RESPIRATORY PATTERNS AND CYTOKINE PROFILES AMONG RECREATIONAL ATHLETES AND A SEDENTARY GROUP

by

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PREFACE

The study indicates original work not submitted in any other form to other academic institutions. The work of other researchers and authors has been appropriately acknowledged in the text.

This research was completed in the Human Physiology, Westville campus, College of Health Sciences, University of KwaZulu-Natal, Durban, South Africa under the supervision of Professor Irene Mackraj and Dr Kogie Moodley.

Prof. I. Mackraj: Date: 12 July 2021

Dr. K. Moodley:____________________ Date: 12 July 2021

Joel Padayachee (971125867):_______________Date: 12 July 2021

DECLARATION

I, Joel Padayachee, declare that:

1. That the work described in this thesis has not been submitted to UKZN or any other tertiary institution for purposes of obtaining an academic qualification, whether by myself or any other party.

2. The contribution made by J. Padayachee to the project was as follows:
   Identification of research topic, experimental design, execution, data interpretation, manuscript & thesis write-up.

3. The contributions to the project were as follows:
   Professor I. Mackraj (supervisor) has dedicated time for the review of the entire project.
   Dr K. Moodley has dedicated time for the review and clinical design of the project.

Prof. I. Mackraj: Date: 12 July 2021

Dr. K. Moodley: ________________________Date: 12 July 2021

Joel Padayachee (971125867):____________**Date**: 12 July 2021

DEDICATION

Dedicated to my Heavenly Father and Mrs Ruby Padayachee (mum) who motivated me to complete this degree but passed away in the year 2020.

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LIST OF ABBREVIATIONS

BMI - Body Mass Index

FEV_1 - Forced Expiratory Volume in one second

FVC - Forced Vital Capacity

IL-6 - Interleukin 6

IL-10 - Interleukin 10

NCD - Non-communicable disease

SA - South Africa

SB - Sedentary Behaviour

TNF-α - Tumour Necrosis Factor alpha

MVV - Maximal Voluntary Ventilation

PEFR - Peak Expiratory Flow Rate

VC - Vital Capacity

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ABSTRACT

Background: An increasing trend in sedentary lifestyles and physical inactivity has contributed to a higher incidence of obesity, a major health concern. Despite the fact that a sedentary lifestyle poses a considerable health risk and contributes to the prevalence of various diseases, sedentary populations are reluctant to modify health behaviours. An array of behaviour adaption models attest to the importance of knowledge and awareness cues regarding the positive physiological effects of exercise when addressing behaviour modification. Within this context, the cross-sectional study intends to describe the physiological effects of three recreational sport disciplines and one sedentary group on respiratory patterns and cytokine profiles within a South African cohort as a means to create knowledge and awareness cues for a sedentary population.

Methods:
The sample for the study comprising four sub-groups (swim-20, soccer-20, volleyball-20, sedentary-20) included 80 participants. Standardized anthropometric techniques were used to complete height (metres), weight (kilograms) and BMI measurements. The spirometry measurements were performed in accordance with the American Thoracic Society (ATS) recommendations using a MIR SPIROLAB II spirometer. The cytokine measurements were completed using the Beckman Coulter Access Immuno-Assay South African Manufacturer Kit as per the commercial laboratory recommendation. Data was analysed with IBM Statistical Package for Social Sciences version 27 (Chicago IL, USA).

Results and Discussion: The respiratory patterns in the swim, soccer and volleyball sport groups were significantly different ($p<0.01$). All the recreational sport groups had significantly increased lung parameters compared to the sedentary group ($p<0.01$). The cytokine expression for the swim, soccer, volleyball and sedentary groups were significantly different ($p<0.01$).

Conclusion: The findings of the study support the use of recreational swimming as a means to reduce obesity caused by sedentary lifestyles which has been identified as a global problem. Swimming is also beneficial for improving respiratory patterns over and above the soccer and volleyball group which is beneficial for the management of restrictive lung conditions. The cytokine expression differed in the recreational sport groups. Recreational swimming, soccer and volleyball support low levels of systemic inflammation but studies with larger samples are required to corroborate the findings, in terms of the influence of cytokine levels on spirometry values.

CHAPTER 1:
BACKGROUND AND LITERATURE REVIEW

1.1 Background to the Study

In light of the recent Coronavirus Disease 2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and subsequent lockdown, the importance of exercise, respiratory function, cytokine profiles and escalating sedentary behaviour (SB) have received considerable attention (Aubertin-Leheudre & Rolland, 2020; Dominski & Brandt, 2020). Respiratory failure and cytokine storms noted in the clinical course of COVID-19 increases the need for mechanical ventilation (Zhou *et al.,* 2020) among sedentary individuals who present with impaired respiratory function and increased inflammatory profiles (Woods *et al.,* 2020). The weakness of the respiratory muscles linked to sedentary lifestyles makes ventilator weaning difficult among SARS-CoV-2 infected patients thus increasing complications in this cohort of patients (Yuen *et al.*, 2020). In light of this, exercise has become an essential lifestyle change during the COVID-19 pandemic.

Yet, despite sedentary lifestyles being a global health concern prior to the inception of the COVID-19 pandemic, the challenge of sedentary lifestyles prevails. Considerably, almost three-quarters of deaths related to non-communicable diseases (NCDs) as a consequence of SB occur in low-and-middle-income countries (LMICs) such as South Africa (SA) (Salnonen *et al.,* 2015; O'Donovan & Hamer, 2018; Dunton *et al.,* 2019; Bedard *et al.,* 2020; Schouw *et al.,* 2020). Research supports that exercise is a necessary tool in the deterrence and control of NCDs (Puoane *et al*., 2012; World Health Organisation, 2015; Marcal *et al*., 2020; Saqib *et al*., 2020). The benefit of exercise for respiratory function and inflammatory profiles has been reported in numerous studies (Luzak *et al.*, 2017; Engel *et al.,* 2019, Nilsson *et al.,* 2019; Dempsey *et al*., 2020; Ahmed *et al.*, 2021). The World Health Organisation 2020 Guidelines further stress that any amount of physical activity is better than no physical activity, even when the recommended thresholds are unmet (WHO, 2020) thus elucidating the important role that exercise plays in public health.

Regular exercise with its multitude of effects on many different organs and systems has numerous beneficial effects on the human body (Azad *et al*., 2011; Fatima *et al*., 2013; Khashaba, 2015; Hudson and Sprow, 2020). In support of the preceding statement, studies report that athletes of different sporting disciplines and professional levels show better pulmonary capacity, respiratory strength and inflammatory profiles in comparison to their sedentary counterparts (Lazovic-Popovic *et al.*, 2016; Kaneko, 2020). More specifically, pulmonary studies support that in cohorts of varying sport disciplines such as swimming, basketball, water-polo and rowing, independently influence lung function differentially (Vaithiyanadane *et al*., 2012). Differential expression of cytokines in athletes from varying sport disciplines was reported (Kaya, 2016; Jürimäe *et al.,* 2018) however attempts to reproduce these findings were inconsistent. Despite the extensive research reported on sports disciplines, there is a paucity of literature in terms of volleyball players' pulmonary function and cytokine profile compared to other sport disciplines (Eliakim *et al.*, 2013), thus highlighting the need for further research in this sporting discipline. Whilst literature on pulmonary function and cytokine expression in professional sport have been extensively reported (Ghafourian *et al*., 2016; Sohail *et al.*, 2020), studies on recreational sports groups from South African cohorts are limited (Braun *et al*., 2013; Quanjer, 2013; Gaurav *et al.*, 2015; Kubayi *et al*., 2017). Hence, studies detailing the cytokine expression [Interleukin-6(IL-6), Interleukin-10 (IL-10) and Tumour necrosis factor alpha (TNF-α)] and respiratory parameters among recreational sports groups are needed within a South African cohort.

Thus far, the uptake of exercise has been limited in most LMICs (Okafor, 2012) and evidence suggests that recommendations on how to reduce SB are currently lacking in this neglected region in the world (World Health Organization, 2010). A major deficit in the literature regarding SB is that current studies were conducted in high-income countries (HIC) (Prince *et al.*, 2017), thus highlighting the need for context-specific research in LMICs (Atkinson *et al.*, 2016). South Africa is presently ranked the third most physically inactive country within the sub-Saharan African continent (Mkhonto *et al.*, 2012; Cois, 2015; Raichlen *et al.*, 2020) and faces the challenge of a quadruple burden of disease including NCDs. The increasing level of NCDs in the South African workforce has had a negative influence on the workforce and productivity of SA organisations (Khoza-Shangase, 2020). Hence, the need for research that creates knowledge and awareness cues regarding the positive physiological benefit of exercise to support health behaviour modification in sedentary populations is relevant for SA.

Therefore, this study investigated respiratory patterns and cytokine profiles among three recreational sports (swim, soccer and volleyball) and a sedentary group to address the gap in literature relating to the sedentary lifestyle of South Africans, thereby providing knowledge and awareness cues to motivate sedentary groups in SA.

1.2 Pulmonary Function

Pulmonary measures such as Forced Vital Capacity (FVC), Forced Expiratory Volume (FEV_1), Vital Capacity (VC), Peak Expiratory Flow Rate (PEFR) and Maximal Voluntary Ventilation (MVV) are widely used to assess pulmonary function (Mazic *et al.*, 2016; Marangoz *et al.*, 2016). The influence of physical activity and anthropometric factors on spirometry values are well known (Womack *et al*, 2000; Ghalavand *et al*., 2015; Abd El-Kader *et al.*, 2016) but there is a paucity of literature that demonstrates the effect of all three factors (physical activity, anthropometry and cytokine characteristics) on specific lung volume measures. According to Bhatti *et al*. VC is a change in lung volume after maximal inhalation followed by maximal exhalation (3 to 5 litres in normal male adults)

(Bhatti *et al*., 2014). FVC is the volume of air exhaled after maximum inhalation, with an emphasis on forced and rapid expiration (Basu *et al.*, 2018). FVC acts as a predictor for lung and chest wall compliance (Miller *et al*., 2005) and FEV_1 is a lung function measure that is explained as the maximal expired air for one second (4.5 to 3.5 litres normal male adults). The PEFR refers to the maximum speed of expiration in an individual (Mehta *et al.*, 2016). MVV is the maximum air volume breathed in one minute using voluntary effort (Shindhe *et al.,* 2015) and determines the endurance of respiratory muscles (Suh *et al.,* 2019).

1.1.1 Factors Influencing Pulmonary Function

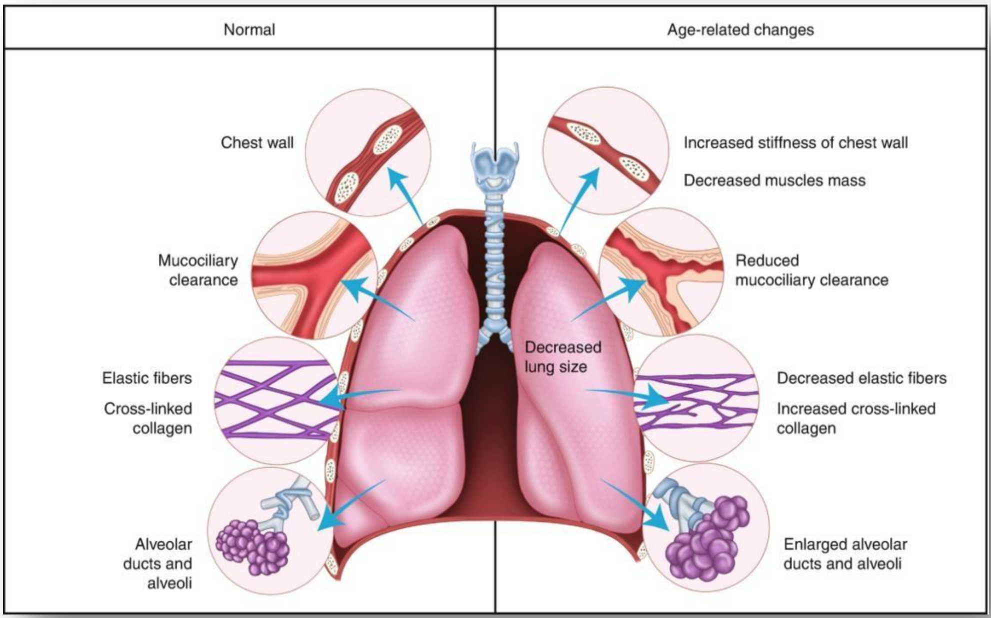
An array of physiological factors affects pulmonary function (Saki *et al*., 2017; Barroso *et al*., 2018).

1.1.1.1 Gender and Pulmonary Function

Guenette *et al*. reported significant structural differences in the anatomy and the pulmonary system of different genders (Guenette *et al*., 2007). Prior to puberty, lung function remains unchanged between males and females however, following puberty males have greater growth in the thorax giving rise to higher lung volumes when compared to females (Moore *et al.,* 2012). Whilst pulmonary function is affected by various menstrual cycle phases, hormonal and metabolic conditions, the relationship with menopause requires further investigation (Moore *et al.,* 2012). Men display sizeable nasal cavities and higher nasal floors relative to women with comparable body structure and size (García-Martínez *et al.,* 2016). Furthermore, age-matched and stature matched studies comparing gender differences demonstrated that lung sizes were sizeable, airways diameters were broader and additional respiratory bronchioles stood out in males (Bastir *et al.,* 2011). The diaphragm length in females is approximately 9% shorter when compared to males (LoMauro & Aliverti, 2018). A lower PEFR and VC in females are supported by diminished airways diameter and lung volumes (Sheel *et al.,* 2016). Gender variations in the rib cage volume are evident with females demonstrating smaller volumes than males. Based on the above findings, it would be expected that males demonstrate significantly larger mean pulmonary values when compared to females (Ekström *et al*., 2018).

1.1.1.2 Age and Pulmonary Function

Various age-associated changes in the anatomy, immunology and physiology of the respiratory system are evident as indicated in Figure 1 (Sharma and Goodwin, 2006). Lung maturation occurs between 20–25 years and is associated with gradual changes in pulmonary function post 35 years of age (Sharm *and* Goodwin, 2006; Lalley, 2013).



Legend – Figure1

Age-related changes in the lunginclude increased stiffness of the chest wall and cross linked collagen. Decreased muscle mass and elastic fibres are noted with aging. Mucociliary clearance is reduced whilst an increase in the alveolar ducts and alveoli occurs

Figure 1: Physiological Changes in the Lung (Adapted from Clark *et al.*, 2019).

Age-associated changes in lung function are attributed to weakened respiration muscles (Thomas *et al.*, 2019), loss of lung elasticity and surface area reduction for gas exchange (Barroso *et al.*, 2018). Age-associated osteoporotic structural variations in the stiffened thoracic cage contributes to a reduction in chest wall compliance and increases residual volume as shown in Figure 1 (Ketata *et al.*, 2012). The MVV reduces with age and the decline in FEV_1 is reported between the ages of 35and 40 years, decreasing two-fold after the age of 70 years. There is a negative correlation between FEV_1 and age which may be due to diminished lung elasticity (Barroso *et al.*, 2018).Whilst FVC and FEV_1 experience age-related decline, FVC begins to decline at a later period and a progressively slower rate than FEV_1 with an eventual decline in the FEV_1/FVC ratio (Dyer, 2012).

1.1.1.3 Anthropometric Characteristics and Pulmonary Function

Anthropometrics can be used both as a baseline and progressive measure for physical fitness (Adhikari and Nugent, 2014; Amoo-Tella *et al.*, 2017) as these measures are established as strong determinants of respiratory parameters (Braun *et al.*, 2013; Quanjer *et al.*, 2013; Soundariya & Neelambikai, 2013; Mohammed *et al.*, 2015; Sgariboldi *et al.*, 2016). Individuals with greater heights are typically associated with higher pulmonary volumes and capacities whilst individuals with higher body weights are associated with lower lung volumes having accounted for differences in gender (Lutfi, 2017). A tall stature is associated with more area for exchange of air thus contributing to higher static lung volumes and capacities (Bhatti *et al.*, 2014). In the discussion of weight, spirometry parameters: FEV_1, FVC, and PEFR are reduced in underweight (BMI < 18.5 kg/m^2)

individuals compared to normal weight ($18.5\ kg/m^2 \leq BMI \leq 24\ kg/m^2$) individuals (Cvijetic *et al.*, 2017; Fukuhara, 2017; Wang *et al.*, 2017). Additionally reduced pulmonary volumes were identified in obese subjects (Ross *et al.*, 2009; Littleton, 2012; Van Huisstede *et al*., 2013). Increased BMI has a known association with an FEV_1 decline (Thomas *et al.*, 2019).

However, the association of BMI with better pulmonary function in adolescents may be explained by the effect of muscularity whereas the elderly may experience decreased lung function due to the effect of adiposity (Gleeson *et al*., 2011; Paralikar *et al*., 2012; Faria *et al*., 2014). Due to regular training, athletes increase muscle mass thus demonstrating higher weights (Marangoz *et al*., 2016), hence the application of weight must be carefully considered when analysing the association with pulmonary measures in athletes. Increased adipose tissue promotes the production of TNF-α and other cytokines (Ouchi *et al*., 2011) whilst inhibiting anti-inflammatory cytokines, this leads to low-grade systemic inflammation. Whilst BMI in particular has been criticised for its use in pulmonary studies, a growing body of evidence supports its application in pulmonary studies (Freedman *et al.*, 2013; Schwarzfischer *et al*., 2017). Therefore, height, weight and BMI measures present a unique opportunity for the assessment of respiratory patterns in the swim, soccer, volleyball and sedentary group. Although pulmonary function is highly regulated by physiological factors, the position of the individual in space imparts a significant influence on measuring lung volume and pulmonary function (Katz *et al.*, 2018).

