HEALTH AND FITNESS OF YOUNG, HEALTHY ADULT FEMALES AND THE EFFECT OF AN EIGHT WEEK PILATES INTERVENTION

BY

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THESIS

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ABSTRACT

Purpose: The first phase of this study aimed to investigate the health and fitness status of young adult females in the local community. The second phase of this study investigated the impact of an eight week progressive Pilates intervention on selected health and fitness parameters in this cohort.

Methods: Healthy young adult females aged 18-26 years (n=96), from the local community, partook in once-off tests including anthropometric measures (stature, body mass, Body Mass Index and waist circumference) as well as fitness parameters including balance, flexibility, muscular strength and endurance, and lastly lumbo-pelvic stability. Health measures investigated included blood pressure and spirometry. Where possible, results were compared to those of similar populations from national surveys or published normative data. Sedentary volunteers from this cohort were then randomised into a Pilates Exercise (PEx, n=12) or an inactive Control (Con, n=11) group, with their results from Phase 1 serving as baseline measures. Pilates classes were held twice weekly (60 minutes per session). All the measures from phase 1 were repeated at weeks 4 and 8. An additional intervention test included Transversus abdominis recruitment. Participants maintained habitual dietary intake and energy expenditure throughout. Nine PEx group and eight Con group participants completed the intervention.

Results: The current sample (phase 1) was found to be healthier than comparative populations from national surveys, and significant differences ($p<0.05$) were found for all comparisons except Forced Expiratory Volume (FEV_1), ($p=0.64$). Physical activity levels (230 $min.week^{-1}$) exceeded that of the recommend weekly threshold (150 $min.week^{-1}$). BMI, waist circumference, blood pressure and spirometry measures were all found to be within suggested healthy normal ranges. Pilates significantly improved lumbo-pelvic stability in the PEx group at weeks 4 ($p<0.005$) and 8 ($p<0.002$). Similarly, abdominal ($p=0.00$, $d=1.1$), upper limb ($p=0.037$, $d=0.9$) and lower limb endurance ($p=0.02$, $d=1.0$, between group $d=0.73$ for PEx) also improved with no changes in the Con group. PEx energy expenditure significantly increased from baseline to weeks 4 ($p=0.007$, $d=10.7$) and 8 ($p=0.027$, $d=0.64$), however body mass was maintained throughout. Conversely, Minute Ventilation decreased in the PEx cohort (p=0.010, *d*=0.95) from weeks 4 to 8. The Con group showed significant increases in body mass (p=0.018), leg strength (within-group Cohen's *d*=-1.08 between weeks 0-8; *d*=-2 between weeks 4-8) and dynamic balance (p=0.01, *d*=-0.5). While no within-group changes were observed, Protein intake was significantly greater (p=0.036, *d*>0.8 at baseline and week 8) in the PEx group throughout the intervention. Medium between-group effect sizes (*d*≥0.5) were noted for PEx BMI and waist circumference measures at all time points. Further, although not significant, the large within-group effect size (*d*=-0.84) between baseline and week 8 for PEx systolic blood pressure, suggested the 9 mm Hg was meaningful. The same time period also indicated a large within-group effect size (*d*=-0.8) for PEx dynamic balance, and a medium Cohen's d for (*d*=0.57) PEx static balance.

Conclusion: The local population of young adult females was found to be significantly healthier than those of comparable national samples. Further, Pilates participation significantly improved lumbo-pelvic stability and muscular endurance with meaningful changes in systolic blood pressure, and balance in previously sedentary young, adult females. Body mass was also maintained.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION AND BACKGROUND TO THE STUDY

Sedentary behaviour has reached pandemic proportions around the globe, and physical inactivity is now considered to be the fourth leading cause of death worldwide (Kohl et al., 2012). Modern society and technological advancements enable this type of behaviour through the increased employment of computer based work and motor-powered commuting, resulting in increased sedentarism (Buckworth & Nigg, 2010). Low physical activity levels are considered one of the major risk factors associated with the global rise in non-communicable diseases (NCDs) (World Health Organisation, 2011). In a report on the initial burden of disease in South Africa (2003), it was suggested that NCDs accounted for 37% of deaths in adults, with 40% of those occurring in South African females (Bradshaw et al., 2004). This report also suggested increasing physical activity as a strategy to promote healthier lifestyles, and thus decrease the risk of premature mortality due to NCDs. Similarly, the World Health Organisation (WHO) also recommends increased physical activity along with decreased energy consumption as ideal behavioural changes in the fight against NCDs (WHO & UNAIDS, 2007). Despite these recommendations, research into interventions to counteract sedentary behaviour and increase physical activity in adults is lacking (Owen et al., 2011).

Males tend to be more physically active than their female counterparts across all age ranges (Buckworth & Nigg, 2010). The South African National Health and Nutrition Examination Survey (SANHANES-1), conducted in 2012, reported that 45.2% of females in the age range 18-40 years were considered unfit, compared to just 27.9% of males in the same age group. It also showed adult women aged 18-24 years to be the least physically fit group in the country (Shisana et al., 2014). These findings are concerning, as early adulthood physical activity levels are strong predictors of activity levels in later life (Hultquist, Duckham, Stinson, & Thompson, 2009). Early adulthood sedentary behaviour thus creates a platform for the entrenchment of life-long sedentary behaviours and consequently, the potential development of NCD's (Mayosi et al., 2009).

The Makana region in the Eastern Cape Province in South Africa consists of a mostly urban populace (particularly in Grahamstown/iRhini) with only 10% of inhabitants living in rural areas (www.statssa.gov.za). The area has a high unemployment rate with 32.5% of economically active individuals unemployed (www.statssa.gov.za, Census 2011). This results in individuals with diverse backgrounds and varied economic statuses living in this unique area (Shisana et al., 2014). Females aged 20-24 years make up the largest group of women in the Makana area (6.5% of the population) (www.statssa.gov.za). Little research has been conducted on levels of physical activity in this cohort. What is known, is that more than half the females in the 18-24 years age group surveyed (50.2%) in the Eastern Cape Province during the SANHANES-1 project were classified as 'unfit'. With this, and the predictive value of early-adulthood physical activity levels in mind, it is evident that more knowledge is needed on this cohort if interventions are to be implemented in an effort to combat this behavioural trend.

Barriers to exercise are various in nature and contribute to increased sedentary behaviour and physical inactivity. Most commonly cited hindrances among women include time management and time availability, access to facilities, family support and child care assistance (Teychenne, Ball, & Salmon, 2011). In addition to this, exercise type and motivation to participate therein, may play a role in an individual's likelihood of involvement (Egli, Bland, Melton, & Czech, 2011). In a qualitative study investigating means of decreasing sedentary behaviour in women, greater access to instructor-led group classes, such as Pilates and Yoga, were suggested by the participants as ways to encourage increased physical activity (Teychenne et al., 2011).

The Pilates method of exercise is popular with women of all ages (Mallin & Murphy, 2013). The low risk and adaptability of the exercises make it attractive to individuals of all fitness levels or abilities (Di Lorenzo, 2011; Latey, 2002). The proposed benefits are also appealing to women, including claims that Pilates improves core strength and control, balance, flexibility and posture, all while promoting a leaner physique (Johnson, Larsen, Ozawa, Wilson, & Kennedy, 2007; Lange, Unnithan, Larkam, &

Latta, 2000; Segal, Hein, & Basford, 2004; Shedden & Kravitz, 2006). Despite its popularity, scientific research into this method is limited, inconclusive and often anecdotal (La Touche, Escalante, & Linares, 2008; Lange et al., 2000; McNeill, 2012b; Shedden & Kravitz, 2006). A large portion of the literature has focused on elderly populations in an attempt to reverse the negative effects of ageing, such as poor balance and high fall rates (de Siqueira Rodrigues, Ali Cader, Bento Torres, Oliveira, & Martin Dantas, 2010; Hyun, Hwangbo, & Lee, 2014; Newell, Shead, & Sloane, 2012; Pérez, Haas, & Wolff, 2014). A 2011 systematic review by Cruz-Ferreira et al., suggested only eight papers examining the effects of Pilates on *healthy* adults had been published, with many having small sample sizes (n=10-62), a lack of randomisation or control groups, and questionable scientific rigour. It has been recommended that well designed, randomised, controlled studies were needed to build the body of knowledge regarding Pilates' effects on healthy adult populations (Bernardo, 2007; Cruz-Ferreira, Fernandes, Laranjo, Bernardo, & Silva, 2011; Shedden & Kravitz, 2006).

The global popularity of Pilates and its incorporation into training and rehabilitation techniques, juxtaposed with the lack of quality research on this method, suggests the need for more exploration into its purported benefits. This is particularly pertinent if low impact mind-body exercise proves a useful solution in encouraging increased physical activity in inactive, young adult women.

1.2 STATEMENT OF THE PROBLEM

The purpose of the first phase of this study was to add new data to the literature pertaining to fitness and health parameters in young females in the Makana region of the Eastern Cape (South Africa). The aim of the second phase of the study was to determine the impact of an eight week progressive Pilates intervention on specific parameters of physical fitness and health in previously sedentary females, aged 18-26 years.

1.3 HYPOTHESES

1.3.1 Research

It was expected that selected health and fitness parameters measured in young females from the Makana region would be representative of those from national cohorts (Phase 1). In addition, it was hypothesized that an eight week progressive Pilates program would positively affect selected parameters of physical fitness (muscular strength and endurance, balance, flexibility and Transversus abdominis activation), lumbo-pelvic stability, selected health measures (lung function and blood pressure) and certain anthropometric measures (body mass, body mass index (BMI) and waist circumference) in a population of previously sedentary, young adult females (Phase 2).

1.3.2 Statistical

Phase 1 – *Population Study*

a) There will be no differences in fitness and health profiles of the local Makana female population (Pop), aged 18-26 years, compared to nationally surveyed or existing norms* (NS).

