and for the care of patients with COPD (Lee *et al.,* 2006). Even though accurate and reproducible spirometric measurements are required to classify disease severity, diagnose airway obstruction, assess reversibility of airway obstruction and evaluate the response to therapeutic interventions, studies have demonstrated that spirometry performed in primary care settings does not satisfy the full criteria for acceptability and reproducibility, nor does it approach the levels obtained in pulmonary function laboratories (Miller *et al.,* 2005a; Lee *et al.,* 2006; White *et al.,* 2007; Derom *et al.,* 2008; Schermer *et al.,* 2009).

In order to read, interpret and assess the data obtained from spirometry tests, it is important to understand the limitations of spirometry (Shiner & Steier, 2013). High-quality spirometry requires the comprehensive training of staff, reliable equipment and standardised procedures (Miller *et al.,* 2005a; Pierce, 2005; Schermer *et al.,* 2009). The results obtained from spirometry tests may be confounded by a number of problems associated with the technicality, practicality and accuracy of the tests (Shiner & Steier, 2013). The technical problems associated with spirometry arise from the equipment itself and the methods of calculation and range of normal values used (Shiner & Steier, 2013; Booker, 2008).The practical problems result from the discrepancies found in inter-spirometer and intra-spirometer variability (Shiner & Steier, 2013). Lastly, the accuracy of the tests, especially in the follow-up and monitoring of COPD, is greatly influenced by whether or not the patient is a smoker, whether he or she has stopped smoking and whether he or she is part of an intervention to stop smoking (Shiner & Steier, 2013).

Additionally, factors such as a lack of experience and routine, limited training, poor quality-assurance activities, a lack of supervision after the completion of training, the beliefs and attitudes of practitioners and technicians towards spirometry and poor interpretation of results, all contribute to the high rate of low-quality spirometry tests (Lee *et al.,* 2006; White *et al.,* 2007; Schermer *et al.,* 2009). Another limitation of spirometry is that it is an effort-dependent manoeuvre (Shiner & Steier, 2013). Thus the interactions between the technician and the patient are vital in obtaining adequate spirometry (Shiner & Steier, 2013). To ensure acceptable and reproducible

spirometry, an enthusiastic and compliant patient and a well-trained and motivated technician are vital (Lee *et al.,* 2006; Derom *et al.,* 2008; Shiner & Steier, 2013). The appropriateness of the software to the patient performing the test also influences the quality of the patient's effort during the spirometry manoeuvre (Shiner & Steier, 2013).

Thus, to ensure regular use and quality execution of spirometric tests, hospitals, primary care and community-based settings need to be equipped with good-quality spirometers (Lee *et al.,* 2006; Derom *et al.,* 2008). Additionally, practitioners and technicians need to be appropriately guided and trained on the use of spirometry (Lee *et al.,* 2006; Derom *et al.,* 2008). More specifically, technicians should be trained on how to perform an accurate and reproducible spirometry test and practitioners should be trained on how to evaluate spirograms (Derom *et al.,* 2008). Remote electronic reporting of primary care-based spirometry may also provide a means of establishing adequate spirometry (White *et al.,* 2007). The immediate feedback and provision of expert interpretation of reports may improve the quality of tests (White *et al.,* 2007). Finally, a technically flawed test and incorrect diagnosis and treatment may result in unnecessary stress and worry for the patient, side-effects from inappropriate treatment and the withholding of effective treatments (Derom *et al.,* 2008).

2.4.1.6. Chest circumference measurements and spirometry testing

Chest circumference measurements have been shown to be positively correlated to pulmonary function in healthy individuals, and have occasionally been used in prediction equations for spirometry (Brokan *et al.,* 1981; Cimbiz *et al.,* 2004; Chambers *et al.,* 2008; Wu *et al.,* 2009). Chest circumference, which can be closely linked to chest dimension, is an anthropometric parameter that influences pulmonary function (Cotes *et al.,* 2006). It is primarily used to measure the expansion of the chest wall during full inspiration and complete expiration (Cimbiz *et al.,* 2004; Cotes *et al.,* 2006; Wu *et al.,* 2009). It is measured with a tape measure at the xyphoid process of the sternum (i.e. at nipple level) (Cimbiz *et al.,* 2004; Cotes *et al.,* 2006; Wu *et al.,* 2009). The integrity of the chest wall influences the effectiveness of the

respiratory pump, which plays an essential role in the flow of air moving in and out of the lungs (Cotes *et al.,* 2006; Shiner & Steier, 2013). The main components of the respiratory pump are the physical properties of the thorax, the muscles and the airways (Cotes *et al.,* 2006). Changes to any of these components will directly affect pulmonary function, such as with ankylosing spondylitis and obesity (Cotes *et al.,* 2006).

A significant correlation between chest circumference and spirometry measures has also been shown in populations with various pulmonary pathologies and postural deviations (Stamm & Docter, 1965; Leong, Lu, Luk & Karlberg, 1999; Hawes & Brooks, 2001; Lopes *et al.,* 2007). Changes to the muscles, the physical properties of the thorax and the airways influence the effectiveness of the respiratory pump (Cotes *et al.,* 2006). Spinal deformity, associated with conditions such as scoliosis, has serious effects on the configuration of the lungs within the chest and reduces the effectiveness of the respiratory muscles (Cotes *et al.,* 2006). Lopes *et al.* (2007) showed that children who suffered from persistent asthma had limited chest expansion at the axillar and xyphoid levels, due to the postural adaptations and muscle shortening caused by the severity of the disease (Lopes *et al.,* 2007). Furthermore, a study conducted by Stamm and Docter (1965) stated that, especially for cystic fibrosis, the relationship between surface area and chest circumference may be an accurate indicator of pulmonary involvement. Hawes and Brooks (2001) reported that when compared to control participants, patients with Idiopathic Scoliosis (IS) exhibited a significantly smaller mean chest circumference and restricted chest mobility. Moreover, a chest expansion capacity of <3.8 cm in IS patients was strongly correlated with diminished FVC (Hawes & Brooks, 2001). The overall stiffness of the thoracic cage and spine may contribute to the mechanical inefficiency and impairment of pulmonary function in patients with scoliosis (Leong *et al.,* 1999).

Based on the literature, circumference measurements of the chest wall during maximal inspiration and complete expiration appear to be closely associated with pulmonary function. Since it is a relatively simple measurement to conduct and does not require the use of costly technical equipment, it may potentially offer practitioners and technicians an additional method for assessing pulmonary function, especially for conditions that are affected by the components of the respiratory pump (Stamm &

Docter, 1965; Leong *et al.,* 1999; Hawes & Brooks, 2001; Cotes *et al.,* 2006; Lopes *et al.,* 2007).

2.5. CARDIORESPIRATORY FITNESS

Cardiorespiratory fitness is considered an element of health-related physical fitness because increases in cardiorespiratory fitness are consistently associated with a decrease in premature death from all causes (Nieman, 2007). Enhanced levels of cardiorespiratory fitness are also linked to higher levels of habitual physical activity, which in turn are associated with a number of health-related benefits (Nieman, 2007). Cardiorespiratory fitness is defined as the ability of the circulatory and pulmonary systems to supply O_2 during physical activity (ACSM, 2006b; Nieman, 2007). More specifically, VO_2 max or maximal oxygen uptake is defined as the maximum rate at which O_2 can be taken up, transported, and utilised by the body during physical activity (ACSM, 2006b; Nieman, 2007). The assessment of VO_2 max represents the criterion against which any estimate of cardiorespiratory fitness is measured (Powers & Howley, 2004). The best method to assess the endurance of heart and lungs during physical activity is through the direct measurement of VO_2 max in a laboratory setting; however, because it is expensive, time-consuming and requires highly trained staff, it is not always practical (Nieman, 2007). Thus, other tests such as field tests have been developed as substitutes (Nieman, 2007). In addition to assessing VO_2 max to determine improvements in cardiorespiratory fitness, it can be used as a prognostic marker prior to surgery (Shiner & Steier, 2013). Furthermore, it can be helpful in unmasking pathophysiological conditions in patients who are asymptomatic and have a pulmonary disease (Shiner & Steier, 2013).

VO_2 max is dependent on the adequate functioning of the pulmonary system, the cardiovascular system and the muscular system (Nieman, 2007). To improve cardiorespiratory fitness an individual must increase his or her participation in aerobic or large motor activities such as walking, running and swimming (Powers &

Howley, 2004; ACSM, 2006b). Healthy participants have demonstrated 10% to 30% increases in VO_2 max, with the greatest relative improvements in the least fit (ACSM, 2006b). Improvements in cardiorespiratory fitness are associated with a number of favourable changes, namely greater O_2 transport, increased maximal stroke volume and cardiac output, changes in heart rate, arteriovenous O_2 difference, blood lactate and ventilation (ACSM, 2006b). To allow for improvements in an individual's cardiorespiratory fitness, the essential principles of training, namely adaptation and specificity, must be considered when designing a physical training programme (ACSM, 2006b). ACSM (2006b: 336) defines the principle of adaptation as *"…when a specific physiological capacity is taxed by a physical training stimulus within a certain range and on a regular basis, this physiological capacity usually expands."* Additionally, adaptation is reliant on two related principles, namely training threshold and training overload (ACSM, 2006b). Training threshold is when the physiological capacity is challenged past a certain minimal intensity, and training overload is when the training stimulus exceeds the training threshold (ACSM, 2006b).

According to ACSM (2006b: 336), the principle of specificity is defined as *"specific physiological capacities expand only if they are stressed in the course of an exercise program".* Therefore, the mode of exercise selected, as well as the frequency, duration, and intensity of training, are vital in achieving fitness results (ACSM, 2006b).

The purpose of BMT is to prepare and equip new recruits with the necessary physical capabilities and skills required to perform their military tasks effectively (Williams, Rayson & Jones, 1999; Wood & Krüger, 2013). One of the physical capabilities required is enhanced cardiorespiratory fitness (Williams *et al.,* 1999).

The literature reveals that the cardiorespiratory fitness of military recruits is positively influenced by regular participation in military training for a predicted period of time (Lim & Lee, 1994; Brock & Legg, 1997; Williams *et al.,* 1999; Cheng, Chiu, Lin, Xu, Hsu & Liang, 2007). When researching the effects of a 20-week BMT programme on body composition, VO_2 max and aerobic fitness of obese recruits, Lim and Lee (1994) observed a significant ($p<0.001$) increase in aerobic fitness, although improvement in VO_2 max was mild. Brock and Legg (1997) demonstrated a statistically significant increase in mean VO_2 ($p<0.05$) when evaluating the influence

of British Army recruit training on physical fitness and strength of female recruits. Moreover, Cheng *et al.* (2007) showed that nine weeks of BMT in first-grade cadets significantly enhanced ($p<0.001$) the cadets' cardiovascular function. Furthermore, when investigating the efficacy of British Army basic training on improving material handling performance of male recruits, Williams *et al.* (1999) observed a statistically significant improvement in VO_2 max ($p<0.014$) over the 10 weeks of BMT.

In summary, participation in regular physical activity has shown to enhance cardiorespiratory fitness (ACSM, 2006b), and, more specifically, BMT proves to produce favourable adaptations in recruits, especially in terms of aerobic fitness (Williams *et al.,* 1999).

2.6. CONCLUSION

The pulmonary system consists of number of anatomical structures that all play a vital role, either dependently or independently, in the functioning of the system. Pulmonary function can be assessed using various methods; however the most popular method is spirometry, due to its practicality. Despite this, spirometry performed in primary care settings is not being used consistently and does not satisfy the full criteria for acceptability and reproducibility. High-quality spirometry is greatly dependent on the comprehensive training of staff, reliable equipment and standardised procedures. An additional method that may be used as a tool for preliminary screening of pulmonary function and volumes is the anthropometrical measurement of chest circumference, measured during maximal inspiration and complete expiration of the chest wall. This method is inexpensive, practical and easy to conduct. The literature shows that a statistically significant correlation exists between chest circumference and spirometry measures in both healthy individuals and individuals with pulmonary pathologies and postural deviations. Moreover, the literature supports the fact that changes in cardiorespiratory fitness influences pulmonary function. Thus it would be of practical value to determine whether this relationship between chest circumference and spirometry measures remains the

same or changes with improvements in cardiorespiratory fitness due to participation in regular physical activity.

CHAPTER 3

METHODOLOGY

In this chapter the following sections are discussed:

- Research approach and design
- Research procedure and strategy
- Ethical approval and considerations
- Setting
- Procedures and instrumentation
- BMT programme
- Statistical analysis
- Sample size

3.1 RESEARCH APPROACH AND DESIGN

The research approach used in biokinetics and spirometry studies can be quantitative or qualitative in nature (Thomas & Nelson, 2001; Brink *et al.,* 2012).

The qualitative paradigm concentrates on investigating subjective data, in particular the perceptions of the people involved. The intention is to illuminate these perceptions and thus gain greater insight and knowledge. The quantitative paradigm concentrates on what can be measured. It involves collecting and analysing objective (often numerical) data that can be organised into statistics (Thomas & Nelson, 2001; Brink *et al.,* 2012). A quantitative research approach was followed in this study, utilising a prospective correlational research design (Thomas & Nelson, 2001; Brink *et al.,* 2012).

In prospective correlational studies a population is selected and observed over time to determine outcomes (Brink *et al.,* 2012). The purpose of correlational studies is to examine the relationship between certain performance variables, traits or attitudes and behaviour (Thomas & Nelson, 2001). It is a descriptive research technique that may only establish whether or not an association between two or more variables exists. It cannot assume a cause-and-effect relationship (Thomas & Nelson, 2001). In this study the participants were observed in weeks 1, 12 and 19 of BMT at the SANDF military base in Lephalale, Limpopo. This study examined whether a strong and significant correlation exists between chest circumference measurements and spirometry measurements in a young healthy active population, and whether this relationship remained consistent with changes to the participants' physical fitness.

Since the data was gathered from participants before the intervention and compared with their own data gathered again after 12 and 19 weeks of training, the sample was, therefore, the self-control (Thomas & Nelson, 2001).

3.2 RESEARCH PROCEDURE AND STRATEGY

The research procedure and strategy followed in this study are outlined in chronological order below and graphically represented in Figure 3.1.

1. Identification of the research question, research approach and research design
2. Compilation of the research proposal
3. Presentation of the research proposal to the research committee of the Department of Sport and Leisure Studies
4. Submission of the research proposal to the Post-Graduate Committee of the University of Pretoria, for approval (Approved) (Appendix A)
5. Submission of the research proposal to the Ethics Committee of the Faculty of Humanities, University of Pretoria, for approval (Approved) (Appendix A)

6. Submission of the research protocol to the Ethics Committee of the SANDF for approval (Approved) (Appendix A)
7. Data Collection in weeks 1, 12 and 19 of BMT
8. BMT programme
9. Data analysis
10. Results and discussion
11. Research conclusion

This chapter highlights and discusses the ethical considerations of the study, the data-collecting process, the BMT programme followed and the data-analysing procedures utilised (Figure 3.1).

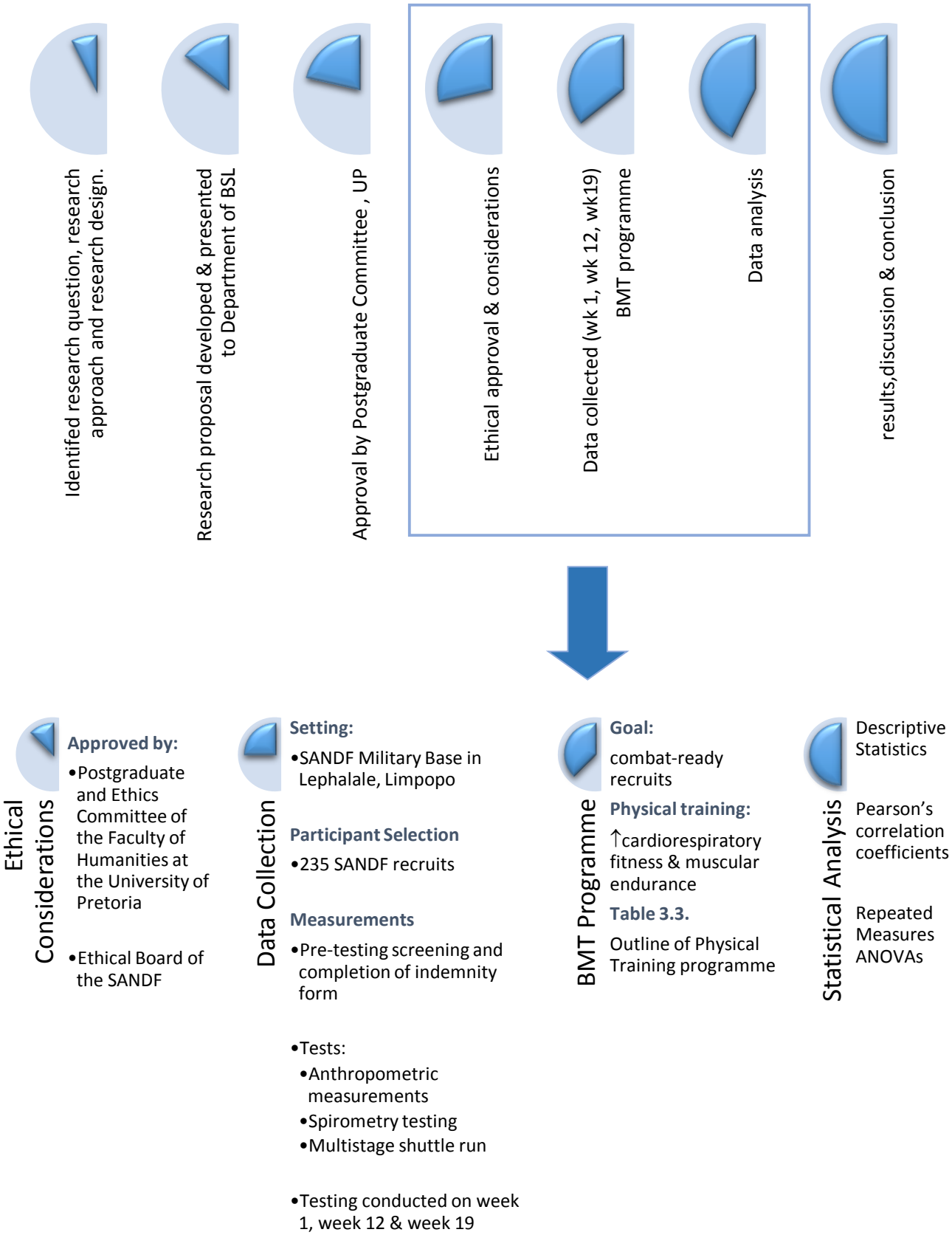


Figure 3.1 Schematic summary of the research procedure, strategy and highlighted sections

3.3 ETHICAL APPROVAL AND CONSIDERATIONS

Prior to the commencement of the data-collecting process, the research protocol was submitted to and approved by the Research Proposal and Ethics Committee of the Faculty of Humanities at the University of Pretoria (Appendix A). The research protocol was also approved by the Ethical Board of the SANDF (Appendix A).

All information obtained during the course of this study was treated confidentially. The data was analysed and reported anonymously.

Participants were informed of the exact nature of the study, and were included only after having given written informed consent (Appendix B). All data will be stored at the Department of Sport and Leisure Sciences for a period of 15 years.

3.4 SETTING

The data was collected at the Lephalale Military Base (SANDF military unit) in Lephalale, Limpopo, South Africa.