1.1.1.4 Body Position and Pulmonary Function

Subject positioning is vital when considering lung volume measurements since factors such as gravity may be experienced differently (Melam *et al*., 2014). In support of this Kera *et al.* reported that the effect of gravity is reduced in sitting when compared to standing with the least effect being experienced in the supine position (Kera *et al*., 2005). Diminished FVC in side-lying positions is attributed to left and right lung variation, a higher resistance in the airway and reduced lung compliance (Katz *et al.*, 2018). $FEV_{1,}$ is increased when sitting relative to lying supine (Ceridon *et al.*, 2011; Patel and Thakar, 2015) however, Miccinilli *et al.* concluded no significant difference for FEV_1 between the sitting and supine position (Miccinilli *et al.*, 2016). Ganapathi & Vinoth indicated that FEV_1 was highest in standing when compared to the other body positions (Ganapathi & Vinoth, 2015) which may be a result of diaphragmatic movement and chest wall recoil (Lufti, 2017). The standing position supports greater thoracic cavity space, lungs volume and expansion (Katz *et al.*, 2018). FEV_1/FVC is highest in sitting when compared to the other body positions (Myint *et al*., 2017) yet some studies show no significant difference when body positions are varied (Tsubaki *et al.*, 2009; Ceridon *et al.*, 2011). Ottaviano *et al*. demonstrated elevated PEFR measures in standing when compared to other body positions (Ottaviano *et al*., 2016).

1.1.1.5 Physical Activity and Pulmonary Function

Thaman *et al*. reported that prolonged activity strengthened respiratory muscles and improved pulmonary function (Thaman *et al*., 2010; Azad *et al*., 2011; Fatima *et al*., 2013). Active individuals when compared to sedentary individuals have more favourable lung volumes (Atan *et al.,* 2012; Vedala *et al.*, 2012). Moreover, studies investigating the effect of physical activities on pulmonary patterns support the role of different physical activities on pulmonary patterns (Prakash *et al.*, 2007; Durmic *et al.,* 2015; Mazic *et al.,* 2016) whilst other studies reported that pulmonary values between different sport disciplines are statistically insignificant (Wilmore and Costill, 1999; Vitaic *et al.*, 2015).

In this regard, Marangoz *et al*. compared the influence of long-term exercise and sedentary lifestyles demonstrating statistically significant differences for MVV, FVC and VC values but findings for FEV_1 and PEFR values were inconclusive (Marangoz *et al*., 2016). When assessing FVC, FEV_1 and MVV between a physically active and sedentary group, Rocha *et al.* found minimal difference in lung values (Rocha *et al.*, 2011). Whilst Rocha *et al.* were unable to demonstrate an association between activity and pulmonary function, other literary sources supports the association between improved pulmonary function and physical activity (Fuertes *et al.*, 2018; Albarrati *et al.*, 2020; Bédard *et al.*, 2020). When comparing swimmers, football, basketball, hockey and volleyball players with a control group, significant differences in FVC, FEV_1 and MVV were recorded in favour of all athletic groups with swimmers portraying the best pulmonary function (Mehrotra *et al*., 1998; Myrianthefs *et al.*, 2014). Therefore, it is possible to speculate that, athletes are more likely to demonstrate increased spirometry measurements than sedentary counterparts (Durmic *et al.*, 2015; Mazic *et al.,* 2016).

1.1.2 Pulmonary Function in Different Sporting Discipline

1.1.2.1 Swimming and Pulmonary Function

Swimming is defined as an aerobic low-intensity exercise (Upadhyaya & Joshi, 2019) and is made unique due to the influence of buoyancy, temperature, pressure, and resistance of the water. Cooler temperatures (21–28 ^{0} C) improve breathing patterns, lower breaths per minute and the pulse rate (Michalak *et al*., 2015). The loss of body weight due to water buoyancy supports a comparable freedom and range of movement when compared to land exercise. The effect of the hydrostatic pressure facilitates greater expiratory volume (Gabrilo *et al*., 2011; Päivinen *et al.*, 2021).

The positioning of the diaphragm is also relevant when investigating the effects of water of the lung capacity and functioning. The horizontal supine position the diaphragm predisposes one to thoracic breathing due to its superior location thus promoting chest flexibility and mobility (Martin-Valero *et al.*, 2012). Furthermore, the horizontal position can reduce 'physiological dead space', and promotes blood flow in relation to lung ventilation contributing to increases in lung diffusion capacity thus supporting better lung function in swimmers (Sable *et al*., 2012; Silvestri *et al*., 2013). Some studies support the role of genetic pre-disposition as a probable explanation whilst other studies support the transformation through sport development (Myrianthefs *et al.*, 2014; Lazovic-Popovic *et al*., 2016). The rationale for larger lung volume in swimmers remains a debateable topic. In a comparative study assessing VC, FVC and FEV_1 higher values were recorded among swimmers than soccer players and the control subjects (Myrianthefs *et al.,* 2014; Lazovic-Popovic *et al.*, 2016). Nevertheless, the benefit of swimming in reference to lung function has ignited much debate within the research community (Martin- Valero *et al*., 2012; Silvestri *et al.,* 2013).

1.1.2.2 Soccer and Pulmonary Function

Soccer is a high-intensity, intermittent activity where players complete regular, repeated sprints throughout the 90-minute game, and studies. Akhade *et al.* found that regular running practice common in soccer training had the potential to increase pulmonary capacity thus promoting lung function (Akhade *et al.*, 2014; Di Paco *et al.,* 2014; Mackała *et al.,* 2019). Reports indicate that soccer players have greater pulmonary functions when compared to their controls (Adegoke and Arogundade, 2002; Singh *et al*., 2015). Even compared to other athletic groups including futsal, soccer players showed significantly higher FVC, FEV_1 and PEFR values (Tareq *et al.,* 2018). Whilst there is an abundance of literature that records a better pulmonary function among professional soccer players relative to control groups (Figueiredo *et al.,* 2009; Singh *et al*., 2015) there is limited research that examines recreational soccer with other recreational sporting groups such as swimming and volleyball in particular (Gil *et al.,* 2010; Kubayi *et al.*, 2017).

1.1.2.3 Volleyball and Pulmonary Function

Volleyball is defined as an aerobic exercise with alternating low and high intensity movements (Billaut *et al*., 2012; Kutáč *et al*., 2020). Volleyball requires players to engage in frequent short episodes of high-intensity exercise, followed by episodes of low-intensity exercise (Sandeep and Kumar, 2017). The high intensity exercise episodes, in conjunction with the duration of the match (90 minutes), places a demand on the aerobic energy systems. Individuals who engage in team sports have also been shown to have improved cardio-respiratory fitness, lower body weight and higher bone density than sedentary individuals (Barber-Westin *et al*., 2015; Vitaic *et al*., 2015). High-intensity intermittent running during volleyball games increases respiratory function (Gaurav and Singh, 2013) as demonstrated in a study that compared volleyball players and controls, VC, FVC, FEV_1 and PEFR were significantly higher for volleyball players in contrast to the control group (Basu *et al.*, 2018).

1.2Anthropometric Measurements

Anthropometric characteristics such as height, weight and BMI are used as indicators of wellness, maturation and development at different age categories (Mohammed *et al.,* 2017).

Figure 2: Categories of BMI (Adapted from Nuttall, 2015).

With reference to Figure 2, BMI is an anthropometric height/weight characteristic and can be classified into groups to assess health risk (Chernenko *et al.,* 2019). A 'normal' BMI is between 18.5 and 24.9 kg/m^2, while 'overweight'categories relate to BMI values between 25-29.9 kg/m^2 and BMI values above 30 kg/m^2 are classified as 'obese'. Anthropometry is concerned with body measurements which can be influenced by gender, physiological, psychological and anatomical factors (Carey *et al*., 2007; Rocha *et al*., 2011; Mondal and Mridha, 2015). A number of studies support that sedentary groups have a significantly higher BMI when compared with the other sporting groups (Popovic *et al*., 2014; Damoon *et al*., 2018; Olutende *et al.*, 2019).

1.2.1 Factors Influencing Anthropometric Characteristics

1.2.1.1 Lifestyle and Anthropometric Characteristics

Lifestyles that support regular physical activity correlate negatively with BMI and waist circumference (Tsai *et al*., 2007; Waller *et al.,* 2008; Tambalis *et al.,* 2013, Pavlovic *et al.,* 2018; Wade *et al*., 2018). High BMI levels traditionally associated with sedentary lifestyles tend to have a negative influence on inflammatory profiles and respiratory patterns (Luna Junior *et al.*, 2016; Erskine *et al.,* 2017; Abd El-Kader, & Al-Dahr, 2018; Henriksson *et al.,* 2020). In contrast, low BMI levels associated with a physically active lifestyle demonstrate improved respiratory muscle strength and lower inflammatory profiles (Puente-Maestu & Stringer, 2018). Aerobic exercises such as walking, soccer, swimming and volleyball support weight and BMI reduction (Miyaki *et al.,* 2009). A loss in weight of almost 10 percent of body weight was reported with lifestyle modifications including diet, exercise and behavioural changes (Mohd *et al.,* 2018). More specifically, low caloric diets support effective weight loss, weight maintenance, and prevent chronic diseases associated with higher weights and BMI (Hu *et al*., 2012; Balliet and Burke, 2013). It is evident that physical activity is necessary for weight and BMI management. However, with restrictions imposed to contain the spread of the COVID-19 virus, lockdown periods have contributed to an increasingly sedentary lifestyle (Pecanha *et al*., 2020; Balanzá–Martínez *et al*., 2020). This is especially significant since sedentary populations have been identified as vulnerable populations.

1.2.2 Anthropometric Characteristics and Pulmonary Measures

Pulmonary measures correlate with age, height, and weight when investigated in different sporting groups (Rong *et al.*, 2008; Basu *et al.*, 2018). Anthropometric characteristics such as age, weight, height and BMI correlated with FVC, MVV, and PEFR (Jiwtode and Raikar, 2017; Chandrashekhar *et al.*, 2020). Height, weight and body surface area were found to be positively correlated to FVC with height demonstrating the strongest correlation with FVC (Pawar *et al*., 2011; Jiwtode *et al.*, 2017). Increased body weight can reduce FEV_1 and FVC measurements (Gundogdu and Eryilmaz, 2011; Chandrashekhar *et al.*, 2020). Vital Capacity, FEV_1 and FVC are influenced by height, as these measures are proportional to body size suggesting that as a tall individual, increases in age, pulmonary volume will decrease. The BMI measure has been cited as an irrelevant factor in earlier studies when considering FVC (D'Ávila Melo *et al.*, 2011), however, in more recent studies, FVC has shown an inverse association with BMI (Durmic *et al.*, 2015; Mazic *et al.*, 2016) thus highlighting the relationship between the two measures. Peak Expiratory Flow Rate is a measure of ventilator capacity (Mrida *et al.*, 2012) and age, gender, height, pulmonary disease and muscle mass are key to determining PEFR (Dratva *et al*., 2016). However, there is a need for further investigation between anthropometric characteristics as determinants of pulmonary function when considering recreational sport groups as the majority of studies investigate professional athletes.

1.2.3 Anthropometrics and Different Sport Disciplines

Anthropometric characteristics are important in the performance of runners (Dessalew *et al*., 2019). In the case of runners, increased heights and weights had a negative effect on sports performance across gender (Arazi *et al.*, 2015). Anthropometric characteristics of basketball players predict athletic performance (Köklü *et al*., 2011; Teramoto *et al.*, 2018). Basketball players with increased heights and weights experience an advantage compared to shorter players (Vaquera *et al.*, 2015; Ferioli *et al.*, 2018; Svilar *et al.*, 2018). Volleyball physiological profiles seem to be similar to those of basketball, however, when compared with each other, basketball players were taller and heavier (Gaurav *et al.*, 2010). Increased height, lean body and low-fat percentage are common characteristics in the anthropometric profile of high-level volleyball players (Nikolic *et al.*, 2008; Peña *et al.*, 2018). Anthropometric characteristics are important factors for football players when evaluating the playing position and the level of competition (Joksimović *et al*., 2019). High body mass was associated with reduced muscle power in the sport disciplines of soccer (Nikolaïdis, 2012), handball (Nikolaidis & Ingebrigtsen, 2012) and basketball (Nikolaidis *et al.*, 2015) which contrasts with Vaquera *et al*., Ferioli *et al*. and Svilar *et al.* that advocate the benefit of higher body mass (Vaquera *et al*., 2015; Ferioli *et al*., 2018; Svilar *et al.*, 2018). Swimmers demonstrate increased heights and length of the limbs (Morais *et al.*, 2012; Barbosa *et al.*, 2015). There is limited literature that draws a comparative analysis of anthropometric characteristics in recreational swim, soccer and volleyball disciplines.

1.3 Inflammatory Markers

Cytokines or inflammatory markers are classified as anti-inflammatory (i.e. IL-8 and IL-10), pro-inflammatory (i.e. TNF-α, IL-12 and IL-1β) or both pro and anti-inflammatory (IL-6) proteins (La Gerche *et al*., 2015; Vijayaraghava and Doreswamy, 2017). Pro-inflammatory cytokines are responsible for initiating and progressing inflammation whilst anti-inflammatory cytokines diminish the progressive inflammatory process (Khazei *et al.,* 2014). Interleukin-6 and TNF-α cytokines regulate inflammation and immune responses (Machado *et al*., 2014) but TNF-α is most noted for its pro-inflammatory role (Townsend *et al.*,2015). Although the relationship with age, inflammation and anthropometrics is unclear, age is believed to be associated with anthropometric and inflammatory profiles. Cytokine response to exercise is influenced by gender variations (Edwards *et al.*, 2006) due to muscle mass differences. Comparatively, studies reported no differences in IL-6, IL-8, and IL-10 levels based on gender (Larsson *et al.*, 2015; Terrink *et al.,* 2018) whilst increased levels of IL-6 are reportedly associated with higher BMI and percent body fat (Fitzgerald *et al.*, 2012).

Both IL-6 and TNF-α are secreted into the circulation when exercising (Heinrich *et al*., 1990; Keller *et al*., 2004; Mugabo *et al.,* 2010; Ouchi *et al*., 2011; Swift *et al.,* 2012). Interleukin-6 produced by skeletal muscle contributes to energy metabolism and elicits benefits of exercise, including improved insulin sensitivity, reduced inflammation and increased fat oxidation (Li *et al.,* 2021). TNF-α regulates the IL-6 expression (Yudkin *et al*., 2000). Further research is required to investigate how these cytokines modulate inflammation and how physical activity can aid in reducing inflammation.

1.3.1 Cytokine Response to Physical Activity

Studies support that in general exercise regulates the expression of pro and anti-inflammatory cytokines such as TNF-α, IL-6 and IL-10 (Balducci *et al.*, 2010; Santos *et al*., 2012; Ghafourian *et al.*, 2015). Furthermore, the type, duration and intensity of the physical activity produces various cytokine responses (Beavers *et al.,* 2010), with specific emphasis noted in IL-6 (Kaminski *et al*., 2009; Ertek and Cicero, 2012). However, the specific cytokine response for varying sport disciplines has been limited. Regular physical activity is known to provoke an anti-inflammatory environment (Santos *et al.,* 2012; Reihmane and Dela, 2014). Low-intensity exercises such as light walking, stretching or swimming are suitable for individuals with chronic health issues. Moderate-intensity exercise increases T-cell function, reduces inflammation, increases IL-10, enhances immune function and prevents acute upper respiratory infections (Cerqueira *et al*., 2020; Gerosa-Neto *et al.*, 2020). High-intensity exercise is known to suppress the production of immune-modulatory cytokines. However, excessive amounts of prolonged high-intensity exercise may cause a down regulation of immune function (Simpson *et al.,* 2020) (Figure 3).

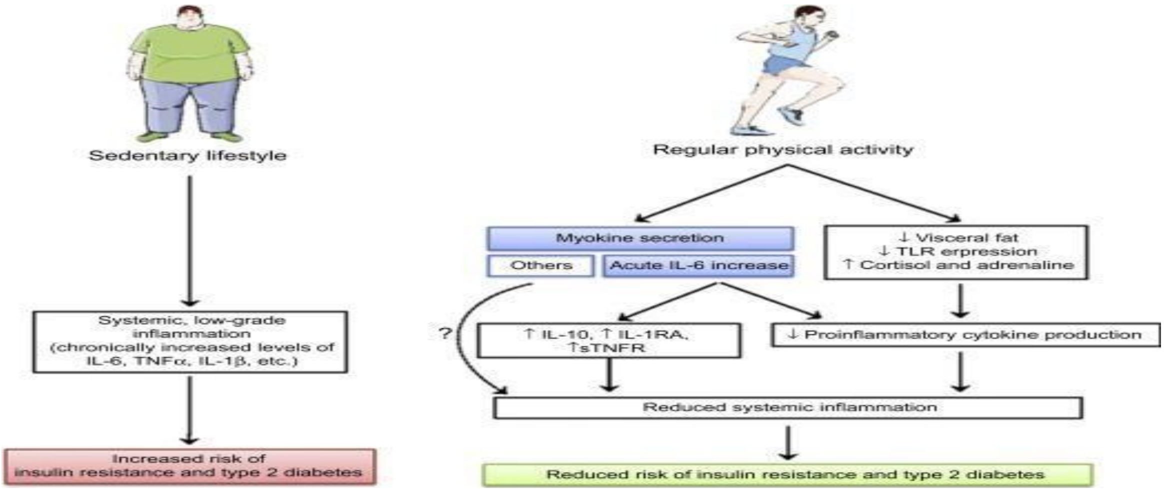


Figure 3: Cytokine Response to Physical Activity and Physical Inactivity (Adapted from Suzuki, 2019).