H_0: $\mu_{Pop} = \mu_{NS}$

H_A: $\mu_{Pop} \neq \mu_{NS}$

in the following measures:

Anthropometry (body mass, body mass index, and waist circumference), systolic and diastolic blood pressure, and spirometry measures (Forced Vital Capacity, Forced Expiratory Volume, Tidal Volume and Total Lung Capacity).

**Normative data were sampled from the South African Demographic and Health Surveys of 1998 and 2003, as well as the South African National Health and Nutrition Examination Survey (2012). Spirometry norms were taken from published textbooks.*

Phase 2 – *Pilates Intervention*

b) There will be no changes in physical fitness parameters over 8 weeks resulting in either a group, time or interaction effect (where Pilates = PEx, Control = Con):

Group Effect:

H_0: $\mu_{PEx} = \mu_{Con}$

H_A: $\mu_{PEx} \neq \mu_{Con}$

Time Effect:

H_0: $\mu_{PEx0} = \mu_{PEx4} = \mu_{PEx8}$ AND H_0: $\mu_{Con0} = \mu_{Con4} = \mu_{Con8}$

H_A: Not all equal

Interaction Effect:

H_0: No interaction Effect

H_A: Interaction Effect

in the following measures:

i) anthropometric measures (stature, body mass, body mass index (BMI), and waist circumference)
ii) static balance
iii) dynamic balance (unilateral and bilateral)
iv) flexibility
v) muscular strength
vi) muscular endurance

c) There will be no changes in physical fitness parameters over 8 weeks resulting in a group effect only (where Pilates = PEx, Control = Con):

Group Effect:

H_0: $\mu_{PEx} = \mu_{Con}$

H_A: $\mu_{PEx} \neq \mu_{Con}$

in the following measures:

vii) lumbo-pelvic stability

viii) Transversus abdominis activation

d) There will be no changes in health parameters over 8 weeks resulting in either a group, time or interaction effect (where Pilates = PEx, Control = Con):

Group Effect:

H_0: $\mu_{PEx} = \mu_{Con}$

H_A: $\mu_{PEx} \neq \mu_{Con}$

Time Effect:

H_0: $\mu_{PEx0} = \mu_{PEx4} = \mu_{PEx8}$ AND H_0: $\mu_{Con0} = \mu_{Con4} = \mu_{Con8}$

H_A: Not all equal

Interaction Effect:

H_0: No interaction Effect

H_A: Interaction Effect

in the following measures:

ix) blood pressure (Systolic)

x) blood pressure (Diastolic)

xi) spirometry (Minute Ventilation, Forced Vital Capacity, Forced Expiratory Volume, Tidal Volume and Total Lung Capacity)

1.4 STRUCTURE OF THE THESIS

The thesis presented comprises of six chapters. Each chapter will discuss Phase 1 and Phase 2 accordingly. Chapter 1 provides a brief background to the study, leading to the research question and the related statistical hypotheses. Chapter 2 examines the literature available regarding physical inactivity levels in women, particularly those in South Africa, along with barriers to exercise participation. This is followed by a critical and in-depth review of the current Pilates-specific evidence, with a focus on interventions featuring female participants. This chapter provides important background information on current knowledge and highlights the gaps remaining in the research. Chapter 3 provides details on the methodology used and measures obtained in Phases 1 and 2. Recruitment, selection and management of participants are also described. Details pertaining to the exercise intervention and workout design used in the Pilates-focused investigation (Phase 2) are provided. Findings from the testing procedures, including the supporting statistical results are detailed in Chapter 4. The data collected in Phase 1 is compared to normative data where possible. The intervention results from Phase 2 will compare the responses of the control and Pilates exercises groups. Chapter 5 includes a critical discussion of these results, with comparisons to the current literature and discussion around the study’s limitations. Finally, Chapter 6 summarises the findings, including conclusions regarding the hypotheses stated in Chapter 1. Recommendations and future research focus areas are discussed. The document is concluded with a list of related appendices, as well as a bibliography of all research papers and documents referred to throughout the dissertation.

CHAPTER 2

REVIEW OF LITERATURE

2.1 PHYSICAL INACTIVITY

The human body is designed for movement, yet globally, physical inactivity levels are steadily rising, largely due to transitioning lifestyles and behaviours (Bunc, 2016; Kangasniemi, Lappalainen, Kankaanpää, Tolvanen, & Tammelin, 2015; Owen et al., 2011). Sedentary activities have increased with the development of technologies such as motorised travel, computer-based work, and similarly screen-based recreational pursuits, including television viewing and computer games (Owen et al., 2011). This shift in behaviour has resulted in a rise in health conditions such as cardiovascular disease and metabolic syndrome, making physical inactivity akin to smoking or obesity in terms of risk (Booth, Roberts, & Laye, 2012; Joubert et al., 2007; Lee et al., 2012). Between 6% and 10% of major diseases, including cancers, type 2 diabetes and coronary heart disease, as well as around 3.2 million deaths annually, are attributed to physical inactivity (Lee et al., 2012; World Health Organisation, 2011a). It is therefore one of the four major risk factors associated with non-communicable disease development – the other three being smoking, alcohol abuse and poor diet (Shisana et al., 2014; World Health Organisation, 2011). Physically active individuals have about a 30% lower risk of stroke and/or death when compared with inactive persons (Booth et al., 2012). Since physical activity levels are easily altered with lifestyle or behavioural modifications, more knowledge is needed on suitable interventions for increasing activity levels in conjunction with sustained adherence.

In a burden of disease analysis, the global impact of physical inactivity on disease occurrence (coronary heart disease, type 2 diabetes, as well as breast and colon cancer) and all-cause mortality, was calculated per country. The Population Attributable Fraction (PAF) was calculated to show the potential reduction in disease incidence which might result from increased physical activity by currently inactive individuals (Lee et al., 2012). The estimates for South Africa were concerning with

PAFs for coronary heart disease and all-cause mortality greater than that of both the United States of America (USA) and the global median (Table 1) (Lee et al., 2012).

Table 1: Comparison of South African estimated coronary heart disease and all-cause mortality PAFs to estimated PAFs for the USA and the global median.

	PAF: Coronary heart disease	PAF: All-cause mortality
South Africa	8.7%	14.0%
USA	6.7%	10.8%
Global Median	5.8%	9.4%

Data adapted from Lee et al., 2012

2.1.1 Physical Inactivity in Females

It is well documented that women are less physically active than men (Camacho-Miñano, LaVoi, & Barr-Anderson, 2011; Salmon, Owen, Crawford, Bauman, & Sallis, 2003; United States Department of Health and Human Services, 1996; World Health Organisation, 2011). Further, over time (>one year) women tend to remain inactive, or are more likely than their male counterparts, to revert back to previous inactivity levels after uptake of an exercise program (Marcus et al., 2000). Life events such as marriage, child birth or even the death of a partner can affect physical activity levels in women (Brown, Heesch, & Miller, 2009). In 2010, the World Health Organisation (WHO) estimated that nearly a quarter of all adults (23%) were insufficiently active, with 27% of adult women failing to reach adequate levels of physical activity, compared to 20% of men (http://www.who.int/gho/ncd/risk_factors/physical_activity_text/en/). It must be noted that these figures showed an improvement on the WHO 2008 estimates, which stated a physical inactivity prevalence of 34% in women and 28% in men (http://www.who.int/dietphysicalactivity/factsheet_inactivity/en/). Reasons for this improvement are not clear.

Physical inactivity and sedentary behaviours, particularly in *younger* generations, are on the rise globally (Coleman, Cox, & Roker, 2008; Kohl et al., 2012; Salmon, Tremblay, Marshall, & Hume, 2011). The WHO estimates from 2010 suggested that adolescents aged 11-17 years had a physical inactivity prevalence of 80%, with young girls showing higher inactivity levels than boys (84% versus 78% respectively) (http://www.who.int/gho/ncd/risk_factors/physical_activity/en/). This is concerning given the large numbers of individuals in the global adolescent and young adult populations (Blum & Nelson-Mmari, 2004). Increased health risks and the resultant disease development in these inactive younger persons will consequently place increased strain on the world's economy as well as health services (Mokdad et al., 2016). Young adult females commonly show poor levels of physical activity, a behaviour pattern which often develops during the transition from high school to college or full-time employment (Coleman et al., 2008; Han et al., 2008). This lack of physical activity may persist into later life, making inactive young women a vulnerable group for increased health risks (Department of Health, Medical Research Council, & OrcMacro, 2007; Hultquist et al., 2009). This also highlights the need for strategies, including lifestyle and behavioural modifications, to be implemented from early adulthood if not sooner, rather than later on in life (Mokdad et al., 2016). Early implementation will serve as a preventative strategy to ensure better health of the population as it ages, leading to maximised economic activity and reduced burden on health care facilities (Mokdad et al., 2016).

2.1.2 Physical Inactivity Levels of South African Females According to the World Health Organisation and Recent National Surveys

Geographically, while physical inactivity levels are typically higher in high-income countries, it has been found that women in middle-income countries, such as South Africa, appear to be experiencing the fastest decline in activity levels (World Health Organisation, 2011). In 2000, South African adults showed higher levels of physical inactivity than that of the global average, and similarly recorded a high number of deaths (17,037) and disability-adjusted life years (176,252) as a result of chronic conditions (Joubert et al., 2007). Further, it was estimated that 40% of deaths in females were attributed to non-communicable diseases over that period – higher than HIV/Aids (34%), communicable/maternal conditions (20%) and injury related fatalities (6%) (Bradshaw et al., 2004). This correlates with the fact that South African women were identified as being particularly prone to low levels of physical activity (Joubert et al., 2007). The 2003 South African Demographic and Health Survey (SADHS) recorded 63% of females, aged 15+ years, as being physically inactive, along with corresponding high levels of overweight and obesity in these individuals (Department of Health et al., 2007). Unfortunately, physical inactivity levels were not recorded during the 1998 SADHS, making the 2003 data the earliest in terms of locally conducted surveys. In 2010, geographical data from the World Health Organisation suggested that 51.6% of South Africa's adult females were "insufficiently active", described as participating in less than 150 minutes of moderate intensity, or 75 minutes vigorous intensity activity per week (http://www.who.int/gho/ncd/risk_factors/physical_activity/en/). This showed a small improvement on the 2003 SADHS data, however it is not clear as to how this WHO information was collected. Similarly they indicated adults as being aged 18+ years compared to the SADHS' 15+ years.