3.5 PROCEDURES AND INSTRUMENTATION

3.5.1 PARTICIPANT SELECTION

Of the total population of military recruits who joined the SANDF Multi-Skill Development programme (n=1400), 235 recruits (16%) – 136 male and 99 female – between the ages of 18–28 years were recruited for the study. The data was collected before the onset of the SANDF BMT programme and again after the 12th

and 19th week of BMT. Participants who complied with the following inclusion criteria were included in the study sample:

- SANDF male and female recruits between the ages of 18–28, enrolled for BMT in the SANDF
- SANDF male and female recruits who willingly completed the Informed Consent Form
- SANDF male and female recruits who completed the medical screening questionnaire (Appendix C)
- Participants who successfully completed all assessments, anthropometry, spirometry and multistage shuttle test, in all three testing sessions

Participants who met any of the following criteria were excluded from the study sample:

- All participants who did not comply with the inclusion criteria
- Participants with a history of cardiovascular, hepatic, respiratory, renal, pulmonary, metabolic, and/or orthopaedic disease
- Participants who had a lung or respiratory tract infection within two weeks prior to testing (Burney & Jarvis, 2007)
- Participants on medication that would have influenced spirometry values, such as
    - beta 2-agonist inhaler
    - anticholinergic inhaler
    - oral beta 2 inhaler
    - oral theophylline
    - oral anti-muscarinic (Burney & Jarvis, 2007)
- Participants who smoked a cigarette less than one hour before their spirometry test (Burney & Jarvis, 2007)

- Participants who used an inhaler less than one hour before their spirometry test (Burney & Jarvis, 2007)
- Participants who were unable to produce technically satisfactory spirometry test manoeuvres in accordance with the acceptability criteria (Table 2.5; page 41 & Table 2.6; page 42)
- Participants who did not successfully complete all assessments, namely anthropometry, spirometry and multistage shuttle run test, in all three testing sessions

3.5.2 PRE-TEST SCREENING

Prior to participation a pre-study orientation and screening session was held. The potential participants were thoroughly informed about the purpose, procedures, benefits and risks associated with the study. Thereafter written consent was obtained. All voluntary participants were screened to ensure compliance with criteria for participation in the study, and biographical data (namely age, date of birth, gender, race and smoking status) was collected.

3.5.3 TEST SESSION

In weeks 1, 12 and 19 of the BMT programme each participant voluntarily participated in a testing session which included the following assessments:

- anthropometric measurements
- spirometry
- multistage shuttle run

The tests and measurements were conducted in the order listed above. All data was recorded on a results sheet (Appendix D).

3.5.3.1 Anthropometric measurements

To ensure the intra-tester reliability, all anthropometric measurements were performed by the same qualified biokineticist during the testing sessions in weeks 1, 12 and 19.

The following anthropometric measurements were conducted:

- standing height (cm)
- mass (kg)
- inspiration chest circumference measurement (cm)
- expiration chest circumference measurement (cm)

Standing height

Standing height was measured using a portable stadiometer (The Leicester Height Measure, Seca, Birmingham, United Kingdom) (Figure 3.2). Height was measured with the participant standing upright and barefoot with his or her heels, buttocks, upper back and head in contact with the stadiometer (MacDougall, Wenger & Green, 1991). The participants hung their arms naturally by their sides and were asked to look straight ahead (MacDougall *et al.,* 1991). The direction of vision was horizontal, with the lower margin of the eye socket and the superior ear orifice in a horizontal plane (MacDougall *et al.,* 1991). The participant was then instructed to take a deep breath in and the headpiece of the stadiometer was brought down and into contact with the highest point on the skull (MacDougall *et al.,* 1991). All hair was removed from underneath the headpiece. The measurements were recorded to the nearest millimetre (MacDougall *et al.,* 1991).

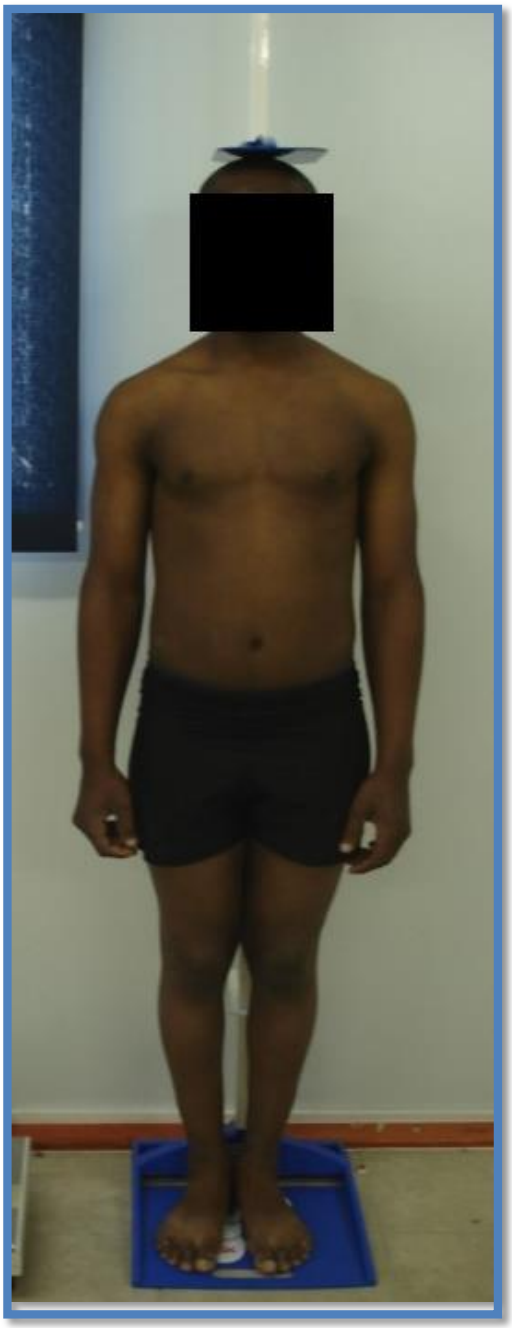


Figure 3.2 Standing height measurement

Mass

Mass was measured using an electronic scale (Tanita Body Fat Monitor BF-350, Tanita Corporation, Tokyo, Japan – maximum: 200kg/400lb) (Figure 3.3). Both male and female participants were weighed wearing their underclothing only (MacDougall

et al., 1991). Male and female participants were weighed separately and privately. The participant was instructed to stand on the centre of the scale (i.e. feet positioned on the right and left silver plates indicated in Figure 3.3) without support and with his or her weight evenly distributed on both feet (Smit, 1979). Mass was registered to the nearest 0.1kg (Smit, 1979).

Figure 3.3 Electronic scale (Tanita Body Fat Monitor BF-350)

Inspiration and expiration chest circumference measurement

Chest circumference was measured using a flexible, spring-loaded tape measure (Hoechstmass Rollfix retractable tape measure, Germany) (Figure 3.4). The participant stood upright in the anatomical position (Smit, 1979; MacDougall *et al.,* 1991; Beachle & Earle, 2008). To allow for the tape measure to be passed around the chest, the participant was asked to slightly abduct his or her arms (MacDougall *et al.,* 1991). For the male participants, chest circumference was measured at the height of the xyphoid process of the sternum (i.e. at nipple level), at the sub-pectoral

circumference of the chest (Smit, 1979; Beachle & Earle, 2008; Wu *et al.,* 2009); for the female participants the circumference was measured at the maximum chest circumference (above the breasts) (Beachle & Earle, 2008). Once the tape measure was passed underneath the arms, the participant hung his or her arms naturally by their sides (Smit, 1979; MacDougall *et al.,* 1991; Beachle & Earle, 2008). The chest circumference readings were obtained at maximal inspiration and at full expiration (Wu *et al.,* 2009) (Figure 3.5). Measurements were recorded in centimetres. The difference between full inspiration and full expiration measurements was also calculated. This difference was calculated by subtracting the expiration chest circumference measurement from the inspiration chest circumference measurement:

$$D = Fe - Fi$$

Where:

$D = Difference$

$Fe = full\ expiration\ and$

$Fi = full\ inspiration$

Figure 3.4 Hoechstmass Rollfix retractable tape measure

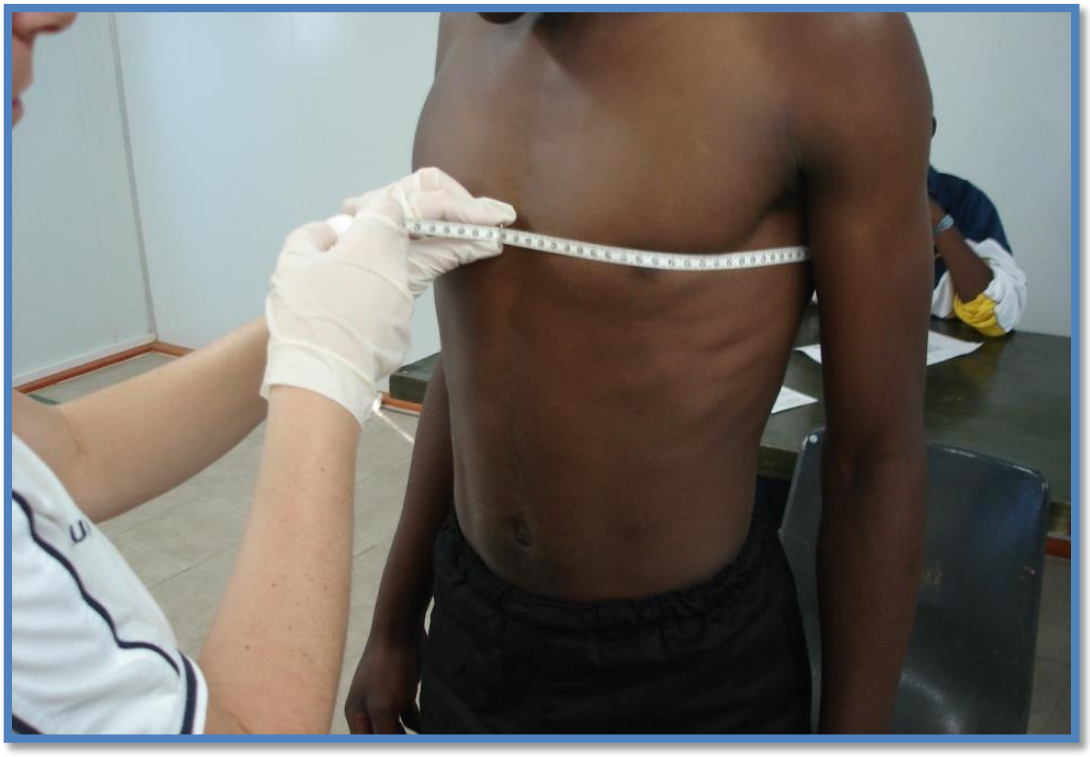


Figure 3.5 Chest circumference measurement

3.5.3.2 Spirometry

Test procedure

The spirometry tests were performed using a portable spirometer (Spiroflow 2000). All spirometry tests were conducted by the same qualified biokineticist during the testing sessions in weeks 1, 12 and 19 to ensure intra-tester reliability. The volume accuracy of the spirometer was checked before each testing session, using a 3L calibration syringe (Appendix E). Standardised procedures conforming to the *Series ATS/ERS Task Force: Standardisation of Lung Function Testing, Number 2: Standardisation of Spirometry* (Miller *et al.,* 2005b) were used.

Each participant's information (including height, weight, age, race and smoking status) was captured into the data base before each spirometry test was performed. Prior to performing the test – in accordance with the assessment procedure stipulated by Miller *et al.* (2005b) – the tester explained the aim of the test to the participants and explained and demonstrated the appropriate technique to perform the test. This was necessary as the majority of the participants had never performed a spirometry test before and had never used any form of spirometry equipment before.

The aim of the test was to determine how much air the participant was able to blow out of his or her lungs and how forcefully he or she could do it. Table 3.1. describes the exact procedure followed with each spirometry test.

Table 3.1. Spirometry assessment procedure (Miller *et al.,* 2005b: 323)

PROCEDURE
Checked the spirometer calibration (Appendix E) Explained test to participant Prepared the participant: • Measured height and weight without shoes and with minimal clothing • Asked about smoking, recent illness and medication use Instructed and demonstrated the test to the participant, including: • Correct posture with head slightly elevated • Inhale rapidly and completely • Position of the mouthpiece • Exhale with maximal force; 'blast' out air Performed manoeuvre (Figure 3.6): • Participant assumed a seated posture with legs uncrossed (Pierson, Dick & Petty, 1976). • Nose clip was attached to nose, mouthpiece was placed in mouth with lips closed around the mouthpiece. • Participant inhaled completely and rapidly with a pause of< 1s at TLC. • Participant then exhaled maximally until no more air could be expelled, while maintaining the torso in an upright posture. • Instructions were repeated as necessary and coached vigorously. • Manoeuvre was repeated for a minimum of three times; no more than eight were required. • Test repeatability was checked and performed again if necessary.

If the participant was a smoker the spirometry testing was carried out at least one hour **after** he or she smoked their last cigarette (Burney & Jarvis, 2007). Similarly, if the participant used an inhaler the spirometry testing was carried out at least one hour **after** the last inhalation (Burney & Jarvis, 2007).

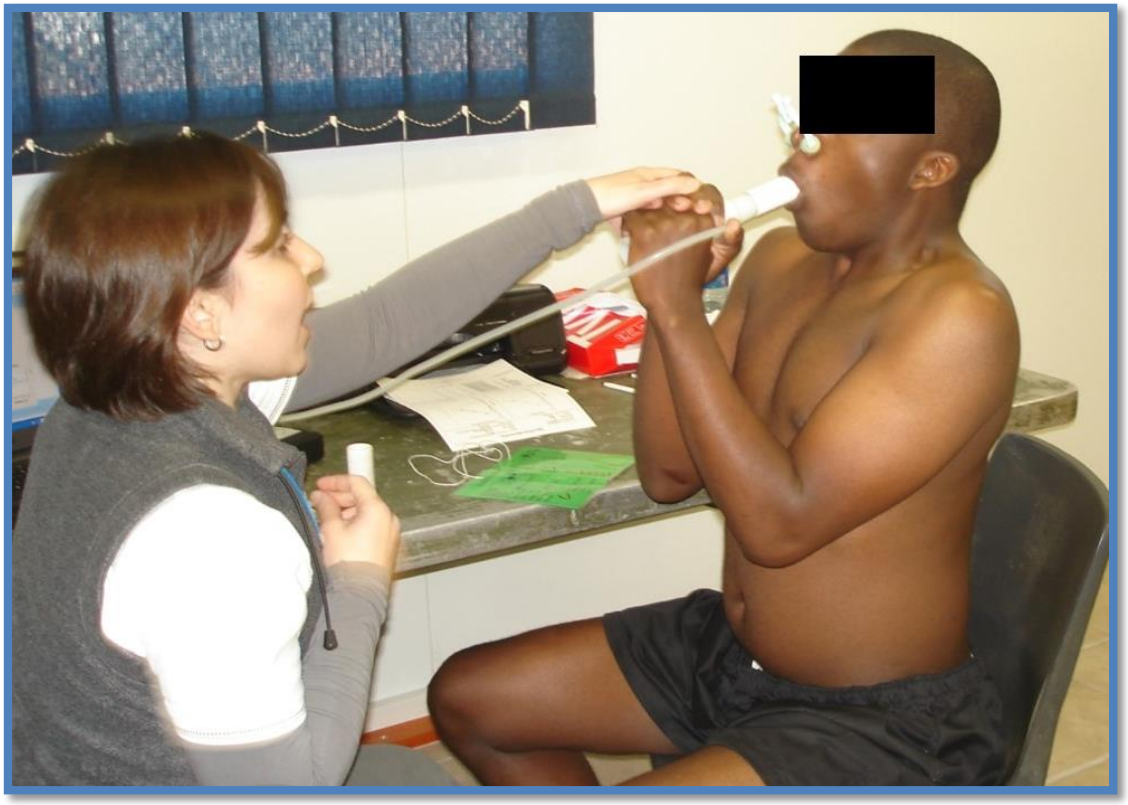


Figure 3.6 Example of a spirometry test

The following spirometry measures were recorded for each participant:

- FVC measured in litres (L);
- FEV_1 measured in litres (L);
- FEV_1/FVC ratio, measured in percentage (%).

Acceptability criteria

Within- and between-manoeuvre acceptability criteria, established by Miller *et al.* (2005b) (Table 2.5; page 41 & Table 2.6; page 42), were used to determine whether spirometry test measurements were acceptable for data analysis.

3.5.3.3 Multistage shuttle run test

This test involved continuous running between two lines 20m apart in time with recorded beeps played from a compact disk (CD) on a CD player (Léger & Lambert, 1982). For this reason the test is also often called the 'beep' or 'bleep' test. At the start of the test, the participants stood behind the first line facing the second line (Figure 3.7). They began running when they were instructed to by the recording. The participants continued running between the two lines, turning when signalled to by the recorded 'beeps'. After one minute, the increase in speed was indicated by the recording, and the 'beeps' became closer together (i.e. participants had less time between 'beeps' to reach the opposing lines). This continued each minute (level) (Léger & Lambert, 1982). If the participants failed to reach the line in time for the 'beep', they had to run to the line, turn and try to catch up with the pace within two more 'beeps'. On the other hand, if the participants reached the line before the 'beep', they had to wait for the 'beep' before they were allowed to continue running to the other line. The test was stopped if the participants failed to reach the line (within 2m) for two consecutive ends (Léger & Lambert, 1982). The initial running velocity was 8.5km/hr. The velocity increased by 0.5km/hr. every minute. The final score recorded was the level and number of shuttles (20m) reached before the participants were unable to keep up with the recording. The speed at the last completed stage was also recorded (Léger & Lambert, 1982). This score was then converted to a VO_2 max equivalent score using the formula by Léger, Mercier, Gadoury & Lambert (1988):

$$Y=31.025 + 3.238 X - 3.248A + 0.1536AX$$

Where

$Y = VO_2$ *max* $(ml.kg^{-1}.min^{-1})$

X= Maximal shuttle run speed (km/hr.)

A= Age (yr.)

(Léger *et al.*, 1988)

The multistage shuttle run test was repeated in the same fashion, by the same testers, during the testing sessions conducted in weeks 1, 12 and 19 of BMT.

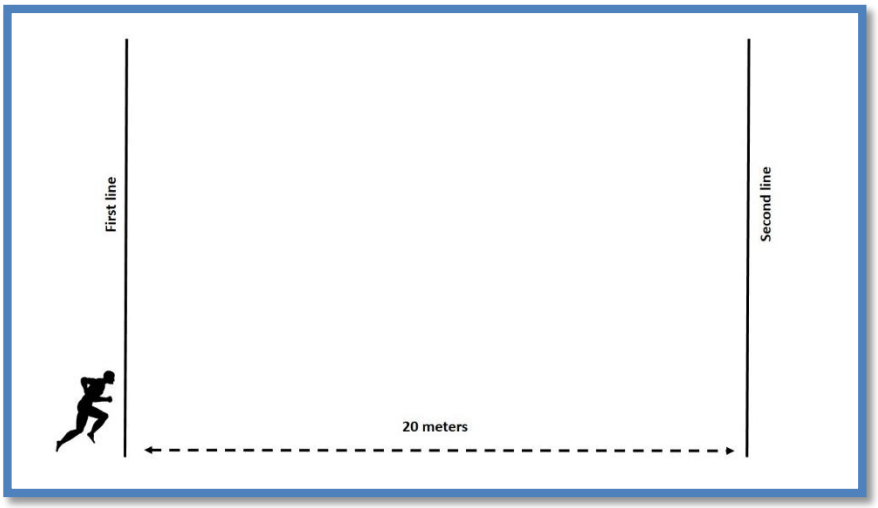


Figure 3.7 Multistage shuttle run: setup

3.6 BASIC MILITARY TRAINING PROGRAMME

The primary goal of the BMT programme in the SANDF was to ensure a combat-ready recruit at the end of the 20-week period. The recruits completed activities including drill, regimental aspects, compliments and saluting, musketry, signal training, mapreading, buddy aid, fieldcraft, general military aspects and physical training. The physical training component aimed at increasing the cardiorespiratory fitness and muscular endurance of the recruits. The fitness standards of the exercises were increased incrementally to allow for adaptation. Table 3.2. provides a summary of the BMT programme followed by the recruits. More specifically, Table 3.3. outlines the physical training programme followed by the recruits.