Strenuous and high intensity long duration exercise may increase the inflammatory profile in the short term (Blackburn *et al*., 2007; Gleeson *et al.*, 2011) however anti-inflammatory effects are associated with long term physical activity. Therefore, physical activity minimises the incidence of chronic diseases (Kasapis *et al*., 2005; Pedersen, 2006; Ji, 2008; Vieira *et al*., 2012; Scott *et al*., 2013; Niyi-Odumosu *et al.*, 2016; Suzuki & Hayashida, 2021). This anti-inflammatory effect may be initiated by the reduction in leptin and increasing adiponectin and insulin sensitivity (Brandt and Pedersen, 2010). In reaction to shorter duration low intensity exercise periods, acute IL-6 elevation suppresses TNF-α and increases IL-10 levels (Figure 3 and 4) (Starkie *et al.*, 2003; Steensberg *et al.*, 2003).

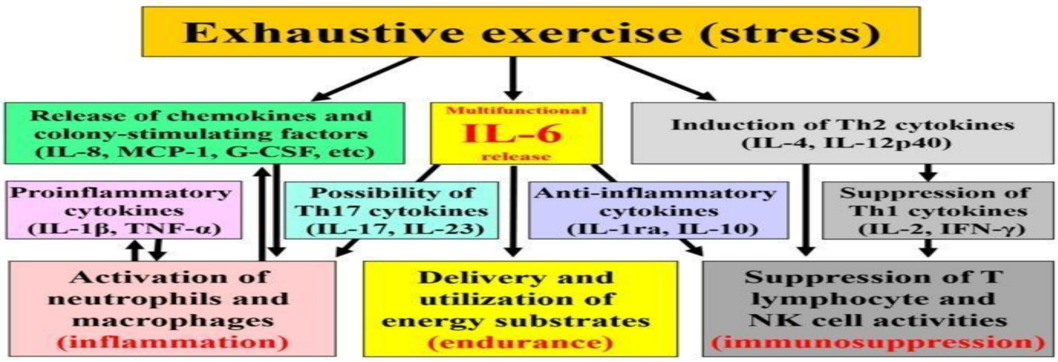


Figure 4: Cytokine Response to Exercise (Adapted from Suzuki, 2018)

Literature suggests that the influence of acute exercise on the cytokine response differs from the responses associated with chronic training (Wilmund, 2007). On the other hand, no difference was reported in the anti-inflammatory IL-10 following a short period of exercise when comparing master athletes with untrained counterparts (Minuzzi *et al*., 2017). Studies investigating acute bouts of physical exercise and the cytokine response have received greater attention (Borges *et al.*, 2013) thus highlighting the need for studies that investigate the chronic effect of exercise and the cytokine response which this study aims to address among the recreational sport disciplines.

1.3.2 Cytokine Response to Different Sporting Disciplines

The IL-6 and TNF-α levels are influenced by different sport disciplines including downhill running, cycling, swimming and athletics (Bishop *et al*., 2002; Gomez *et al.*, 2003; Ascensao *et al*., 2008; Ispirlidis *et al.*, 2008; Walsh *et al*., 2011; Avila *et al*., 2015). At rest, the cytokine profile of athletes appears similar to control subjects (Borges *et al.*, 2013). Marathon running is associated with IL-6 increases (Peake *et al*., 2017). The gender comparison between cytokine responses in soccer players showed similar IL-6 measures but, TNF-α levels post-match demonstrated increased level for males in comparison to female soccer players. IL-6, and TNF-α values were diminished in soccer players relative to control subjects (Souglis *et al*., 2015). Chronic exercise improves the inflammatory profile by reducing cytokine production (Thorpe and Sunderland, 2012). There is a lack of scientific evidence demonstrating possible variations that may occur in the resting serum IL-6, IL-10 and TNF-α level between different sport disciplines. Furthermore, there is a lack of consistency in the data and reproducibility with reference to recreational sport cohorts in South Africa.

1.3.3 Cytokine Response and Pulmonary Measures

Higher levels of IL-6 are associated with reduced FEV_1 and FVC measure (Donaldson *et al*., 2005; Thorleifsson *et al*., 2009; Gimeno *et al*., 2011); however, this data is not sport specific. A negative correlation between IL-6 and FEV_1 is reported in studies with respiratory inflammation (Abd El-Maksoud *et al*., 2010; Attaran *et al*., 2010; Ramadan *et al*., 2010) however, no correlation was reported in similar studies between IL-6 and FEV_1 or FEV_1 /FVC values (Akbulut *et al*., 2009; El-Shimy *et al.*, 2014). Contrary to these studies, a significant inverse relationship between serum levels of IL-6 and FEV_1 ($r=-0.341$, $p<0.001$) and IL-6 and FEV_1/FVC ($r=-0.309$, $p<0.001$) values were noted in a study investigating cytokines in patients with Chronic Obstructive Pulmonary Disease (Wang *et al.,* 2018). In the case of TNF-α levels Amer *et al*. reported a negative correlation with FEV_1, but Abd El-Maksoud *et al*. found no correlation with TNF-α and FEV_1 (Amer *et al*., 2010; Abd El-Maksoud *et al*., 2010). There is a great contrast in reports investigating respiratory inflammation and specific sports, particularly in SA. Hence, further research investigating respiratory inflammation and physical activity in a South African population is essential.

1.4 Problem Statement

The recent COVID-19 pandemic has brought to attention the importance of exercise for respiratory function and cytokine profiles. Based on the research findings presented, there is a lack of scientific evidence regarding respiratory patterns, anthropometric characteristics and cytokine profiles emerging from varying recreational sport groups (swim, soccer and volleyball) and a sedentary group in a South African cohort. Furthermore, data on the cytokine expression in athletes has been contradictory, with limited research noted in a sedentary population. Hence this study investigated respiratory patterns and cytokine profiles among recreational soccer, volleyball and swim groups as well as a sedentary group.

1.5 Significance of the Study

Prior to the inception of the COVID-19 pandemic, the lack of physical activity has been recognised as a global public health problem (WHO, 2018). Barriers towards physical activity have necessitated a unique approach to motivating individuals to improve the level of physical activity (Farah *et al.*, 2021). In this regard, research suggests that redirecting the focus towards the benefits of physical activity is more effective for behaviour modification than presenting the risks associated with a sedentary lifestyle (Sullivan, & Lachman, 2017). The goal of this study was to investigate respiratory patterns and cytokine profiles among athletes that participate in recreational sport groups such as swimming, soccer and volleyball due to its high accessibility to the general population as well as a sedentary group. Studies that incorporate these sports in a South African cohort may prove more relatable to the general public and may potentially support improved behavioural and lifestyle adaptations. This study bears relevance since SA ranked as the third most physically inactive country within the sub-Saharan African continent (Mkhonto *et al.,* 2012; Okafor, 2012; Cois, 2015; Raichlen *et al.,* 2020). The outcome of the study can provide scientific evidence to support the role of specific sporting disciplines for sedentary population groups who seek optimal pulmonary health, especially in the presence of COVID-19. It also creates knowledge and awareness cues for sedentary groups regarding their anthropometric characteristics, respiratory patterns and cytokine profiles. Furthermore, the study provides insight into cytokine profiles of various recreational sport disciplines which adds to the body of literature regarding sport and the resting cytokine response.

1.6 Hypothesis

The present study aims to determine the respiratory patterns and cytokine profiles among recreational athletes from swimming, soccer and volleyball clubs due to the type of training and a sedentary group within a South African cohort.

The hypotheses are stated as follows:

1.6.1 There are significant differences in anthropometric characteristics for the three sport groups

1.6.2 There are significant differences in respiratory patterns in athletes from recreational swim, soccer and volleyball sport groups.

1.6.3 Respiratory patterns in each of the recreational sport groups are better compared to the sedentary group.

1.6.4 There are significant differences in cytokine profiles (IL-6, IL-10 and TNF-α) in athletes from recreational swim, soccer and volleyball sport groups.

1.6.5 Cytokine profiles in each of the recreational sport groups are better compared to the sedentary group.

1.7 Research Aim

The study investigates respiratory patterns and cytokine profiles for athletes in recreational sport groups such as swimmers, volleyball and soccer players and a sedentary group. Moreover, the study aims to determine which anthropometric characteristics and cytokines correlate with lung volumes and flows in the recreational sport groups and the sedentary group.

1.8 Research Objectives

- To determine anthropometric characteristics and respiratory patterns among athletes from recreational swim, soccer and volleyball sport groups and the sedentary group.
- To determine cytokine profiles (IL-6, IL-10 and TNF-α) among athletes from recreational swim, soccer and volleyball sport groups and a sedentary group.
- To provide suitable recommendations for improved pulmonary function and cytokine profiles in a sedentary population.

1.9 Strengths and Limitations of the Study

The strength of the study is noted in the unique reporting of the effectiveness of recreational sporting (either land or water based) in respiratory patterns and cytokine profiles to promote physical activity in sedentary populations in SA. The present study synthesizes evidence for recreational sport groups and a sedentary group that is important and relevant for the modification of health behaviours among sedentary populations in SA. The study sample was limited in that the sample size consisted of 20 athletes per recreational sport group and a sedentary group. The total sample size only included 80 participants (swim-20, soccer-20, volleyball-20 and sedentary-20), thus the study could have benefitted from larger samples. The participants were self-recruited thus a random sampling design would have benefitted the study. The study comprised a cross sectional design and could have benefitted from a longitudinal study design. Therefore, the findings of the study must be carefully considered and may be limited in its applicability and generalization to other populations.

1.10 Thesis Structure

This thesis comprises of the background Chapter 1 and manuscripts presented in Chapters 2 to 3, with Chapter 4 presenting an amalgamation of the manuscript chapters, representing how they interconnect. Chapter 4 concludes with a set of recommendations and outcomes.

Chapter one is an introductory chapter and provides a background to the study. The research methodology applied to the study and a comprehensive literature review is included. The hypothesis, research aims and objectives are presented herein.

Chapter two includes the first manuscript. It addresses the determination of the spirometry and anthropometric values and in turn anthropometric characteristics are investigated for its association with spirometry values.

Chapter three includes the second manuscript. It addresses the determination of the spirometry and cytokine levels and the cytokines are investigated for their association with pulmonary function.

Chapter four includes the synthesis, conclusions and recommendations for the study. This chapter links the previous chapters to determine the respiratory patterns in recreational athletes. This is achieved by determining the anthropometric characteristics and their association with spirometry values. The cytokine profile of participants is also assessed to determine their association with spirometry values.

1.11 Conclusion

This chapter provides a literary overview of the research project. Pulmonary function, anthropometrics and inflammatory markers are discussed. The background, aim and objectives of the study are elaborated. Chapter Two follows as a manuscript.

Original Article: Respiratory Patterns among Recreational Athletes and a Sedentary Group

After the review of literature in Chapter one, it became evident that limited research is available on the anthropometric characteristics and pulmonary function among recreational athletes in swim, soccer and volleyball sport groups and a sedentary group. Chapter two was therefore dedicated to the assessment of the anthropometric characteristics and respiratory patterns among recreational athletes (swim, soccer and volleyball) and a sedentary group. The association between the anthropometric profile and pulmonary function was assessed for the recreational swim, soccer and volleyball sport groups and a sedentary group in accordance with research objective one.

CHAPTER 2:

Respiratory Patterns among Recreational Athletes and a Sedentary Group

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Abstract

Background: Respiratory patterns among varying recreational sport disciplines and a sedentary group within a South African cohort are limited and needs to be elucidated. This study aims to determine if there is a varied influence on anthropometry and spirometry values in recreational sport disciplines (swim, soccer and volleyball) and in turn anthropometric characteristics (Height, weight and BMI) are investigated for their association with spirometry values.

Method: The sample of 80 participants consisted of 20 self-recruited males being 18 years or older from each group (Swim, volleyball, soccer [Training frequency -3 sessions per week x 1 hour per session] and a sedentary group). Smokers, former smokers, medication usage and medical history with respiratory diseases were excluded from our study. Standardised anthropometric measures were applied in the measurement of height, weight and BMI. American Thoracic Society (ATS) recommendations determined the spirometry protocol.

Results and Discussion: The respiratory patterns in the swim, soccer and volleyball sport groups were significantly different ($p<0.01$). All the recreational sport groups had significantly increased lung parameters compared to the sedentary group ($p<0.01$). The association of anthropometric characteristics and respiratory patterns were significant for height and weight among all the swim, soccer, volleyball and sedentary group.

Conclusion: Respiratory patterns are sport-specific. Thus, swimming has the potential to improve pulmonary function and reduce the incidence of obesity in a sedentary population.

Introduction

The recent Coronavirus (COVID-19) pandemic has necessitated the use of lockdown interventions as a containment measure to reduce the spread of the virus. As a consequence, the importance of exercise, escalating sedentary patterns and respiratory function has gained considerable attention (Aubertin-Leheudre & Rolland, 2020; Dominski & Brandt, 2020). Since sedentary individuals have been identified as a high risk group in the management of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Woods *et al.*, 2020) exercise has become an essential lifestyle change during the COVID-19 pandemic.

Sedentary behaviour (SB) emerged as an important public health issue prior to the inception of the COVID-19 pandemic and has been recognised for its association with impaired respiratory function and systemic inflammation (Emadian & Thompson, 2017; Shrestha *et al.*, 2019). Sedentary behaviour has been described as any waking behaviour regarded as $\leq$1.5 metabolic equivalents (METs)of energy expenditure, while occupying a posture of sitting, reclining or lying (Tremblay *et al.*, 2017) and lends itself to increased levels of physical inactivity. A study by Rawlings *et al.* found that whilst participants' showed a limited knowledge of sedentary behaviour, they were cognisant of the health risks associated with a sedentary lifestyle and physical inactivity (Rawlings *et al.*, 2019*).* Given that individuals recognise the detrimental effect of prolonged SB, but remain reluctant to change, it becomes apparent that there is a paucity of research available to bridge the gap between what sedentary individuals know and what they need to do to bring about positive change. Hence, advocating behaviour modification for sedentary individuals through education and comparative research based on active and sedentary lifestyles is effective as a change strategy (Martínez-Ramos *et al.,* 2015; Sullivan, & Lachman, 2017).

South Africa has been ranked as the third most physically inactive country within the sub-Saharan African continent (Mkhonto *et al.,* 2012; Okafor, 2012; Raichlen *et al.,* 2020) which is supported by the increasing levels of NCDs, high body mass index (BMI) levels and obesity related pulmonary impairment (Bedard *et al.,* 2020; Schouw *et al.,* 2020). Comparatively, studies report that athletes of different sporting disciplines and professional levels show better pulmonary capacity and respiratory strength in comparison to the sedentary counterparts (Figueiredo *et al.,* 2009; Silvestri *et al.*, 2013; Singh *et al*., 2015; Lazovic-Popovic *et al.,* 2016; Kaneko, 2020). Therefore, it is possible to speculate that, athletes are more likely to demonstrate increased spirometry measurements than sedentary counterparts (Durmic *et al.,* 2015; Mazic *et al.,* 2016). Subsequently, one may infer that incorporating recreational sporting activity in sedentary lifestyles has the potential to produce better health outcomes for sedentary populations (Cois, 2015). In this regard, recreational swimming, soccer or volleyball training may prove more relatable to the general public and may potentially support improved behavioural and lifestyle adaptations in a South African cohort. Whilst exercise may alter the pulmonary capacity (Luzak *et al.,* 2017; Engel *et al.,* 2019, Nilsson *et al.,* 2019; Dempsey *et al*., 2020; Ahmed *et al.*, 2021) the relationship of varying sport disciplines with spirometry may vary across sport disciplines. Studies reporting on spirometry values (Vaithiyanadane *et al*., 2012; Khosravi *et al.,* 2013) from varying sport disciplines have yielded inconsistent findings. Hence, there is a need to determine which sporting discipline has the potential to yield significant benefit for a sedentary population to support sustained change.

Anthropometry is closely related with exercise physiology and literature documents how specific sport disciplines influence anthropometry parameters (Malina *et al.,* 2004; Adhikari & Nugent, 2014; Radu *et al.,* 2015; Casadei & Kiel, 2021). A number of studies support that sedentary groups have a significantly higher BMI when compared with the other sporting disciplines (Popovic *et al*., 2014; Damoon *et al*., 2018; Olutende *et al.,* 2019). However, more emphasis is placed on professional athletes when investigating anthropometric characteristics in the discipline of swimming (Lätt *et al.*, 2010; Saavedra *et al.*, 2010; Morais *et al*., 2012), soccer (Gil *et al*., 2010; Braun *et al*., 2013; Quanjer, 2013; Kubayi *et al*., 2017)and volleyball (Gaurav *et al.*, 2015). Furthermore, most of the descriptive data concerning anthropometric and respiratory characteristics of professional soccer and volleyball players come from America and Western Europe (Milanovic *et al.*, 2012). It is clear that studies investigating anthropometric characteristics in recreational athletes remain myopic and a significant lack of data is noted within a South African cohort.

This study seeks to address the gap in literature by investigating anthropometric characteristics (Height, weight and BMI) and respiratory patterns (Forced Vital Capacity [FVC], Forced Expiratory Volume in one second [FEV_1], Vital Capacity [VC], Peak Expiratory Flow Rate [PEFR] and Maximal Voluntary Ventilation [MVV] among recreational swim, soccer and volleyball groups and a sedentary group within a South African cohort to educate sedentary populations. In addition, anthropometric characteristics are investigated for its association with spirometry values. We hypothesise that: a) There are significant differences in anthropometric and respiratory patterns in athletes from recreational swim, soccer and volleyball sport groups and b) Respiratory patterns in each of the recreational sport groups are better compared to the sedentary group.