The most recent data on national physical activity levels in South African's is limited to the latest South African National Health and Nutrition Examination Survey (SANHANES-1), conducted in 2012. These findings concurred that women remained less physically active than men, but found that only 45.2% of South African adult females, aged 18-40 years, were physically unfit (Shisana et al., 2014). While this suggests another improvement in physical activity levels from the 2010 WHO figures, the defined age bracket was again dissimilar. Nevertheless, it still showed that approximately one out of every two adult females in the country remains inactive (Shisana et al., 2014). Further, data on physical inactivity in *young* adult females is limited to the SANHANES-1 survey. Women aged 18-24 years were the least physically fit group nationally, with 50.2% of those surveyed falling into the 'unfit' category (Shisana et al., 2014). Only 38% of this group were considered fit, while 11.8% showed 'average' fitness levels (Shisana et al., 2014). Young women in South Africa are thus a particularly vulnerable group. While they face increased mortality risk from high levels of maternal disorders, sexually transmitted diseases (HIV/AIDs) and high rates of alcohol or drug misuse, they are likewise exposed to the increased possibility of non-communicable disease development through physical inactivity (Bradshaw et al., 2004; Mokdad et al., 2016). There is thus a need for interventions that encourage engagement and lifelong participation in physical activity for this cohort (Department of Health et al., 2007).

2.1.3 Inactivity Levels of Females in the Eastern Cape Province and the Makana/Grahamstown Region

The Eastern Cape Province, the second largest provincial region in South Africa, covers an area of 168 966 km^2, and is the third most populated province after Gauteng and KwaZulu-Natal (Statistics South Africa, 2014). Unfortunately, this region currently experiences high levels of poverty and unemployment and as such, is considered one of the country's poorest provinces. This is evident in an area such as the Makana region, comprising of the university town of Grahamstown/iRhini, and the surrounding rural and farming regions. Although only 10% of this population resides in the rural regions, unemployment levels are at 32.5% (Statistics South Africa, 2014).

Females aged 20-24 years make up the largest group of women in the Makana area (6.5% of the population) (www.statssa.gov.za), yet little is known about the physical activity levels and general health of this group. Area specific investigations have not been conducted and there is thus a paucity in the health and wellness knowledge for this demographic. Physical activity data at the provincial level are similarly limited to that recorded during national surveys. While we know that women aged 18-24 years are the least fit group nationally, results for this group provincially are not available. What is known is that 52% of *all* women in the Eastern Cape are considered unfit – second only to those in the Western Cape (67%). Further, the SANHANES-1 survey suggests that only 31% of all females in the province have a healthy Body Mass Index (BMI), while over 41% of women fall into the obese BMI range (>30 kg.m^{-2}).

2.1.4 Consequences of Physical Inactivity

High levels of physical inactivity in women result in associated health risks, such as high obesity and Body Mass Index (BMI) scores due to weight gain, as well as increased cardiovascular disease, hypertension and cancer risk (Jayalakshmi, Prabhu, Shanmukhappa, & Smilee, 2011; Rezende et al., 2006; Shisana et al., 2014). Furthermore, increases in BMI and waist circumference have been associated with an increase in fasting blood glucose and triglyceride levels, along with an increase in blood pressure (Rezende et al., 2006).

Prevalence of overweight and obesity in South African females during 2012 was recorded at 24.8% and 39.2% respectively (Shisana et al., 2014). In 2014, the WHO suggested similar estimates, proposing that 37.3% of South African adult women (aged ≥18 years) were obese (World Health Organisation, 2015). Associated obesity also appears to be more prevalent among women than men (Shisana et al., 2014). The national mean BMI for all adult females was 28.9 $kg.m^{-2}$, categorised as 'overweight', compared to the male national average 'healthy' mean BMI of 23.6 $kg.m^{-2}$ (Shisana et al., 2014). Women in the 18-24 years age group nationally were slightly better as a sub-group, with 48.5% falling within the healthy BMI range according to the SANHANES-1 report. Still, 25% were found to be overweight and a further 21% were classified as obese (Shisana et al., 2014).

Hypertension, classified as having a systolic blood pressure of ≥140 mm Hg and a diastolic blood pressure of ≥90 mm Hg (Table 2), is a common risk factor associated with the development of NCDs (Norman, Bradshaw, & Steyn, 2011). The 1998 South African Demographic and Health Survey suggested that around 25% of South African females suffer from hypertension (with 16% of those presenting with moderate or severe hypertension), increasing their risk of cardiovascular diseases development (Booth et al., 2012; South African Department of Health, Medical Research Council, & DHS +, 2002). The survey also suggested that the number of *young* individuals with uncontrolled hypertension, and thus increased risk of organ damage over time, was disturbing (South African Department of Health et al., 2002).

Table 2: Adult blood pressure (BP) classification, adapted from the JNC 7 Report (NHLBI Joint National Committee, 2004).

Systolic BP (mm Hg)	Diastolic BP (mm Hg)	BP Classification
<120	<80	Normal
120-139	80-89	Pre-hypertension
≥140	≥90	(Stage 1) Hypertension
≥160	≥100	(Stage 2) Hypertension

It is worth noting that blood pressure records from the 2003 SADHS showed large decreases in diastolic blood pressure. The findings suggested a nearly 50% drop in hypertension prevalence from previous research figures. These findings were deemed unrealistic and unreliable (Department of Health et al., 2007). The researchers suggested that field worker error may have affected the results and recommend that the data be interpreted with caution. The survey did however note that high risk for the development of hypertension from lifestyle factors, such as high salt intake or obesity, still persisted (Department of Health et al., 2007). In addition to this, under-diagnosis is common, meaning many individuals are unaware they are hypertensive (Hasumi & Jacobsen, 2012). Prevention and control of hypertension is generally thought to stem from the adoption of healthy lifestyles, including maintaining a healthy weight, diet management, limiting alcohol intake and increasing physical activity levels (Booth et al., 2012; Shisana et al., 2014). Further, the American College of Sports Medicine suggests that performing resistance training 2-3 times per week can reduce blood pressure in normotensive and hypertensive adults (Pescatello et al., 2004). Small decreases of between 2-4 mm Hg in both systolic and diastolic BP have been equated to a 5-9% decrease in coronary heart disease risk, and an 8-14% decrease in all-cause mortality risk (Pescatello, 2005; Pescatello et al., 2004). It is thus important to ascertain which forms of exercise and physical activity may assist in reducing blood pressure, as these have not been adequately identified (Pescatello et al., 2004).

Hormone-based contraception products are similarly known to increase blood pressure in females, particularly in the case of oral contraceptives, although this effect can be repealed with the cessation of usage (Fisch, 1977; NHLBI Joint National Committee, 2004; Oelkers, Foidart, Dombrovicz, Welter, & Heithecker, 1995). While these effects are reversible (Fisch, 1977), younger women are similarly said to respond favourably with exercise (Pescatello et al., 2004). This is important as cessation of oral contraceptive use is not always a suitable option for this group, and exercise may therefore serve as a useful tool in combatting associated increases in blood pressure (Pescatello et al., 2004). This suggests a need to investigate the effects of different exercise methods on blood pressure in younger women, particularly those making use of oral contraception.

Given the consequences associated with physical inactivity and the prevalence of this behaviour within South African females, more investigation is required into suitable exercise interventions for inactive, but otherwise healthy, young adult females.

2.2 PHYSICAL ACTIVITY INTERVENTIONS AND FACTORS AFFECTING COMPLIANCE

It has been suggested that interventions altering sedentary behaviours are likely to have a larger impact on a population's health, as physical inactivity is often a more prevalent behaviour than other risk factors (Lambert & Kolbe-Alexander, 2006). Even small improvements in physical activity levels can be beneficial for health, and often, larger health gains can be seen in those who shift from inactive to physically active lifestyles (Warburton, Nicol, & Bredin, 2006). Similarly, adherence is necessary in order to experience the associated health benefits of physical activity. Despite this, interventions implemented to date have yielded minimal success, and long-term adherence is poorly documented (Marcus et al., 2000; White, Ransdell, Vener, & Flohr, 2005). Given only 50% of interventions on healthy adults are thought to successfully change activity-related behaviours (Rhodes & Pfaeffli, 2010), it is necessary to determine which modalities are most effective, both in improving health and fitness parameters, as well as encouraging continued participation. In order to assess this, we also need to understand the factors that might affect compliance.

There are numerous aspects that impact on the success of an intervention, as well as the long term adherence of females participants, and these develop from different influences (Sternfeld, Ainsworth, & Quesenberry, 1999). The literature describes reasons such as time-commitments, social/family support, motherhood, as well as obstacles affecting willingness to exercise such as convenience, weather conditions, access to facilities and safety concerns (Arikawa, O'Dougherty, & Schmitz, 2011; Kao et al., 2014; Salmon et al., 2003; Verhoef & Love, 2009). Many of these factors appear to impact on younger individuals too. School-going females in Australia listed deterrents such as lack of motivation, time limitations as well as social expectations and pressures, while adolescent girls in the United Kingdom suggested that family, as well as one's friendship group, served as primary influences in either participation or avoidance of physical activity (Coleman et al., 2008; O'dea, 2003). College-going female students have been shown to experience a significant decrease in physical activity levels during the transition from high-school to tertiary studies (Han et al., 2008; Leslie et al., 1999). Interestingly, those that remained physically active reported extrinsic factors such as weight management and appearance as influences on their physical activity engagement (Egli et al., 2011). An individual's preference and personal situation (family commitments, education level, marital status), clearly play a role in determining which exercise regimes might see initial and long-term participation (Arikawa et al., 2011; Pescatello, 2005; White et al., 2005). Similarly, enjoyment of the activity is necessary for increased adherence levels and has shown to be a strong predictor of initial participation (Huberty et al., 2013; Salmon et al., 2003; White et al., 2005). While the link between physical activity levels and long-term adherence is still not clear (White et al., 2005), it has been proposed that supervised activity adherence is greater (95.4% attendance rate) than that of non-supervised (64.5%), suggesting commitment and participation are greater when overseen (Arikawa et al., 2011).