Table 3.2. Basic Military Training programme

Basic Military Training programme			
Description	**Number of periods**	**Minutes**	**Hours**
General military aspects (theory)	279	11 160	186
General military aspects (practical)	94	3 760	63
Drill	41	5 640	94
Regimental aspects	17	680	11
Compliments and saluting	4	160	3
Musketry	62	2 480	41
Signal training	10	400	7
Map reading	32	1 280	21
Buddy aid	22	880	15
Fieldcraft	45	1 800	30
Physical training	62	2 480	41
Route march	11	640	11

Table 3.3. BMT Physical Training (PT) Programme

PT programme component	Quantity	Details of progression
PT periods (number)	62	
Total PT hours	41	
Warm-up (minutes)	434	
Upper body muscle endurance exercises (number)	124	Weeks 1-6: completed 2 sets of 10-12 repetitions Weeks 7-10: completed 3 sets of 10-12 repetitions Weeks 11-17: completed 3 sets of 12-15 repetitions
Lower body muscle endurance exercises (number)	124	
Abdominal muscle endurance exercises (number)	124	Weeks 1-11: completed 2 sets to maximum Weeks 12-17: completed 3 sets to maximum
Back exercises (number)	64	
Upper body stretching exercises (number)	62	Completed each stretch 3 x held for 20 seconds each
Lower body stretching exercises (number)	124	
Back stretching exercises (number)	62	
Jogging (minutes)	1 510	Weeks 1-3: 15 seconds walking/45 seconds jogging Weeks 4&5: 5 seconds walking/55 seconds jogging Week 6: 25 minutes jogging (2 x per week) Weeks 7 – 12: 30 minutes jogging (2 x per week) Weeks 13-17: 30 minutes jogging (4 x per week)
Interval training (minutes)	236	Week 7: 1 minute slow jog/30 seconds sprint x 15 (2 x per week) Week 8: 45 seconds slow jog/30 seconds sprint x 20 (2 x per week) Week 9: 30 seconds slow jog/30 seconds sprint x 15 (2 x per week) Week 10: 30 seconds slow jog/30 seconds sprint x 20 (2 x per week) Week 11: 30 seconds slow jog/30 seconds sprint x 25 (2 x per week) Week 12: 20 seconds slow jog/30 seconds sprint x 25 (2 x per week)
Route march (distance in km)	31	

3.7 STATISTICAL ANALYSIS

Statistical analysis was performed by the Internal Statistical Consultation Service of the University of Pretoria, Department of Statistics (Appendix F), using IBM SPSS Statistics 21.

The data analysis consisted of univariate frequency tables, as well as two-way frequency tables by gender. Pearson's correlation coefficient was calculated to quantify the strength of the association between the chest circumference measurements and the spirometry measures, as well as between the spirometry measures and relative VO_2 max values. Repeated measures ANOVA, controlling for gender, was used to assess whether chest circumference measurements, spirometry measures and relative VO_2 max changed over the duration of the basic training programme. The conventional 5% level of significance was specified for all tests.

3.8 SAMPLE SIZE

The initial sample size of the study was 235 participants. Once the data-collecting process was completed, a stringent application of the inclusion and exclusion criteria for each assessment measure was applied to the data collected. This process resulted in a reduction in the size of the initial sample. The final sample size used for statistical analysis was 26 participants. The main reasons for excluding participants from the analysis were spirometry test failure and unreliable spirometry tests (i.e. did not comply with the 'within- and between-manoeuvre' acceptability criteria for spirometry measures (Table 2.5; page 41 & Table 2.6; page 42). This was despite the tester explaining and demonstrating the aim and technique of the spirometry manoeuvre to the participants before each test was conducted, allowing a maximum of eight attempts per participant and strictly following the standardised procedures stipulated by the *Series ATS/ERS Task Force: Standardisation of Lung Function Testing, Number 2: Standardisation of Spirometry* by Miller *et al.* (2005b). Table 3.4.

shows the number of participants tested in each testing session and the number of participants who complied with the spirometry criteria.

Table 3.4. Number of participants tested and the number of participants complying with the spirometry criteria per testing session.

Testing Session	Number of participants tested	Number of participants complying with spirometry criteria
Week 1	235	62
Week 12	233	85
Week 19	232	72

Of the participants who complied with the spirometry acceptability criteria, only 31 were able to produce acceptable and reproducible spirometry measures in all three testing sessions.

In addition to the poor compliance with the spirometry criteria, a number of participants did not complete all three assessment measures (namely, anthropometric measures, spirometry and multistage shuttle run) in all three testing sessions, due to absence caused by illness or injury.

In weeks 1, 12 and 19 of testing, 31, 27 and 30 participants, respectively, successfully completed all three assessment measures performed. However only 26 of these participants were able to successfully complete all three assessment measures in **all three** testing sessions held in week 1, week 12 and week 19 of BMT, therefore presenting with a complete data set over the 19 weeks of testing. Thus, the final sample size represents the number of participants who successfully completed all three assessment measures in **all three** testing sessions over the 19 weeks of testing.

CHAPTER 4

RESULTS AND DISCUSSION

To recapitulate, the aim of the study was to determine whether there was a significant correlation ($p \leq 0.05$) between:

- Inspiration chest circumference and various spirometry measurements at the commencement and for the duration of a 19-week intense training programme;
- Expiration chest circumference and various spirometry measurements at the commencement and for the duration of a 19-week intense training programme;
- The difference between inspiration chest circumference and expiration chest circumference and various spirometry measurements at the commencement and for the duration of a 19-week intense training programme;
- Spirometry measures (FVC, FEV_1 and FEV_1/FVC) and relative VO_2 max at the commencement and for the duration of a 19-week intense training programme.

Additionally, the study aimed to:

- Determine whether there was a statistically significant ($p \leq 0.05$) change between the measured variables (i.e. ICC, ECC, ICC-ECC, FVC, FEV_1, FEV_1/FVC and VO_2 max) over the 19-week intense training programme.

The aim of the study was to assist with validating the use of various inexpensive chest circumference measurements as a measurement of pulmonary function in a young healthy active population.

The results of the study are presented in tabular (Tables 4.1. to 4.12.) and graphic (Figures 4.1 to 4.3) form. All statistically significant results are reported at the 95% level of confidence, unless otherwise specified, and are subsequently discussed within the context of the applicable literature.

4.1 DESCRIPTIVE STATISTICS

The initial study population consisted of 235 participants (aged 18–28 years; 136 male and 99 female). Of the 235 participants, 31 (aged 18–24 years; 17 male and 14 female; 13% of initial sample) produced acceptable and reliable spirometry tests in all three testing sessions conducted in week 1, week 12 and week 19 of BMT, respectively. Furthermore, only 26 of the 31 participants (aged 18–24 years; 16 male and 10 female; 11% of initial sample) completed all the assessment measures of this study, namely height, weight, chest circumference measures, spirometry measures and the multistage shuttle run test, in all three respective testing sessions conducted during BMT. The results of the final sample of 26 participants were used for statistical analysis and are referred to as the validation group. In addition to the participants' inability to produce technically satisfactory spirometry test manoeuvres and to complete all assessment measures in all three testing sessions, the following exclusion criteria were also applied:

- Non-compliance with the inclusion criteria (Section 3.5.1; page 55)
- A history of cardiovascular, hepatic, respiratory, renal, pulmonary, metabolic, and/or orthopaedic disease
- A lung or respiratory tract infection within two weeks prior to testing
- Consumption of medication that would have influenced spirometry values (Section 3.5.1; page 55)
- Smoking a cigarette less than one hour before their spirometry test
- Use of an inhaler less than one hour before their spirometry test

When considering other studies that used spirometry as an assessment tool, considerable reductions in sample size were also noted. In a study screening the pulmonary function of 20 460 Swiss participants, only 8 684 participants (42.4% of the initial sample) fulfilled all the study criteria and were included in the study (Kuster, Kuster, Schindler, Rochat, Braun, Held & Brändli, 2008). Table 4.1. shows the exclusion criteria applied by Kuster *et al.* (2008).

Table 4.1. Exclusion criteria applied by Kuster et al. (2008: 861)

Exclusion Criteria
Former or current smokers ≥1 pack-yrs.
Current acute respiratory disease
Common cold
Acute bronchitis
Current respiratory symptoms
Cough
Wheezing
Shortness of breath with rest or exertion
Phlegm
History of asthma
Current treatment with asthma medication
History of chronic obstructive pulmonary disease or chronic bronchitis
History of other lung diseases
Lung operations
Pulmonary embolism

Lubiński and Gólczewski (2010) examined 9 846 male and female Polish participants, of whom 2 745 (27.9% of the initial sample) complied with all study criteria. Participants were excluded from the study if they were younger than 18 years or older than 85 years of age, smokers, diagnosed with COPD or asthma, reported the occurrence of chronic cough or dyspnea within the last 12 months and if they were unable to undergo correct spirometry (Lubiński & Gólczewski, 2010). Wu *et al.* (2009) studied the pulmonary function of 5 063 healthy male and female participants from North China, of whom 2 897 (57% of initial sample) fulfilled the study criteria. As with the present study, spirometry test failure, unreliable spirometry test measures and pulmonary or cardiac diseases or symptoms were criteria used to exclude participants from the analysis (Wu *et al.,* 2009). Interestingly, a lung or respiratory tract infection, the consumption of medication and the use of an inhaler

were not used as exclusion criteria by Wu *et al.* (2009) and Lubiński and Gólczewski (2010), as they were in this study and by Kuster *et al.* (2008).

The consideration of a lung or respiratory tract infection, the consumption of medication and the use of an inhaler as exclusion criteria by this study was motivated by the literature. Firstly, lung and respiratory infections are associated with the narrowing of the respiratory airways, causing airway limitations as well as bronchial hyper-reactivity (Melbye, Kongerud & Vorland, 1994; Cotes *et al.,* 2006). The narrowing of the respiratory airways can be either extra-thoracic (pharynx, larynx, and extra-thoracic portion of the trachea) or intra-thoracic (intra-thoracic trachea and main bronchi) (Pellegrino *et al.,* 2005; Cotes *et al.,* 2006). Numerous factors may cause the narrowing of the airways, namely an accumulation of viscous mucus in the lumen, thickening of the epithelial or sub-epithelial tissue or external compression by mucus glands (Cotes *et al.,* 2006). Furthermore, intra-thoracic airways are participant to increases in bronchomotor tone caused by histamine, exposure to dust and other causes of bronchoconstriction (Cotes *et al.,* 2006). Thus the associated airway limitations and bronchial hyper-reactivity influence the spirometry values obtained by an individual with a lung and respiratory infection (Melbye *et al.,* 1994; Pellegrino *et al.,* 2005; Cotes *et al.,* 2006). Pellegrino *et al.* (2005) states that the maximal expiratory flow – especially at peak flow – is lower in both intra- and extra-thoracic airway obstructions and that maximal inspiratory flow is significantly lower with extra-thoracic obstruction. The lower maximal inspiratory flow with extra-thoracic obstruction is because the pressure surrounding the airways is not able to oppose the negative intra-luminal pressure (Pellegrino *et al.,* 2005). A temporary decrease in FEV_1 has also been identified as a common feature of respiratory infections in otherwise healthy individuals (Melbye *et al.,* 1994). More importantly, individuals recovering from lung or respiratory infections have shown improvements in their spirometry values (Melbye *et al.,* 1994; Cotes *et al.,* 2006). Melbye *et al.* (1994) showed that the median FEV_1 of patients who reported recovery from infection was significantly ($p<0.05$) higher than that of the patients who had not recovered. Additionally, Booker (2008) recommends that to prevent cross-infection from spirometry, individuals with an active respiratory infection should not be tested.

Secondly, the administration of medication (Section 3.5.1; page 55) or the use of inhalers are primarily intended to reverse airflow limitation, especially in patients with

asthma and COPD (Melbye *et al.,* 1994; Miller *et al.,* 2005b; Cotes *et al.,* 2006; Shiner & Steier, 2013). Administering beta 2-adrenergic receptor agonists results in an absolute improvement in FEV_1 of >400ml in patients with a suggestive diagnosis of asthma (Shiner & Steier, 2013). Moreover, after taking a course of oral corticosteroids patients have shown improvements of more than 15% in FEV_1 (Melbye *et al.,* 1994). The use of bronchodilators is also known to reverse bronchial obstruction and cause improvements in FEV_1 of at least 200ml in patients with asthma and COPD (Melbye *et al.,* 1994; Shiner & Steier, 2013). Therefore, the administration of medication or the use of inhalers immediately before a spirometry test would influence the spirometry values obtained.

Within the initial study group, 88% (n=207) of the participants were non-smokers and 12% (n=28) were smokers. The smokers were all male and of African descent. The demographic representation of the initial sample was as follows: 224 African participants (95%), eight Coloured participants (3.4%), two Caucasian participants (0.9%) and one Asian participant (0.4%).

Within the validation group, 19% (n=5) of the participants were smokers. Interestingly they were all male. The demographic representation of the validation group was as follows: 21 African participants (80.8%), three Coloured participants (11.5%), one Caucasian participant (3.8%) and one Asian participant (3.8%).

A study by Klesges, Haddock, Chang, Talcott and Lando (2001), who reported the demographic representation of the active duty recruits who entered the US Air Force from August 1995 to August 1996, stated that 30.2% of the recruits were of 'other ethnic descent', namely African-Americans, Hispanics, Asian or Pacific Islanders and Native Americans, thus the remaining 69.8% of the recruits were of Caucasian descent.

The demographic representation of this study had a higher representation of African recruits than those reported by Klesges *et al.* (2001). Although the literature states that Africans have a lower thoracic diameter and chest volume than Caucasians, resulting in lower TLC, FEV_1 and FVC values (Rossiter & Wiell, 1973; Lapp *et al.*, 1974; Donnelly *et al.*, 1991; Ebomoyi & Iyawe, 2005), Whittaker *et al*. (2005) stated that when investigating whether race differences in lung function could be explained by chest size, the influence of chest dimensions on pulmonary function was

insignificant. Furthermore, Lapp *et al*. (1974) observed that when the differences in lung size were evened out by matching African and Caucasian participants of the same TLC, no significant differences in flow rates were observed. In the past, ethnicity was based on race only, but, recently, the description has changed due to the strong influence of a number of factors, namely geographical, social, economic and dietary, on race (Cotes *et al.*, 2006). Therefore the influence of the race factor on pulmonary function has become less simple than it originally appeared (Cotes *et al.*, 2006).

When considering the percentage of recruits who were smokers in comparison to other recruits enlisted in the military, Klesges *et al.* (2001) reported that 28.5% of the male and female active duty recruits who entered the US Air Force from August 1995 to August 1996 (n=29 044; age 19.7 ± 2.05 years) were smokers at the start of BMT. Additionally, Ward**,** Van der Weg**,** Kovach**,** Klesges**,** DeBon**,** Haddock**,** Talcott**,** and Lando (2002) reported that 24.9% of the US Air Force recruits smoked daily at the time of entry into BMT. Both percentages were substantially higher than in the population of the current study. However, in a systematic review article by Bergman, Hunt and Augustson (2012), the range of prevalence was between 0.4%–50%, and the calculated weighted mean prevalence of current use was 9.4% in 21 studies based on the US military population. Of possible importance in interpreting the incidence of smokers in this sample is that Ward *et al.* (2002) documented significantly important gender and ethnic differences in cigarette smoking among military recruits.

Although Klesges *et al.* (2001) reported that their sample had a 25.3% representation of women, their results did not differentiate smokers by gender. Bergman *et al.* (2012) also indicated that in the 39 reviewed studies, the majority of US military smokers were enlisted Caucasian males under the age of 30; only one study looked at smoking within a female-only sample (Vander Weg, DeBon, Peterson, Sherrill-Mittleman, Klesges & Relyea, 2005), rendering gender comparisons impossible.

Tables 4.2., 4.3. and 4.4. represent the anthropometric, spirometric and VO_2 max characteristics respectively of both the study and validation groups in week 1, week 12 and week 19 of testing.

Table 4.2. Anthropometric, spirometric and VO_2 max characteristics of the study and validation groups in week 1 of testing

Measurements	Total		Male		Female	
	Study group (n=235)	Validation group (n=26)	Study group (n=136)	Validation group (n=16)	Study group (n=99)	Validation group (n=10)
Age (yr.)	20.8 ± 1.3	21.0 ± 1.3	21.1 ± 1.3	21.0 ± 0.8	20.5 ± 1.3	20.9 ± 1.8
Height (cm)	165.5 ± 8.2	163.3 ± 7.2	169.7 ± 7.2	166.7 ± 6.0	159.6 ± 5.3	157.7 ± 5.4
Mass (kg)	62.6 ± 9.1	59.2 ± 6.0	63.2 ± 8.6	59.8 ± 4.0	61.8 ± 9.8	58.3 ± 8.6
ICC (cm)	90.7 ± 5.8	89.4 ± 4.0	89.7 ± 4.6	88.4 ± 2.5	92.0 ± 6.9	91.0 ± 5.4
ECC (cm)	85.4 ± 6.2	84.0 ± 4.6	83.9 ± 4.8	82.7 ± 2.5	87.4 ± 7.3	86.1 ± 6.4
ICC-ECC (cm)	5.3 ± 2.1	5.4 ± 1.6	5.8 ± 2.2	5.7 ± 1.5	4.6 ± 1.7	4.9 ± 1.7
FVC (L)	4.2 ± 0.9	3.9 ± 0.7	4.7 ± 0.8	4.2 ± 0.5	3.5 ± 0.6	3.3 ± 0.5
FEV_1 (L)	3.4 ± 0.8	3.4 ± 0.5	3.8 ± 0.8	3.6 ± 0.5	2.9 ± 0.5	3.0 ± 0.4
FEV_1/FVC (%)	82.6 ± 10.9	87.4 ± 7.2	81.3 ± 12.0	85.7 ± 8.1	84.3 ± 9.0	90.0 ± 4.5
VO_2 max ($ml.kg^{-1}.min^{-1}$)	34.9 ± 7.1	34.8 ± 6.3	39.6 ± 5.3	38.4 ± 4.9	28.6 ± 3.1	29.0 ± 3.3

Data is presented as Means ± Standard Deviation. ICC=inspiration chest circumference; ECC= expiration chest circumference; FVC=forced vital capacity; FEV_1=forced expiratory volume in 1 second; VO_2 max=maximal O_2 consumption.

Table 4.3. Anthropometric, spirometric and VO_2 max characteristics of the study and validation groups in week 12 of testing

Measurements	Total		Male		Female	
	Study group (n=234)	Validation group (n=26)	Study group (n=136)	Validation group (n=16)	Study group (n=98)	Validation group (n=10)
Age (yr.)	20.8 ± 1.3	21.2 ± 1.3	21.1 ± 1.3	21.3 ± 0.8	20.5 ± 1.3	21.1 ± 1.8
Height (cm)	165.5 ± 8.1	163.8 ± 6.9	169.7 ± 7.1	167.2 ± 5.7	159.7 ± 5.4	158.5 ± 5.1
Mass (kg)	62.6 ± 9.1	60.6 ± 6.3	63.2 ± 8.6	62.1 ± 4.4	61.8 ± 9.8	58.2 ± 8.2
ICC (cm)	90.8 ± 5.3	88.9 ± 3.6	90.3 ± 4.3	88.4 ± 2.4	91.4 ± 6.4	89.8 ± 5.0
ECC (cm)	85.5 ± 5.6	84.2 ± 4.1	84.8 ± 4.3	83.6 ± 2.9	86.4 ± 7.0	85.1 ± 5.6
ICC-ECC (cm)	5.3 ± 1.9	4.7 ± 1.2	5.5 ± 1.7	4.8 ± 1.3	5.0 ± 2.2	4.7 ± 1.2
FVC (L)	4.1 ± 0.9	3.8 ± 0.7	4.5 ± 0.8	4.1 ± 0.6	3.5 ± 0.5	3.2 ± 0.4
FEV_1 (L)	3.4 ± 0.7	3.2 ± 0.5	3.8 ± 0.7	3.5 ± 0.5	2.9 ± 0.4	2.9 ± 0.3
FEV_1/FVC (%)	84.3 ± 8.4	87.3 ± 7.8	84.1 ± 8.9	86.0 ± 8.9	84.5 ± 7.7	89.4 ± 5.4
VO_2 max ($ml.kg^{-1}.min^{-1}$)	42.0 ± 7.7	41.5 ± 6.3	47.1 ± 4.5	45.4 ± 3.9	34.1 ± 4.1	35.3 ± 3.8

Data is presented as Means ± Standard Deviation. ICC=inspiration chest circumference; ECC= expiration chest circumference; FVC=forced vital capacity; FEV_1=forced expiratory volume in 1 second; VO_2 max=maximal O_2 consumption.