Study Method

Participants

A recreational athlete for the purpose of this study is defined as a male athlete participating in active sport playing for a minimum of three one-hour sessions weekly as stipulated by the club training protocol (Stamatakis *et al.*, 2019; Hadgraft *et al.,* 2020). The cross-sectional study comprised of 80 athletes with subgroups of 20 from recreational swim, soccer, volleyball sport groups and a sedentary group (sedentary behaviour (SB) for each participant was categorized as: ≥8 h/day as per a cohort study that reported a detrimental association between SB ≥ 8 h/day and all-cause mortality) (Peterson *et al.,* 2012; Win, *et al.,* 2015; Koyanagi *et al.,* 2018). The inclusion criteria for recreational athletes were participation in swimming, soccer or volleyball with a frequency of 3 sessions per week of one hour per session. Adult males ≥ 18 years were required for the study. Individuals with a history of smoking, respiratory diseases or the use of medication were excluded. Participants were self-recruited by placing invitational notices at various sports clinics, physiotherapy clinics, sport clubs and local gyms. Participants were informed of the study aim as a means to motivate their interest in pursuing the study. Participants were informed of the study protocol and provided informed consent.

Ethical Approval

The Biomedical Research Ethics Committee (BREC) of the University of KwaZulu-Natal (UKZN), South Africa provided regulatory ethical and institutional approval (BE 012/18).

Design

Standardized anthropometric techniques were used to complete height (metres) and weight (kilograms) measurements. Full attention was given to ensure that that the participant's body is fully upright and the participant was barefoot with minimal clothing. Subjects' backs were in contact with the wall, both heels placed side by side and touching the base of the wall for the height measurement. Weight was measured using a scale and height was measured using a stadiometer. BMI calculations were completed (kilogram/m squared) using an average of three measurements (Ettarh *et al*., 2013). BMI was categorized as <18.5 (underweight), 18.5–24.9 (normal), 25.0–29.9 (overweight), and ≥30 (obese) kg/m^2 (Koyanagi *et al.,* 2018).

The spirometry measurements were performed by a trained physiotherapist using the MIR SPIROLAB II spirometer following a two week no training period. The American Thoracic Society (ATS) recommendations were followed (Graham *et al.,* 2019). Tests were performed while sitting with the use of a nose clip. Subjects were required to perform a maximal inhalation, with sealed lips over the mouthpiece, then followed by a rapid maximal exhalation. Subjects continued exhaling for 6 seconds to facilitate FEV_1 and FVC measurements. Tests were performed in triplicate until the two highest recorded values varied by less than 3%. Measurements were completed under standard environmental conditions based on temperature (18 - 22 ^{0} C), atmospheric pressure (760 mmHg) and a relative atmospheric humidity (30% - 60%) (Durmic *et al*.,2015). Measurements were taken in the morning between 8am and 12 noon in order to avoid diurnal variations in lung function.

Statistics

Data were analysed with IBM Statistical Package for Social Sciences (SPSS) version 27 (Chicago, IL, USA) and are presented inter-group and intra-group. Continuous data for the anthropometric characteristics and the spirometry values were presented with the mean and standard deviation value. Pearson's correlation coefficient assessed the intra-group relationship between anthropometric characteristics and pulmonary function (Durmic *et al*., 2015). An ANOVA analysis was conducted for the comparison of spirometry values inter-group among the swim, soccer and volleyball groups. Independent t- tests were conducted for the comparison of each sport discipline with the sedentary group. A value of $p<0.05$ was considered statistically significant.

Results

A) Anthropometric Characteristics of the Swim, Soccer, Volleyball and Sedentary Group

Table 1 represents the anthropometric characteristics of the swim, soccer, volleyball and the sedentary group.

Table 1: Anthropometric Characteristics of the Swim, Soccer, Volleyball and Sedentary Group

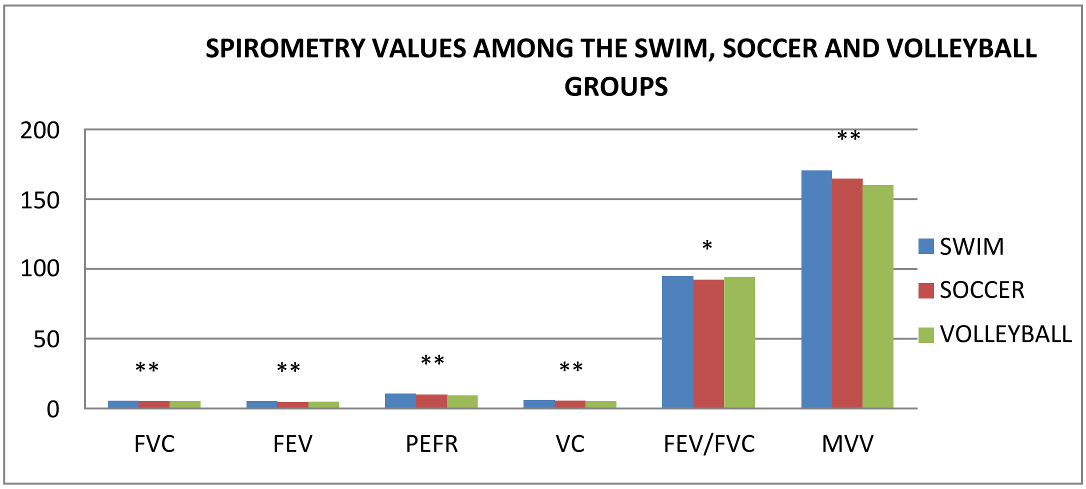
GROUPS		HEIGHT	WEIGHT	BMI
n=80		Metres	Kilograms	Kg/m^2
SWIM (20)	Mean	1.72±0.05	53.72±3.97	18.23±0.86
SOCCER (20)	Mean	1.82+0.01	68.52+2.96	20.73+0.85
VOLLEYBALL (20)	Mean	1.75+0.05	62.32+2.25	20.37+0.85
SEDENTARY GROUP(20)	Mean	1.68+0.03	82.20+2.53	28.89+1.35

Note: Data are presented as means ± SD for all groups comprising the swim, soccer, volleyball and sedentary group. Height, weight and Body Mass Index –BMI.

In the swim group the findings were as follows: mean height of 1.72 ±0.05 m, weight of 53.72 ±3.97 kg and BMI of 18.23 ±0.86 kg/m^2. The soccer group showed a mean height of 1.82 ±0.01 m, weight of 68.52 ±2.96 kg and BMI 20.73 ±0.85 kg/m2. From Table 1, the volleyball group measures reflect a mean height of 1.75 ±0.05 m, weight of 62.32 ±2.25 kg and a BMI of 20.37 ±0.85 kg/m^2. The sedentary group had a mean height of 1.68±0.03 m, weight of 82.20+2.53 kg and BMI of 28.89+1.35 kg/m^2.

B) Spirometry Values of the Groups

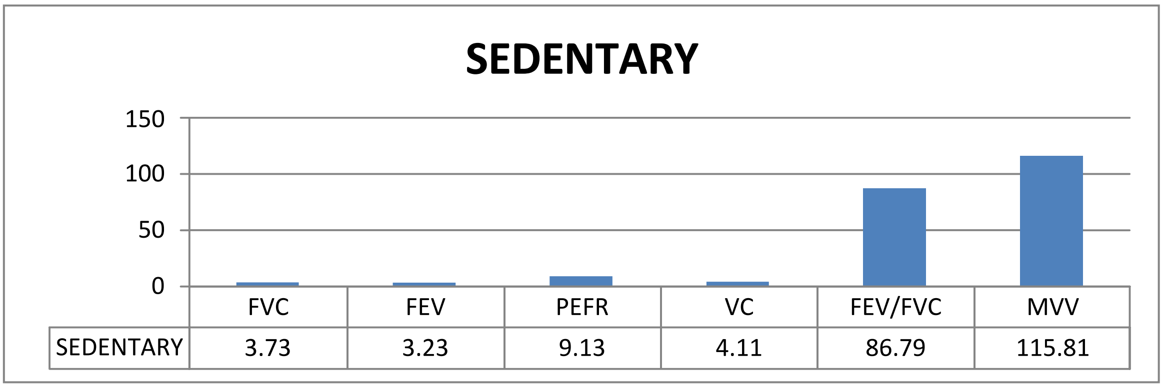
This section of the results presents Figure 1 which represents the difference in spirometry values among the swim, soccer and volleyball group. Figure 2 represents the mean distribution of the spiromtery values in the sedentary group.



Note: Data are presented as means for all groups comprising the swim, soccer and volleyball. FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV_1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation. Level of significance *$p<0.05$, ** $p<0.01$.

Figure1: Spirometry Values among Swim, Soccer and Volleyball Groups

The swim group findings were as follows: FVC - 5.51 L, FEV - 5.21 L, PEFR – 10.51 L/min, VC- 5.63 L, FEV^1/FVC ratio – 94.63% and MVV – 170.66 L/min. The soccer group findings were as follows: FVC - 4.99 L, FEV - 4.59 L, PEFR - 9.86 L/min, VC- 5.34 L, FEV_1/FVC ratio-92.06% and MVV – 164.53 L/min. The volleyball group findings were as follows: FVC - 5.10 L, FEV - 4.82 L, PEFR - 9.30 L/min, VC- 5.11 L, FEV1/FVC ratio- 94.18% and MVV -160.12 L/min.



Note: Data are presented as means for all groups comprising the swim, soccer and volleyball. FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV_1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation.

Figure 2: Mean Distribution of Spirometry values for the Sedentary Group

The sedentary group findings were as follows: FVC - 3.73 L, FEV - 3.23 L, PEFR - 9.13 L/min, VC- 4.11 L, FEV1/FVC ratio- 86.79% and MVV -115.81 L/min (Figure 2).

C) Intra-Group Correlation for Anthropometric Characteristics and Spirometry

Tables 2-5 represent the association of anthropometric characteristics with spirometry values for the swim, soccer, volleyball and sedentary groups.

Table 2: Correlation of Anthropometric Characteristics and Spirometry -Swim Group

Swim Group (n=20)		FVC	FEV_1	PEFR	VC	FEV/FVC	MVV
HEIGHT	Pearson Correlation	0.76**	0.75**	0.45*	-0.09	-0.20	0.74**
	Sig. (2-tailed)	0.00	0.00	0.04	0.68	0.39	0.00
WEIGHT	Pearson Correlation	0.59**	0.57**	0.15	-0.42	-0.16	0.79**
	Sig. (2-tailed)	0.00	0.00	0.51	0.06	0.47	0.00
BMI	Pearson Correlation	0.02	0.01	-0.30	-0.53*	-0.02	0.34
	Sig. (2-tailed)	0.91	0.96	0.19	0.01	0.90	0.14

Note: A significant difference between anthropometric characteristics is shown by*p<0.05; **p<0.01. Pearson correlation data is presented for the swim group between anthropometry characteristics and spirometry values [FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation].

In the swim group, FVC (r=0.76), FEV_1 (r=0.75), PEFR (r=0.45) and MVV correlated positively with height (r= 0.74) strongest correlation between FVC and height (r= 0.76). In the swim group, no correlations were noted between height, VC and the FEV_1/FVC ratio. With reference to the correlation between weight and spirometry values, FVC (r=0.59) FEV_1 (r=0.57) and MVV correlated with weight in the swim group; strongest correlation being MVV and weight (r=0.79). There were no correlations noted with weight and PEFR, VC and the FEV_1/FVC ratio. Only VC correlated negatively with BMI in the swim group (r=-0.53). No correlations were noted with BMI and FVC, FEV, PEFR, FEV_1/FVC ratio and the MVV spirometry values.

Table 3: Correlation Analysis of Spirometry and Anthropometric Characteristics- Soccer Group

Soccer Group(n=20)		FVC	FEV	PEFR	VC	FEV/FVC	MVV
HEIGHT	Pearson Correlation	0.79**	0.85**	0.46*	0.45*	-0.50*	-0.01
	Sig. (2-tailed)	0.00	0.00	0.04	0.04	0.02	0.94
WEIGHT	Pearson Correlation	0.32	0.31	0.25	0.03	-0.23	0.31
	Sig. (2-tailed)	0.16	0.18	0.27	0.88	0.32	0.17
BMI	Pearson Correlation	0.05	0.02	0.10	-0.12	-0.06	0.34
	Sig. (2-tailed)	0.82	0.91	0.66	0.59	0.79	0.14

Note: A significant difference between anthropometric characteristics is shown by *p<0.05, **p<0.01. Pearson correlation data is presented for the soccer group between anthropometry characteristics and spirometry values [FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation].

In the soccer group, significant correlations were noted with height among all the spirometry values with the exception of MVV. The correlation between spirometry and height in the soccer groups is noted as follows: FVC (r=0.79), FEV (r=0.85), PEFR (r=0.46), and VC (r=0.45). The strongest correlation was noted with FEV_1 (r=0.85) and height in the soccer group. No correlation was noted with weight and BMI for spirometry.

Table 4: Correlation Analysis of Spirometry and Anthropometric Characteristics- Volleyball Group

Volleyball (n=20)		FVC	FEV_1	PEFR	VC	FEV_1/FVC ratio	MVV
HEIGHT	Pearson Correlation	0.82**	0.85**	0.09	0.80**	0.73**	-0.24
n=20	Sig. (2-tailed)	0.00	0.00	0.68	0.00	0.00	0.29
WEIGHT	Pearson Correlation	0.59**	0.59**	0.08	0.42	0.42	-0.20
n=20	Sig. (2-tailed)	0.01	0.01	0.71	0.06	0.06	0.38
BMI	Pearson Correlation	-0.61**	-0.67**	-0.08	-0.74**	-0.66**	0.16
n=20	Sig. (2-tailed)	0.00	0.00	0.73	0.00	0.00	0.47

Note: A significant difference between anthropometric characteristics is shown by *p<0.05; **p<0.01. Pearson correlation data is presented for the volleyball group between anthropometry characteristics and spirometry values [FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation].

Table 4 represents the intra-group results for the volleyball group. FVC (r=0.82), FEV_1 (r=0.85), VC (r=0.80) and FEV_1/FVC ratio (r=0.73) correlated with height; strongest positive correlation being FEV_1 and height (r= 0.85) in the volleyball group. PEFR and MVV showed no correlation with height in the volleyball group. FVC and FEV_1 correlated equally with weight (r=0.59) in the volleyball group. BMI correlated negatively with FVC (r=-0.61), FEV_1 (r=-0.67), VC (r=-0.74) and FEV_1/FVC ratio (r=-0.66) with VC demonstrating the strongest negative correlation (r=-0.74).

Table 5: Correlation Analysis of Spirometry and Anthropometric Characteristics- Sedentary Group

Sedentary Group (n=20)		FVC	FEV	PEFR	VC	FEV/FVC	MVV
HEIGHT	Pearson Correlation	0.70**	0.54*	0.56*	0.70**	-0.60**	0.26
	Sig. (2-tailed)	0.00	0.01	0.01	0.00	0.01	0.26
WEIGHT	Pearson Correlation	0.05	0.15	0.15	0.17	0.12	0.49*
	Sig. (2-tailed)	0.84	0.52	0.54	0.47	0.62	0.03
BMI	Pearson Correlation	-0.50*	-0.31	-0.33	-0.43	0.54*	0.12
	Sig. (2-tailed)	0.02	0.18	0.15	0.06	0.02	0.63

Note: A significant difference between anthropometric characteristics is shown by*p<0.05; **p<0.01. Pearson correlation data is presented for the volleyball group between anthropometry characteristics and spirometry values [FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation].

In the sedentary group FVC (r=0.70), FEV_1 (r=0.54), PEFR (r=0.55), VC (r=0.70) and the FEV_1/FVC ratio (r=-0.60) correlated with height. MVV correlated with weight (r= 0.49) and BMI correlated negatively with FVC (r= -0.50) with the strongest correlation between with the FEV_1 ratio and weight (r = 0.54).

D) Inter-Group Analysis for the Individual Recreational Sport Group and the Sedentary Group

Table 6: Comparison in Spirometry Values between the Swim and Sedentary Group

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
FVC	Equal variances assumed	.002	.961	15.964	38	.000	1.77600	.11125	1.55079	2.00121
	Equal variances not assumed			15.964	37.835	.000	1.77600	.11125	1.55075	2.00125
FEV	Equal variances assumed	.883	.353	24.123	38	.000	1.98150	.08214	1.81521	2.14779
	Equal variances not assumed			24.123	35.634	.000	1.98150	.08214	1.81485	2.14815
VC	Equal variances assumed	2.215	.145	14.470	38	.000	1.51800	.10491	1.30562	1.73038
	Equal variances not assumed			14.470	36.931	.000	1.51800	.10491	1.30542	1.73058
PEFR	Equal variances assumed	2.947	.094	16.034	38	.000	1.37400	.08569	1.20052	1.54748
	Equal variances not assumed			16.034	35.067	.000	1.37400	.08569	1.20005	1.54795
FEV/FVC	Equal variances assumed	9.092	.005	6.947	38	.000	7.84515	1.12921	5.55919	10.13112
	Equal variances not assumed			6.947	29.767	.000	7.84515	1.12921	5.53824	10.15206
MVV	Equal variances assumed	8.924	.005	25.825	38	.000	54.84500	2.12369	50.54582	59.14418
	Equal variances not assumed			25.825	22.026	.000	54.84500	2.12369	50.44104	59.24896

Note: Comparisons are significant at $p<0.05$. Spirometry values [FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV-Maximal Voluntary Ventilation].

Since $p > 0.05$ for FVC, FEV_1, VC and PEFR we can accept the null hypothesis, and conclude that the mean FVC, FEV_1, VC and PEFR for the swim and sedentary group are not significantly different. In the case of the FEV_1/FVC ratio and MVV, $p < 0.05$; we can reject the null hypothesis and conclude that the mean FEV_1/FVC ratio and the MVV for the swim and sedentary group is significantly different.