It is thought that lower intensity exercise types may be preferred by women due to the lack of perspiration, a decreased perceived 'soreness' and no need to change clothes after the workout (Marcus et al., 2000; White et al., 2005). A comparison of exercise-uptake between men and women according to intensity level showed that women were more likely to adhere to a moderate-intensity workout than a vigorous-intensity one (Sallis et al., 1986). In addition, activities with low levels of energy expenditure (500 kcal/2100 kJ per week) may be enough to initiate acceptable health gains in previously sedentary individuals, however this theory requires more research (Warburton et al., 2006). The implication for sedentary individuals is a greater likelihood of increasing activity levels through minor behavioural changes. Therefore, minimalist interventions that promote whole-body training and long-term maintenance, while diminishing negative influences associated with exercise, may provide a platform for increased activity levels in sedentary adult females (Garber et al., 2011; Kangasniemi et al., 2015).

A 2005 systematic review highlighted that while *walking* was listed a preferred mode of exercise for women, little research has been done into other exercise options and the adherence to these alternatives (White et al., 2005). The long-term effects of *vigorous versus moderate intensity* exercise regimes for weight-loss in sedentary, overweight women suggested the resulting difference between the two intensities at various time durations is not significant after twelve months (Jakicic, Marcus, Gallagher, & Napolitano, 2003). This research, while long-term, did however include large dietary restrictions for the participants which may have impacted on the results

(Jakicic et al., 2003). Percentage body fat as well as muscular strength showed significant positive changes as a result of twelve *resistance training* sessions over 4 weeks in sedentary women aged 25.3 ± 3.2 years (Moghadasi & Siavashpour, 2013). In a comparison of *jogging* to *football training* in sedentary middle-aged females (aged 36.5 ± 8.2 years), maximal oxygen uptake and mean arterial blood pressure showed significant changes for both groups after 16 weeks, when compared to a matched, inactive control. Maximal oxygen uptake increased by 10% and 16% in the running and football groups respectively, whilst mean arterial blood pressure decreased by 3 mm Hg and 5 mm Hg respectively (Andersen et al., 2010). This study also highlighted the effect of different exercise types (dynamic endurance versus interval training) on different fitness parameters. Lastly, *Bikram yoga has* been shown to improve strength and flexibility in healthy adults (both males and females - age range 21–39 years) when practiced thrice weekly at 90 minutes per session (Tracy & Hart, 2013).

Interventions targeting *young,* sedentary, but otherwise healthy females are scarce. This is likely due to the associated 'low risk' status of this population's overall health. However, finding novel solutions to mitigate poor activity levels is clearly necessary for this group, given the long-term impact of crucial lifestyle choices made at this stage (Gordon-Larsen, Nelson, & Popkin, 2004; Hultquist et al., 2009; Kloubec, 2011; Mokabane, Mashao, Staden, Potgieter, & Potgieter, 2014; Salmon et al., 2011; US Department of Health and Human Services, 2000). A progressive *stair climbing* regime has been shown to induce significant improvement in cardiorespiratory fitness of young women (aged 18 years) in just 7 weeks. However, this research consisted of just 15 individuals, with eight forming the intervention group (Boreham, Wallace, & Nevill, 2000). A comparison of *aerobic training versus resistance training versus a combination* group (cross training including both training types) as well as a matched, inactive control group, was investigated in previously inactive, young women (mean age 20.4 ± 1 years). Cardiovascular fitness as well as body composition were investigated. The intervention consisted of 16 weeks of training followed by 6 weeks of detraining. The results suggested that aerobic training significantly improved cardiorespiratory fitness (25% increase, $p<0.05$) and decreased body fat percentage (13.2%, $p<0.05$) during the training period, but that these results were reversed during the detraining period. There was no change in body mass or BMI measures for this group (LeMura et al., 2000). The resistance and cross-training groups showed significantly increased strength in the upper body (29% & 19% respectively, $p<0.001$) and lower body (38% and 25% respectively, $p<0.0001$) and maintained a significant difference from baseline even after the 6-week detraining program. Participants in these two groups also showed decreased body fat percentage post-training, however these results were not significant (LeMura et al., 2000). Interestingly the aerobic training group participated in 4 workout sessions per week, while the resistance training group was limited to 3 sessions per week on non-consecutive days. The cross-training group participated in 4 sessions per week consisting of two aerobic and two resistance sessions respectively which may have accounted for the varying results. Young, sedentary females (aged 25.3 ± 3.2 years, n=10) participated in three 60-minute long *resistance training* sessions per week over a 12 week intervention period, while the matched control group (n=10) remained physically inactive. While there were no changes in body mass, BMI, waist-to-hip ratio or other anthropometric measures, it was found that muscle strength showed significant increases after 12 weeks ($p<0.05$) compared to the control cohort. Improvements were seen in both upper and lower extremities in 1-repetition max measures (Moghadasi & Siavashpour, 2013). Similar research into the effects of twelve sessions of *combined exercise* (endurance-resistance) on young, healthy inactive women (aged 20 ± 2.8 years) suggested that abdominal ($p<0.001$) and upper body ($p<0.01$) endurance was significantly improved compared to the control group. Body fat percentage also improved significantly for the intervention group along with running speed and agility, however explosive power remained unchanged (Arabnejad, 2015). This research suggests that as little as 12 sessions can have a significant impact on physical fitness parameters in young women.

A popular exercise method among women is Pilates (Bernardo, 2007). This low-intensity, 'mindful' workout may be an attractive option to women who don't enjoy over exertion, or for sedentary females wishing to transition to an active lifestyle (DeSimone, 2016; Kloubec & Banks, 2004; Tolnai, Szabó, Köteles, & Szabo, 2016; White et al., 2005). The adaptability and modifications available in the Pilates method make it an activity one could pursue throughout life, which may promote adherence and sustainability into late adulthood (White et al., 2005). In terms of enjoyment, young girls participating in 20 Pilates sessions rated their participation at 4.4/5 on a validated enjoyment scale, along with a low Mean Perceived Exertion level (5.9/10) (Jago, Jonker, Missaghian, & Baranowski, 2006). Similarly, a 6-month observational study of middle-aged Pilates practitioners, found that Pilates provided more enjoyment from participation than negative results (Segal et al., 2004). Pilates may therefore serve as a suitable option as it is low impact, enjoyable and supervised by an instructor. As an indoor/studio-based workout program there are diminished environmental interferences and safety concerns, which could negatively affect walking or outdoor sports program participation (Salmon et al., 2003). A position stand published by the American College of Sports Medicine, recommends yoga in order to achieve suggested exercise targets for adults (Garber et al., 2011). These targets include "strength training for each major muscle group two or three days each week, and flexibility and neuromotor exercises two or three times per week" (Garber et al., 2011). However, given that Pilates postures and manoeuvres share many similarities with yoga, researchers have suggested that it could also be a suitable exercise method for meeting these recommended requirements (Kibar et al., 2015).

2.3 PILATES AS AN EXERCISE METHOD

2.3.1 Introduction

Pilates has seen considerable growth in popularity and participation in the last two decades (Bernardo, 2007; Lange et al., 2000; Sekendiz, Altun, Korkusuz, & Akın, 2007). Historically, it has been prevalent in the professional dance community, but is now common in rehabilitation and general exercise settings (Di Lorenzo, 2011; Latey, 2001). The exercises are resistance based, using an individual's own body weight or supplementary resistant springs, with movements performed in a slow, co-ordinated and precise manner (de Siqueira Rodrigues et al., 2010). Pilates classes can be taught to individuals in a private capacity, or to small groups, and are generally 60 minutes long. Exercises are performed on the floor, termed 'matwork', or on specialised equipment (McNeill, 2011; Wells, Kolt, & Bialocerkowski, 2012).

Pilates has been described as "a mind-body exercise method that focuses on strength, core stability, flexibility, muscle control, posture and breathing" (Bernardo & Nagle, 2006; Słupik, Jaworski, Mosiołek, & Białoszewski, 2015; Wells et al., 2012). Another description mentions it as being "generally integrated, whole body movements, involving low and/or high threshold muscle contraction, often in sequence, exploring both neutral and full joint ranges" (McNeill, 2011). The low impact and adaptability of the exercises may be reasons for its popularity. While Pilates offers a full-body workout, the manoeuvres are executed at a slow pace and lower intensity and are easily tailored to an individual's needs (Latey, 2002; McNeill & Blandford, 2013; Rogers & Gibson, 2009). It is considered a 'safe' exercise method and is thus popular with healthy individuals, as well as special populations, such as athletes, dancers and the elderly (Endleman & Critchley, 2008). Further, individuals requiring a low-impact workout due to functional limitations, injury or chronic conditions, may find Pilates suitable, as it places less stress on joints and muscles (Endleman & Critchley, 2008; Kloubec, 2011; Petrofsky et al., 2005). Similarly, prenatal Pilates is popular with expectant women as the exercises are easily tailored to suit the mother throughout her pregnancy (Latey, 2002; McNeill, 2011). Yet research into the safety and efficacy of Pilates during pregnancy is limited and requires further investigation.

2.3.2 A Brief History of Pilates

The Pilates method was developed by Joseph H. Pilates (1880-1967), a German national and professional boxer, body builder and circus performer. Pilates had an inherent interest in health and wellness and enjoyed Yoga, Thai chi, Karate and even meditation. Yet the Pilates method itself was only developed and fine-tuned during his time as a prisoner of war (Latey, 2001). As a foreign national living in the United Kingdom at the outbreak of World War I (1918), he was interned, but later found himself assisting in a war hospital on the Ilse of Man. It was here that his attention turned to rehabilitation, and developing exercises that wounded soldiers could perform whilst supine, prone, kneeling or seated (Latey, 2001; Owsley, 2005). Altering the hospital beds by attaching springs and pulleys to them added resistance and progression to the exercises he prescribed. These modified beds formed the prototypes for Pilates machinery and equipment used today, including the Reformer and Trapeze Table, or Cadillac (Di Lorenzo, 2011; Owsley, 2005). Joseph Pilates immigrated to New York after the war. It was here that he built a loyal client base and trained individuals who would take the Pilates method out to the global domain. Over time the method spread, gaining a small following, but it has only been in the last two decades that it has seen exponential growth (Latey, 2001).