Table 4.4. Anthropometric, spirometric and VO_2 max characteristics of the study and validation groups in week 19 of testing

Measurements	Total		Male		Female	
	Study group (n=232)	Validation group (n=26)	Study group (n=136)	Validation group (n=16)	Study group (n=96)	Validation group (n=10)
Age (yr.)	20.8 ± 1.3	21.4 ± 1.3	21.1 ± 1.3	21.4 ± 0.8	20.5 ± 1.3	21.3 ± 1.8
Height (cm)	165.5 ± 8.1	164.0 ± 6.9	169.7 ± 7.1	167.4 ± 5.8	159.7 ± 5.4	158.7 ± 5.0
Mass (kg)	62.6 ± 9.1	60.1 ± 5.8	63.2 ± 8.6	61.9 ± 4.1	61.8 ± 9.8	57.4 ± 7.1
ICC (cm)	89.8 ± 5.0	88.6 ± 3.6	89.6 ± 4.4	88.4 ± 3.9	90.1 ± 5.6	88.8 ± 3.2
ECC (cm)	84.8 ± 5.2	83.7 ± 3.7	84.2 ± 4.5	83.1 ± 3.5	85.7 ± 5.9	84.6 ± 3.9
ICC-ECC (cm)	5.0 ± 2.4	4.9 ± 2.9	5.4 ± 2.7	5.3 ± 3.5	4.4 ± 1.8	4.3 ± 1.3
FVC (L)	4.0 ± 0.8	3.6 ± 0.6	4.4 ± 0.8	4.0 ± 0.4	3.4 ± 0.5	3.1 ± 0.5
FEV_1 (L)	3.4 ± 0.7	3.2 ± 0.5	3.7 ± 0.6	3.4 ± 0.5	2.9 ± 0.4	2.8 ± 0.3
FEV_1/FVC (%)	85.6 ± 7.4	87.9 ± 6.4	84.7 ± 7.7	86.8 ± 7.5	86.8 ± 6.9	89.7 ± 3.7
VO_2 max ($ml.kg^{-1}.min^{-1}$)	41.7 ± 7.2	41.1 ± 6.6	46.7 ± 3.9	45.3 ± 4.0	34.6 ± 4.1	34.4 ± 3.2

Data is presented as Means ± Standard Deviation. ICC=inspiration chest circumference; ECC= expiration chest circumference; FVC=forced vital capacity; FEV_1=forced expiratory volume in 1 second; VO_2 max=maximal O_2 consumption.

Williams (2005) researched the effects of BMT on regular and reserve British Army male recruits (aged 18 ± 1 years and 23 ± 5 years, respectively) with no previous military experience (as with the recruits of this study). The recruits in Williams' study had greater mass (67.9 ± 5.3kg and 76.1 ± 13.2kg, respectively) and relative VO_2 max (44.8 ± 4.9$ml.min^{-1}.kg^{-1}$ and 40.9 ± 6.1$ml.min^{-1}.kg^{-1}$, respectively) baseline values than the male recruits of the validation group of this study (Williams, 2005). Interestingly, however, after 12 weeks of BMT – despite the increases in the relative VO_2 max values of both groups of British Army recruits (50.6 ± 4.5$ml.min^{-1}.kg^{-1}$ and 43.5 ± 4.1$ml.min^{-1}.kg^{-1}$, respectively) – the relative VO_2 max values of the reserve group were lower than the values obtained by the male recruits of the validation group of this study (Williams, 2005).

The differences noticed in the relative VO_2 max values between the two groups may be attributed to the changes observed in the absolute VO_2 max values achieved by the recruits, as when changes in body mass of both the reserve group and this

study's male validation group are compared the changes are similar (+2kg and +2.3kg, respectively). The male recruits of the validation group of this study achieved a greater difference in absolute VO_2 max over 12 weeks of BMT than the reserve group of the British Army, translating to a higher relative VO_2 max value after 12 weeks of BMT. When comparing the improvements in relative VO_2 max after 12 weeks of BMT, the male recruits of the current study showed greater improvements in relative VO_2 max (+7ml.min^{-1}.kg^{-1}) than both groups of British Army recruits (+5.8ml.min^{-1}.kg^{-1} and +2.6ml.min^{-1}.kg^{-1}, respectively) (Williams, 2005).

This difference may be attributed to the training stimulus offered by the BMT and the physical training programme followed. When comparing the physical training programmes followed by the regular and reserve groups of the British Army, and the recruits of the current study, it was found that the number of physical training sessions and hours differed. The training programmes followed by the regular and reserve groups of British Army included 90 sessions of physical training (a total of 3 600 minutes over 12 weeks) and 10 sessions of physical training (a total of 450 minutes over 12 weeks) respectively (Williams, 2005). Within the first 12 weeks of BMT followed by the recruits of this study, a total of 44 sessions of physical training (a total of 1 760 minutes over 12 weeks) were completed. Despite these differences, regular participation in physical training induced improvements in VO_2 max in all groups; hence the larger difference observed in the relative VO_2 max values of the male recruits of the validation group of this study may then be explained by their lower relative VO_2 max baseline values at the start of the BMT programme, compared to the recruits of both the regular and reserve groups of the British Army.

A study by Fatemi *et al.* (2012) demonstrated mean values for VO_2 max and spirometry measures similar to those in the present study, when comparing dynamic pulmonary function volumes between different levels of maximal oxygen uptake in healthy, physically active and non-smoking male Iranian students aged 19–24 years. Table 4.5. shows the values obtained by Fatemi *et al.* (2012).

Table 4.5. Values of pulmonary variables of the three groups (Fatemi *et al.*, 2012:670)

Variable	Group A VO2 max=27.51 ml.min^{-1}.kg^{-1}	Group B VO2 max=39.24 ml.min^{-1}.kg^{-1}	Group C VO2 max=49.76 ml.min^{-1}.kg^{-1}
FEV1 (L)	4.03 ± 0.40	3.34 ± 0.45	2.88 ± 0.54
FVC (L)	4.36 ± 0.41	3.92 ± 0.44	3.60 ± 0.55
FEV1/FVC (%)	90.78 ± 4.32	82.83 ± 3.68	80.00 ± 3.48

When comparing the relative VO_2 max values of the female recruits in the validation group of this study with the British Army female recruits (age 17–23 years) studied by Brock and Legg (1997), the British Army female recruits had higher relative VO_2 max values before and after seven weeks of BMT (pre: 45.66 ± 5.16ml.min^{-1}.kg^{-1} and post: 46.66 ± 4.40ml.min^{-1}.kg^{-1}, respectively). Again, the training stimulus offered by the BMT and physical training programmes may explain the differences seen. Differences in the number of hours dedicated to physical training are evident when comparing the BMT programme followed by the British Army female recruits with the BMT programme followed by the female recruits of the current study. The BMT programme followed by the British Army female recruits was seven weeks in duration and allocated a total of 51 sessions to physical training (a total of 34 hours of physical training over seven weeks) (Brock & Legg, 1997). The BMT programme followed by the female recruits of the current study was 20 weeks in duration and allocated a total of 62 sessions of physical training (a total of 41 hours of physical training over 20 weeks). When considering the number of sessions and hours dedicated to physical training in relation to the duration of the BMT programme, fewer sessions and hours were dedicated to physical training per week in the BMT programme followed by the female recruits of the current study. Despite this, the improvements in VO_2 max from the commencement to the end of BMT were greater in the female recruits of the current study than in the British Army female recruits. The female recruits of the current study had a 5.4ml.min^{-1}.kg^{-1} improvement in VO_2 max and the British Army female recruits had a 1ml.min^{-1}.kg^{-1} improvement in VO_2 max. The initial lower VO_2 max baseline values of the female recruits of the current

study, compared to the baseline values of the British Army female recruits, may explain these results.

4.2. CORRELATION ANALYSIS

Correlation significance was set at p=0.05 level. Table 4.6. indicates the categorisation used as a guideline to determine the strength of the correlations (Thomas & Nelson, 2001; Dancey & Reidy, 2004). The correlation coefficient can be in either a positive or negative direction (i.e. r lies between -1 and +1) (Thomas & Nelson, 2001).

Table 4.6. Categorisation for correlation coefficient strength (Thomas & Nelson, 2001; Dancey & Reidy, 2004)

Correlation Coefficient (+ OR -)	Strength of Correlation
1	Perfect
>0.6	Strong
0.4–0.6	Moderate
<0.4	Weak
0	Zero

Tables 4.7., 4.8. and 4.9. summarise the statistical correlation (Pearson's correlation coefficient) between spirometry parameters and chest circumference measurements and VO_2 max in the three subsequent testing sessions.

Table 4.7. Correlation of spirometry parameters with chest circumference measurements and VO_2 max in week 1 of testing

	Parameters	FVC (r)	FEV_1 (r)	FEV_1/FVC (r)
Total (n=26)	ICC	0.011	-0.024	-0.020
	ECC	-0.093	-0.083	0.084
	ICC-ECC	0.299	0.183	-0.296
	VO_2 max	0.682**	0.628 **	-0.230
Males (n=16)	ICC	0.425	0.112	-0.390
	ECC	0.325	0.092	-0.293
	ICC-ECC	0.168	0.033	-0.164
	VO_2 max	0.617*	0.558*	0.019
Females (n=10)	ICC	0.260	0.366	0.160
	ECC	0.163	0.286	0.261
	ICC-ECC	0.208	0.082	-0.482
	VO_2 max	-0.134	-0.223	-0.151

Data are presented as *r*; ** p<0.01; * p<0.05. ICC=inspiration chest circumference; ECC=expiration chest circumference; FVC=forced vital capacity; FEV_1=forced expiratory volume in 1 second; VO_2 max=maximal O_2 consumption.

Table 4.8. Correlation of spirometry parameters with chest circumference measurements and VO_2 max in week 12 of testing

	Parameters	FVC (r)	FEV_1 (r)	FEV_1/FVC (r)
Total (n=26)	ICC	0.138	0.080	-0.123
	ECC	0.109	0.053	-0.107
	ICC-ECC	0.038	0.057	0.001
	Vo_2 max	0.616 **	0.554 **	-0.162
Males (n=16)	ICC	0.522*	0.251	-0.371
	ECC	0.341	0.130	-0.256
	ICC-ECC	0.224	0.186	-0.127
	Vo_2 max	0.417	0.385	-0.013
Females (n=10)	ICC	0.287	0.309	0.019
	ECC	0.341	0.330	-0.064
	ICC-ECC	-0.419	-0.268	0.385
	Vo_2 max	-0.321	-0.290	0.107

Data are presented as *r;* ** p<0.01; * p<0.05. ICC=inspiration chest circumference; ECC=expiration chest circumference; FVC=forced vital capacity; FEV_1=forced expiratory volume in 1 second; VO_2 max=maximal O_2 consumption.

Table 4.9. Correlation of spirometry parameters with chest circumference measurements and VO_2 max in week 19 of testing

	Parameters	FVC (r)	FEV_1 (r)	FEV_1/FVC (r)
Total (n=26)	ICC	0.167	0.019	-0.305
	ECC	0.065	0.027	-0.058
	ICC-ECC	0.123	-0.010	-0.303
	Vo_2 max	0.697**	0.658 **	-0.144
Males (n=16)	ICC	0.309	0.010	-0.391
	ECC	0.346	0.201	-0.118
	ICC-ECC	-0.008	-0.191	-0.311
	Vo_2 max	0.366	0.395	0.143
Females (n=10)	ICC	0.249	0.238	-0.106
	ECC	0.180	0.169	-0.097
	ICC-ECC	0.068	0.073	0.032
	Vo_2 max	0.244	0.237	-0.222

Data are presented as *r*; ** p<0.01; * p<0.05. ICC=inspiration chest circumference; ECC=expiration chest circumference; FVC=forced vital capacity; FEV_1=forced expiratory volume in 1 second; VO_2 max=maximal O_2 consumption.

4.2.1 CHEST CIRCUMFERENCE MEASUREMENTS VS SPIROMETRY MEASUREMENTS

There is agreement in the literature that chest circumference measurements are positively correlated with pulmonary function in both healthy individuals and in individuals with various pulmonary pathologies and postural deviations (Stamm & Docter, 1965; Brokan *et al.,* 1981; Hawes & Brooks, 2001; Cimbiz *et al.,* 2004; Lopes *et al.,* 2007; Chambers *et al.,* 2008; Wu *et al.,* 2009). Chest circumference measures are mainly used to measure the expansion of the chest wall during full inspiration and complete expiration (Cimbiz *et al.,* 2004; Cotes *et al.,* 2006; Wu *et al.,* 2009). It has been stated that the integrity of the chest wall influences the effectiveness of the respiratory pump, and that changes to any of the components of the respiratory pump directly affect pulmonary function (Cotes *et al.,* 2006; Shiner & Steier, 2013). Numerous studies, especially studies investigating the association between pulmonary function and chest dimensions in populations with pulmonary pathologies, such as COPD, and postural deviation, such as scoliosis, have supported this argument (Stamm & Docter, 1965; Leong *et al.,* 1999; Hawes & Brooks, 2001; Lopes *et al.,* 2007).

However, this study showed weak and non-significant correlations ($r<0.4$) between the chest circumference measurements and spirometry measurements in all three testing sessions, with the exception of the moderate, positive, significant correlation between FVC and ICC in the male sample ($r=0.522$; $p<0.05$) in week 12.

Studies conducted on healthy participants have shown similar findings (Wu *et al.,* 2009; Lanza *et al.,* 2013). Wu *et al.* (2009) observed weak correlations ($r<0.3$) between chest circumference measurements (ICC, ECC, ICC-ECC) and spirometry measures (FEV_1, FVC, FEV_1/FVC) in healthy female and male participants from North China. Furthermore, when Lanza *et al.* (2013) researched whether chest mobility is related to respiratory muscle strength and lung volumes in healthy Brazilian participants (age 24 ± 3 years), they observed weak correlations between chest circumference measurements made at the auxiliary levels and FEV_1 and FVC ($r=0.30$ & $r=0.32$, respectively).

Structural and anatomical changes to the chest wall associated with pulmonary pathologies and a number of postural deviations may offer an explanation for the difference in the correlational findings between chest circumference measurements and spirometry measures in healthy individuals versus special populations (Cotes *et al.,* 2006; Shiner & Steier, 2013). Changes to the muscles, the physical properties of the thorax and the airways influence the effectiveness and functioning of the respiratory pump (Cotes *et al.,* 2006). Spinal deformity, associated with conditions such as scoliosis, has serious effects on the arrangement of the lungs within the chest and reduces the effectiveness of the respiratory muscles (Cotes *et al.,* 2006). Hawes and Brooks (2001) stated that when compared to control participants, patients with IS exhibited significantly smaller mean chest circumference measures and restricted chest mobility. Moreover, a chest expansion capacity of <3.8cm in IS patients was strongly correlated with diminished FVC (Hawes & Brooks, 2001). Additionally, Leong *et al.* (1999) mentioned that the overall stiffness of the thoracic cage and spine in patients with scoliosis contributes to the mechanical inefficiency of the pulmonary system and impairment of pulmonary function. Furthermore, Lopes *et al.* (2007) showed that children who suffered from persistent asthma had limited chest expansion at the axillar and xyphoid levels, due to the postural adaptations and muscle shortening of both respiratory and non-respiratory muscles caused by the severity of the disease.

The findings of this study therefore corroborate the findings in the literature that chest circumference measures and spirometry measures are significantly associated in populations with pulmonary pathologies and postural deviations (Stamm & Docter, 1965; Leong *et al.,* 1999; Hawes & Brooks, 2001; Lopes *et al.,* 2007) but not in healthy individuals (Wu *et al.,* 2009; Lanza *et al.,* 2013).

4.2.2 SPIROMETRY MEASUREMENTS VS RELATIVE VO_2 max

This study showed strong, positive and significant correlations between spirometry measures and VO_2 max in all three testing sessions.

At the start of BMT a strong, positive, significant correlation was noticed between FVC and VO_2 max in the total validation group (r=0.682; p<0.01) as well as in the male sample (r=0.617; p<0.05). Similarly, a strong, positive, significant correlation was also observed between FEV_1 and VO_2 max in the total validation group (r=0.628; p<0.01). A moderate, positive, significant correlation between FEV_1 and VO_2 max in the male sample (r=0.558; p<0.05) was also noted.

In week 12 of testing, the correlation between FVC and VO_2 max in the total validation group remained strong, positive and significant (r=0.616; p<0.01). The correlation between FEV_1 and VO_2 max in the total validation group was moderate, positive and significant (r=0.554; p<0.01).

Finally, at the end of BMT the strong, positive and significant correlations between FVC and VO_2 max, and FEV_1 and VO_2 max in the total validation group, remained (r=0.697; p<0.01 and r=0.658; p=<0.01, respectively).

Scientific studies investigating the relationships between VO_2 max and measures of pulmonary function, especially in patients with pulmonary pathologies, observed similar findings (McGavin, *et al.,* 1979; Fisher *et al.,* 1990; Ganju *et al.,* 2011). McGavin *et al.* (1979) observed strong, positive and significant correlations between VO_2 max and FEV_1 (r=0.65; p<0.01) and FVC (r=0.67; p<0.01) in patients with chronic bronchitis. Furthermore, Ganju *et al.* (2011) observed a significant correlation between VO_2 max and FEV_1 in patients with COPD, despite the correlation being weak (r=0.39; p=0.011). More specifically, in a study by Fisher *et al.* (1990), a moderate, positive and significant correlation was observed between vital capacity and VO_2 max (r=0.53; p<0.01) in patients with ankylosing spondylitis.

These findings are supported by the notion that participation in regular physical activity influences pulmonary function (Hagberg *et al.,* 1988; Rasmussen *et al.,* 2000; Jakes *et al.,* 2002; Pelkonen *et al.,* 2003; Garcia-Aymerich *et al.,* 2009; Hirayama *et al.,* 2010; Suzuki *et al.,* 2011). Fatemi *et al.* (2012) mentioned that pulmonary function may limit VO_2 max in conditions with airway obstruction, increased breathing resistance or inhalation of high-density gas mixtures. Furthermore, FEV_1 has proven to be a valuable measure of airway obstruction and closely related to VO_2 max, especially in patients with COPD (Babb *et al.,* 1997; Fatemi *et al.,* 2012). Babb *et al.* (1997) stated that despite patients with mild COPD being able to achieve similar

maximal heart rates and ventilatory reserve as age-matched normal patients, they had lower VO_2 max levels which were in proportion to their reduced FEV_1. Additionally, participation in regular physical activity has been associated with delaying the rate at which pulmonary function (especially FEV_1) decreases with ageing and inactivity (Hagberg *et al.,* 1988; Jakes *et al.,* 2002; Pelkonen *et al.,* 2003). Despite this, however, recent literature states that there is inconclusive data regarding the change in pulmonary function in high-level aerobic performers, and more specifically in young active military recruits (Cochet *et al.,* 2013; Degens *et al.,* 2013). This confirms that regular participation in endurance training does not seem to result in significant functional adaptations of the lungs and airways (McKenzie, 2012; Degens *et al.,* 2013). Additionally, studies comparing athletes to untrained individuals provide little evidence that high demands on the pulmonary system during exercise changes the underlying values of pulmonary function tests (McKenzie, 2012).

The small representation of female participants in the validation group (n=10) may possibly be the reason that a statistically significant correlation between VO_2 max and FVC and FEV_1 respectively was not observed, as was noted in the male sample in week 1.

4.3 CHANGES IN VARIABLES OVER TIME

It is known that changes in chest circumference measures, spirometry measures and relative VO_2 max are confounded by gender, age, height and mass (Rossiter & Wiell, 1973; Lapp *et al.,* 1974; Donnelly *et al.,* 1991; Gulsvik *et al.,* 2001; Ebomoyi & Iyawe, 2005; Whittaker *et al.,* 2005; ACSM, 2006; Cotes *et al.,* 2006; Ostrowski & Barud, 2006; Watsford *et al.,* 2007; Harms & Rosenkranz, 2008; Wu *et al.,* 2009). However, over a period of 19 weeks, the changes in age and height of participants should be minor. This was confirmed by the descriptive statistics. Furthermore, considering the average age of the validation group (i.e. 18–24 years), their pulmonary function and their height should have reached its peak. Cotes *et al.* (2006), Ostrowski and Barud

(2006) and Wu *et al.* (2009) stated that pulmonary function in healthy individuals reaches its peak at approximately 20–25 years of age. Additionally, Cotes *et al.* (2006) stated that girls reach their adult stature by 15 years of age and boys by 19 years of age. The changes in mass were also not statistically significant when controlled for by gender, age and height. Hence the statistical analysis of the changes in chest circumference measures, spirometry measures and relative VO_2 max over the 19 weeks of BMT were controlled for by gender only.