- There was a significant difference in the FEV_1/FVC ratio between the swim and sedentary group ($t_{29.767} = 6.94$; $p < 0.05$). The FEV_1/FVC ratio was 7.84 % greater for the swim group than the sedentary group.
- There was a significant difference in the MVV between the swim and the sedentary group ($t_{22.026} = 25.82$; $p < 0.05$). The MVV for the swim group was 54.84 (L/min) higher in the swim group than the sedentary group.

Table 7: Comparison in Spirometry Values between the Soccer and Sedentary Group

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
FVC	Equal variances assumed	2.144	.151	12.468	38	.000	1.26150	.10118	1.05667	1.46633
	Equal variances not assumed			12.468	35.076	.000	1.26150	.10118	1.05611	1.46689
FEV	Equal variances assumed	.772	.385	21.889	38	.000	1.36450	.06234	1.23831	1.49069
	Equal variances not assumed			21.889	35.070	.000	1.36450	.06234	1.23796	1.49104
PEFR	Equal variances assumed	25.190	.000	3.275	38	.002	.72500	.22136	.27689	1.17311
	Equal variances not assumed			3.275	21.131	.004	.72500	.22136	.26484	1.18516
VC	Equal variances assumed	.085	.772	14.016	38	.000	1.23350	.08800	1.05534	1.41166
	Equal variances not assumed			14.016	36.817	.000	1.23350	.08800	1.05516	1.41184
FEV/FVC	Equal variances assumed	12.272	.001	4.742	38	.000	5.26845	1.11101	3.01933	7.51757
	Equal variances not assumed			4.742	28.525	.000	5.26845	1.11101	2.99454	7.54237
MVV	Equal variances assumed	10.543	.002	23.193	38	.000	48.71750	2.10054	44.46519	52.96981
	Equal variances not assumed			23.193	21.148	.000	48.71750	2.10054	44.35106	53.08394

Note: Spirometry values [FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation]

As shown for FVC, FEV_1 and VC p >0.05 we can accept the null hypothesis, and conclude that the mean FVC, FEV_1, VC for the soccer and sedentary group are not significantly different. In the case of PEFR, FEV_1/FVC ratio and MVV, p <0.05; we can reject the null hypothesis and conclude that the mean PEFR, FEV_1/FVC ratio and the MVV for the soccer and sedentary group is significantly different. Based on the results from Table 8, we can state the following:

- There was a significant difference in the PEFR between the soccer and sedentary group ($t_{21.131} = 3.27$, $p < 0.05$). The PEFR was 0.72 (L/min) greater for the soccer group than the sedentary group.
- There was a significant difference in the FEV_1/FVC ratio between the soccer and sedentary group ($t_{28.525} = 4.742$, $p < 0.05$). The FEV_1/FVC ratio was 5.26% greater for the soccer group than the sedentary group
- There was a significant difference in the MVV between the soccer and the sedentary group ($t_{21.148} = 23.19$, $p < 0.05$). The MVV for the soccer group was 48.71 (L/min) higher than the sedentary group.

Table 8: Comparison of Spirometry Values between the Volleyball and Sedentary Group

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
FVC	Equal variances assumed	4.951	.032	9.930	38	.000	1.37300	.13827	1.09310	1.65290
	Equal variances not assumed			9.930	34.671	.000	1.37300	.13827	1.09221	1.65379
FEV	Equal variances assumed	27.396	.000	10.702	38	.000	1.59300	.14885	1.29166	1.89434
	Equal variances not assumed			10.702	23.765	.000	1.59300	.14885	1.28562	1.90038
PEFR	Equal variances assumed	.183	.671	2.162	38	.037	.16300	.07541	.01034	.31566
	Equal variances not assumed			2.162	37.745	.037	.16300	.07541	.01031	.31569
VC	Equal variances assumed	.015	.903	10.962	38	.000	1.00350	.09155	.81818	1.18882
	Equal variances not assumed			10.962	37.696	.000	1.00350	.09155	.81813	1.18887
FEV/ FVC	Equal variances assumed	1.745	.194	5.615	38	.000	7.39335	1.31671	4.72780	10.05889
	Equal variances not assumed			5.615	37.440	.000	7.39335	1.31671	4.72649	10.06020
MVV	Equal variances assumed	13.711	.001	21.253	38	.000	44.30850	2.08477	40.08810	48.52890
	Equal variances not assumed			21.253	20.552	.000	44.30850	2.08477	39.96722	48.64978

The FVC, PEFR, VC and FEV_1/FVC ratio has p>0.05; we can accept the null hypothesis and conclude that the mean values for the FVC, PEFR, VC and the FEV_1/FVC ratio for the volleyball and sedentary group are not significantly different. In the case of the $FEV_1$and MVV values p< 0.05, we can reject the null hypothesis and conclude that the FEV_1 and MVV values for the volleyball and the sedentary group are significantly different. Based on the results from, we can state the following:

- There was a significant difference in the FEV_1 between the volleyball and sedentary group ($t_{23.76}$ = 10.70, $p < 0.05$). The FEV was 1.59 (L) higher for the volleyball group than the sedentary group.

- There was a significant difference in the MVV between the volleyball and the sedentary group ($t_{20.55} = 21.25$, $p < 0.05$). The MVV for the volleyball group was 44.30 (L/min) higher than the sedentary group.

E) Analysis of Variance Inter-group (between groups) and Intra-group (within groups) for the Swim, Soccer and Volleyball Group

Table 9: Analysis of Variance Inter-group (between groups) and Intra-group (within groups)

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
FVC	Between Groups	2.930	2	1.465	10.016	.000
	Within Groups	8.338	57	.146		
	Total	11.268	59			
FEV	Between Groups	3.892	2	1.946	11.548	.000
	Within Groups	9.605	57	.169		
	Total	13.498	59			
PEFR	Between Groups	14.690	2	7.345	20.328	.000
	Within Groups	20.596	57	.361		
	Total	35.286	59			
VC	Between Groups	2.657	2	1.329	14.836	.000
	Within Groups	5.104	57	.090		
	Total	7.761	59			
FEV/FVC	Between Groups	75.725	2	37.862	4.288	.018
	Within Groups	503.350	57	8.831		
	Total	579.075	59			
MVV	Between Groups	1120.022	2	560.011	113.177	.000
	Within Groups	282.041	57	4.948		
	Total	1402.064	59			

The analysis of variance indicates that the respiratory patterns between the three sport groups are significant ($p<0.05$). There was a statistically significant difference between groups for FVC values as demonstrated by the one-way ANOVA ($F(2,57) = 10.02$, $p < 0.05$). There was a statistically significant difference between groups for FEV_1 values as demonstrated by the one-way ANOVA ($F(2,57)=20.33$, $p < 0.05$). There was a statistically significant difference between groups for PEFR values as demonstrated by the one-way ANOVA ($F(2,57)=11.55$, $p < 0.05$). There was a statistically significant difference between groups for VC values as demonstrated by the one-way ANOVA ($F(2,57)=14.84$, $p < 0.05$). There was a statistically significant difference between groups for $FEV_{1/}FVC$ values as demonstrated by the one-way ANOVA ($F(2,57)=4.29$, $p < 0.05$). There was a statistically significant difference between groups for MVV values as demonstrated by the one-way ANOVA ($F(2,57)=113.18$, $p < 0.05$).

Discussion

This study aims to determine the anthropometry and spirometry values for three recreational sport groups and the sedentary group. Anthropometric characteristics in turn, are investigated for its association with spirometry values intra-group for the three recreational sport groups and the sedentary group. Inter- group analysis includes a comparison of spirometry values; firstly between individual recreation sport groups compared with the sedentary group and secondly between the three sports groups.

Anthropometric Characteristics

Based on the data acquired from this study anthropometric height, weight and BMI significant differences are reported inter-group (recreational swim, soccer, volleyball group) ($p<0.05$). The BMI mean values among all the sport groups were within healthy weight levels in our study (Kerr, 1995; Nuttall, 2015). More specifically, we found that the swim group presented with low weight and BMI levels in comparison to the other groups in the study. Penaforte *et al.* noticed that a short-term water aerobics program (8 weeks, 3 sessions per week) in obese women caused a significant reduction of weight, BMI, fat mass, arm circumference, and hip circumference (Penaforte *et al.,* 2015). Pereira *et al.* conducted a 12-week water aerobics program in older adults and they recorded a reduction in body mass and a loss of fat mass (Pereira *et al.,* 2018). Swimming is an effective aerobic exercise that causes a decrease in body composition factors (body mass, body mass index, body fat percent and waist circumference) in cohorts of professional athletes and obese individuals (Roelofs *et al*., 2017). From a physiological perspective, regular swimming contributes to the enhancement of glucose uptake into skeletal muscles which activates hormones like adiponectin which favours the oxidation of fat and glucose uptake into muscles (Omar *et al.*, 2021) which supports the finding of low weight and BMI among swimmers in this study.

The soccer group in our study showed weight and BMI levels that were over and above the swim and volleyball groups. Previous studies show that there is a positive relationship between BMI and regular exercise (Bilim *et al.*, 2017). Popovic *et al.* who studied a cohort of professional soccer and volleyball players with a healthy sedentary group to determine anthropometry reported that soccer players demonstrated increased weights compared to volleyball players which concur with the findings of this study (Popovic *et al.,* 2014). With respect to height for the recreational volleyball group in this study, Popovic *et al.* findings contradicts our finding where the recreational volleyball group demonstrated increased heights comparative to the recreational soccer group (Popovic *et al.,* 2014). Martinez-Santos *et al*. observed higher height and weight values in a cohort of elite professional soccer athletes when compared to semi-professional soccer athletes, although body fat and body mass index were not assessed (Martinez-Santos *et al*., 2016). However, it is also expected that BMI may increase in athletes due to the fact that regular exercise increases muscle mass in the body. The mean BMI of the recreational soccer players participating in our study, parallels with the existing literature (Bunc *et al.*, 2015). Therefore, anthropometric variations may be concluded to be sport specific in our study which is aligned with other studies where athletes, who competed in different sport disciplines, differed in their anthropometric characteristics (Stojanovic *et al.*, 2016; Morteza *et al*., 2017).

The sedentary group in our study demonstrated high weight and BMI levels that fall within the overweight BMI grouping as per the BMI categories (Nuttall, 2015). However, it should be reported that the participants for our study were self recruited thus accounting for the possible high BMI level among the sedentary group. Nevertheless, there is sufficient evidence to reinforce the finding that sedentary individuals present with higher body weight and BMI levels when compared to individuals who engage in physical activity and relative to other sporting groups (Peter *et al.*,2013; Popovic *et al*., 2014; Barber-Westin *et al*., 2015; Damoon *et al*., 2018; Olutende *et al.*, 2019). Therefore it may be concluded from the present study that sedentary groups are at greater risk of higher weights and BMI due to the lack of physical activity.

Respiratory Patterns

The data acquired in this study, reinforces the association between physical activity and changes in respiratory parameters. All respiratory patterns for the swim, soccer and volleyball sport groups were within the normal range. The FVC, $FEV_{1,}$ VC, PEFR, FEV_1 ratio and MVV values in this study for the swim group were improved relative to the other sport groups. Regular swimming practice tends to transform elasticity in the respiratory wall and lung which leads to improved pulmonary function. Overall, swimmers' respiratory muscles and diaphragms develop greater pressure due to water immersion thus supporting more effective respiratory muscles and better lung function (Holmen *et al.*, 2002; Ranu *et al.*, 2011; Morais *et al.*, 2012). Cooler water temperatures (21–28 ^{0}C) improve respiratory pattern, reduce breaths per minute and pulse rates (Michalak *et al*., 2015). The loss of body weight due to water buoyancy supports a comparable freedom and range of movement when compared to land exercises such as soccer and volleyball. The facilitating effect of the hydrostatic pressure facilitates greater expiratory volume (Gabrilo *et al*., 2011). The positioning of the diaphragm is also relevant when investigating the effects of water of the lung capacity and functioning. For example, in the horizontal supine position the diaphragm predisposes one to thoracic breathing due to its superior location thus promoting chest flexibility and mobility (Martin-Valero *et al.*, 2012). Furthermore, the horizontal position can reduce "physiological dead space", and promotes blood flow in relation to lung ventilation contributing to increases in lung diffusion capacity. Previously published work supports our study findings for increased lung volume in swimmers when compared with other sports and controls (Bougault *et al.,* 2009; Zlatkovic-Svenda *et al.*, 2016; Lazovic-Popovic *et al*., 2016).

Akhade *et al.* found that regular running practice associated with soccer training produced a positive effect on the lungs (Akhade *et al.*, 2014). Whilst there is an abundance of literature that records a better pulmonary function among soccer players relative to control groups (Prakash *et al.,* 2007; Figueiredo *et al.,* 2009; Singh *et al*., 2012; Vedala *et al.*, 2013; Myrianthefs *et al*., 2014; Singh *et al.*, 2015; Henrique *et al*., 2019; Rani & Indira, 2019), there is limited research that examines soccer with other recreational sporting groups such as swimming and volleyball in particular. Therefore the findings in our study add to the existing body of literature. In our study, the recreational volleyball group demonstrated an overall higher spirometry relative to the recreational soccer group. Volleyball requires players to engage in frequent short episodes of high-intensity exercise, followed by episodes of low-intensity exercise. The high intensity exercise episodes, in conjunction with the duration of the match (90 min), places a demand on the aerobic and anaerobic energy systems. High-intensity intermittent running increases respiratory function (Gaurav and Singh,2013) thus supporting increased VC, FVC, FEV_1 and PEFR in volleyball players relative to control subjects (Basu *et al.,* 2018).

Height and weight and spirometric correlations were noted for the swim, soccer and volleyball group. BMI demonstrated negative correlations with spirometric values among the swim, and volleyball group in our study. When assessing lung volumes and anthropometric characteristics, Morteza *et al*. reported that higher lung volumes are presumed among tall athletes (Morteza *et al.,* 2017). This presumption was not met in the present study as swimmers displayed increased pulmonary values despite the fact that soccer players demonstrated increased height. In keeping with the literature (Myrianthefs *et al.*, 2014) athletes in water-based sports demonstrated higher pulmonary values. Similarly, other authors support that swimmers have larger lung volumes and better pulmonary function (Sable *et al.*, 2012; Pareek and Modak, 2013; Lazovic-Popovic *et al.,* 2016).

Pulmonary function tests were correlated negatively with BMI when investigated in different athletic groups (Littleton, 2012; Kharodi *et al*., 2019; Kochli *et al.,* 2019). In our study, the soccer group showed no correlation with weight and BMI in relation to the spirometry values. In keeping with the literature, athletes increase muscle mass thus demonstrating higher weights as a result of regular training, (Marangoz *et al*., 2016). In the spirometry measurement analysis, between the swim and the sedentary group, only the FEV_1/FVC ratio and the MVV values were significantly different, whilst differences in the PEFR, FEV_1/FVC ratio and the MVV in the soccer and sedentary group was statistically significant. The difference in the FEV_1 and MVV for the volleyball and sedentary group was statistically significant. Active individuals when compared to sedentary individuals have more favourable lung volumes (Atan *et al.,* 2012; Vedala *et al.*, 2012). Minute Ventilatory Volume, measures the ability to breathe in and out as rapidly as possible over 12 seconds (Dempsey *et al.*, 2018) with normal ranges for healthy males between 140 and 180 L/min (McArdle *et al.*, 2015). Athletes generally present with higher spirometry values in comparison with the general population and tend to have a higher MVV due to operating at higher proportions of their maximum ventilatory capacity (Mazic *et al*., 2016; Faull *et al.*, 2016) which agrees with the findings of our study. The MVV for all three sport groups was significantly different but the swim group showed the most difference compared to the soccer and volleyball group. Therefore it can be concluded that the MVV spirometry value in recreational sport groups are improved compared to the sedentary group.

The inter-group differences between the three sport groups in investigation of respiratory patterns were significant. Studies investigating the effect of physical activities on pulmonary patterns support the role of different physical activities on pulmonary patterns (Prakash *et al.*, 2007; Durmic *et al.*, 2015; Mazic *et al.*, 2016). In a comparative study assessing VC, FVC and FEV_1 higher values were recorded among swimmers than soccer players and the control subjects (Myrianthefs *et al.*, 2014; Lazovic-Popovic *et al*., 2016). Soccer players showed significantly higher FVC, FEV_1 and PEFR values when compared to other land based sport disciplines (Tareq *et al.*, 2018). The preceding statements reinforce our finding that respiratory patterns are sport specific.

Conclusion

The study concludes that anthropometric characteristics and spirometry values differ among the swim, soccer and volleyball group. The swim group showed low weight and BMI versus the soccer and volleyball group. Overall the swim, soccer and volleyball groups showed lower weight and BMI levels comparative to the sedentary group. The swim group showed the most improved pulmonary values versus the soccer and volleyball groups. Height and weight measurements are associated with pulmonary function in varied sports groups. Overall the swim, soccer and volleyball groups showed improvements in MVV comparative to the sedentary group. The findings of the study support the use of recreational swimming as a means to reduce obesity caused by sedentary lifestyles which has been identified as a global problem. Swimming is also beneficial for improving respiratory patterns over and above the soccer and volleyball group. Further studies are required to determine the effects of a swimming intervention in a sedentary group to elucidate the difference in body composition and respiratory patterns pre and post intervention.