Pilates originally called his form of exercise 'Contrology' due to the targeted focus on building core strength, improving balance, flexibility and proprioception, all while enhancing an individual's overall wellbeing (Latey, 2001; Muscolino & Cipriani, 2004a; Segal et al., 2004). His method was based around six original principles (Di Lorenzo, 2011; McNeill, 2012a; Muscolino & Cipriani, 2004a; Owsley, 2005; Wells et al., 2012):

1) *Centering*: working from the centre of the body, i.e. 'the core'. Some Pilates practitioners refer to the core is referred to as the 'powerhouse' of the body.
2) *Concentration*: by bringing 'the mind into the muscle' and focusing on one's movement is said to allow for greater control over the body.
3) *Precision* (of movement): it is ideal to work the body in its correct, natural form. Pilates believed strongly that poor posture was a precursor for ill health and he believed in the ability of these exercises to improve and strengthen postural muscles.
4) *Control*: one must aim to be in total control of all facets of the body in space, allowing for accurate and specific range of motion in a 3-dimentional environment.
5) *Flow/Fluidity* (of movement): the flow and grace of Pilates exercises results in a seemingly effortless transition between positions during the exercises and encouraging sustained motion throughout the workout.
6) *Breath*: the breath is considered critical in assisting the activation of the deep abdominal muscles thereby engaging the core. Pilates believed the breath to be an 'internal shower' allowing one to rid the body of toxins, improve oxygenation, increase sweat production and promote better digestion.

Given these principles, it is worth noting that Pilates should not be confused with other techniques such as the Alexander Technique or the Franklin Method (Krasnow et al., 1997). These alternative methods focus on using active thought to induce good posture and alignment through the body to aid health and wellness and are considered 'body therapies' rather than specific exercise methodologies (Krasnow et al., 1997). The Alexander Technique was in fact developed around the time of Joseph Pilates' birth and is different in that it focuses on improving one's posture in functional positions or daily actions such as standing, sitting and walking. This is said to improve postural tone and neuromuscular coordination through thought and a mindful activation of musculature, rather than taking one through an actual exercise routine (Kristl, 2001; Little et al., 2014; Stallibrass, Sissons, & Chalmers, 2002). The Franklin Method (http://franklinmethod.com/about) was developed primarily for dancers and focuses heavily on imagery, or *Ideokinesis,* to activate a body-mind connection to facilitate in the most efficient and optimal body movement possible (Overby & Dunn, 2011). Developed in 1994, this is a fairly new method which has not been well researched. The aim of alleviating stress on associated structures through correct alignment and movement is a common thread between Pilates, the Franklin Method and the Alexander Technique.

2.3.3 Pilates and Core Stability

Pilates is typically described as a 'core workout', or as a method for 'strengthening the core' in an effort to improve its stability (Gladwell, Head, Haggar, & Beneke, 2006; Kloubec, 2011; Muscolino & Cipriani, 2004b; Owsley, 2005; Phrompaet, Paungmali, Pirunsan, & Sitilertpisan, 2011; Pumpa, Dzialdowski, Stiffle, & Gavran, 2015; Rogers & Gibson, 2009; Wells et al., 2012). While the terms 'core control', 'core strength' and 'core stability' are commonly associated with Pilates, they are not clearly defined and are often used interchangeably (Key, 2013; McNeill, 2010). Suggestions in the literature state that core strength/strengthening refers to exercising weak muscles or improving the recruitment of those within the trunk that may be underactive, while 'core stability' refers to "all motor control training around the trunk" and is thus akin to "core strength and balance" (Christopher, Casebolt, Silver, & Kwon, 2006; McNeill, 2010). Core stability has also been described as the ability of the lumbo-pelvic region to resist perturbations, typically from limb movement (Sherry, Best, & Heiderscheit, 2005).

Similarly, the anatomical definition of the core is not always agreed on by researchers or Pilates practitioners, and the exact description of core musculature is ill-defined (Key, 2013; Muscolino & Cipriani, 2004a). Joseph Pilates never described the core, but referred to the 'powerhouse' as the centre of strength in the human body (Muscolino & Cipriani, 2004a). It is generally accepted that the core lies within the trunk of the body, beginning within the pelvic girdle and ending inferiorly to the ribcage at the diaphragm; in essence, the thoraco-abdominal-pelvic cavity (Figure 1) (Key, 2013; Muscolino & Cipriani, 2004a). Still, the exact musculature involved varies in description among scientists (Key, 2013; Muscolino & Cipriani, 2004a).

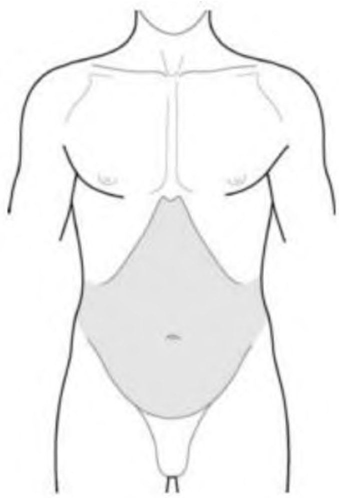

Figure 1: Location of the core or 'powerhouse' (from Muscolino & Cipriani, 2004).

The related musculature has been described as a box with "the abdominals in the front, paraspinals and gluteals in the back, the diaphragm as the roof, and the pelvic floor and hip girdle musculature as the bottom" (Akuthota & Nadler, 2004). Specific muscles include the Transverse abdominis, internal and external obliques, multifidus, quadratus lumborum, iliopsoas, deep erector spinae, the diaphragm and, the muscles of the pelvic floor (Owsley, 2005) (Figure 2).

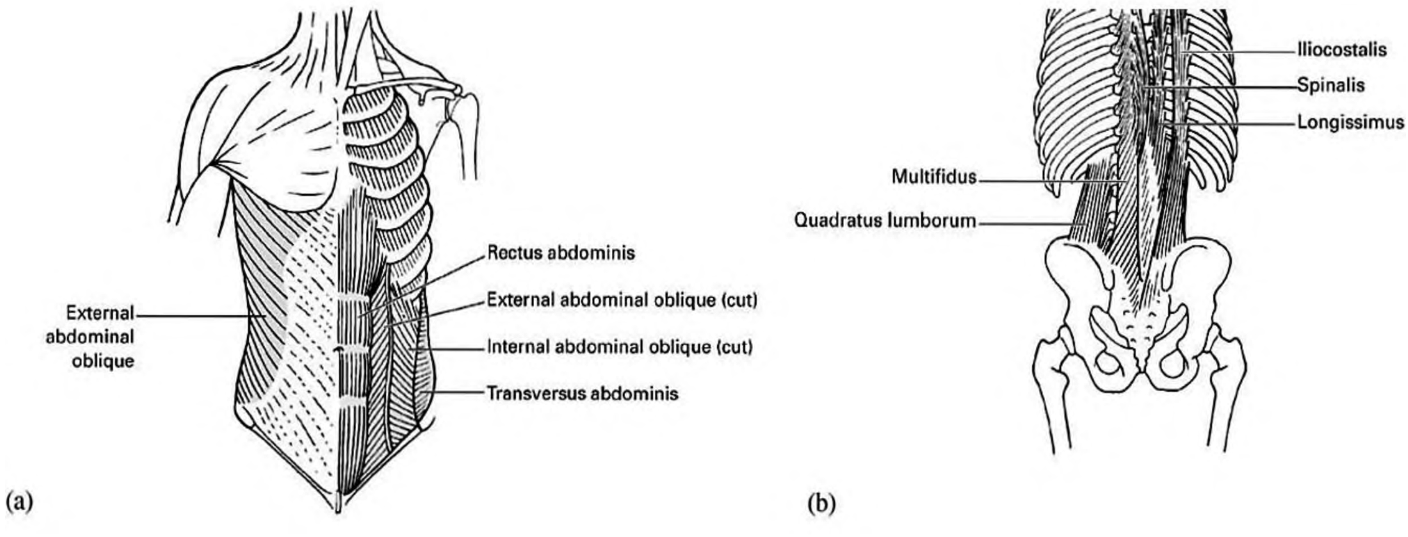

Figure 2: Core musculature highlighting, (a) the anterior abdominals and (b) posterior abdominals or lower back musculature (from Muscolino & Cipriani, 2004).

It is thought that the core musculature acts like a corset to stabilise the trunk, in particular the lumbar spine and pelvis, both in static positions and during movement (Akuthota & Nadler, 2004; Christopher et al., 2006). This is said to occur via co-contraction and activation of the global and local musculature in this region, as well as the ligamentous structures which provide passive support (Akuthota & Nadler, 2004; Imai et al., 2010; Muscolino & Cipriani, 2004; Owsley, 2005). The global muscle system is made up of larger torque generating muscles that act on the spine to create movement and motion, without necessarily attaching to it (Borghuis, Hof, & Lemmink, 2008; Czaprowski et al., 2014). These includes the rectus abdominis and iliocostalis lumborum (Rossi et al., 2014). The local muscle system features those attached to the lumbar vertebrae which act to stabilize this region. Examples include the lumbar multifidus and the Transversus abdominis, which also attaches to the pelvis and ribcage (Hodges, 2003; O'Sullivan, 2000; Rossi et al., 2014). The type I muscles fibres found within the local musculature increases their endurance, making them ideal support structures (Carter, Beam, Mcmahan, Barr, & Brown, 2006). Activation or contraction of the Transversus abdominis results in a reduction of the abdominal circumference as muscle fibres run in a horizontal orientation around the abdomen (Hodges, 1999). This, along with co-contraction of the multifidus, the pelvic floor muscles and the diaphragm, results in increased tension in the thoraco-lumbar fascia, thus providing support for the spine through correct lumbar posture (Hodges, 1999; Hodges & Richardson, 1997; Kloubec, 2011; Sherry et al., 2005). It is this increased stability that is thought to play a role in the prevention of injury or the onset of chronic lower back pain (Herrington & Davies, 2005). Conversely, poor muscular control and lack of support in this region are thought to be potential predictors of these conditions (Gladwell et al., 2006; Izzo, Guarnieri, Guglielmi, & Muto, 2013; Sherry et al., 2005). Interestingly, electromyography results in sedentary individuals with poor seated posture showed an increase in Transverse abdominis and internal oblique muscle fatigue after just one hour of sitting (Waongenngarm, Rajaratnam, & Janwantanakul, 2015). This suggests that sedentary individuals are at increased risk for the development of lower back pain or injury through decreased muscular endurance and support.