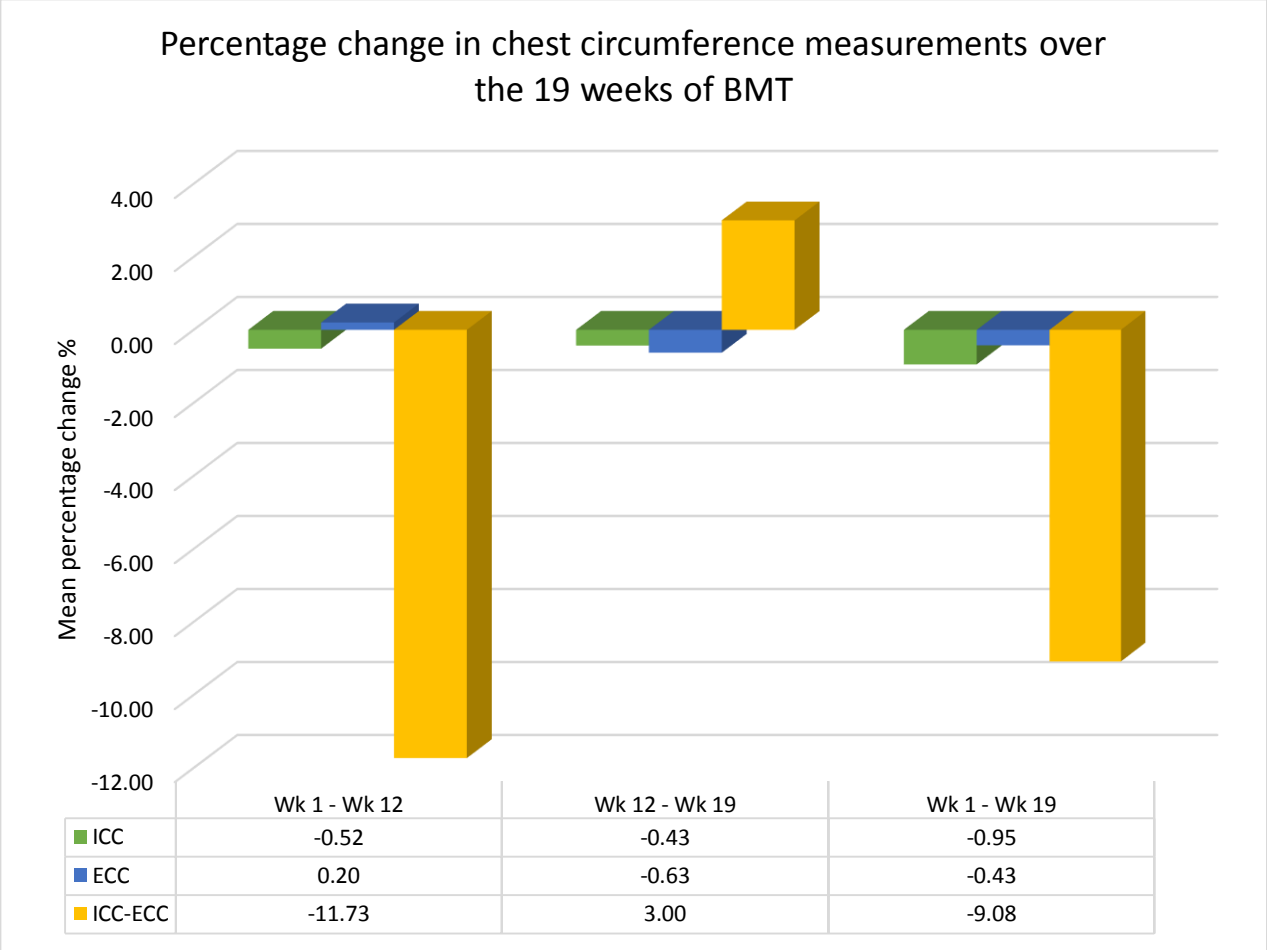
4.3.1 CHEST CIRCUMFERENCE

Over the 19 weeks of BMT, there were no statistically significant changes in chest circumference measures (p=0.401). Table 4.10. represents the mean values of the chest circumference measurements of the total validation group measured in week 1, week 12 and week 19, respectively. Additionally, the p-value representing the statistical change in the measures over time is presented. Figure 4.1 illustrates the percentage change in the chest circumference measurements between week 1 and 12, week 12 and 19, and week 1 and 19, respectively.

Table 4.10. Mean values and p-values of the chest circumference measurements over the 19 weeks of Basic Military Training

		Week 1		Week 12		Week 19		
Chest Circumference	No	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	**p value**
ICC	26	89.4	4.0	88.9	3.6	88.6	3.6	**0.29**
ECC	26	84.0	4.6	84.2	4.1	83.7	3.7	**0.62**
ICC-ECC	26	5.4	1.6	4.7	1.2	4.9	2.9	**0.37**

* $p<0.05$. ICC=inspiration chest circumference; ECC= expiration chest circumference



	Wk 1 - Wk 12	Wk 12 - Wk 19	Wk 1 - Wk 19
ICC	-0.52	-0.43	-0.95
ECC	0.20	-0.63	-0.43
ICC-ECC	-11.73	3.00	-9.08

ICC=inspiration chest circumference; ECC=expiration chest circumference

Figure 4.1 Percentage change in chest circumference measurements over the 19 weeks of Basic Military Training

Interestingly, although there were no statistically significant changes in chest circumference measurements over time, a -11.73% and -9.08% change in the ICC-ECC measurement was noticed between week 1 and week 12, and week 1 and week 19, respectively. This may be explained by the reported concerns with the reliability of repeated chest circumference measurements (Schrader *et al.,* 1984; Wu *et al.,* 2009).

Although chest circumference measurements may theoretically be a good predictor of pulmonary function because of its link to chest dimension, studies have reported that the reproducibility of the measurements are poor (Schrader *et al.,* 1984; Wu *et al.,* 2009). This is one of the reasons given for why it has been excluded from predictive equations for spirometry (Wu *et al.,* 2009).

4.3.2 SPIROMETRY MEASURES

With regard to the spirometry measurements taken, there was a statistically significant change over the 19 weeks of BMT ($p<0.001$). Significant changes in the spirometry measures between the three testing sessions were observed between some, but not all, of the testing sessions. Table 4.11. represents the mean values of the spirometry measurements of the total validation group measured in week 1, week 12 and week 19, respectively. The p-value representing the statistical change in the measures over time is also presented and significant p-values identified. Figure 4.2 illustrates the percentage change in the spirometry measurements between week 1 and 12, week 12 and 19, and week 1 and 19, respectively.

Table 4.11. Mean values ± standard deviations and p-values of the spirometry measurements over the 19 weeks of Basic Military Training

		Mean ± SD			p values		
Spirometry measurements	No	Week 1	Week 12	Week 19	**Wk1-12**	**Wk12-19**	**Wk1- 19**
FVC	26	3.9 ± 0.7	3.8 ± 0.7	3.6 ± 0.6	**p=0.021***	**p=0.025***	**p<0.001****
FEV_1	26	3.4 ± 0.5	3.2 ± 0.5	3.2 ± 0.5	**p=0.027***	**p=0.206**	**p<0.001****
FEV_1/FVC	26	87.4 ± 7.2	87.3 ± 7.8	87.9 ± 6.4	**p=0.936**	**p=0.475**	**p=0.533**

** p<0.01; * p<0.05. FVC=forced vital capacity; FEV_1=forced expiratory volume in 1 second

Statistically significant changes in FVC between week 1 and week 12 (0.1L; -2.22%; p=0.021); between week 1 and week 19 (0.3L; -5.69%; p<0.001); and between week 12 and week 19 (0.2L; -3.55%; p=0.025) were observed. Additionally, statistically

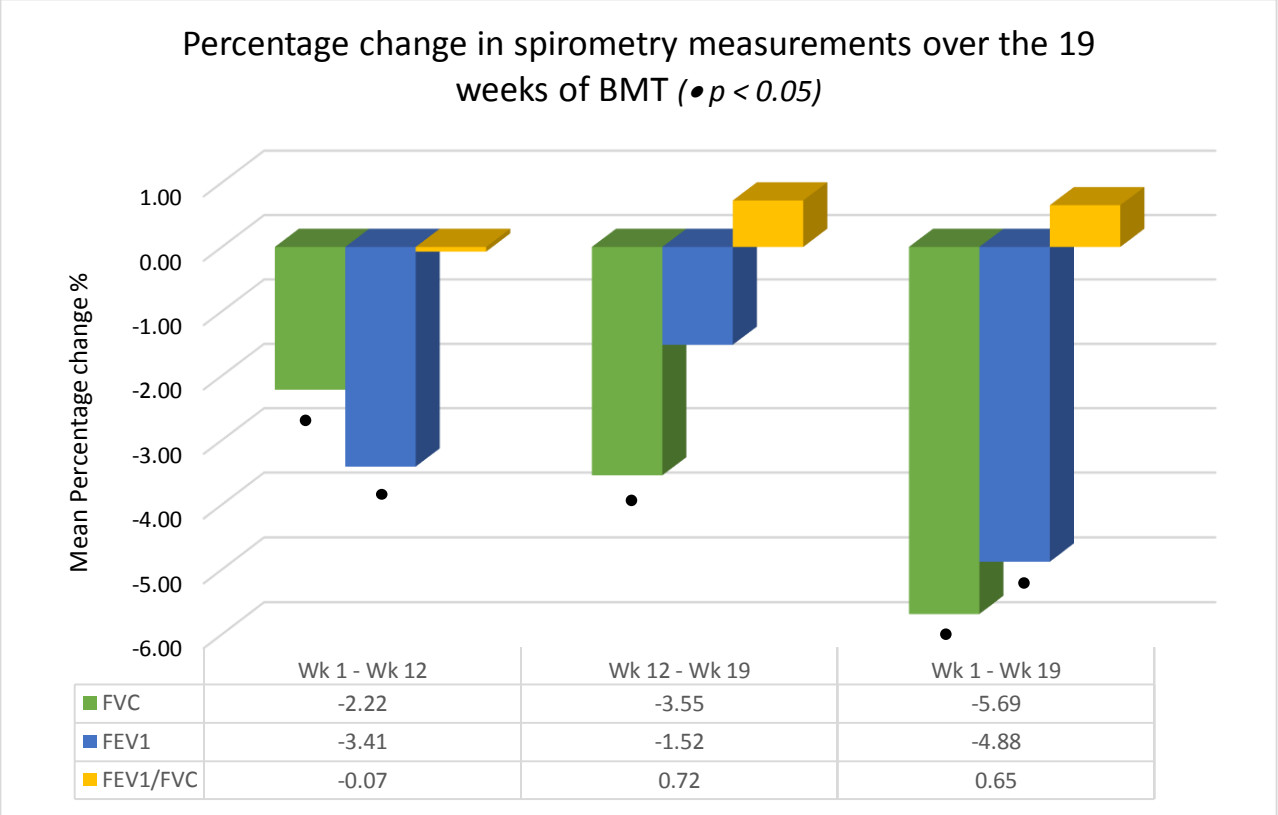
significant differences in FEV_1 between week 1 and week 12 (0.2L; -3.41%; p=0.027) and between week 1 and week 19 (0.2L; -4.88%; p<0.001) were noted.

No statistically significant change in FEV_1 between week 12 and week 19 (0.05L; -1.52%; p=0.206) was observed, along with FEV_1/FVC between week 1 and week 12 (0.1%; -0.07%; p=0.936), between week 1 and week 19 (0.5%; 0.65%; p=0.533) and between week 12 and week 19 (0.6%; 0.72%; p=0.475) of BMT.

When controlled for gender, the overall statistical difference in spirometry measures over the 19 weeks of BMT remained statistically significant (p<0.001).

The statistical changes in FVC and FEV_1 remained statistically significant (p=0.001 & p=0.002 respectively) and FEV_1/FVC remained statistically non-significant (p=0.806), when controlled for gender.

More specifically, when analysing the statistical changes between each of the testing sessions – while controlling for gender – changes in FVC between week 1 and week 12 (p=0.025), between week 1 and week 19 (p<0.001) and between week 12 and week 19 (p=0.043) remained statistically significant. Similarly, the changes in FEV_1 remained statistically significant between week 1 and week 12 (p=0.039) and between week 1 and week 19 (p<0.001), but the change between week 12 and week 19 (p=0.199) remained statistically non-significant.



FVC=forced vital capacity; FEV_1=forced expiratory volume in 1 second

Figure 4.2 Percentage changes in spirometry measurements over the 19 weeks of Basic Military Training

Cigarette smoking is associated with a decline in pulmonary function (Xu *et al.,* 1992; Burchfiel *et al.,* 1995; Gold *et al.,* 1996; Scanlon *et al.,* 2000; Anthonisen *et al.,* 2002; Cotes *et al.,* 2006). This may offer a possible explanation for the statistically significant differences observed in FEV_1 and FVC over time. A total of 19% of the participants in the validation group reported that they were smokers. Continued cigarette smoking has been proven to cause a decline in FEV_1 (Xu *et al*., 1992; Burchfiel *et al.,* 1995; Anthonisen *et al.,* 2002; Shiner & Steier, 2013). Burchfiel *et al.* (1995) reported that Japanese-American males (n=4,451; 45–68 years) who continued to smoke experienced greater rates of decline in FEV_1 in comparison to males who never smoked (-33ml/year versus -22ml/year, respectively; p=0.0001). Furthermore, when Anthonisen *et al.* (2002) examined the pulmonary function of participants who entered the Lung Health Study after 11 years, they observed a decline in FEV_1 of 66.1ml/year in males who had continued smoking and 54.2

ml/year in females who had continued smoking. When studying the effects of cigarette smoking on pulmonary function in 5 158 adolescent boys and 4 902 girls (age 10–18 years), a dose–response relation between smoking and lower levels of both FEV_1/FVC and $FEF_{25–75}$ was observed (Gold *et al.,* 1996). Each pack of cigarettes smoked per day was associated with a 3.2% decrease in $FEF_{25–75}$ for girls (p=0.01) and a 3.5% decrease in $FEF_{25–75}$ for boys (p=0.007) (Gold *et al.,* 1996).

Additionally, the prevalence of smoking in this study was based on self-reporting, thus the possibility of underestimating the prevalence of smoking amongst the recruits cannot be ignored. Reports on the impact of military training on smoking behaviour are conflicting. In a study of Norwegian army recruits (n=2,112; ages 18–25 years), Schei and Sogaard (1994) showed that military service had a negative influence on smoking behaviour. The study reported that among the recruits who smoked, 55.7% had increased their smoking during military service, and 7.8% of the recruits who were non-smokers had started to smoke (Schei & Sogaard, 1994). Similarly, at a one-year follow-up after commencement of military service most cigarette smokers had either maintained or increased their tobacco use (Klesges *et al.,* 2010). Williams and co-workers (1996) showed that the overall smoking prevalence for US military male recruits decreased between baseline (second day of BMT) and 90 days after BMT (12.7% to 9.8%). The mandatory tobacco abstinence policy of the US military during BMT was reported to have had a positive, though small, effect on smoking after BMT (Williams *et al.,* 1996).

Another possible reason for the observed differences in the spirometry measures over time is the participants' lack of experience in performing spirometry tests. This was despite the tester explaining and demonstrating the aim and technique of the spirometry manoeuvre to the participants before each test was conducted, allowing a maximum of eight attempts per participant and strictly following the standardised procedures conforming to the *Series ATS/ERS Task Force: Standardisation of Lung Function Testing, Number 2: Standardisation of Spirometry* by Miller *et al.* (2005b). Spirometry is an effort-dependent manoeuvre, thus in addition to well-trained technicians, a compliant and enthusiastic participant is necessary in order to obtain reproducible and acceptable results (Lee *et al.,* 2006; Derom *et al.,* 2008; Shiner & Steier, 2013). When considering the differences in FEV_1 specifically, statistically

significant differences where noted when FEV_1 values were assessed in relation to week 1 (i.e. between week 1 and week 12; between week 1 and week 19). The participants had the least experience in performing spirometry tests in week 1. Interestingly, however, when assessing the differences between weeks 12 and 19, no statistically significant differences in FEV_1 were observed. A possible explanation for this it that the participants were more familiar with the spirometry manoeuvre in weeks 12 and 19, and were therefore able to concentrate primarily on giving maximal effort when 'blasting' the air out during exhalation.

In summary, this study maintains that cigarette smoking, the prevalence of smoking amongst military recruits and the participants' lack of experience in spirometry manoeuvres may have influenced the spirometry results obtained and the observed changes in these values over time (Xu *et al.,* 1992; Schei & Sogaard,1994; Burchfiel *et al.,* 1995; Gold *et al.,* 1996; Williams *et al.,* 1996; Scanlon *et al.,* 2000; Anthonisen *et al.,* 2002; Cotes *et al*., 2006; Lee *et al.,* 2006; Derom *et al.,* 2008; Klesges *et al.,* 2010; Shiner & Steier, 2013).

4.3.3 RELATIVE VO_2 max

A statistically significant difference in relative VO_2 max was observed over the 19 weeks of BMT ($p<0.001$). Table 4.12. represents the mean values for relative VO_2 max of the total validation group measured in week 1, week 12 and week 19 respectively, together with the p-values. Figure 4.3 illustrates the percentage change in relative VO_2 max between week 1 and 12, week 12 and 19, and week 1 and 19, respectively.

Table 4.12. Mean values ± standard deviations and p-values of relative VO_2 max over the 19 weeks of Basic Military Training

	N	Week 1	Week 12	Week 20	Wk1-12	Wk12-19	Wk1-19
VO_2 max ($ml.kg^{-1}.min^{-1}$)	26	34.8 ± 6.3	41.5 ± 6.3	41.1 ± 6.6	**p≤0.001****	**p=0.543**	**p≤0.001****

** p<0.01; * p<0.05.

The changes in relative VO_2 max between week 1 and week 12 (19.23%; p≤0.001) and between week 1 and week 19 (18.18%; p≤0.001) of BMT were statistically significant. Interestingly, there was no statistically significant change in relative VO_2 max between week 12 and week 19 (-0.88%; p=0.543).

These findings remained the same when controlled for gender. The overall statistical changes in relative VO_2 max over the 19 weeks of BMT remained statistically significant (p<0.001). Additionally, the changes in relative VO_2 max remained statistically significant between week 1 and week 12 (p<0.001) and between week 1 and week 19 (p<0.001). No statistically significant difference was observed between week 12 and week 19 (p=0.457).

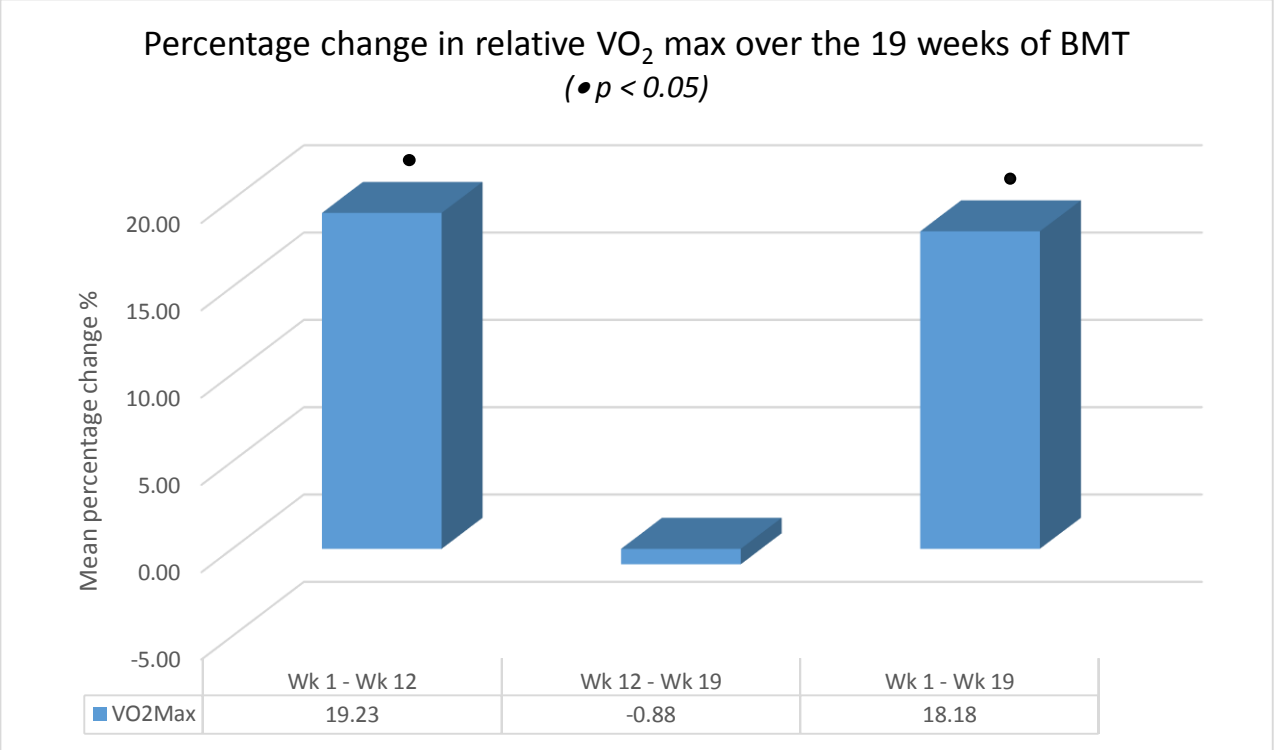


Figure 4.3 Percentage changes in relative VO_2 max over the 19 weeks of Basic Military Training

There was a positive percentage change in VO_2 max over the 19 weeks of BMT (18.18%), with the greatest change being observed between week 1 and week 12 (19.23%).