Strengths and Limitations of the Study

The strength of the study is noted in the unique reporting of the effectiveness of recreational sporting (either land or water based) in respiratory patterns and cytokine profiles. The present study synthesises evidence for recreational sport groups and a sedentary group, that is important and relevant for the modification of health behaviours among sedentary populations in SA. The study sample was limited in that the sample size consisted of 20 athletes per recreational sport group and a sedentary group. Thus, the total sample size only included 80 participants (swim-20, soccer-20, volleyball-20 and sedentary-20), thus the study could have benefitted from larger samples. The participants were self recruited and a more random sampling design would have benefitted the study. The study comprised a cross sectional design and could have benefitted from a longitudinal study design. The study was limited to male participants and does not take into consideration gender differences and its influence on respiratory patterns. The study may be limited with respect to the quantity and intensity of the training for the athletes in the three recreational sport groups. Therefore, the findings of the study must be carefully considered and may be limited in its applicability and generalization to other populations.

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Original Article: Cytokine and Respiratory Profiles in Recreational Athletes and a Sedentary Group

Following the review of literature in Chapter 1, it is clear that there is a lack of studies that examine the cytokine profile and pulmonary function in recreational athletes and a sedentary group. Therefore, chapter three focused on determining the cytokine profile and its association with pulmonary function in recreational swim, soccer and volleyball sport groups and a sedentary group.

The following paper will be submitted to the African Journal for Physical Activity and Health Sciences:

CHAPTER 3:

Cytokine and Respiratory Profiles in Recreational Athletes and a Sedentary Group

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Abstract

Background: There is a lack of scientific evidence demonstrating possible variations that may occur in the resting serum IL-6, IL-10 and TNF-α levels and associations with respiratory patterns among different sport disciplines and a sedentary group. Furthermore, there is a lack of consistency in the data and reproducibility with reference to recreational sport cohorts in South Africa.

Methods: This study investigates cytokine levels and respiratory patterns in a sample of 80 self-recruited participants comprising of 20 participants from each recreational sport subgroups (swim, soccer and volleyball) and a sedentary group. Spirometry values for FVC, FEV_1, PEFR, VC, FEV_1/FVC and MVV were determined across the groups using the American Thoracic Society Recommendations for spirometry. Fasting plasma interleukin (IL) IL-6, IL-10, and Tumor necrosis factor alpha (TNF-α) levels were determined among the recreational sport groups following a two week break from sport training and a sedentary group with ≥ 8 hours of sedentary behaviour per day, using the Beckman Coulter Kit (SA).

Results and Discussion: The respiratory patterns in the swim, soccer, volleyball and sedentary groups were significantly different ($p<0.01$). All the recreational sport groups had significantly increased lung parameters compared to the sedentary group ($p<0.01$). The cytokine expression for IL-10 and TNF-α in the swim, soccer, volleyball and sedentary group were significantly different ($p<0.01$). The study confirms that an increase in anti-inflammatory cytokines such as IL-10 may be associated with an increase in spirometry values and the TNF-α cytokine expression may be associated with a reduction in spirometry values.

Conclusion: Swimming in particular supports improved lung values when compared to other land-based sports such as soccer and volleyball. Long term physical activity even at a recreational level supports a lower inflammatory profile over and above a sedentary group. Further studies with sizeable samples are required to corroborate the findings, in terms of the relationship between cytokine levels and spirometry values. It can be concluded that recreational swimming, soccer and volleyball proves to be of physiological benefit to a sedentary population.

Introduction

Studies investigating the effect of physical activities on pulmonary patterns support the role of different physical activities on pulmonary patterns (Prakash *et al.*, 2007; Durmic *et al.,* 2015; Mazic *et al.,* 2016) whilst other studies reported that pulmonary values between different sport disciplines are statistically insignificant (Wilmore and Costill, 1999; Vitaić *et al.,* 2015). When comparing various cohorts of football players, hockey players, volleyball players, swimmers, basketball players and a control group, significant differences in FVC, FEV_1 and MVV were recorded in favour of all athletic groups with swimmers portraying the best pulmonary function (Mehrotra *et al*., 1998; Myrianthefs *et al.,* 2014). Therefore, one would assume that, athletes are more likely to demonstrate increased spirometry measures than the sedentary counterparts (Durmic *et al.,* 2015; Mazic *et al.,* 2016). However, most of the descriptive data concerning anthropometric and respiratory characteristics come from America and Western Europe (Milanovic *et al*., 2012). Respiratory patterns in individual sport with sedentary groups have been extensively researched, but there is a scarcity noted in the study of multiple recreational sport groups (Sreenivasulu & Begum, 2019). Further investigation is required from a South African cohort in the case of recreational sport groups (Akhade & Muniyappanavar, 2014; Bamne, 2017). Inconclusive findings and the lack of data for pulmonary patterns in a South African cohort of recreational sport groups is needed to address the gap in literature.

Some studies have shown that exercise may alter the cytokine levels (Nieman, 2011; Kim, 2014; Ghafourian *et al*., 2016; Vijayaraghava & Doreswamy, 2017) albeit that the exercise and cytokine association is complex and may be differentially expressed in different sport branches (La Gerche *et al*., 2015). Interleukin 6 (IL-6) and TNF-α act as pro-inflammatory cytokines and play a role in the acute inflammatory response and its levels are elevated when acute moderate to extreme intensity exercise (>85–90% of maximal heart rate) is performed (Bernecker *et al*., 2013; Comassi *et al.,* 2015). However, IL-6 can be both pro and anti-inflammatory in nature (Di Battista *et al.,* 2020) thus increasing the complexity of this particular cytokine. Both IL-6 and IL-10 are associated with the activation of anti-inflammatory cascades, and may also inhibit TNF-α, which is a known mediator of tissue damage (Tanaka & Kishimoto, 2014). Prolonged bouts of intense exercise are characterized by higher concentrations of IL-6 followed by increases in cytokine inhibitors, such as the anti-inflammatory cytokine IL-10 (Hennigar *et al*., 2017). Chronic training on the other hand could reduce the release of IL-6 by skeletal muscle because exercise improves the energy performance of the myocytes (Sponder *et al*., 2017).

There is a lack of scientific evidence demonstrating possible variations that may occur in the resting serum IL-6, IL-10 and TNF-α levels between different sport disciplines. However, some findings have reflected that differences among cytokine levels between individuals who exercised and the control group were not statistically significant (Windsor *et al.*, 2018; Gómez-Rubio & Trapero, 2019). Based on the above contrasting evidence reported in studies with respiratory inflammation and the lack of sport specific studies, the need for further investigation is essential. With reference to the investigation of exercise and cytokine levels, inconsistent findings and a lack of available data for recreational athletes in a South African cohort, the determination of the best inflammatory profile as influenced by recreational sport disciplines is undertaken (Salamat *et al.*,2016; Terink *et al.*,2018). Hence, the present study investigated respiratory profiles as well as cytokine profiles (IL-6, IL-10, TNF-α) in adult males participating in three different recreational sporting branches.

Materials and methods

Participants

The study was conducted between April 2018 and March 2019. A recreational athlete for the purpose of this study is defined as an athlete participating in active sport playing three times a week (60-minute duration per session) (Stamatakis *et al.*,2019; Hadgraft *et al.*,2020). A cross-sectional study included 80 male participants comprising recreational athletes from three subgroups (soccer (20), swimming (20) and volleyball (20) and a sedentary group of 20. The inclusion criteria for recreational athletes are participation in recreational soccer, volleyball or swimming having a training frequency of 3 one hour sessions weekly. Adult males who are 18 years or older are required for the study. Smokers, former smokers, medication usage and medical history with respiratory diseases were excluded from the study. Participants were self-recruited by placing invitational notices at various sports clinics, physiotherapy clinics and local gyms. Participants were informed of the study aim as a means to motivate their interest in pursuing the study. Participants were informed of study protocol and informed consent.

Ethical Approval

Regulatory ethical and institutional approval was obtained from the Biomedical Research Ethics Committee (BREC) of the University of KwaZulu-Natal (UKZN) (BE 012/18), South Africa.

Design

Lung Function Measurements

The spirometry measurements were performed by a trained physiotherapist using the MIR SPIROLAB II spirometer. The American Thoracic Society (ATS) recommendations were followed (Graham *et al.*, 2019). The test was performed in a seated position with the use of a nose clip.

Subjects were required to perform a maximal inhalation, with sealed lips over the mouthpiece, then followed by a rapid maximal exhalation. Subjects continued exhaling for a minimum of 6 seconds to facilitate FEV_1 and FVC measurements. Tests were performed in triplicate until the two highest recorded values varied by less than 3%. Measurements were completed in standard environment conditions based on temperature (18 – 22 ^{0} C), atmospheric pressure (760 mmHg) and a relative atmospheric humidity of 30% - 60% (Durmic *et al*., 2015). Measurements were taken in the morning between 8am and 12am in order to avoid diurnal variations in lung function.

Cytokine Measurement

Groups of 10 participants were taken to the NSN LAB over a period of 8 sessions to collect the resting blood samples. In order to control for circadian rhythm, all testing was performed in the morning hours at the NSN LAB using the Beckman Coulter Access Immuno-Assay System. Enzyme-linked immunosorbent assay (ELISA) (Beckman Coulter Kit, South Africa) was performed for determination of TNF-α, IL-6 and IL-10 levels. Blood samples (6ml) were obtained (antecubital vein) in the recreational athletic and sedentary groups by a medical doctor (Health professional Council of South Africa registered) to ensure uniformity in the collection of blood. The samples were collected, anonymous labels (e.g. SW1 for the first swimming participant, S1 for the first soccer participant, and V1 for the first volleyball participant) were placed on each tube and analysed immediately. The cytokine levels in the samples were determined as per Beckman Coulter South Africa manufacturer kit instruction. The data findings were presented in a table.

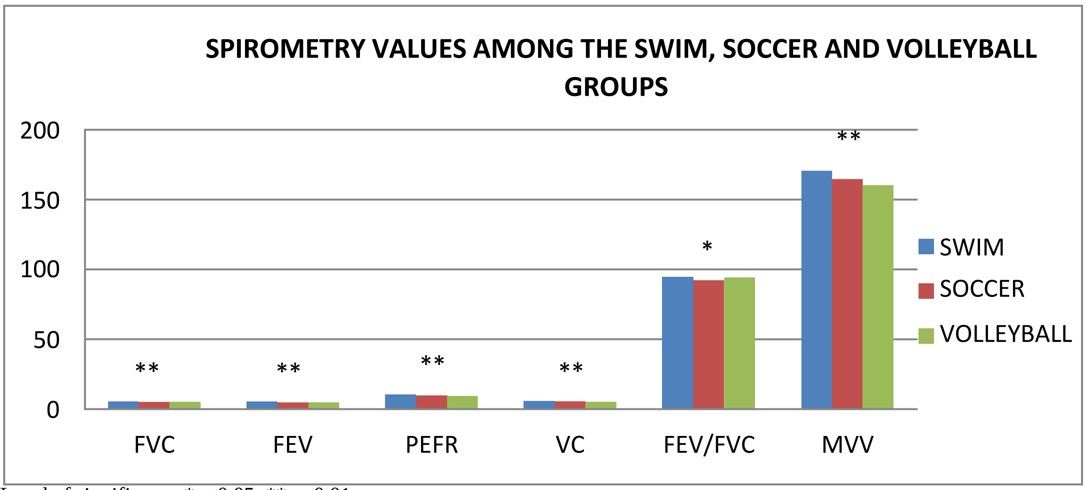
Statistics

IBM Statistical Package for Social Sciences (SPSS) version 27 (Chicago IL, USA) was utilised to analyse the data. Mean and standard deviations were used for presenting the continuous data. The Kolmogorov-Smirnov test assessed the normality of the data. Pearson correlation analysis assessed the strength of the relationship for cytokine and respiratory profiles. A $p<0.05$ value indicated a significant difference.

Results

A) Respiratory Patterns in the Swim, Soccer, Volleyball and Sedentary Groups

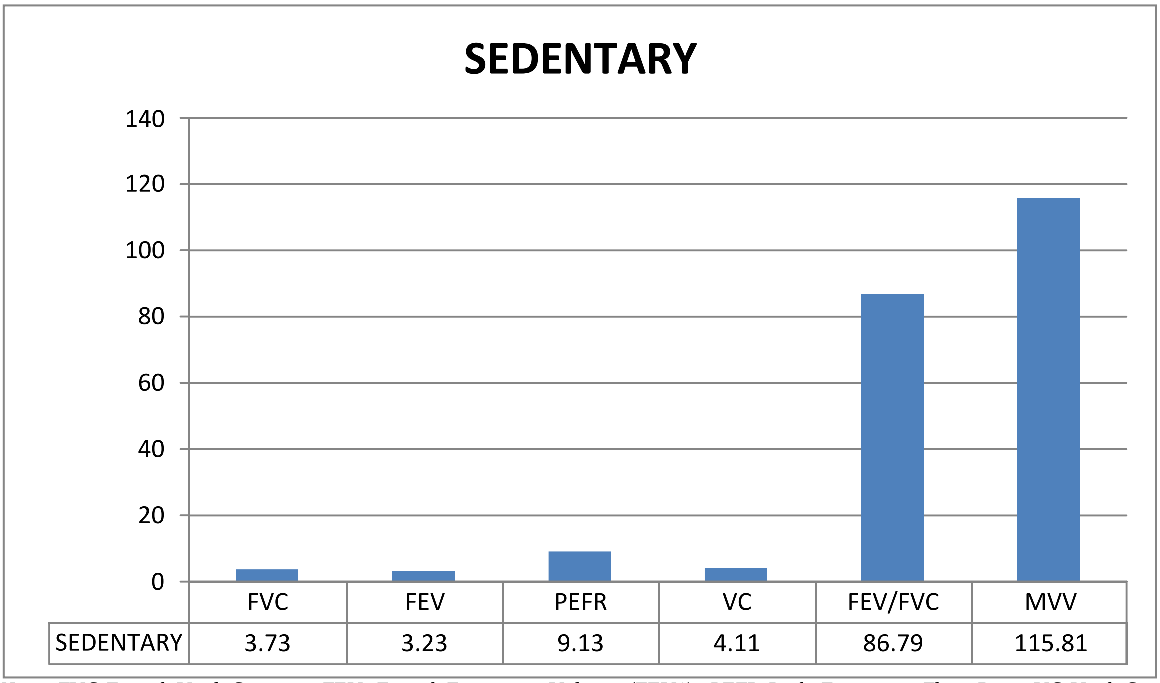
Figure 1 represents the difference in spirometry values among the swim, soccer and volleyball group. Differences in FVC, FEV_1, VC, PEFR and MVV are significant at $p<0.01$ and the FEV_1 ratio difference is significant at $p<0.05$. Figure 2 provides a mean distribution of the respiratory patterns in the sedentary group.



Level of significance *$p<0.05$, ** $p<0.01$.

Figure 1: Spirometry Values among Swim, Soccer and Volleyball Groups

The swim group findings were as follows: FVC - 5.51 L, FEV_1 - 5.21 L, PEFR – 10.51 L/min, VC- 5.63 L, FEV_1/FVC ratio – 94.63% and MVV – 170.66 L/min. The soccer group findings were as follows: FVC - 4.99 L, FEV_1 - 4.59 L, PEFR - 9.86 L/min, VC- 5.34 L, FEV_1/FVC ratio-92.06% and MVV – 164.53 L/min. The volleyball group findings were as follows: FVC - 5.10 L, FEV_1 - 4.82 L, PEFR - 9.30 L/min, VC- 5.11 L, FEV_1/FVC ratio- 94.18% and MVV -160.12 L/min.



Note: FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation.

Figure 2: Mean Distribution of Spirometry Values in the Sedentary Group

The sedentary group findings were as follows: FVC – 3.73 L, FEV_1 – 3.23 L, PEFR - 9.13 L/min, VC- 4.11 L, FEV_1/FVC ratio- 86.79 % and MVV -115.81 L/min.

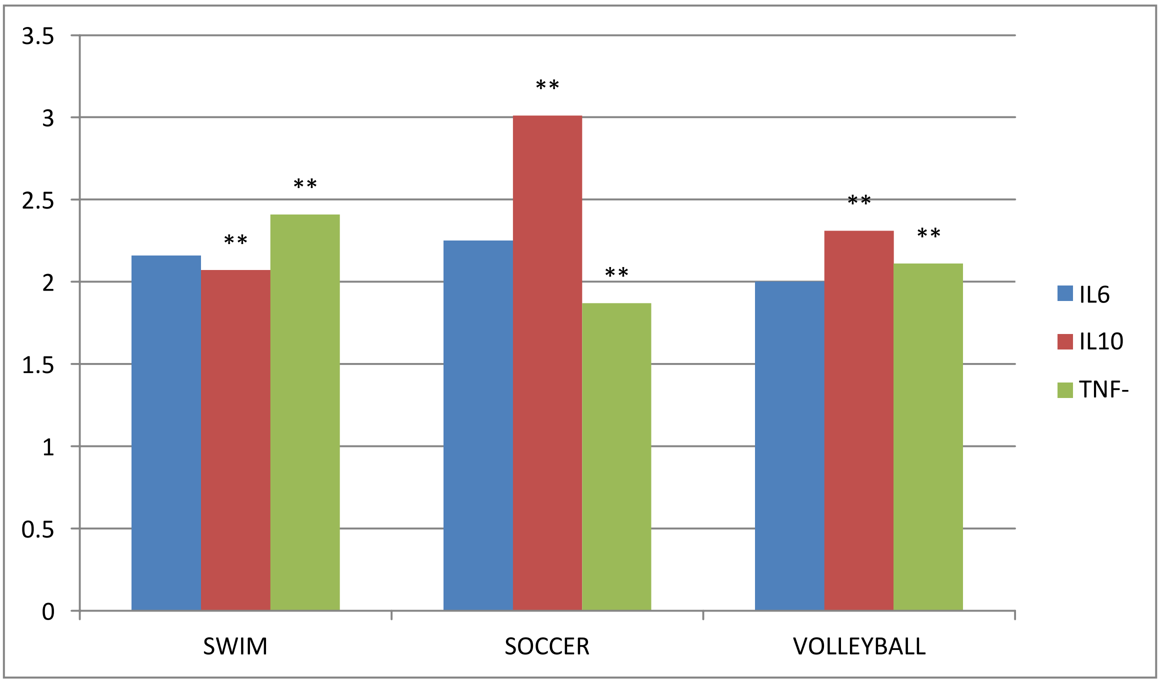
B) Cytokine Profile of the Groups

Table 1: Cytokine Profile of the Groups

GROUP (n=80)		IL-6 (pg/ml)	IL-10 (pg/ml)	TNF-α (pg/ml)
SWIM	Mean	2.16	2.07	2.41
(20)	Std. Deviation	0.23	0.19	0.17
SOCCER	Mean	2.25	3.01	1.87
(20)	Std. Deviation	0.23	0.16	0.60
VOLLEYBALL	Mean	2.00	2.31	2.11
(20)	Std. Deviation	0.69	0.15	0.24
SEDENTARY	Mean	10.72	9.91	11.04
(20)	Std. Deviation	0.74	1.14	1.58

Note: The cytokine profile are indicated as IL6 –Interleukin 6, IL10- Interleukin 10 and TNF-α Tumor Necrosis Factor Alpha.