Much focus has been placed on the Transversus abdominis and its role in lumbo-pelvic support. It is thus often signposted as the main muscle for improving core stability. This dogma has seen it targeted as the sole solution for a variety of problems including back pain and poor posture (Key, 2013). This could be as a result of research by Hodges and Richardson (1996) on Transversus abdominis dysfunction in individuals with lower back pain (Rossi et al., 2014; Urquhart, Barker, Hodges, Story, & Briggs, 2005). Lower back pain sufferers showed delayed Transversus abdominis activation with rapid shoulder movements. This suggested that the Transversus abdominis may be crucial in stabilising the body before dynamic movement of the limbs occurs (Hodges & Richardson, 1996). Crucially, this delay was absent in healthy individuals, suggesting neuromuscular reorganisation and adaptations of motor strategies in those presenting with lower back pain (Lederman, 2010). Likewise, research involving lower limb movements in healthy/asymptomatic adults suggested that the Transversus abdominis was the first muscle to react to perturbation, whilst activity of the multifidus or obliques was dependant on limb movement direction (Hodges & Richardson, 1997). These theories have guided the development of rehabilitation strategies, as well core stability training, which has been widely used in the treatment of back pain pathologies, regardless of the limited evidence base (Allison & Morris, 2008; Cholewicki & VanVliet IV, 2002; Di Lorenzo, 2011). The inconclusive nature of research done into lower back pain causes and the rehabilitation techniques currently in use, has left scientists somewhat divided on the core's function and its actual identification (Key, 2013; Lederman, 2010). Despite this, it is generally accepted that the different muscles of the trunk contribute to stability and that their action may change according to varying tasks (Akuthota & Nadler, 2004; Lederman, 2010).

It is suggested that only a low level of co-contraction (less than 50% of maximal voluntary contraction) is required for the development of improved core muscular endurance and stability against minor shifts in equilibrium or low movement velocities (Carter et al., 2006; Di Lorenzo, 2011). This theory corresponds with the Pilates approach to core stability training (Carter et al., 2006; Di Lorenzo, 2011). The core-centric focus of Pilates stems from the concept of 'centering' during Pilates manoeuvres. This principle involves the gentle recruitment of the Transversus abdominis with an associated sub-maximal lift of the pelvic floor musculature (Culligan et al., 2010; Marques, Morcelli, Hallal, & Gonçalves, 2013; Sapsford, 2004). The aim of every exercise is to stabilise through, and strengthen the core, so as to provide a strong platform from which to generate movement, all while protecting the spine (Key, 2013; Muscolino & Cipriani, 2004b). Ultrasound scanning of the Transversus abdominis has positively demonstrated increased thickness of the musculature during Pilates manoeuvres when the centering principle is employed (Endleman & Critchley, 2008). This engagement is additionally enhanced by the unique Pilates breathing pattern (Barbosa et al., 2015). The Transversus abdominis assists in respiration when expiration is forced voluntarily, as is done through the Pilates breathing technique (Kloubec, 2011). This is in contrast to normal breath patterns where the Transversus abdominis is not involved (Hodges & Richardson, 1997; Kloubec, 2011). It is believed that the Pilates breathing technique assists with the sustained contraction of the core muscles, allowing for stabilisation, without encouraging rigidity or bracing (Latey, 2002).

Limited research has investigated the effect of Pilates on the ability of individuals to activate the Transversus abdominis or the endurance of this muscle (Bernardo, 2007; Christopher et al., 2006; Phrompaet et al., 2011), however, some research has suggested that Pilates practice may result in improved lumbo-pelvic stability through improved core engagement (Herrington & Davies, 2005; Phrompaet et al., 2011; Pumpa et al., 2015). Pilates practitioners have shown improved Transversus abdominis recruitment abilities when compared to individuals who only performed abdominal curl up exercises as well as an inactive control cohort (Herrington & Davies, 2005). Healthy adult females, aged 20-54 years, were randomly assigned to a Pilates, abdominal curl up or inactive control group, which then participated in their respective routines for 6 months (an average of one session per week). They were then assessed in a Transversus abdominis isolation test using a pressure biofeedback unit. Within the Pilates group, 83% of participants successfully performed the test while the abdominal curl up and control groups showed 33% and 25% success rates respectively (Herrington & Davies, 2005). Other research found that healthy adults have more success in performing the Pilates centring principle than individuals experiencing lower back pain (Marques et al., 2013). It was also found that Pilates exercise had the same effect on pelvic floor muscle tone enhancement as that of the equivalent number of pure pelvic floor muscle training sessions – between 20-24 classes over three weeks (Culligan et al., 2010). Interestingly, the participants in this study received private/individual Pilates training, an uncommon occurrence in the literature.

Unfortunately, the transfer of core stabilising exercise benefits into the activities of daily living or functional tasks is not well documented (Critchley, Pierson, & Battersby, 2011; Lamoth, Meijer, Daffertshofer, Wuisman, & Beek, 2006; Liebenson, 2012; McGalliard et al., 2010). Similarly, there is no conclusive evidence supporting an improvement in physical performance from improved core stability, yet related exercises are often prescribed for sportspersons in order to improve their execution (Borghuis et al., 2008). As low levels of abdominal activation are required during standing, it is thought that working this musculature may ultimately be of little advantage (Lederman, 2010). It is also suggested that overworking these muscles and forcing a neutral position, may be detrimental rather than advantageous, resulting in more compressive loads on the spine, increased stress on the body, as well as trigger point development (Wallden, 2009).

Education is also an important factor. Teaching an individual to engage through their core is difficult (Endleman & Critchley, 2008) and may result in them bracing or stiffening the back, due to a misunderstanding of the cues or explanations. This bracing may lead to compression through the lumbar spine, inducing pain and potentially, injury (McNeill, 2014). This makes teaching core stability a difficult task for physiotherapists or other instructors, and is hard to detect through accurate measurements (Worth, Henry, & Bunn, 2007).

2.3.4 A Contemporary Approach

The contemporary Pilates method taught in fitness studios today sees some minor adaptations from the original exercises and movements developed by Joseph Pilates (Latey, 2001; Muscolino & Cipriani, 2004a). These changes are as a result of improved understanding of kinesiology, as well as muscle activation and lumbar spine stabilisation (Latey, 2002; Sekendiz et al., 2007). That said, current-day Pilates still incorporates the ideologies and principles originally advocated by Joseph Pilates, including a mindful state of being during controlled, introspective movements, supplemented with purposeful breathing (Latey, 2001; Owsley, 2005). The idea of working from the core in conjunction with the specific breathing technique is still the principle focus of Pilates (Wells et al., 2012). Joseph Pilates encouraged the use of the ‘powerhouse’ and working with the ‘navel to the spine’, emphasising a ‘flattening’ of the back, particularly the lumbar vertebra (Muscolino & Cipriani, 2004a). Today, Pilates is primarily taught around a 'neutral' spinal and pelvic position. This is said to be biomechanically and functionally correct and thus the optimal position for conditioning (Owsley, 2005; Wallden, 2009). This is particularly important in the case of the Transversus abdominis which is said to function optimally in a neutral spine (Wallden, 2009).

Contemporary Pilates is not a standardised method, and does not have an international regulations board or similar umbrella organisation overseeing related institutes or Pilates as a method (McNeill & Blandford, 2013; Muscolino & Cipriani, 2004a). The resultant commercial branding of Pilates is a large part of its success in the global fitness industry today and many health-focused organisations claim to be the experts in the method, providing superior teacher-training programs (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011). Some international examples include BASI Pilates®, Peak Pilates® and STOTT Pilates® (a branch of Merrithew Health and Fitness™, Canada). All of these organisations offer instructor qualifications in South Africa. The South African Pilates Association (SAPA), a non-profit organisation, aims to support the local Pilates community including instructors, studios and Pilates practitioners alike. However, as of 2015 they appear to be under the guidance of the Register of Exercise Professionals South Africa (REPSSA), who now manage Pilates-related affairs on behalf of SAPA. Electronic communications with REPSSA (2016) suggested that there are currently only 83 accredited Pilates instructors within South Africa, according to the REPSSA database. Another online source, www.pilatesinfo.co.za (accessed 2016), showed over 800 certified instructors and studios in their national directory.

This lack of regulation or standardisation makes it difficult to assess the Pilates method and poses some challenges for research investigations. Some of these challenges are discussed below.

Individual versus group sessions:

There are both research-specific as well as organisational weaknesses when it comes to the Pilates method. From a research perspective, interventions require large sample sizes in order to ensure scientific rigour and validity. This need for 'numbers' results in

Pilates research being conducted primarily on groups rather than individuals, as was intended in the original method. This approach is ideal for large samples and 'overall' results, but may eradicate the individualised approach and focus that one would receive in private lessons. Outside the research environment, group classes are the reality for most Pilates studios or exercise centres. The same concern remains in that focus is divided between multiple participants. Exercises consisting of eight repetitions might not afford an instructor enough time to move from person to person correcting technique or form, thus putting class participants at risk of not receiving the attention they require (McNeill & Blandford, 2013). Studios use the 'group class' model as it allows for maximum client intake over a reduced time period, thereby increasing profits. On the other hand, the cost of private classes are generally higher and thus may also fall outside the financial means of most individuals, making group classes more accessible to a larger population (White et al., 2005). It would thus be interesting to determine if improved results were seen in individuals who received private training, as opposed to group sessions commonly employed in Pilates research. The same can be said for matwork based Pilates versus equipment options. Limited research has been done on Pilates practitioners using the uniquely developed machinery (da Luz et al., 2013). This could similarly present a cost bias as the machinery is expensive to purchase and is limited to one practitioner per piece of equipment. Again this would limit the number of individuals that could participate at any given time, be it in a research or studio environment.