Regular participation in aerobic or large motor activities is associated with increases in VO_2 max (Powers & Howley, 2004; ACSM, 2006b). Healthy participants have demonstrated 10% to 30% increases in VO_2 max (ACSM, 2006b). Improvements in cardiorespiratory fitness are associated with a number of favourable changes, namely greater O_2 transport, increased maximal stroke volume and cardiac output, changes in heart rate, arteriovenous O_2 difference, blood lactate and ventilation (ACSM, 2006b).

The purpose of BMT is to equip new recruits with the physical capabilities and skills required to perform their military tasks effectively (Williams *et al.,* 1999; Wood & Krüger, 2013). The physical training component of BMT programmes is essential for the physical preparation and conditioning of the military recruits (Wood & Krüger, 2013). Studies investigating the effects of BMT on VO_2 max have shown similar

findings to this study (Lim & Lee, 1994; Brock & Legg, 1997; Williams *et al.,* 1999; Cheng *et al.,* 2007). Brock and Legg (1997) demonstrated statistically significant increases in mean VO_2 max (from 45.7ml.kg^{-1}.min^{-1} to 46.7ml.kg^{-1}.min^{-1}; $p<0.05$) in female British Army recruits enrolled in a seven-week BMT programme. Similarly, Cheng *et al.* (2007) observed statistically significant ($p<0.001$) increases in the VO_2 max of first-grade cadets who completed nine weeks of BMT. Furthermore, when investigating the efficacy of British Army BMT in improving material handling performance, Williams *et al.* (1999) observed a statistically significant improvement in VO_2 max ($p<0.05$; 6.1% change) over the 10 weeks of BMT.

Significant changes in VO_2 max were also observed in studies involving longer BMT programmes (Lim & Lee, 1994; Williams, 2005; Chai *et al.,* 2009). Lim and Lee (1994) observed statistically significant changes in VO_2 max (28.1 ± 6.3ml.kg^{-1}.min^{-1} to 32.1 ± 5.1ml.kg^{-1}.min^{-1}; $p<0.001$) of obese military recruits going through a 20-week BMT programme. Interestingly, in a study by Chai *et al.* (2009), military recruits who underwent 16 weeks of modified BMT (involving a six-week preparatory training phase and 10 weeks of traditional BMT) had greater improvements in cardiorespiratory fitness – despite being statistically non-significant ($p<0.085$) – than recruits who enlisted for the traditional BMT prgramme only. In a 12-week BMT programme, the recruits in the regular group of the British Army showed improvements in VO_2 max before and after the programme (44.8 ± 4.9ml.kg^{-1}.min^{-1} to 50.6 ± 4.5ml.kg^{-1}.min^{-1}; $p<0.0005$) (Williams, 2005).

To allow for improvements in an individual's cardiorespiratory fitness, the essential principles of training, namely adaptation and specificity, must be considered when designing a physical training programme (ACSM, 2006b). Therefore, the mode of exercises selected, as well as the frequency, duration, and intensity of training, are vital in achieving fitness results (ACSM, 2006b). The physical training component of the BMT programme completed by the recruits of this study, and of BMT programmes reported in the literature (Lim & Lee, 1994; Brock & Legg, 1997; Williams *et al.,* 1999; Cheng *et al.,* 2007; Chai *et al.,* 2009) provided the recruits with the necessary stimulus to allow for physiological adaptation. The modes of training selected in these BMT programmes were specific to the physical fitness components that needed improvement (i.e. cardiorespiratory fitness, muscle strength and

endurance and flexibility), and the frequency, duration and intensity were combined in a progressive overload that resulted in improvements in cardiorespiratory fitness.

Hence, this study supports the statement that BMT produces favourable adaptations in recruits, especially in terms of aerobic fitness (Williams *et al.,* 1999).

4.3.4 RELATIONSHIP BETWEEN SPIROMETRY MEASURES AND RELATIVE VO_2 max OVER TIME

The minimal negative percentage change in FVC and FEV_1 over the 19 weeks of BMT in relation to the positive percentage change in VO_2 max over the 19 weeks of BMT is in opposition to the correlational findings discussed earlier in this chapter. Positive correlations between VO_2 max and FVC and FEV_1 over the 19 weeks of BMT were noted. Thus pulmonary function values would be expected to increase with increases in VO_2 max over time; however, an indirect relationship between these variables was observed over time. This may be explained by claims that VO_2 max and pulmonary function may not be related and that the data regarding the change in pulmonary function in individuals participating in regular aerobic activities is inconclusive (Cochet *et al.,* 2013; Degens *et al.,* 2013).

Regular participation in endurance training results in significant adaptations within the cardiovascular, musculoskeletal and haematological systems (McKenzie, 2012; Cochet *et al.,* 2013). However, the structural and functional properties of the lungs and airways do not change in response to repetitive physical activity (McKenzie, 2012; Degens *et al.,* 2013). Suzuki *et al.* (2011) discovered that when comparing three different levels of VO_2 max (i.e. high, normal and low) with pulmonary function, not all pulmonary function measures were associated with VO_2 max in healthy male and female volunteers. Furthermore, Suzuki *et al.* (2011) noticed that pulmonary function continued to decrease with age despite the physical fitness levels of the individuals, and concluded that exercise does not inhibit the age-associated decline of pulmonary function in healthy individuals.

Although participation in whole-body endurance activities has proved to increase the strength of the respiratory muscles (Cotes *et al.,* 2006; Kroff & Terblanche, 2010) and thus increase the function of the respiratory pump in moving air in and out of the lungs (Cotes *et al.,* 2006; Shiner & Steier*,* 2013), Lanza *et al.* (2013) stated that lung volumes obtained in spirometry tests are related not only to the strength of the respiratory muscles, but also to the elastic recoil, compliance and resistance of the lungs and airways. Pulmonary causes of restriction are attributed to changed compliance of the lung, a measure of elasticity, with fast retraction following complete inflation (Shiner & Steier*,* 2013). Additionally, pulmonary causes of obstruction – thus increased airway resistance – are attributed to reduced cross-sectional airway diameter (ACSM, 2006b). Interestingly, Cotes *et al.* (2006) stated that the usefulness of chest dimensions for describing the pulmonary function of children appears to be less meaningful in adults.

Moreover, McKenzie (2012) stated that there are four factors associated with limitations in pulmonary function in healthy individuals, namely arterial hypoxemia, expiratory flow limitations, vocal cord dysfunction and respiratory muscle fatigue. The demands of ventilation and gaseous exchange during exercise exceed the capacity of the pulmonary system (McKenzie, 2012). Additionally, the pulmonary system's inability to increase its diffusion capacity with training may contribute to the often-observed exercise-induced hypoxemia in athletes (Degens *et al.,* 2013). Studies comparing athletes to untrained individuals provide little evidence that high demands on the pulmonary system during exercise change the underlying values of pulmonary function tests (McKenzie, 2012).

Granted that active duty military recruits, with a greater emphasis on regular physical fitness, are supposed to have above-normal pulmonary function test values when compared to non-active duty military recruits, Cochet *et al.* (2013) observed that there was no significant difference in pulmonary function tests in active duty versus non-active duty recruits of the same age range. Moreover, Cochet *et al.* (2013) concluded that the pulmonary function test values of active duty military recruits should not be assumed by virtue of their active duty status.

Thus the findings in this study support the claim that if pulmonary function levels are within normal ranges, they are not necessarily related to the individual's level of VO_2 max (Suzuki *et al.,* 2011).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Pulmonary disease, especially COPD, is a common cause of morbidity and mortality (Miravitlles *et al.,* 2006, Joo *et al.,* 2009, Arne *et al.,* 2010). However a large number of individuals remain undiagnosed, preventing them from receiving the appropriate treatment such as smoking cessation counselling and regular follow-ups (Miravitlles *et al.,* 2006). Possible reasons for this include a lack of knowledge about pulmonary disease and its associated symptoms and risks, the inconsistent use of spirometry in primary care settings and the inability to produce results that satisfy the full criteria for acceptability and reproducibility (Lee *et al.,* 2006; Miravitlles *et al.,* 2006; White *et al.,* 2007; Schermer *et al.,* 2009).

A simple test, namely chest circumference measurements, has proven to be positively correlated with pulmonary function in both healthy individuals and in individuals with various pulmonary pathologies, such as COPD, and postural deviations such as scoliosis (Stamm & Docter, 1965; Brokan *et al.,* 1981; Leong *et al.,* 1999; Hawes & Brooks, 2001; Cimbiz *et al.,* 2004; Lopes *et al.,* 2007; Chambers *et al.,* 2008; Wu *et al.,* 2009). It has been stated that the integrity of the chest wall influences the functioning of the respiratory pump and that changes to any of the components of the respiratory pump will directly affect pulmonary function (Cotes *et al.,* 2006; Shiner & Steier, 2013). Hence, based on the literature, chest circumference measurements potentially offers practitioners and technicians an additional method for assessing pulmonary function, especially for conditions that affect the expansion of the lungs and thoracic cage.

Additionally, regular participation in aerobic or large motor activities, and more specifically BMT, has proven to increase VO_2 max in healthy individuals (Lim & Lee, 1994; Brock & Legg, 1997; Williams *et al.,* 1999; Powers & Howley, 2004; Williams, 2005; ACSM, 2006; Cheng *et al.,* 2007; Chai *et al.,* 2009). Moreover, regular participation in whole-body endurance activities increases the strength of the respiratory muscles (Cotes *et al.,* 2006; Kroff & Terblanche, 2010) and thus increases the function of the respiratory pump, which moves air in and out of the lungs (Cotes *et al.,* 2006; Shiner & Steier, 2013).

Thus, the purpose of the study was to determine whether a strong and significant correlation existed between chest circumference measurements and spirometry measurements in a young healthy active population, and whether this relationship remained consistent with changes to an individual's physical fitness.

A quantitative research approach, utilising a prospective correlational research design, was used to determine the objectives of the study.

The study aimed to determine whether there was a strong ($r>0.6$) and significant correlation ($p\leq0.05$) between:

- Inspiration chest circumference and spirometry measurements (FVC, FEV_1 and FEV_1/FVC) at the commencement and for the duration of a 19-week intense training programme;
- Expiration chest circumference and spirometry measurements (FVC, FEV_1 and FEV_1/FVC) at the commencement and for the duration of a 19-week intense training programme;
- The difference between inspiration chest circumference and expiration chest circumference and spirometry measurements (FVC, FEV_1 and FEV_1/FVC) at the commencement and for the duration of a 19-week intense training programme;
- Spirometry measures (FVC, FEV_1 and FEV_1/FVC) and relative VO_2 max at the commencement and for the duration of a 19-week intense training programme

Additionally, the study aimed to:

- Determine whether there was a statistically significant ($p \leq 0.05$) change between the measured variables (i.e. ICC, ECC, ICC-ECC, FVC, FEV_1, FEV_1/FVC and VO_2 max) over the 19-week intense training programme.

Determining these study aims was intended to help validate the use of inexpensive chest circumference measurements as a measurement of pulmonary function in a young healthy active population.

A pre-study orientation and screening session held in week 1, along with anthropometric measurements (height, mass and chest circumference), spirometry and the multistage shuttle run test (all conducted in weeks 1, 12 and 19 of the BMT programme) assisted with determining the objectives of the study.

The procedures and instrumentation used to conduct these measurements and tests are discussed in Chapter 3 (Section 3.5. “Procedures and Instrumentation”; pages 54-67).

When determining whether strong ($r > 0.6$) and significant correlations ($p \leq 0.05$) exist between chest circumference measurements and spirometry measures as well as spirometry measures and relative VO_2 max over 19 weeks of BMT, the study revealed the following results:

a) There were weak and non-significant correlations ($r < 0.4$) between the chest circumference measurements (ICC, ECC and ICC-ECC) and spirometry measurements (FEV_1, EVC and FEV_1/FVC) taken in weeks 1, 12 and 19 of the BMT programme – with the exception of the moderate, positive and significant correlation between FVC and ICC in the male sample ($r = 0.522$; $p < 0.05$) in week 12.
b) Strong, positive and statistically significant correlations between FVC and VO_2 max in the total validation group were observed in weeks 1, 12 and 19 of BMT ($r = 0.682$, $p < 0.01$; $r = 0.616$, $p < 0.01$ and $r = 0.697$; $p < 0.01$, respectively).
c) Strong, positive and statistically significant correlations between FEV_1 and VO_2 max in the total validation group were observed in week 1 and week 19 of BMT ($r = 0.628$; $p < 0.01$ and $r = 0.658$; $p < 0.01$, respectively), with a moderate,

positive and statistically significant correlation between FEV_1 and VO_2 max, in the total validation group, in week 12 of BMT ($r=0.554$; $p<0.01$).

When considering the changes in the measured variables (i.e. ICC, ECC, ICC-ECC, FVC, FEV_1, FEV_1/FVC and VO_2 max) over the 19 weeks of BMT, the following was observed:

a) There were no statistically significant changes in chest circumference measures over time ($p=0.401$);
b) There were statistically significant changes in FVC between week 1 and week 12, week 1 and week 19 and week 12 and week 19 of BMT ($p=0.021$; $p<0.001$ and $p=0.025$, respectively).
c) There were statistically significant changes in FEV_1 between week 1 and week 12 and week 1 and week 19 of BMT ($p=0.027$ and $p<0.001$).
d) There was no statistically significant change in FEV_1 between week 12 and week 19 of BMT ($p=0.206$).
e) There was no statistically significant change in FEV_1/FVC between week 1 and week 12, week 1 and week 19 and week 12 and week 19 of BMT ($p=0.936$; $p=0.533$ and $p=0.475$, respectively).
f) When controlled for by gender, the overall changes in FVC and FEV_1 remained statistically significant ($p=0.001$ & $p=0.002$, respectively) and FEV_1/FVC remained statistically non-significant ($p=0.806$).
g) There were statistically significant changes in relative VO_2 max between week 1 and week 12 and week 1 and week 19 of BMT ($p\leq0.001$ and $p\leq0.001$, respectively).
h) There was no statistically significant change in relative VO_2 max between week 12 and week 19 ($p=0.543$).
i) When controlled for by gender, the overall changes in relative VO_2 max over the 19 weeks of BMT remained statistically significant ($p<0.001$).

Nevertheless this study had limitations. The first was the study's small sample size. The initial study population consisted of 235 participants; however, after the inclusion and exclusion criteria of the study were applied to the data, the sample size was reduced to 26 observations. The second limitation was the participants' lack of

experience in performing spirometry tests. This was despite the tester explaining and demonstrating the aim and technique of the spirometry test to the participants before each test was conducted and allowing a maximum of eight attempts per participant. Spirometry is an effort-dependent manoeuvre and – in addition to well-trained technicians – compliant participants are vital for obtaining reproducible and acceptable results (Lee *et al.,* 2006; Derom *et al.,* 2008; Shiner & Steier, 2013). Lastly, spirometry is a clinical test, predominately performed in hospital-based pulmonary function laboratories or clinics, in primary care settings and in community-based service settings (Derom *et al.,* 2008); thus, not being able to perform spirometry in a clinical setting, due to the nature of the BMT, was a limitation.

It is recommended that future research be conducted on a larger sample size to increase the statistical power of the findings, especially if the detection of differences over time is required. Additionally, to minimise the exclusion of data due to the participants not being able to produce technically satisfactory spirometry test manoeuvres, a pre-training spirometry session is recommended before official data collection begins. This will allow the participants to familiarise themselves with spirometry, the equipment and how to accurately perform the spirometry manoeuvres. Moreover, it would be ideal to conduct the spirometry tests in a controlled clinical environment.

In summary, after thorough review of the existing literature, the results obtained and the limitations of this study, it may be concluded that this study did not find a statistically significant correlation between chest circumference measurements and pulmonary function, despite the statistically significant increase in the VO_2 max of the young military recruits over the 19 weeks of BMT. Of particular value for future studies may be the confirmation that regular participation in endurance training does not seem to result in significant functional adaptations of the lungs and airways (McKenzie, 2012; Degens *et al.*, 2013). Therefore, these findings do not support the use of inexpensive chest circumference measurements as a measurement of pulmonary function in a young healthy active population. Future research, carefully considering the recommendations made, is required to further investigate this relationship.

REFERENCES

American College of Sports Medicine (ACSM), 2006a, *Guidelines for Exercise Testing and Prescription,* 7th ed., Lippincott Williams & Wilkins, Philadelphia.

American College of Sports Medicine (ACSM), 2006b, *Resource Manual for Guidelines for Exercise Testing and Prescription,* 5th ed., Lippincott Williams & Wilkins, Philadelphia.

Arne, M., Lisspers, K., Stöulberg, P., Baman, G., Hedenström, H., Janson, C. & Emtner, M., 2010, 'How often is diagnosis of COPD confirmed with spirometry?', *Respiratory Medicine,* 104(4), 550-556.

Anthonisen, N.R., Connett, J.E., & Murray, R.P., 2002, 'Smoking and lung function of Lung Health Study participants after 11 years', *American Journal of Respiratory and Critical Care Medicine*, 166(5), 675-679.

Babb, T.G., Long, K.A. & Rodarte, J.R., 1997, 'The relationship between maximal expiratory flow and increases of maximal exercise capacity with exercise training', *American Journal of Respiratory and Critical Care Medicine*, 156(1), 116-121.

Beachle, T.R. & Earle, R.W., 2008, *Essentials of Strength Training and Conditioning*, 3rd ed., Human Kinetics, Champaign, Illinois, USA.

Bergman, H.E., Hunt, Y.M. & Augustson, E., 2012, 'Smokeless tobacco use in the United States military: a systematic review', *Nicotine and Tobacco Research*, 14(5), 507-515.

Bockenhauer, S.E., Cheng, H., Julliard, K.N. & Weedan, J., 2007, 'Measuring thoracic excursion: reliability of cloth tape measure technique', *Journal of American Osteopathology Association*, 107(5), 191-196.

Booker, R., 2008, 'Simple spirometry measurement', *Nursing Standard,* 22(32), 35-39.

Brink, H., Van der Walt, C. & Van Rensburg, G., 2012, *Fundamentals of Research Methodology for Healthcare Professionals,* 3rd ed., Juta, Cape Town, South Africa.

Brock, J.R. & Legg, S.J., 1997, 'The effects of 6 weeks training on physical fitness of female recruits of British Army', *Ergonomics*, 40(3), 400-411.

Brokan, G.A., Glynn, R.S., Bachman, S.S., Bassé, R. & Weiss, S.T., 1981, 'Relationship between cigarette smoking, chest size and body size in health-screened adult males', *Annals of Human Biology*, 8(2), 153-160.

Burchfiel, C.M., Marcus, E.B., Curb, J.D., MacLean, C.J., Vollmer, W.M., Johnson, L.R., Fong, K., Rodriguez, B.L., Masaki, K.H. & Buist, A.S., 1995, 'Effects of smoking and smoking cessation on longitudinal decline in pulmonary function', *American Journal of Respiratory and Critical Care Medicine,* 151(6), 1778-1785.

Burney, P. & Jarvis, D., 2007, 'Lung function protocol, data sheets and lung function questionnaire', *The European Community of Respiratory Health Survey*, 7(5), 954-60.

Chai, L.Y.A., Ong, K.C, Kee, A., Earnest, A., Lim, F.C.L. & Wong, J.C.M., 2009, 'A prospective cohort study on the impact of a modified basic military training (mBMT) programme based on pre-enlistment fitness stratification amongst Asian military enlistees', *Annals Academy of Medicine,* 38(10), 862-868.

Chambers, E.C., Heshka, S., Huffaker, L.Y., Xiong, Y., Wang, J., Eden, E., Gallagher, D. & Pi-Sunyer, F.X., 2008, 'Truncal adiposity and lung function in older black women', *Lung*, 186(1), 13-17.