Table 1 represents the cytokine profile for IL-6, IL-10 and TNF-α. The cytokine profile for the swim group is as follows: IL-6 (2.16 pg/ml), IL-10(2.07pg/ml) and TNF-α (2.41pg/ml).



Note: The cytokine profile are indicated as IL6 –Interleukin 6, IL10- Interleukin 10 and TNF-α Tumor Necrosis Factor Alpha. The level of significance **$p<0.01$.

Figure 3: Frequency Distribution of Cytokine Profile for the Swim, Soccer, Volleyball and Sedentary Group

The cytokine profile for the soccer group follows (Figure 2): IL-6 (2.25 pg/ml), IL-10 (3.01pg/ml) and TNF-α (1.87pg/ml). The cytokine profile for the volleyball group follows: IL-6 (2.00 pg/ml), IL-10

(2.31pg/ml) and TNF-α (2.11pg/ml). The cytokine profile for the sedentary group follows: IL-6 (10.72 pg/ml), IL-10 (9.91pg/ml) and TNF-α (11.04 pg/ml).

C) Relationship between Cytokine and Spirometry Values Intra-group

Correlations between IL-6 and pulmonary values lacked significance ($p>0.05$) for the three recreational sport groups and the sedentary group as represented in Table 2.

Table 2: Correlation of IL-6 and Spirometry among the Groups

Group (n=80)		FVC	FEV	PEFR	VC	FEV/FVC	MVV
Swim (20)	Pearson Correlation	0.14	0.16	0.29	-0.02	0.01	0.19
	Sig. (2-tailed)	0.56	0.5	0.21	0.95	0.97	0.42
Soccer (20)	Pearson Correlation	0.01	-0.04	-0.31	-0.24	-0.09	-2.70
	Sig. (2-tailed)	0.96	0.89	0.18	0.32	0.69	0.25
Volley Ball (20)	Pearson Correlation	-0.27	-0.33	-0.14	-0.34	-0.39	0.04
	Sig. (2-tailed)	0.24	0.16	0.54	0.14	0.88	0.86
Sedentary (20)	Pearson Correlation	0.14	0.16	0.29	-0.02	0.01	0.19
	Sig. (2-tailed)	0.56	0.5	0.21	0.95	0.97	0.42

Note: A significant difference in IL-6 values with spirometry values is shown by $p<0.05$. Spirometry values [FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation].

No significant correlations between IL-10 and spirometry values were reported with the recreational athletes ($p>0.05$) in Table 3. There was a significant correlation ($p<0.05$) in the case of FVC, PEFR and the FEV/FVC ratio in the sedentary group.

Table 3: Correlation of IL10 and Spirometry among Recreational Athletes

GROUP (n=80)		FVC	FEV	PEFR	VC	FEV/FVC	MVV
Swim (20)	Pearson Correlation	0.31	0.24	0.05	0.19	-0.23	0.18
	Sig. (2-tailed)0.18	0.18	0.31	0.83	0.43	0.32	0.46
Soccer (20)	Pearson Correlation	-0.06	-0.52	-0.01	-0.14	-0.02	-0.03
	Sig. (2-tailed)	0.81	0.83	0.95	0.55	0.93	0.90
Volleyball (20)	Pearson Correlation	-0.21	-0.23	-0.16	-0.32	-0.21	0.14
	Sig. (2-tailed)	0.37	0.33	0.51	0.17	0.38	0.56
Sedentary (20)	*Pearson Correlation*	0.48*	0.33	0.45*	0.43	0.49*	0.34
	Sig. (2-tailed)	0.03	0.16	0.05	0.06	0.29	0.18

Note: A significant difference in IL-10 values with spirometry values is shown by $p<0.05$. Spirometry values [FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation].

Table 4: Correlation of TNF-*α* and Spirometry Values Among Groups

Groups (n=80)		FVC	FEV	PEFR	VC	FEV/FVC	MVV
Swim (20)	Pearson Correlation	-0.06	-0.04	0.04	0.12	0.06	-0.09
	Sig. (2-tailed)	0.79	0.87	0.86	0.63	0.81	0.71
Soccer (20)	Pearson Correlation	-0.40	-0.40	-0.24	-0.24	0.29	0.26
	Sig. (2-tailed)	0.08	0.08	0.32	0.31	0.22	0.27
Volleyball (20)	Pearson Correlation	-0.38	-0.47*	0.21	-0.54*	-0.58**	0.3
	Sig. (2-tailed)	0.09	0.04	0.38	0.01	0.00	0.21
Sedentary (20)	Pearson Correlation	0.14	0.16	0.29	-0.02	0.01	0.19
	Sig. (2-tailed)	0.56	0.5	0.21	0.95	0.97	0.42

Note: A significant difference in TNF-α values with spirometry values is shown by *p<0.05; **p<0.01. Spirometry values [FVC-Forced Vital Capacity, FEV_1-Forced Expiratory Volume (FEV1), PEFR-Peak Expiratory Flow Rate, VC-Vital Capacity, FEV1/FVC ratio- Forced Expiratory Volume-Forced Vital Capacity Ratio and MVV- Maximal Voluntary Ventilation].

No correlation was reported between TNF-α and the spirometry values (p>0.05) in the swim and soccer group and sedentary group. TNF-a correlated with FEV_1 (r=0.47), VC (r=0.54) and the FEV_1/FVC ratio (r=0.58, p<0.05) in the volleyball players.

D) Comparison of Cytokine Profiles between the Recreational Sport Group and the Sedentary Group

Table 5: Comparison of IL-6, IL-10 and TNF-*α* values between the Swim and Sedentary Group

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
IL-6	Equal variances assumed	33.275	.000	-49.345	38	.000	-8.55400	.17335	-8.90493	-8.20307
	Equal variances not assumed			-49.345	22.645	.000	-8.55400	.17335	-8.91291	-8.19509
IL-10	Equal variances assumed	29.174	.000	-30.335	38	.000	-7.83400	.25825	-8.35679	-7.31121
	Equal variances not assumed			-30.335	20.025	.000	-7.83400	.25825	-8.37265	-7.29535
TNF-α	Equal variances assumed	32.673	.000	-24.305	38	.000	-8.62450	.35485	-9.34285	-7.90615
	Equal variances not assumed			-24.305	19.424	.000	-8.62450	.35485	-9.36611	-7.88289

In the case of the IL-6, IL-10 and TNF-α values p< 0.05, we can reject the null hypothesis and conclude that these values for the swim and the sedentary group are significantly different.

Based on the results, we can state the following:

- There was a significant difference in the IL-6 values between the swim and sedentary group ($t_{22.65}$ = -49.35, $p < 0.05$). The IL-6 value was 8.55 lower for the swim group than the sedentary group.
- There was a significant difference in the IL10 values between the swim and the sedentary group ($t_{20.03}$ = -30.34, $p < 0.05$). The IL-10 value for the swim group was 7.83 lower than the sedentary group.
- There was a significant difference in the TNF-α values between the swim and the sedentary group ($t_{19.42}$ = -24.31, $p < 0.05$). The TNF-α for the swim group was 8.62 lower than the sedentary group.

Table 6: Comparison of IL-6, IL-10 and TNF-*α* values between the Soccer and Sedentary Group

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
IL-6	Equal variances assumed	35.933	.000	-48.846	38	.000	-8.46950	.17339	-8.82051	-8.11849
	Equal variances not assumed			-48.846	22.665	.000	-8.46950	.17339	-8.82848	-8.11052
IL-10	Equal variances assumed	32.422	.000	-27.040	38	.000	-6.95750	.25731	-7.47839	-6.43661
	Equal variances not assumed			-27.040	19.741	.000	-6.95750	.25731	-7.49468	-6.42032
TNF-α	Equal variances assumed	38.306	.000	-25.976	38	.000	-9.17300	.35314	-9.88789	-8.45811
	Equal variances not assumed			-25.976	19.054	.000	-9.17300	.35314	-9.91198	-8.43402

In the case of the IL-6, IL-10 and TNF-α values p< 0.05, we can reject the null hypothesis and conclude that these values for the soccer and the sedentary group are significantly different.

Based on the results, we can state the following:

- There was a significant difference in the IL-6 values between the soccer and sedentary group ($t_{22.67}$ = -48.85, $p < 0.05$). The IL-6 value was 8.47 lower for the soccer group than the sedentary group.
- There was a significant difference in the IL10 values between the soccer and the sedentary group ($t_{19.74}$ = -27.04, $p < 0.05$). The IL-10 value for the soccer group was 6.96 lower than the sedentary group.
- There was a significant difference in the TNF-α values between the soccer and the sedentary group ($t_{19.05}$ = -25.98, $p < 0.05$). The TNF-α, for the soccer group was 9.17 lower than the sedentary group.

Table 7: Comparison of IL-6, IL-10 and TNF-*α* values between the Volleyball and Sedentary Group

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
IL-6	Equal variances assumed	4.515	.040	-38.688	38	.000	-8.75250	.22623	-9.21048	-8.29452
	Equal variances not assumed			-38.688	37.811	.000	-8.75250	.22623	-9.21055	-8.29445
IL-10	Equal variances assumed	31.410	.000	-29.733	38	.000	-7.64150	.25701	-8.16178	-7.12122
	Equal variances not assumed			-29.733	19.651	.000	-7.64150	.25701	-8.17822	-7.10478
TNF-α	Equal variances assumed	28.306	.000	-25.007	38	.000	-8.92450	.35688	-9.64697	-8.20203
	Equal variances not assumed			-25.007	19.864	.000	-8.92450	.35688	-9.66926	-8.17974

In the case of the IL-6, IL-10 and TNF-α values $p < 0.05$, we can reject the null hypothesis and conclude that these values for the volleyball and the sedentary group are significantly different.

Based on the results, we can state the following:

- There was a significant difference in the IL-6 values between the volleyball and sedentary group ($t_{37.81}$ = -39.69, $p < 0.05$). The IL-6 value was 8.75 lower for the volleyball group than the sedentary group.

- There was a significant difference in the IL10 values between the volleyball and the sedentary group ($t_{19.65}$ = -29.73 $p < 0.05$). The IL-10 value for the volleyball group was 7.64 lower than the sedentary group.
- There was a significant difference in the TNF-α values between the volleyball and the sedentary group ($t_{19.86}$= -25.00, $p < 0.05$). The TNF-α, for the volleyball group was 8.92 lower than the sedentary group.

Table 8: Analysis of Variance Inter-group (between groups) and Intra-group (within groups) for the Recreation Sport Groups

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
IL-6	Between Groups	.844	2	.422	2.176	.123
	Within Groups	11.059	57	.194		
	Total	11.903	59			
IL-10	Between Groups	8.488	2	4.244	154.017	.000
	Within Groups	1.571	57	.028		
	Total	10.058	59			
TNF-α	Between Groups	3.017	2	1.509	51.466	.000
	Within Groups	1.671	57	.029		
	Total	4.688	59			

Table 8 represents the ANOVA results for the three recreational sport groups. There was a lack of statistical significance in the difference between IL-6 values among the swim, soccer and volleyball group. There was a statistically significant difference between groups for IL-10 values as demonstrated by the one-way ANOVA ($F(2,57) = 154.02$, $p < 0.05$). There was a statistically significant difference between groups for TNF-α values as demonstrated by the one-way ANOVA ($F(2,57) = 51.47$, $p < 0.05$).

Discussion

In the present study we determined the respiratory and cytokine profiles in the three sport groups and the sedentary group. Thereafter we examined the correlation between individual cytokine levels (IL-6, IL-10, and TNF-α) and respiratory patterns (FVC, FEV_1, PEFR, VC, FEV_1/FVC and MVV) in three recreational sport groups (swim-20, soccer-20 and volleyball-20) and a sedentary group of 20.

In our study, swimmers showed increased lung volumes and respiratory capacity relative to both the recreational soccer and volleyball groups which is in agreement with previously published literature (Naeije& Chesler, 2012; Sable *et al*., 2012; Lazovic-Popovic *et al*., 2015; Lazovic-Popovic *et al.*, 2016; Bovard *et al*., 2018). Anatomical and mechanical factors may account for the differences in lung volume in swimmers as noted in our study (Howard *et al.,* 2012; Atan, 2013; Myrianthefs *et al.*, 2013; Durmic *et al.,* 2017; Cicek *et al.,* 2018; Hernández-Álvarez *et al.,* 2018; Rawashdeh & Alnawaiseh, 2018). From a physiological perspective swimming can improve breathing patterns, lower breaths per minute and the pulse rate due to the effect of buoyancy, temperature, pressure and resistance of the water (Michalak *et al.,* 2015). The spirometry values in the swim, soccer and volleyball groups were improved over and above the sedentary group in our study. Active individuals when compared to sedentary individuals have more favourable lung volume (Atan *et al.,* 2012; Durmic *et al.,* 2015; Marangoz *et al.,* 2016) which supports our finding.

Lower levels in the IL-6 cytokine expression in the three recreational sport groups in our study are consistent with previous studies (Jankor & Jemiolo, 2004; Corpeleijn *et al.,* 2005; Fitzgerald *et al.,* 2012; Vianna *et al.,* 2014; Jürimäe *et al.,* 2018). Long-term exercise training as evidenced in the case of the three sample sport groups of this study reduced plasma inflammatory states (Kleiner *et al.,* 2013; Han *et al*., 2019). Long term physical activity is associated with lower peripheral inflammatory mediator levels relative to sedentary lifestyles (Windsor *et al.,* 2018; Gómez-Rubio & Trapero,2019). In our study the volleyball group showed the lowest IL-6 level followed by the swim and soccer group. Our finding contrasts with other studies in that the swim groups in other studies had the lowest IL-6 Levels. Swimming is different from land-based sports, in that swimming is predominantly concentric and low impact, which causes different biochemical reactions compared to land-based sports. Swimming also induces a lower inflammatory response and less muscle damage, compared to eccentric activities which induce considerable inflammation (Peake *et al.,* 2017). It is also possible that the reduced muscle forces generated in a water-based sport can explain the lower exercise related muscle damage compared to land sports. There also seems to be a relationship with IL-6 responses and the intensity of the exercise (Pedersen *et al.,* 2012; Muñoz-Cánoves *et al.,* 2013 Niemelä *et al.,* 2016). Mendham *et al.* suggested that the number of muscle groups required during exercise may increase the IL-6 concentration, and postulated that football and volleyball players who utilised both the upper and lower limb muscle groups may experience higher IL-6 levels (Mendham *et al.*, 2015). The finding of Mendham *et al* agrees with our findings for the IL-6 values for the soccer group but disagrees with our findings for the IL-6 expression and the volleyball group (Mendham *et al.*, 2015).

The swim, soccer and volleyball group showed lower pro-inflammatory IL-10 expressions compared with the sedentary group in our study. There are several possible reasons for the discrepant finding. Firstly one has to consider that age differences have been associated with varying inflammatory profiles (Howard *et al.,* 2015). Also given the potential impact of dietary habits on inflammatory profiles (Nilsson *et al.,* 2019) the risk of differential dietary intake among cohorts may serve as a confounding variable when elucidating the link between sedentary behaviour and inflammation. The modulating effects of IL-6 and TNF-α on the IL-10 expression may also account for the elevated IL 10-levels in our study since the IL-6 and TNF-α were elevated in the sedentary group. The sedentary sample was self-recruited which may limit the applicability of the cytokine expression to other young male sedentary populations.

In the swim, soccer, volleyball and sedentary group the association between IL-6 expression and respiratory patterns was statistically insignificant. Higher levels of IL-6 are typically associated with a lower FEV_1 and FVC (Donaldson *et al*., 2005; Thorleifsson *et al*., 2009; Gimeno *et al*., 2011). A negative correlation with IL-6 and FEV_1 is reported in studies with respiratory inflammation (Abd El-Maksoud *et al*.,2010; Attaran *et al*.,2010; Ramadan *et al*. 2010) however, no correlation was reported in similar studies between the IL-6 value and FEV_1 and FEV_1 /FVC values (Akbulut *et al*.2009; El-Shimy *et al.*,2014). Our study finding for the IL-6 cytokine agrees with Akbulut *et al*. and El-Shimy *et al.* (Akbulut *et al*.2009; El-Shimy *et al.,* 2014). In the swim, soccer, and volleyball group the association between IL-10 cytokine expression and respiratory patterns was statistically insignificant. However, the IL-10 expression was associated with FVC, PEFR and the FEV_1 ratio, in the sedentary group. Studies support a potential role for IL-10 in modulating an inflammatory response and lung function (Williams *et al*., 2015; LeVan *et al.,* 2018). In the swim, soccer and sedentary group the association between TNF-α expression and respiratory patterns was statistically insignificant. TNF-α correlated negatively with spirometric values in the volleyball group which agrees with previously published work (Gan, 2004; Rong *et al.*, 2008).