Cost of participation:

Given the exercise complexity and muscle control required during manoeuvres, a trained professional is needed to guide a Pilates class (Campos et al., 2016). Instructors use verbal cues and tactile guidance to assist practitioners in attaining this precision (Anderson & Spector, 2000). Instructor lead classes and in particular, unique methods such as Pilates, can be expensive and the cost of these exercise programs may therefore serve as a barrier to participation (Salmon et al., 2003). While local gymnasiums or health centres may include sessions as part of a monthly fee, private studios may charge higher rates for the specialised space, instruction and equipment they offer. Frequency of attendance can vary between 1 and 5 sessions per week (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011) although it is suggested that one hour per week is the most common training schedule for Pilates practitioners (Segal et al., 2004). The cost of attendance could thus be a deciding factor for those who cannot afford it (Keays, Harris, Lucyshyn, & MacIntyre, 2008), making Pilates unrealistic as an exercise intervention for a historically disadvantaged population.

Instructor training:

There are various options for qualification (McNeill & Blandford, 2013) ranging from online (e.g. Trifocus Pilates, http://www.trifocuspilates.co.za/) to weekend courses, as well as more intensive courses (>10 days duration), which are naturally more costly. Often the shorter courses require no examination and merely an accumulation of practical hours, while the longer courses require a practical and theoretical exam to be taken along with the accumulation of annual continued education points (e.g. Stott Pilates®). While these organisations all claim to offer high level teacher training and products, they fail to provide evidence for their claims. Similarly, while some organisations state that they do research, they don't make their findings available to the general public.

Education (beginner level):

A key component in Pilates training is education. Beginner practitioners need an introduction to the principles of Pilates before commencing with a class in order to follow cues from the instructor, as well as to maximise the benefits of each exercise. They may need a description of the differences between a neutral spine and the Pilates 'imprint' position, the breathing technique, as well as correct activation of core musculature. Disregarding this initial component may lead to faulty alignment, poor execution and the development of incorrect habits in beginner practitioners. However, the monitoring of this initial education by a regulatory body would be challenging and is thus not controlled in any way.

2.3.5 Purported Benefits of Pilates and Investigations to Date

The supposed benefits of Pilates are vast and range from specific physical and health gains to its ability to be adapted to the individual. Suggested performance benefits include improved balance and flexibility, as well as enhanced muscular strength and endurance (Bernardo, 2007; de Siqueira Rodrigues et al., 2010; Kloubec, 2011; Lange et al., 2000). Possibly the most popularly endorsed fitness benefit is related to core control and improved core strength (Christopher et al., 2006; Key, 2013). Other proposed advantages include improved posture, neuromotor fitness and movement patterns, muscle sequencing and body awareness, in conjunction with enhanced wellbeing and sleep quality (Bernardo, 2007; Cancela, de Oliveira, & Rodríguez-Fuentes, 2014; Leopoldino et al., 2013; McNeill, 2012a; Shea & Moriello, 2014). Lastly, purported benefits for psychological health included improved mood and life satisfaction (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011; Tolnai et al., 2016).

Given the popularity and global uptake of this exercise phenomenon, there is little evidence to support the claims made by instructors and training organisations (Bernardo, 2007). Although developed almost one hundred years ago, the international impression of Pilates is that of a relatively 'new' exercise method and, as a result, scientific research supporting the claims of these organisations is limited, inconclusive and often anecdotal (Kloubec, 2011; La Touche et al., 2008; Lange et al., 2000; McNeill, 2012a; Shedden & Kravitz, 2006). Weak study design, low participant numbers and poor reproducibility of methodologies have been common limitations in previous investigations. Often, the exercise progression is not defined and indeed individual exercises are not specified, making it difficult to establish if it was in fact the Pilates method utilised in the research (Bernardo, 2007).

Randomised controlled trials investigating Pilates outcomes have repeatedly been conducted on unique groups or populations with specific conditions (Cancela et al., 2014; Cruz-Ferreira, Fernandes, Laranjo, et al., 2011; La Touche et al., 2008; Posadzki, Lizis, & Hagner-Derengowska, 2011), such as professional dancers returning from injury (Lange et al., 2000). Similarly, the benefits of Pilates for the elderly have been explored (Amorim, Sousa, Machado, & Santos, 2011; Bernardo & Nagle, 2006; Bird, Hill, & Fell, 2012; Cancela et al., 2014; de Siqueira Rodrigues et al., 2010; Hyun et al., 2014; Irez, Ozdemir, Evin, Irez, & Korkusuz, 2011; Newell et al., 2012; Pérez et al., 2014). These investigations have paid particular attention to balance enhancements and improvements in gait and mobility (de Siqueira Rodrigues et al., 2010; Hyun et al., 2014; Newell et al., 2012). Given the large medical costs incurred annually due to accidental falls in aged adults, methods of fall prevention are understandably sought after (Newell et al., 2012). Of further medical importance is the effects of Pilates on specific and non-specific lower back pain (Alves de Araújo et al., 2012; dos Santos Rodrigues, de Oliveira, & Matos, 2014; Rydeard, Leger, & Smith, 2006; Stieglitz, Vinson, & Hampton, 2015). While it has proven beneficial when compared to minimal intervention strategies, there is limited evidence to suggest that Pilates is more effective than other exercise regimes (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011; Posadzki et al., 2011; Wajswelner, Metcalf, & Bennell, 2012).

This focus on special populations has left a paucity in the research regarding the effects of Pilates for healthy, asymptomatic individuals (Bernardo, 2007). An early appraisal of the Pilates literature published up to 2005 found cautious support for improvements in flexibility, core muscle activation, as well as general muscle activity in healthy adults (Bernardo, 2007). However, this assessment came from just three papers. The author listed poor experimental design, small sample sizes and lack of description of the Pilates method as decreasing the validity of these investigations (Bernardo, 2007). A 2011 systematic review found sixteen papers published on healthy adults trials, however they were similarly rated as having low scientific rigour (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011). Strong evidence was found for the improvement in flexibility and dynamic balance, with only moderate evidence for enhanced muscular endurance (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011). In 2016, a new systematic review suggested only nine randomised controlled trials existed (Campos et al., 2016). However, this review narrowed its search results by eliminating papers that included children, the elderly or dancers as investigation populations (Campos et al., 2016). This review also acknowledged improvements in muscular endurance (abdominal endurance) as well as dynamic balance (Campos et al., 2016). Interestingly, their findings suggested that Pilates did not affect flexibility, which they attributed to the lack of static stretching within Pilates exercises. Again the papers reviewed were considered to have poor methodological quality (Campos et al., 2016). Both systematic reviews called for more research to be conducted on the effects of Pilates on healthy adults, and that investigations should include larger sample sizes, randomisation, blinding criteria and allow for reproducibility (Bernardo, 2007; Campos et al., 2016; Cruz-Ferreira, Fernandes, Laranjo, et al., 2011). It is clear that more evidence is needed to confirm any effects of Pilates on flexibility, muscular endurance and balance in healthy adults. Similarly, there is minimal evidence for other health and fitness parameters and they thus require further investigation.

Young adults have not received much focus in Pilates investigations to date, and those that have were, athletes or dancers (English & Howe, 2007). Furthermore, poor study design, lack of replication, as well as inconclusive results have left paucity in the evidence to support this method for young, healthy individuals (Aladro-Gonzalvo, Machado-Díaz, Moncada-Jiménez, Hernández-Elizondo, & Araya-Vargas, 2012; Bernardo, 2007). Similarly, there has been limited research focusing on beneficial effects of Pilates for *sedentary* individuals, younger than 60 years of age (Sekendiz et al., 2007). Middle-aged sedentary females participating in 15 Pilates sessions over 5 weeks showed improved abdominal endurance and strength as well as flexibility, when compared to a matched control group (Sekendiz et al., 2007). In another study, both clinical Pilates as well as verbal education were shown to have a positive influence on the beliefs of sedentary women (aged 20-45 years) regarding exercise, with Pilates (3 sessions per week over 8 weeks) having the greater impact of the two (Küçük & Livanelioglu, 2015). Pilates may therefore serve as an attractive option for transitioning from a sedentary to a more active lifestyle, which is pertinent to young, sedentary females. Ultimately, evidence to support potential benefits of Pilates for inactive, but healthy, young adult women is lacking (Arslanoğlu, Arslanoğlu, Reza, & Şenel, 2011; Giacomini, Silva, Weber, & Monteiro, 2016; Phrompaet et al., 2011; Sekendiz et al., 2007) and to date, only four recent investigations have considered this cohort (Table 3).

Table 3: Current research on the effects of Pilates on sedentary, but otherwise healthy, young adult females.