Chen, H.I. & Kuo, C.S., 1989, 'Relationship between respiratory muscle function and age, sex, and other factors', *Journal of Applied Physiology,* 6(2), 943-948.

Cheng, K.W., Chiu, P., Lin, I., Xu, K.F., Hsu, M. & Liang, M.T., 2007, 'A study of basic military training on physical fitness and physical self-concept for cadets', *Journal of Physical Education and Recreation (Hong Kong)*, 13(2), 6-12.

Cheng, Y.J., Macera, C.A., Addy, C.L., Sy, F.S., Weilnad, D. & Blour, S.N., 2003, 'Effects of physical activity on exercise tests and respiratory function', *British Journal of Sports Medicine*, 37(6), 521-528.

Chlif, M., Keochkerian, D., Choquet, D., Vaidie, A., & Ahmaidi, S., 2009, 'Effects of obesity on breathing pattern, ventilator neural drive and mechanics', *Respiratory Physiology and Neurobiology,* 168(3), 198-202.

Cimbiz, A., Vahdeltin, B. & Hallaceli, H., 2004, 'Assessment of chest and postural alignment in healthy Turkish coal miners', *Journal of Medical Science*, 4(3), 240-245.

Cochet, A.A., Lucero, P.F., Zacher, L.L. & Morris, M.J., 2013, 'Prevalence of supranormal pulmonary function testing values between a military and non-military cohort', *Respiratory Care,* Sep 17 (Epub ahead of print).

Cotes, J.E., Chinn, D.J. & Miller, M.R., 2006, *Lung Function*, 6th ed., Blackwell Publishing Ltd, Oxford, UK.

Dancey, C.P. & Reidy, J., 2004, *Statistics without maths for psychology using SPSS for Windows*, 3rd ed., Pearson Prentice Hall, London, UK.

Degens, H., Rittweger, J., Parviainen, T., Timonen, K.L., Suominen, H., Heinen, A. & Korhonen, M.T., 2013, 'Diffusion capacity of the lung in young and old endurance athletes', *International Journal of Sports Medicine,* 34(12), 1051–1057.

Derom, E., Van Weel, C., Lilstro, G., Buffels, J., Schermer, T., Lammers, E., Wouters, E. & Decramer, M., 2008, 'Primary care spirometry', *European Respiratory Journal*, 31(1), 197-203.

Donnelly, P.M., Yang, T.S., Peat, J.K. & Woolcook, A.J., 1991, 'What factors explain racial differences in lung volumes?', *European Respiratory Journal,* 4(7), 829-838.

Ebomoyi, M.I. & Iyawe, V.I., 2005, 'Variations of peak expiratory flow rate with anthropometric determinants in a population of healthy adult Nigerians', *Nigerian Journal of Physiological Sciences*, 20(1-2), 85-89.

Ehrlich, R., White, N., Myers, J., Thompson, M., Churchyard, G., Barnes, D. & De Villiers, D.B., 2000, 'Development of lung function reference tables suitable for use in the South African mining industry', *Safety in Mines Research Committee, Draft Final Report*, 2-57.

Fatemi, R., Shakerian, S., Ghanbarzade, M., Habibi, A. & Moghaddam, H.F., 2012, 'The comparison of dynamic volumes of pulmonary function between different levels of maximal oxygen uptake', *International Research Journal of Applied and Basic Sciences,* 3(3), 667-674.

Fisher, L.R., Cawley, M.I.D. & Holgate, S.T., 1990, 'Relation between chest expansion, pulmonary function, and exercise tolerance in patients with ankylosing spondylitis', *Annals of the Rheumatic Diseases,* 49(11), 921-925.

Ganju, A.A., Fuladi, A.B., Tayade, B.O. & Ganju, N.A., 2011, 'Cardiopulmonary exercise testing in evaluation of patients of chronic obstructive pulmonary disease', *Indian Journal of Chest Diseases and Allied Sciences,* 53(2), 87-91.

Garcia-Aymerich, J., Serra, I., Gómez, F.P., Farrero, E., Balcell, E., Rodriguez, D.A., De Batlle, J., Gimeno, E., Donaire-Gonzalez, D., Orozco-Levi, M., Sauleda, J., Gea, J., Rodriguez-Roisin, R., Roca, J., Agusti, A.G., Antó, J.M. & PAC-COPD Study Group, 2009, 'Physical activity and clinical and functional status in COPD', *Chest*, 136(1), 62-70.

Gold, D.R., Wang, X., Wypij, D., Speizer, F.E., Ware, J.H. & Dockery, D.W.,1996, 'Effects of cigarette smoking on lung function in adolescent boys and girls', *New England Journal of Medicine*, 335(13), 931-937.

Gulsvik, A., Tosteson, T., Bakke, P., Humerfelt, S., Weiss, S.T. & Speizer, F.E., 2001, 'Expiratory and inspiratory forced vital capacity and one-second forced volume in asymptomatic never-smokers in Norway', *Clinical Physiology*, 21(6), 648-660.

Hagberg, J.M., Yerg, J.E. & Seals, D.R., 1988, 'Pulmonary function in young and older athletes and untrained men', *Journal of Applied Physiology,* 65(1), 101-105.

Harms, C.A. & Rosenkranz, S., 2008, 'Sex differences in pulmonary function during exercise', *Medicine & Science in Sports & Exercise*, 40(4), 664-668.

Hawes, M.C. & Brooks, W.J., 2001, 'Improved chest expansion in idiopathic scoliosis after intensive, multi-modality, non-surgical treatment in an adult', *Chest*, 120(2), 672-674.

Hemilä, H., 1996, 'Vitamin C and common cold incidence: a review of studies with subjects under heavy physical stress', *International Journal of Sports Medicine,* 17(5), 379-383.

Hirayama, F., Lee, A.H. & Hiramatsu, T., 2010, 'Life-long physical activity involvement reduces the risk of chronic obstructive pulmonary disease: a case-control study in Japan', *Journal of Physical Activity and Health,* 7(5), 622-626.

Hunter, A.G.W., Reid, C.S., Pauli, R.M. & Scott Jr, C.I., 1996, 'Standard curves of chest circumference in achondroplasia and the relationship of chest circumference to respiratory problems', *American Journal of Medical Genetics*, 62(1), 91-97.

Jackson, B., Kubzansky, L.D., Cohen, S., Weiss, S. & Wright, R.J., 2004, 'A matter of life and breath: childhood socioeconomic status is related to young adult pulmonary function in the CARDIA study', *International Epidemiological Association,* 33(2), 271-278.

Jakes, R.W., Day, N.E., Patel, B., Khaw, K.T., Oakes, S., Luben, R., Welch, A., Bingham, S. & Wareham, N.J., 2002, 'Physical inactivity is associated with lower Forced Expiratory Volume in 1 second', *American Journal of Epidemiology*, 159(2), 139-147.

Janssens, J.P., Pache, J.C., & Nicod, L.P., 1999, 'Physiological changes in respiratory function associated with aging', *European Respiratory Journal,* 13(1), 197-205.

Joo, M.J., Au, D.H. & Lee, T.A., 2009, 'Use of spirometry in the diagnosis of chronic obstructive pulmonary disease and efforts to improve quality of care', *Translational Research,* 153(3), 103-110.

Juroszek, B., 2006, 'The error of method in spirometry', *Measurement,* 39(5), 458-465.

Klesges, R. C., Haddock, C.K., Chang, C.F., Talcott, G. W. & Lando, H.A., 2001, 'The association of smoking and the cost of military training', *Tobacco Control*, 10(1), 43-47.

Klesges, R.C., Sherrill-Mittleman, D., Ebbert, J.O., Talcott, G.W. & DeBon, M., 2010, 'Tobacco use harm reduction, elimination, and escalation in a large military cohort', *American Journal of Public Health*, 100(12), 2487-2492.

Kohansal, R. , Martinez-Camblor, P., Agustí, A., Buist, A.S., Mannino, D.M. & Soriano, J.B., 2009, 'The natural history of chronic airflow obstruction revisited', *American Journal of Respiratory and Critical Care Medicine*, 180(1), 3-10.

Kroff, J. & Terblanche, E., 2010, 'The kinanthropometric and pulmonary determinants of global respiratory muscle strength and endurance indices in an athletic population', *European Journal of Applied Physiology*, 110(1), 49-55.

Kuster, S.P., Kuster, D., Schindler, C., Rochat, M.K., Braun, J., Held, L. & Brändli, O., 2008, 'Reference equations for lung function screening of healthy never-smoking adults aged 18–80 years', *European Respiratory Journal,* 31(4), 860-868.

Lanza, F.d.C., De Camargo, A., Archija, L.R.F., Selman, J.P.R., Malaguti, C. & Dal Corso, S., 2013, 'Chest wall mobility is related to respiratory muscle strength and lung volumes in healthy subjects ', *Respiratory Care*, 58(12), 2107-2112.

Lapp, N.L., Amandus, H.E., Hall, R. & Morgan, W.K., 1974, 'Lung volumes and flow rates in black and white subjects', *Thorax*, 29(2), 185-188.

Lee, T.A., Bartle, B. & Weiss, K.B., 2006, 'Spirometry use in clinical practice following diagnosis of COPD', *Chest*, 129(6), 1509-1515.

Léger, L.A. & Lambert, J., 1982, 'A maximal multistage 20m shuttle run test to predict VO_2 max', *European Journal of Applied Physiology*, 49(1), 1-5.

Léger, L.A., Mercier, D., Gadoury, C. & Lambert, J., 1988, 'The multistage 20 metre shuttle run test for aerobic fitness', *Journal of Sports Sciences,* 6(2), 93-101.

Leong, J.C., Lu, W.W., Luk, K.D. & Karlberg, E.M., 1999, 'Kinematics of chest cage and spine during breathing in healthy individuals and in patients with adolescent idiopathic scoliosis', *Spine*, 24(13), 1310-1315.

Lim, C.L. & Lee, L.K.H., 1994, 'The effects of 20 weeks basic military training program on body composition, VO_2 max and aerobic fitness of obese recruits', *Journal of Sport Medicine and Physical Fitness*, 34(3), 271-278.

Lim, S., Kwon, S.Y., Yoon, J.W., Kim, S.Y., Choi, S.H., Park, Y.J., Yoon, H.I., Chang, Y.S., Lee, J.H., Lee, C.T., Kim, K.W. & Jang, H.C., 2011, 'Association between body composition and pulmonary function in elderly people: the Korean longitudinal study on health and aging', *Obesity,* 19(3), 631-638.

Lopes, E.A., Fanelli-Galvani, A., Prisco, C.C.V., Gonçalves, R.C., Jacob, C.M.A., Cabral, A.L.B., Martins, M.A. & Carvalho, C.R.F., 2007, 'Assessment of muscle shortening and static posture in children with persistent asthma', *European Journal of Pediatrics*, 166(7), 715-721.

LoRusso, T.J., Belman, M.J., Elashoff, J.D. & Koerner, S.K., 1993, 'Prediction of maximal exercise capacity in obstructive and restrictive pulmonary disease', *Chest*, 104(6), 1748-1754.

Lubiński, W. & Gólczewski, T., 2010, 'Physiologically interpretable prediction equations for spirometric indexes', *Journal of Applied Physiology,* 108(5), 1440-1446.

MacDougall, J.D., Wenger, H.A. & Green, H.J., 1991, *Physiological Testing of the High Performance Athlete*, 2nd ed., Human Kinetics Books, Champaign, Illinois, USA.

Malaguti, C., Rondelli, R.R., De Souza, L.M., Domingues, M. & Dal Corso, S., 2009, 'Reliability of chest wall mobility and its correlation with pulmonary function in patients with chronic obstructive pulmonary disease', *Respiratory Care*, 54(2), 1703-1711.

McGavin, C.R., Gupta, S.P. & McHardy, G.J.R., 1979, 'Twelve-minute walking test for assessing disability in chronic bronchitis', *British Medical Journal,* 1(6013), 822-823.

McKenzie, D.C., 2012, 'Respiratory physiology: adaptations to high level exercise', *British Journal of Sports Medicine,* 46(6)**,** 381-384.

Melbye, H., Kongerud, J. & Vorland, L., 1994, 'Reversible airflow limitation in adults with respiratory infection', *European Respiratory Journal,* 7(7), 1239-1245.

Meo, S.A., 2010, 'Significance of spirometry in diabetic patients', *International Journal of Diabetes Mellitus,* 2(1), 47-50.

Miller, M.R., Carpo, R., Hankinson, J., Brusasco, V., Burgos, F., Casaburi, R., Coates, A., Enright, P., Van der Grinten, C.P.M., Gustafsson, P., Jensen, R., Johnson, D.C., MacIntyre, N., McKay, R., Navajas, D., Pedersen, O.F., Pellegrino, R., Viegi, G. & Wanger, J., 2005a, 'Series "ATS/ERS Task Force: Standardisation of Lung Function Testing", Number 1: 'General considerations for lung function testing', *European Respiratory Journal*, 26(1), 153-161.

Miller, M.R., Hankinson, J., Brusasco, V., Burgos, F., Casaburi, A., Cotes, A., Carpo, R., Enright, P., Van der Griten, C.P.M., Gustafsson, P., Jensen, R., Johnson, D.C., MacIntyre, N., McKay, R., Navajas, D., Pedersen, O.F., Pellegrino, R., Viegi, G. & Wanger, J., 2005b, 'Series "ATS/ERS Task Force: Standardisation of Lung Function Testing", Number 2: Standardisation of Spirometry', *European Respiratory Journal*, 26(2), 319-338.

Miravitlles, M., De le Roza, C., Morera, J., Montemayor, T., Gobartt, E., Martin, A. & Alvarez-Sala, J., 2006, 'Chronic respiratory symptoms, spirometry and knowledge of COPD among general population', *Respiratory Medicine,* 100(11), 1973-1980.

Nieman, D.C., 2007, *Exercise Testing and Prescription*, 6th ed., McGraw-Hill, New York, USA.

Ostrowski, S. & Barud, W., 2006, 'Factors influencing lung function: are the predicted values for spirometry reliable enough?', *Journal of Physiology and Pharmacology: an official journal of the Polish Physiological Society,* 57(suppl 4), 263-271.

Pelkonen, M., Notkola, I.L., Lakka, T., Tukiainen, H.O., Kivinen, P. & Nissinen, A., 2003, 'Delaying decline in pulmonary function with physical activity', *American Journal of Respiratory and Critical Care Medicine*, 168(4), 494-499.

Pellegrino, R., Viegi, G., Brusasco, V., Crapo, R.O., Burgos, F., Casaburi, R., Coates, A., Van der Grinten, C.P.M., Gustafsson, P., Hankinson, J., Jensen, R., Johnson, D.C., MacIntyre, N., McKay, R., Miller, M.R., Navajas, D., Pedersen, O.F., & Wanger, J., 2005, 'Series "ATS/ERS Task Force: Standardisation of Lung Function Testing", Number 5: Interpretative strategies for lung function tests', *European Respiratory Journal*, 26(5), 948-968.

Pierce, R., 2005, 'Spirometry: an essential clinical measurement', *Australian Family Physician,* 34(7), 535-539.

Pierson, D.J., Dick, N.P. & Petty, T.L., 1976, 'A comparison of spirometric values with subjects in standing and sitting positions', *Journal of the American College of Chest Physicians*, 70(1), 17-20.

Powers, S.K. & Howley, E.T., 2004, *Exercise Physiology: Theory and Application to Fitness and Performance*, 5th ed., McGraw-Hill, New York, USA.

Quanjer, P.H., 2013, 'Lung function, race and ethnicity: a conundrum', *European Respiratory Journal,* 41(6), 1249-1251.

Radovanovic, D., Aleksandrovic, M., Stojiljkovic, N.P.J., Ignjatovic, A., Popovic, T. & Marinkovic, M., 2009, 'Influence of physical training on cardiorespiratory endurance in preadolescent age', *Acta Medica Medianae,* 48(1), 37-40.

Rasmussen, F., Lambrechtsen, J., Siersted, H.C., Hansen, H.S. & Hansen, N.C.G., 2000, 'Low physical fitness in childhood is associated with the development of asthma in young adulthood: the Odense schoolchild study', *European Respiratory Journal*, 16(5), 866-870.

Rossiter, C.E. & Weill, H., 1973, 'Ethnic differences in lung function: evidence for proportional differences', *International Journal of Epidemiology,* 3(1), 55-61.

Saladin, K.S., 2010, *Anatomy and Physiology: The Unity of Form and Function,* 5th ed., McGraw-Hill, New York, USA.

Santana, H., Zoico, E., Turcato, E., Tosoni, P., Bissoli, L., Olivieri, M., Bosello, O. & Zamboni, M., 2001, 'Relation between body composition, fat distribution, and lung function in elderly men', *American Journal of Clinical Nutrition,* 73(4), 827-831.

Scanlon, P.D., Connett, J.E., Waller, L.A., Altose, M.D., Bailey, W.C., Buist, S.A. & Lung Health Study Research Group, D.P.T.F.T., 2000, 'Smoking cessation and lung function in mild-to-moderate chronic obstructive pulmonary disease: the Lung Health Study', *American Journal of Respiratory and Critical Care Medicine*, 161(2), 381-390.

Schei, E., & Sogaard, A.J., 1994, 'The impact of military service on young men's smoking behavior', *Preventive medicine*, 23(2), 242-248.

Schrader, P.C., Quanjer, P.H., Borsboom, G. & Wise, M.E., 1984, 'Evaluating lung function and anthropometric growth: data in a longitudinal study on adolescents', *Human Biology,* 56(2), 365-381.

Schermer, T.R., Crockett, A.J., Poels, P.J., Van Dijke, J.J., Akkermans, R.P., Vlek, H.F. & Pieters, W.R., 2009, 'Quality of routine spirometry tests in Dutch general practices', *British Journal of General Practice*, 59(569), 376-382.

Seeley, R.R., Stephens, T.D. & Tate, P., 2006, *Anatomy & Physiology,* 7th ed., McGraw-Hill, New York, USA.

Shiner, R. & Steier, J., 2013, *Lung Function Tests Made Easy,* 1st ed., Elsevier Churchill Livingstone, Edinburgh, UK.

Smit, P.J., 1979, *Growth and Sport*, Butterworth, Durban, SA.

Stamm, S.J. & Docter, J., 1965, 'Chest measurements as an aid in diagnosis of cystic fibrosis', *Diseases of the Chest,* 47(1), 98-101.

Suzuki, M., Aoyama, S., Shindo, D. & Ishiyama, I., 2011, 'Regular exercise and age-associated decline of pulmonary and renal function in healthy individuals', *Advances in Exercise and Sports Physiology,* 17(1), 7-14.

Thomas, J.R. & Nelson, J.K., 2001, *Research Methods in Physical Activity*, 4th ed., Human Kinetics, Champaign, USA.

Vander Weg, M.W., DeBon, M., Peterson, A.L., Sherrill-Mittleman, D., Klesges, R.C. & Relyea, G.E., 2005, 'Prevalence and correlates of lifetime smokeless tobacco use in female military recruits', *Nicotine & Tobacco Research,* 7(3), 431-441.

Ward, K.D., Vander Weg, M.W., Kovach, K.W., Klesges, R.C., DeBon, M.W., Haddock, C.K., Talcott, G.W. & Lando, H.A., 2002, 'Ethnic and gender differences in smoking and smoking cessation in a population of young adult air force recruits', *American Journal of Health Promotion*, 16(5), 259-266.

Watsford, M., Murphy, A. & Pine, M., 2007, 'The effects of ageing on respiratory muscle function and performance in older adults', *Journal of Science and Medicine in Sport,* 10(1), 36-44.

White, P., Wong, W., Fleming, T. & Gray, B., 2007, 'Primary care spirometry: test quality and the feasibility and usefulness of specialist reporting', *British Journal of General Practice*, 57(542), 701-705.

Whittaker, A.L., Sutton, A.J. & Beardsmore, C.S., 2005, 'Are ethnic differences in lung function explained by chest size?', *Archive of Disease in Childhood: Fetal and Neonatal Edition*, 90(5), 423-428.

Williams, A.G., 2005, 'Effects of basic training in the British army on regular and reserve army personnel', *Journal of Strength and Conditioning Research*, 19(2), 254-259.

Williams, A.G., Rayson, M.P. & Jones, D.A., 1999, 'Effects of basic training on material handling ability and physical fitness of British Army recruits', *Ergonomics,* 42(8), 1114-1124.