Conclusion

Swimming in particular supports improved lung values when compared to other land-based sports. Long term swimming exercise supports a low inflammatory profile. Further studies with sizeable samples are required to corroborate the findings, in terms of the influence of cytokine levels on spirometry values. Physical activity reduces inflammation thus reducing the severity of infections. The use of recreational physical activity may redice the respiratory complications arising from COVID-19.

Strengths and Limitations of the Study

The study was limited with respect to the sample size which only included 80 participants (swim-20, soccer-20, volleyball-20 and sedentary-20), thus the study could have benefitted from larger samples. The participants were self recruited and a more random sampling design would have benefitted the study. The study comprised a cross sectional design and could have benefitted from a longitudinal study design. The study may be limited with respect to the quantity and intensity of the training for the athletes in the three recreational sport groups. Therefore, the findings of the study must be carefully considered and may be limited in its applicability and generalization to other populations. Nevertheless, the study synthesized evidence with reference to respiratory patterns and cytokine profiles to reinforce the positive physiological benefit of exercise for sedentary population.

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CHAPTER 4:
SYNTHESIS, CONCLUSIONS AND RECOMMENDATIONS

4.1 Synthesis

This thesis comprises of two sub-projects connected together to address the main objective for the study which was to investigate respiratory and cytokine patterns among 80 participants (swim-20, soccer-20, volleyball-20 and sedentary-20). The key findings generated from this thesis are outlined below and placed in the context of other studies. The general conclusions and recommendations for further studies are presented.

4.1.1 Anthropometric Characteristics and Respiratory Patterns in Recreational Athletes and the Sedentary Group

In Chapter 2 the anthropometric and respiratory patterns of the swim, soccer and volleyball group were determined. We hypothesised that anthropometric characteristics would be sport specific among the three recreation sport groups (swim, soccer and volleyball). The anthropometric characteristics and respiratory patterns were determined for the sedentary group. We hypothesised that respiratory patterns in the recreational sport groups would be better over the sedentary group.

4.1.1.1 Anthropometric Characteristics in the Swim, Soccer and Volleyball Group

The anthropometric characteristics were determined among the three recreational sport groups. All three sport groups were categorised as having a healthy weight based on their BMI in the present study. The swim group reflected a low weight and BMI level versus the soccer and volleyball players. Soccer players presented with higher weights and BMI versus the swim and volleyball group. The volleyball group presented with weight and BMI higher than the swim group but lower than the soccer group.

Previous research reported that athletes' who competed in different sport disciplines including swimming, differed in their physical and physiological characteristics (Barber-Westin *et al*., 2015; Stojanovic *et al.,* 2016; Morteza *et al*., 2017). Swimming has proven to be an effective aerobic exercise that supports a reduction in body composition factors (body mass, body mass index, body fat percent and waist circumference) (Roelofs *et al*., 2017) which reinforces the low weight and BMI among the swim group in the present study. Popovic *et al.* (2014) reported that soccer players were significantly heavier than other sporting groups. The weight finding for soccer players in this study is in alignment with Popvic *et al*.(2014) Con *et al.* (2012) found that the average BMI value of volleyball players was 23.4 kg/m^2 whilst Ergin and Bereket found the average values of volleyball players in their studies as follows: body weight being 77.2kg and BMI of 21.5 kg/m^2 (Ergin & Bereket, 2011; Con *et al*., 2012). The average body weight and BMI for the volleyball players in our study was lower comparative to their findings. This could be attributed to the fact that the cohort of volleyball players investigated in their studies was elite volleyball athletes with a longer history of training versus the volley players in our study. Therefore it can be concluded that the anthropometric characteristics for the study wassport specific and the hypothesis has been met.

4.1.1.2 Anthropometric Characteristics in the Sedentary Group

Based on the weight and BMI value, the sedentary group in our present study was categorized as being overweight bordering onto obesity (Nuttall, 2015). Trends in increasing SB among males older than 18 years of age are associated with higher BMI and waist circumference (Micklesfield, *et al.*, 2021). We did not include body composition measures which could have benefitted the interpretation of the BMI in the sedentary group. The body composition measure can be included in future studies for sedentary populations.

4.1.1.3 Key Findings based on Anthropometric Characteristics for the Recreational Sport Groups and the Sedentary Group

Therefore, based on our findings it may be recommended that being consistently more active in any of the three sports being swimming, soccer or volleyball is associated with more favourable anthropometric measures among South African males. Given the high burden of overweight and obesity in SA (Ng *et al*., 2014) a renewed focus on lifestyle behaviour modification through the inclusion of recreational sports such as swimming, soccer or volleyball will be beneficial for sedentary populations. Furthermore, Hajifathalian *et al.* (2020) has explained that obesity is associated with worse outcomes in COVID-19 patients, thus a change that includes physical activity is imperative. Whilst the nature of the anthropometric findings are relevant for both the sport population and the sedentary population, due to the self-recruitment of participants, the anthropometric findings of the study may be limited in its applicability and generalisability.

4.1.1.4 Respiratory Patterns in the Swim, Soccer and Volleyball Group

The spirometry values for swim, soccer and volleyball ball were all within normal rages for health adult males and the spirometry findings between the three sport groups were significantly different. The FVC, $FEV_{1,}$ VC, PEFR, FEV_1/FVC and MVV were higher in swimmers versus the soccer and volleyball group. The study findings support previously published work that reported increased lung volume in swimmers due to various water based factors including buoyancy, temperature, pressure, and resistance (Holmen *et al.*, 2002; Prakash *et al.*, 2007; Bougault *et al.*, 2009; Lazovic-Popovic *et al*., 2016; Zlatkovic-Svenda *et al.*, *2*016; Rani & Indira, 2019).

The soccer group in this study had higher PEFR, VC and MVV levels versus the volleyball group. Akhade *et al.* (2014) found that regular running practice in soccer training improved the lung functioning which could account for the higher values in these spirometry measures. This finding is consistent with other studies, which postulated that athletes who engage in aerobic exercise experienced pulmonary improvement, due to lung expansion resulting in a larger volume of air introduced into the airways and a widening of the respiratory tract (Park & Han, 2017; Rawashdeh & Alnawaiseh, 2018). Our findings agrees with that of Tareq *et al*. who compared futsal and soccer players and showed significantly higher FVC, FEV1 and PEFR values in the soccer cohort (Tareq *et al.,* 2018).

The volleyball group had higher FVC and FEV_1 values compared to the soccer group but these values were lower than the swim group in our study. Volleyball games increase respiratory function (Gaurav and Singh, 2013) as demonstrated in a study that compared volleyball players and controls. Furthermore, VC, FVC, FEV_1 and PEFR were significantly higher for volleyball players in contrast to the basketball players and the control group (Basu *et al.,* 2018).

4.1.1.5 Respiratory Patterns in the Sedentary Groups

The FVC, PEFR, VC and $FEV_{1/}$FVC ratio were within normal ranges in the sedentary group in the present study, but the FEV_1 and MVV was lower than the normal range for males (McCardle *et al.,* 2015; Basu *et al.,* 2018). Many studies report that FEV_1, is a strong indicator of lung function, as it declines noticeably due to a sedentary lifestyle (Mehta *et al.,* 2016; Kaneko, 2020). In addition, a high BMI as reported in the sedentary group for our study may be associated with a FEV_1 decline (Thomas *et al.,* 2019). In fact, a sedentary lifestyle can cause the deterioration of respiratory indices and may potentially increase the risk for developing chronic obstructive pulmonary disease (Makwana *et al.,* 1988; Peter *et al*., 2013; İşleğen & Dağlıoğlu, 2020).

4.1.1.6 Key Findings based on Respiratory Patterns for the Recreational Athletes and the Sedentary Group

In the analysis for respiratory patterns among the recreational sport groups in our study, the swim group demonstrated improved spirometry values over and above the soccer and volleyball group. The inter-group differences between the three sports in investigation of respiratory patterns were significant, therefore it can be concluded that respiratory patterns are sport specific. The swim, soccer and volleyball sport groups in our study showed better respiratory patterns over the sedentary group. Therefore it can be concluded that respiratory patterns in recreational sport groups are improved compared to the sedentary group.

4.1.1.7 Relationship between Anthropometric Characteristics and Respiratory Patterns

In the swim group, FVC, FEV_1, PEFR and MVV correlated positively with height, strongest correlation reported in FVC and height. FVC, FEV_1 and MVV correlated with weight in the swim group; strongest correlation being MVV and weight. VC correlated negatively with BMI among the swimmers. In keeping with the literature, higher pulmonary measures prevail among athletes in water sports (Myrianthefs *et al.,* 2014) and swimmers are known to have larger lung volumes and better pulmonary function (Sable *et al.,* 2012; Pareek and Modak, 2013; Lazovic-Popovic *et al.,* 2016). Our study showed that among the swim, soccer and volleyball group PEFR showed no association with height in the soccer and volleyball group which contrasts with Basu *et al.* where height and body weight were demarcated as chief determinants of PEFR in a cohort of volleyball, basketball and sedentary groups when anthropometric characteristics were concerned (Basu et al., 2018).

In the soccer group, significant correlations were noted with height among all the spirometry values with the exception of MVV. The strongest correlation with height was noted with FEV_1. These findings concur with other studies that investigated anthropometric characteristics and spirometry values. Anthropometric characteristics such as age, height, weight, and BMI correlated with FVC, and PEFR (Jiwtode and Raikar, 2017; Chandrashekhar *et al.*, 2020). Height, weight and body surface area were found to be positively correlated to FVC with height demonstrating the strongest correlation (Pawar *et al*., 2011; Jiwtode *et al.*, 2017).

In the volleyball group, FVC, FEV_1, FEV_1/FVC and VC correlated with height; strongest positive correlation being FEV_1 and height. FVC and FEV_1 correlated equally with weight and BMI correlated negatively with FVC, $FEV_{1,}$ FEV_1/FVC and VC with the strongest correlation being VC. Pulmonary function tests negatively correlated with BMI when investigated in athletes (Kharodi *et al*., 2019; Kochli *et al.*, 2019). FVC has shown an inverse association with BMI (Durmic *et al.*, 2015; Mazic *et al.*, 2016) thus highlighting the relationship between the two measures.

In the sedentary group, FVC, FEV_1, FEV_1/FVC VC and PEFR correlated with height with the strongest correlation noted for FVC and VC. There was a correlation with MVV and weight in the sedentary group with a negative association between FVC and BMI. Therefore, it is evident that height and weight were significantly correlated with the majority of the pulmonary function parameters in the three recreational sport groups and the sedentary group.

4.1.2 Cytokine Levels and Pulmonary Function in Recreational Athletes

Chapter three determined the cytokine levels and investigated the relationship with cytokine values and respiratory patterns.

4.1.2.1 Cytokine Levels in the Recreational Athlete Groups and the Sedentary Group

Swim, soccer and volleyball groups showed lower levels of IL-6 when compared to the normal range for IL-6 but in the case of the IL-10 cytokine, all three sport groups had values within the normal range. The TNF- α levels in all three sport groups were lower than the normal range (Kim *et al.*, 2011). Training as evidenced in the three recreational sport groups in our study showed reduced plasma inflammatory states. Lower cytokine measures with athletes are common with prior studies (Jankor & Jemiolo, 2004; Corpeleijn *et al.*, 2005; Fitzgerald *et al*., 2012; Jürimäe *et al.*, 2018). Physical activity is associated with lower level inflammatory mediators when compared with sedentary lifestyles and favours an anti-inflammatory status, which appears to be the key factor in improving health, mainly in chronic diseases (Scheffer & Latini, 2020). It is generally accepted that long term exercise improves the inflammatory profile by decreasing cytokine production (Thorpe and Sunderland, 2012; Han *et al*., 2019).

The IL-6 values were not statistically significant between the three sport groups, but IL-10 and TNF-α were statistically significant between the groups. In keeping with the literature, the type, duration and intensity of the sport produces various cytokine responses (Beavers *et al.,* 2010) with specific emphasis note in the IL-6 cytokine (Kaminski *et al*., 2009; Ertek & Cicero, 2012). Studies support that the cytokine profile for IL-6, and TNF-α values were lower in soccer players relative to the control group (Souglis *et al*., 2015) but in our study, only TNF-α and Il-10 showed sport specific differences.

In the sedentary group, the IL-6, IL-10 and TNF-α level were higher than the normal ranges (Kim *et al.,* 2011). Associations have been evidenced between prolonged sedentary time and systemic inflammation which reinforces the finding in this study with reference to elevated pro inflammatory cytokine Il-6 and TNF- α (Hamer *et al.*, 2015; Howard, *et al*., 2016). The IL-10 expression was also elevated in the sedentary group in our study. Previous findings show higher levels of IL-10 expression in physically active populations when compared to sedentary older men (Ferrer *et al.,* 2018; Cerqueira *et al.,* 2020) which contrasts with our findings for IL-10. There are several possible reasons for the discrepant finding. Firstly one has to consider that their study included older sedentary men whereas our study looked at younger sedentary men and age differences have been associated with varying inflammatory profiles (Howard *et al.,* 2015). Also given the potential impact of dietary habits on inflammatory profiles (Nilsson *et al.,* 2019) the risk of differential dietary intake among cohorts of differential sedentary populations may serve as a confounding variable when elucidating the link between sedentary behaviour and inflammation. The modulating effects of IL-6 and TNF-α on the IL-10 expression may also account for the elevated IL 1-levels in our study. However, the sedentary sample was self-recruited which may limit the applicability of the cytokine expression to other young male sedentary populations.

4.1.2.2 Relationship between Cytokine Levels and Pulmonary Values in Recreational Athletes and the Sedentary Group

In the swim, soccer, volleyball and sedentary group the association between cytokine expression and respiratory patterns was statistically insignificant for the IL-6 expression. Higher levels of IL-6 are typically associated with a lower FEV_1 and FVC (Donaldson *et al*., 2005; Thorleifsson *et al*., 2009; Gimeno *et al*., 2011). A negative correlation with IL-6 and FEV_1 is reported in studies with respiratory inflammation (Abd El-Maksoud *et al*.,2010; Attaran *et al*.,2010; Ramadan *et al*. 2010) however, no correlation was reported in similar studies between the IL-6 value and FEV_1 and FEV_1/FVC values (Akbulut *et al*.2009; El-Shimy *et al.*,2014). Our study findings for the IL-6 cytokine agrees with Akbulut *et al*. and El-Shimy *et al.* (Akbulut *et al*.2009; El-Shimy *et al*.,2014).

In the swim, soccer and volleyball group the association between the IL-10 cytokine expression and respiratory patterns was statistically insignificant. The correlation analysis showed that IL-10 cytokine expression correlated with spirometric values (FVC, PEFR, and FEV_1/FVC ratio) in the sedentary groups. This suggests that the effect of the anti-inflammatory cytokine may have a positive effect on respiratory patterns.The cytokine expression for IL-6, IL-10 and TNF-α was significant in the comparison between the swim, soccer, volleyball and sedentary groups. There was no reported association with TNF-α and spirometry values in the swim, soccer and sedentary group in our study. In our study TNF-α correlated negatively with spirometric values (FEV_1, FEV_1/FVC and VC) in the volleyball group which agrees with previously published work (Gan, 2004; Rong *et al.,* 2008). In the case of TNF-α level Amer *et al*. (2010) reported a negative correlation with FEV_1, but Abd El-Maksoud *et al*. (2010) reported no correlation between TNF-α and FEV_1 but the study did not compare associations in different sports.

4.2 Conclusions

Based on the study findings, anthropometric characteristics and respiratory patterns are sport-specific. Height and weight are significant determinants of respiratory patterns for both the recreational sport groups and the sedentary group. BMI is a determinant of respiratory parameters in certain athletic groups and has a negative association with most of the respiratory parameters, but this finding must take the consideration of muscle mass into account.

When assessing physical activity and the respiratory system, the type of the activity determines the effect on the respiratory system. Swimming supports increased pulmonary values when compared to land-based sports such as soccer and volleyball. Long term physical activity regardless of the sport group supports a low inflammatory profile. This study provides new insight for recreational athletes within a South African cohort with respect to respiratory patterns and cytokine profiles. It also adds to the existing body of literature for sedentary populations.

From a public health perspective, recent studies found a significant reduction in developing severe COVID-19 among infected patients who in the preceding years to COVID-19 infection had adhered to the recommended WHO physical activity guidelines. Furthermore, COVID-19 patients who had engaged in less physical activity than recommended had lesser risks of developing severe disease outcomes or dying, than COVID-19 patients who were consistently inactive (World Health Organisation, 2020). Sedentary behaviour has been linked to metabolic related conditions which contribute to rising NCDs. In an effort to reduce the incidence of sedentary behaviour, it is clear from the present study that a physically active lifestyle even at the level of recreational sport activity yields favourable outcomes in terms of the anthropometric characteristics, respiratory patterns and cytokine profiles as compared to a sedentary lifestyle.

4.3 Future Research

The following studies are recommended to further the ideas explored in this thesis.

1. The current study focused on anthropometric characteristics such as BMI, but there is need to include other body fat composition measures in additional studies. Furthermore, the inclusion of other measurements such as waist circumference and waist to hip ratio may be useful in studies in addition to BMI to determine the level of adiposity for cardiovascular analysis.
2. The current study focused on the resting cytokine levels among three sport groups with small samples. It is recommended that further studies include larger samples and more sport groups when determining the immune response and the relationship with pulmonary function for different sport disciplines. In addition studies should incorporate a pre and post exercise intervention with blood samples obtained pre and post exercise to determine the acute effects of pro-inflammatory cytokines.

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