Williams, L., Hermesch, C., Gackstetter, G., Lando, H. & Fiedler, E., 1996, 'Prevalence of tobacco use among first-term Air Force personnel before and after basic military training', *Military Medicine*, 161(6), 318-323.

Wood, P.S. & Krüger, P.E., 2013, 'Comparison of physical fitness outcomes of young South African military recruits following different physical training programs during basic military training', *South African Journal for Research in Sport, Physical Education and Recreation,* 35(1), 203-217.

Wu, Y., Zang, Z., Gang, B. & Love, E.J., 2009, 'Predictive equations for lung function based on a large occupational population in North China', *Journal of Occupational Health*, 51(6), 471-477.

Xu, X., Dockery, D.W., Ware, J.H., Speizer, F.E. & Ferris Jr, B.G., 1992, 'Effects of cigarette smoking on rate of loss of pulmonary function in adults: a longitudinal assessment', *American Review of Respiratory Disease*, 146(5), 1345-1348.

APPENDICES

APPENDIX A

Letters of Ethical Approval

- Letter of Ethical Approval from Research Ethics Committee, UP
- Letter of Ethical Approval from SANDF

APPENDIX B

Informed Consent

APPENDIX C

Medical Screening Questionnaire

APPENDIX D

Data collection form

APPENDIX E

Calibration Log

APPENDIX F

Statistical Support

APPENDIX A

Letters of Ethical Approval

Letter of Ethical Approval from Research Ethics Committee, UP

Letter of Ethical Approval from SANDF

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Office of the Deputy Dean

4 May 2010

Dear Dr Wood,

Project:	**A prospective cohort study of the correlation between chest circumference and spirometry measurements over a 19 week intense training programme**
Researcher:	**TCT Camacho**
Supervisor:	**Dr P Wood**
Department:	**Biokinetics, Sport and Leisure Science**
Reference number:	**21127973**

I am pleased to be able to tell you that the above application was **approved** by the **Postgraduate Committee** on 13 April 2010 and the **Research Ethics Committee** on 29 April 2010. Data collection may therefore commence.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should the actual research depart significantly from the proposed research, it would be necessary to apply for a new research approval and ethical clearance.

The Committee requests you to convey this approval to the researcher.

We wish you success with the project.

Sincerely

Prof John Sharp
Chair: Postgraduate Committee &
Research Ethics Committee
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: john.sharp@up.ac.za

CONFIDENTIAL

1MH/302/6

Tel: 012 314 0487
Fax: 012 314-0013
Enquiries: Lt Col MK Baker

1 Military Hospital
Private Bag X1026
Thaba Tshwane
0143
19 October 2009

CLINICAL TRIAL APPROVAL: "THE INFLUENCE OF A BASIC TRAINING PROGRAM ON SOUTH AFRICAN MILITARY RECRUITS."

1. The 1 Military Hospital Research Ethics Committee (1MHREC), comprised of the following members, and adhering to GCP/ICH and SA Clinical Trial guidelines, evaluated the above-mentioned protocol and additional documents:

a. Lt Col M. Baker: Neurologist, male, chairman 1MHREC.
b. Col H. du Plessis: Surgeon, male, member 1MHREC.
c. Lt Col C. Duvenage: Specialist Physician, female, member 1MHREC.
d. Lt. Col. D. Mahapa: Dermatologist, female, member 1MHREC
e. Lt. Col. L. Hofmeyr: Otorhinolaryngologist, male, member 1MHREC (non-voting on this study).
f. Ms C. Jackson: Layperson, independent of the organization, female, member 1 MHREC.

2. The following study protocol was evaluated **"The Influence of a Basic Training Program on South African Military Recruits."**
Documentation submitted included the protocol description and covering letter.

CONFIDENTIAL

3. *The recommendations are:*

The study was ethically approved on 19 October 2009. The principal investigator will be Lt Col E.Terblanche. Report backs are to be made to the 1MHREC six monthly, in the event of any serious adverse events and on completion or termination of the study.

(M.K BAKER)
CHAIRMAN 1 MILITARY HOSPITAL RESEARCH ETHICS COMMITTEE: LT COL

DIST

For Info

Lt Col E. Terblanche

Ward Class Clinical Service
CONFIDENTIAL

APPENDIX B

Informed Consent

INFORMED CONSENT

University of Pretoria

Pretoria 0002 Republic of South Africa

http://www.up.ac.za

FACULTY OF HUMANITIES

Dept Biokinetics, Sport and Leisure Sciences

Tel: 012- 420-6040 Fax: 012-420-6099

www.bsl.up.ac.za

Contact Details

Mrs T.C. Camacho

Department of Biokinetics, Sport and Leisure Sciences

University of Pretoria

Tel: (012) 420 6038

Fax: (012) 420 6099

Email: tanya.camacho@up.ac.za

A PROSPECTIVE COHORT STUDY OF THE CORRELATION BETWEEN CHEST CIRCUMFERENCE AND SPIROMETRY MEASUREMENTS OVER A 19 WEEK INTENSE TRAINING PROGRAMME

PURPOSE

A research project conducted by the University of Pretoria aims to examine the correlation between chest circumference and spirometry measurements over a 19 week intense training programme.

PROCEDURES

If you volunteer for this study you will assist us in the objectives described above. You will be required to complete a medical history questionnaire and to allow physical testing in anthropometry (height, weight, chest circumference), spirometry (lung function test) and physical work capacity (multi-stage shuttle test). The duration of the study is 19 weeks.

BENEFITS

There are no direct benefits to participating in this study. However, participation may lead to a better understanding of your anthropometric status, such as your height, weight and chest circumferences, your lung function and your physical fitness.

RISKS AND DISCOMFORTS

There are no known risks associated with the anthropometric and spirometry tests. The physical fitness test is moderate to intense in nature, and may result in some feelings of fatigue and stiffness if you are unfit.

RESPONSIBILITIES OF THE PARTICIPANT

Information you possess about your health status, and medication use may affect your safety in this study and the results of the tests. You are responsible for fully disclosing this information, and for the prompt reporting of any problems that may occur during the study which affect your ability to participate.

CONFIDENTIALITY

The information that is obtained from this study in all tests will be treated as private and confidential. It will not be released or reported to any person other than the researchers involved in the study and yourself. However, the information may be used for statistical analysis as well as for current and/or future scientific purposes with your details remaining anonymous. All data will be stored at the University of Pretoria, Department of Biokinetics, Sport and Leisure Sciences for 15 years.

ENQUIRIES

You are encouraged to ask any questions about the testing you might undergo and the procedures you will need to follow. If you have any concerns or questions, please ask the researcher for further explanations.

FREEDOM OF CONSENT

I, _____ (full name of subject), have read the abovementioned description, and have been informed of the procedures, requirements, benefits and risks of participating in this research project.

I therefore declare that I willingly cooperate in this project at my own risk, and will not withhold any information that may be of importance to the researchers or for my own safety. I am aware that I participate voluntarily, and may withdraw from this project at any time if I so wish, without any cost to myself.

I hereby also grant the researchers permission to use my results for publication and/or presentation purposes, with my anonymity being ensured.

_____ _____

Signature of subject Signature of researcher

_____ _____

Signature of witness Date

Contact telephone number: _____

E-mail address: _____

Force number: _____

APPENDIX C

Medical Screening Questionnaire

University of Pretoria

MEDICAL SCREENING QUESTIONAIRE

A. Biographical information

Please use CAPITALS to complete the following information

1. Initials: ☐☐☐ 2. Name: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐
3. Surname: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐
4. ID number: ☐☐☐☐☐☐☐☐☐☐☐☐☐ Force number: ☐☐☐☐☐☐☐☐
5. Postal Address: ______________________________
6. Telephone number: ☐☐☐☐☐☐☐☐☐☐ Cell phone number: ☐☐☐☐☐☐☐☐☐☐
7. Email address: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐
8. Age: ☐ Date of Birth: ☐
9. What is your gender? Male ☐ Female

B. Family History

Do any of your immediate family members (grandparents, parents, brothers or sisters) suffer, take medication or have died from any of the following health factors?

☐ Heart attack	☐ Heart disease	☐ Lung disease
☐ Any cancer	☐ Overweight	☐ High blood pressure
☐ High cholesterol levels	☐ Any dependency	☐ None

C. Personal Medical Conditions

Do you suffer or take medication for any of the following chronic conditions?

☐ Heart attack	☐ Heart disease	☐ Lung disease
☐ Any cancer	☐ Overweight	☐ High blood pressure
☐ High cholesterol levels	☐ Substance Dependencies	☐ None of the above

Do you take any of the following medication? If yes, please indicate with a tick √:

- ☐ Beta 2-agonist inhaler
- ☐ Anticholinergic inhaler
- ☐ Oral beta 2 inhaler
- ☐ Oral theophylline
- ☐ Oral antimuscarinic

If you are on any other medication, please state below:

____

____

APPENDIX D

Data collection form

DATA COLLECTION FORM

University of Pretoria

TEST WEEK		DATE			
NAME					
FORCE NUMBERS					
AGE		YRS			
DATE OF BIRTH		YR /		MONTH/	DAY
SMOKING STATUS		SMOKER		NON-SMOKER	
RACE					

ANTHROPOMETRIC MEASUREMENTS						
HEIGHT		CM				
MASS		KG				
INSPIRATION CHEST CIRCUMFERENCE (ICC)		CM		CM		CM
AVERAGE		CM				
EXPIRATION CHEST CIRCUMFERENCE (ECC)		CM		CM		CM
AVERAGE		CM				
ICC - ECC		CM				

SPIROMETRY (BEST VALUE OF MAX 8 ATTEMPTS)		
FVC		L
FEV1		L
FVC/FEV1		%

MULTI-STAGE SHUTTLE TEST	
LEVEL	
NUMBER OF SHUTTLES	
MAX SHUTTLE SPEED	
RELATIVE VO2 MAX	

Department of Biokinetics, Sports and Leisure Sciences

APPENDIX E

Calibration Log

Calibration Log

fast loop volume : Ins 3.06/ Exp 2.91
fast peak flows : Ins -3.135027/ Exp 3.65827
****
Check calibration at 2010-05-27 11:03:28
Altitude at :1650

slow loop volume : Ins 2.97/ Exp 3.01
slow peak flows : Ins -3.377117/ Exp 2.25767

medium loop volume : Ins 2.99/ Exp 2.99
medium peak flows : Ins -2.282404/ Exp 2.33443

fast loop volume : Ins 2.96/ Exp 2.98
fast peak flows : Ins -2.454619/ Exp 2.37258
****
Check calibration at 2010-05-28 13:07:51
Altitude at :1650

slow loop volume : Ins 3.00/ Exp 2.72
slow peak flows : Ins -1.702918/ Exp 1.36865

medium loop volume : Ins 3.07/ Exp 2.96
medium peak flows : Ins -2.282404/ Exp 2.14134

fast loop volume : Ins 3.07/ Exp 2.97
fast peak flows : Ins -3.406752/ Exp 3.65827
****
Check calibration at 2010-07-02 08:52:16
Altitude at :1650

slow loop volume : Ins 3.03/ Exp 3.00
slow peak flows : Ins -3.196395/ Exp 2.92756

medium loop volume : Ins 3.00/ Exp 2.92
medium peak flows : Ins -3.010556/ Exp 3.17650

fast loop volume : Ins 3.04/ Exp 2.93
fast peak flows : Ins -3.523941/ Exp 3.14129
****
Check calibration at 2010-07-06 07:10:32
Altitude at :1650

slow loop volume : Ins 0.00/ Exp 0.00
slow peak flows : Ins 0.000000/ Exp 0.00000

medium loop volume : Ins 3.11/ Exp 2.93
medium peak flows : Ins -3.667445/ Exp 4.63791

fast loop volume : Ins 3.06/ Exp 2.86
fast peak flows : Ins -5.864113/ Exp 6.54514
****
Check calibration at 2010-07-06 07:11:40
Altitude at :1650

slow loop volume : Ins 3.05/ Exp 2.90
slow peak flows : Ins -3.917722/ Exp 3.62449

medium loop volume : Ins 3.09/ Exp 2.89
medium peak flows : Ins -4.489526/ Exp 5.64756

fast loop volume : Ins 3.04/ Exp 2.89
fast peak flows : Ins -5.619244/ Exp 6.09207
****
Check calibration at 2010-07-06 09:08:24
Altitude at :1650

slow loop volume : Ins 3.16/ Exp 3.01
slow peak flows : Ins -3.406752/ Exp 3.55667

Calibration Log

medium loop volume : Ins 3.12/ Exp 2.93
medium peak flows : Ins -4.660653/ Exp 5.48996

fast loop volume : Ins 3.10/ Exp 2.94
fast peak flows : Ins -5.387244/ Exp 6.31724
****
Check calibration at 2010-07-07 08:01:31
Altitude at :1650

slow loop volume : Ins 3.09/ Exp 3.10
slow peak flows : Ins -2.141650/ Exp 2.29613

medium loop volume : Ins 3.17/ Exp 3.09
medium peak flows : Ins -3.287384/ Exp 3.10597

fast loop volume : Ins 3.18/ Exp 3.01
fast peak flows : Ins -4.966156/ Exp 5.61600
****
Check calibration at 2010-07-07 13:45:02
Altitude at :1650

slow loop volume : Ins 3.09/ Exp 3.11
slow peak flows : Ins -1.925423/ Exp 1.78338

medium loop volume : Ins 3.12/ Exp 3.07
medium peak flows : Ins -3.436252/ Exp 3.48846

fast loop volume : Ins 3.19/ Exp 3.04
fast peak flows : Ins -5.079717/ Exp 6.12409
****
Check calibration at 2010-07-14 13:30:24
Altitude at :1650

slow loop volume : Ins 3.08/ Exp 2.95
slow peak flows : Ins -4.636502/ Exp 3.69195

medium loop volume : Ins 3.13/ Exp 2.94
medium peak flows : Ins -4.684707/ Exp 5.26971

fast loop volume : Ins 3.09/ Exp 2.91
fast peak flows : Ins -5.660614/ Exp 5.99626
****
Check calibration at 2010-07-21 07:16:40
Altitude at :1650

slow loop volume : Ins 3.05/ Exp 2.97
slow peak flows : Ins -3.751997/ Exp 2.59835

medium loop volume : Ins 3.07/ Exp 2.96
medium peak flows : Ins -4.131949/ Exp 2.89151

fast loop volume : Ins 0.00/ Exp 0.00
fast peak flows : Ins 0.000000/ Exp 0.00000
****
Check calibration at 2010-07-22 13:28:33
Altitude at :1650

slow loop volume : Ins 3.06/ Exp 3.05
slow peak flows : Ins -2.851649/ Exp 3.03497

medium loop volume : Ins 3.05/ Exp 3.03
medium peak flows : Ins -3.998941/ Exp 3.10597

fast loop volume : Ins 3.07/ Exp 2.97
fast peak flows : Ins -3.494845/ Exp 2.74601
****
Check calibration at 2010-07-23 08:24:19
Altitude at :1650

Calibration Log

fast loop volume : Ins 3.10/ Exp 2.97
fast peak flows : Ins -4.158204/ Exp 3.82584
****
Check calibration at 2010-09-16 13:20:42
Altitude at :1650

slow loop volume : Ins 3.05/ Exp 3.10
slow peak flows : Ins -2.883730/ Exp 2.85533

medium loop volume : Ins 3.07/ Exp 3.01
medium peak flows : Ins -3.257195/ Exp 3.28145

fast loop volume : Ins 3.03/ Exp 2.98
fast peak flows : Ins -4.514273/ Exp 3.99140
****
Check calibration at 2010-09-19 11:58:46
Altitude at :1650

slow loop volume : Ins 3.13/ Exp 3.02
slow peak flows : Ins -2.622794/ Exp 2.37258

medium loop volume : Ins 3.04/ Exp 2.94
medium peak flows : Ins -4.105579/ Exp 4.57415

fast loop volume : Ins 3.02/ Exp 2.93
fast peak flows : Ins -6.561674/ Exp 6.70994
****
Check calibration at 2010-09-20 07:54:26
Altitude at :1650

slow loop volume : Ins 3.12/ Exp 3.06
slow peak flows : Ins -2.787032/ Exp 2.67246

medium loop volume : Ins 3.08/ Exp 2.97
medium peak flows : Ins -4.313389/ Exp 4.70152

fast loop volume : Ins 3.05/ Exp 2.93
fast peak flows : Ins -5.556737/ Exp 5.71072
****
Check calibration at 2010-09-27 08:18:37
Altitude at :1650

slow loop volume : Ins 3.11/ Exp 3.00
slow peak flows : Ins -3.135027/ Exp 2.74601

medium loop volume : Ins 3.06/ Exp 2.84
medium peak flows : Ins -3.779928/ Exp 4.76500

fast loop volume : Ins 2.93/ Exp 2.90
fast peak flows : Ins -6.042992/ Exp 5.96440
****
Check calibration at 2010-09-30 12:41:00
Altitude at :1650

slow loop volume : Ins 3.06/ Exp 3.05
slow peak flows : Ins -2.819417/ Exp 3.28145

medium loop volume : Ins 3.09/ Exp 2.96
medium peak flows : Ins -3.226866/ Exp 3.99140

fast loop volume : Ins 3.09/ Exp 2.90
fast peak flows : Ins -3.944915/ Exp 3.85911
****
Check calibration at 2010-10-05 09:03:51
Altitude at :1650

slow loop volume : Ins 3.06/ Exp 3.01
slow peak flows : Ins -4.287800/ Exp 3.62449

Calibration Log

slow loop volume : Ins 3.10/ Exp 3.06
slow peak flows : Ins -3.779928/ Exp 4.05711

medium loop volume : Ins 3.10/ Exp 2.97
medium peak flows : Ins -4.287800/ Exp 3.82584

fast loop volume : Ins 3.01/ Exp 2.91
fast peak flows : Ins -4.850463/ Exp 5.01786
****
Check calibration at 2010-11-22 07:27:25
Altitude at :1650

slow loop volume : Ins 3.10/ Exp 2.95
slow peak flows : Ins -2.754494/ Exp 3.41987

medium loop volume : Ins 3.03/ Exp 2.97
medium peak flows : Ins -3.890409/ Exp 3.52261

fast loop volume : Ins 3.13/ Exp 2.87
fast peak flows : Ins -4.236295/ Exp 5.48996
****
Check calibration at 2010-11-23 05:39:06
Altitude at :1650

slow loop volume : Ins 3.09/ Exp 3.07
slow peak flows : Ins -2.754494/ Exp 1.98395

medium loop volume : Ins 3.15/ Exp 3.08
medium peak flows : Ins -3.779928/ Exp 3.35087

fast loop volume : Ins 3.13/ Exp 3.00
fast peak flows : Ins -5.191251/ Exp 5.86904
****
Check calibration at 2011-01-10 06:39:23
Altitude at :1650

slow loop volume : Ins 3.01/ Exp 3.01
slow peak flows : Ins -2.979073/ Exp 3.69195

medium loop volume : Ins 2.99/ Exp 2.98
medium peak flows : Ins -3.347344/ Exp 2.70930

fast loop volume : Ins 3.04/ Exp 2.95
fast peak flows : Ins -3.667445/ Exp 3.48846

APPENDIX F

Statistical Support

DEPARTMENT OF STATISTICS

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Denkleiers • Leading Minds • Dikgopolo tša Dihlalefi

LETTER OF STATISTICAL SUPPORT

Date: 25 March 2010

This letter is to confirm that **Tanya Camacho**, studying at the University of Pretoria, discussed the project with the title **A PROSPECTIVE COHORT STUDY OF THE CORRELATION BETWEEN CHEST CIRCUMFERENCE AND SPIROMETRY MEASUREMENTS OVER A 19 WEEK INTENSE TRAINING PROGRAMME** with me.

I hereby confirm that I am aware of the project and also undertake to assist with the statistical analysis of the data generated from the project.

The data analysis will consist of univariate frequency tables, as well as frequency tables by gender; repeated measures ANOVAs, controlling for gender, to assess whether fitness has improved over the duration of the basic training program; Pearson's correlation coefficients and scatter plots to assess the strength of the association between the chest circumference and the spirometry measurements; hypothesis tests to establish whether the correlations have remained the same or changed over time.

The sample will consist of volunteers among the July 2010 intake of SANDF recruits.

Dr Lizelle Fletcher
Department of Statistics
Internal Consultation Service
Tel 012 420 3967