Authors & Publication Year	Sample Size	Participant Age Range	Duration/ No. of Sessions	Main Findings	Additional Points of Interest
C. Sinzato et al., **2013**	Np = 11 Nc = 10	18-25 years	10 weeks 20 sessions	Gains in flexibility were apparent, but not in postural alignment.	*Only 12 Pilates exercises used* & repeatedly performed throughout intervention period. No details of instructor qualification.
S. Kibar et al., **2015**	Np = 23 Nc = 24	18-25 years	8 weeks 16 sessions	Significant improvements in waist circumference, flexibility, lumbo-pelvic stability, abdominal strength & static balance.	*No description of exercises* resulting in poor reproducibility. No details of instructor qualification. Some participants had 'moderate' activity levels at commencement of intervention.
N. Tolnai et al., **2016**	Np = 32 Nc = 18	19-24 years	10 weeks 10 sessions	Significant improvements in dynamic balance, flexibility and abdominal muscle strength. Significant improvements in body awareness & psychological measures.	Pilates protocol included other *non-Pilates exercises* (e.g. plank & standing balance exercises). Focused stretching. Instructor qualification was unclear.
*B. Donaheo-Fillmore et al., **2015**	Np = 27 Nc = 30	18-35 years	3 weeks 3 sessions, then 7 weeks 2 sessions	Significant increases in dynamic balance, trunk flexor endurance, and flexibility.	*Unsupervised home-based protocol. No instructor. Larger age range. Control group may have been active. Activity levels of participants was not specified.

Where Np denotes sample size of Pilates groups; Nc denotes sample size of Control groups

Although the studies listed in Table 3 were randomised controlled trials, each study comprised of different sample sizes, varying intervention durations or number of Pilates sessions. Methodologies were questionable in terms of the exercises performed, the inclusion of non-Pilates manoeuvres or an unsupervised program. The first paper by Sinzato and colleagues (2013), focused on just two measures, namely flexibility and postural alignment changes, over a 10-week period and 20 Pilates sessions (Sinzato et al., 2013). Although the sample sizes for each group were small, the results suggested that Pilates has a significant impact on flexibility, specifically in the lower back and hamstring regions, as indicated through a “sit and reach” test. Flexibility measures in the Pilates cohort increased by 19.1% ($p=0.036$, Cohen’s $d=0.43$) post-intervention (Sinzato et al., 2013). No changes were observed in postural analysis. Interestingly, all 20 Pilates sessions repeatedly covered the same twelve exercises out of a possible 50+ manoeuvres. In addition to this the protocol included a ‘side-plank’ within the prescribed exercises, which is not a traditional Pilates movement. It is also difficult to determine the progression used as some of the exercises listed are considered to be of an intermediate level. It would be ill-advised to include these exercises in the initial sessions given the increased risk of injury to the novice participants. If preparatory exercises were used, they were not mentioned within the article text. The qualification of the instructor was also not reported, however given they were listed as a qualified physiotherapist, it is likely that they were suitable for the task (Sinzato et al., 2013).

The second investigation included participations with both low and *moderate* activity levels, suggesting some of the participants were physically active at the commencement of the intervention (Kibar et al., 2015). This makes it challenging to determine the effects of Pilates on purely inactive individuals. The intervention period consisted of bi-weekly sessions and was only 8 weeks in duration. No details as to the specific Pilates exercises used were given, thus preventing replication. Post-intervention hamstring flexibility, again measured via the “sit and reach” test, significantly improved ($p<0.00$, $f^2 = 0.44$, +5 cm) (Kibar et al., 2015). Transversus abdominis and lower back musculature activity, measured via a pressure biofeedback unit, showed a significant improvement ($p<0.001$) in the exercise group after 6 weeks, with no change in the abilities in the control group (Kibar et al., 2015). The authors’ description of this specific measurement technique was unclear, particularly for that of multifidus activation. In addition, it was suggested to be a measure of strength even though they referred to it as ‘activity’ throughout. These results should therefore be interpreted with caution. A 60 second curl up test showed a significant improvement when comparing the abdominal endurance of the Pilates group to that of the control cohort ($p<0.00$, Cohens' $f^2 = 0.51$). The same outcome was observed for static balance, while only within-group differences were observed for dynamic balance and waist circumference (Kibar et al., 2015). Both static and dynamic balance were measured using a "Sport Kinesthetic Ability Trainer (KAT) 4000" machine (Med-Fit Systems Inc., Fallbrook, C.A., USA). The investigation also attempted to determine if there was a correlation between the various fitness measures and improved balance however none was found (Kibar et al., 2015). Given the larger cohort sizes, the differences in participant activity levels, the measures investigated and the significant differences found in results after 16 sessions (and in some cases 12 sessions) it is difficult to compare the results from this research with those of the previous paper.

The research conducted by Tolnai et al*.,* (2016) is novel as, not only did it make use of a low training session frequency (10 sessions in 10 weeks), but it also focused on psychological impacts as well as physiological measures. Statistically significant improvements were seen in the Pilates cohort for dynamic balance ($p=0.001$), flexibility ($p=0.012$), core muscle strength ($p=0.001$), abdominal muscle strength ($p=0.001$) and skeletal muscle mass ($p=0.016$) (Tolnai et al., 2016). Interestingly, the core and abdominal muscle "strength" measures employed are ultimately endurance tests. The core strength test was measured by means of a timed static plank test while abdominal muscle strength was determined by counting the number of sit ups performed during sixty seconds. Given the nature of these tests it suggests a flawed methodology, where other tests should have been used to identify strength changes over time. Psychological effects were also impacted after the 10 sessions, with an increase in body awareness and decreased negative effect (Tolnai et al., 2016). While it was stated that they were qualified, the specifics of the Pilates instructor's qualifications and experience were neglected. Notably, non-Pilates exercises were listed in the given exercise program, similar to that of the paper by Sinzato et al., (2013). Examples included "downward dog" – a common yogic position, single leg standing balance exercises, a 30 second prone plank position, and lastly the ending of each Pilates session with a focused stretching and cool down period. Given these additional inputs, balance and flexibility results should be read with caution as it is unlikely that they were solely affected by the Pilates practice alone.

The final study in Table 3 employed a unique protocol. This research investigated the effects of a *home-based* Pilates regime for young, healthy women (n=57, aged 18-35 years – a greater age range). The intervention was 10 weeks in duration and the exercise cohort followed a DVD series at home. Measures investigated included core endurance, hamstring flexibility, bilateral dynamic balance, body composition, and perceived stress. Improvements were seen in both the Pilates and control group for the first three measures. This may have been due to the lack of restrictions regarding additional physical activity participation for the control cohort. No record of their activity levels was kept during the intervention period thus confounding the results (Donahoe-Fillmore, Fisher, & Brahler, 2015). The premise of an 'at home' Pilates regime is not ideal for beginner or novice Pilates practitioners. As an instructor-based system, the purpose of the instructor is to guide the beginner through manoeuvres by adjusting postures and correcting technique and execution (Anderson & Spector, 2000; Campos et al., 2016). An instructor is also able to modify exercises when a participant is not able to perform them correctly. Beginners participating in these exercises unsupervised, at home, would thus not receive the necessary guidance during the workout. Similarly, there is reduced management with of exercise progression and participants are therefore at greater risk of injury. Given the mentioned limitations, this investigation could be seen as possessing questionable methodology, decreasing its scientific rigour.

Ultimately the four investigations in Table 3 cast doubt as to the frequency of Pilates sessions required to impact physical fitness or health parameters in a cohort of young, sedentary adult females. They provide some evidence to suggest that Pilates may improve hamstring and lower back flexibility in this group, as this measure showed significant increases in all three studies (Kibar et al., 2015; Sinzato et al., 2013; Tolnai et al., 2016). However, given the inclusion of yoga manoeuvres and specific stretch routines, this evidence should be read with caution and further research is needed. In addition, the dissimilarities in the measures investigated within these three papers makes it difficult to compare and contrast their results.

Given the low number of investigations currently available on this cohort, further research is required in order to confirm or refute these findings. In addition, other parameters that also warrant investigation in this population group include changes in muscular endurance, over and above those of the abdominal muscles (Christopher et al., 2006). Similarly, health measures such as blood pressure or lung function have not yet been considered. The remainder of this section will therefore focus on additional physical fitness and health parameters that should be considered for future Pilates research, particularly in a young, sedentary female population.

2.3.5.1 Effects of Pilates on certain physical fitness and health parameters

i) Anthropometry

Joseph Pilates did not promote his exercise method as a means of altering body composition or aiding in weight management (Aladro-Gonzalvo et al., 2012). Despite this, some researchers suggest that there may be beneficial effects of Pilates practice on elements of anthropometry (body mass, Body Mass Index and waist circumference). These results are however inconclusive and thus require further investigation (Aladro-Gonzalvo et al., 2012; Donahoe-Fillmore et al., 2015). While it is known that large, sustainable changes in body mass are as a result of diet combined with exercise programs (Miller, Koceja, & Hamilton, 1997), the American College of Sports Medicine suggests that regular resistance training can induce changes in body composition, although this appears to apply more to older females (Garber et al., 2011). Given Pilates is considered a form of resistance exercise (de Siqueira Rodrigues et al., 2010), changes in body composition could potentially be expected, yet there is limited evidence to support this.

A 2012 systematic review suggested that this lack of empirical evidence may be due to limitations within the investigations such as weak experimental design, small sample sizes, lack of measurement standardisation or use of certified instructors (Aladro-Gonzalvo et al., 2012). In addition to this, the control of variables such as nutritional status have been neglected (Aladro-Gonzalvo et al., 2012). Further, investigations (some observational only) have been conducted in distinct population groups such as the elderly (aged 65+ years) or hypertensive individuals, over short time intervals (5 weeks) (Bergamin et al., 2015; Segal et al., 2004; Sekendiz et al., 2007; Tsai, Liou, Kao, Wang, & Huang, 2013).

Physically active individuals (men and women) participating in three Pilates classes per week over 8 weeks showed a statistically significant within-group decrease in waist circumference (-2.7 cm) compared to no changes in the matched, physically active control group participants (Rogers & Gibson, 2009). A study on obese, hypertensive women, using prescribed anti-hypertensive medication, similarly showed significant decreases in waist circumference after 16 weeks of twice weekly sessions (Martins-Meneses, Antunes, de Oliveira, & Medeiros, 2015). While changes in BMI for this cohort were not significant, the exercise group did manage to alter their overall BMI status from 'obese' to 'overweight (according to classifications as per Table 4) whilst the control group remained within the obese category (Martins-Meneses et al., 2015). The intervention group therefore decreased their risk for the development of health complications associated with a high BMI and obesity, including cardiovascular diseases and metabolic syndrome (Martins-Meneses et al., 2015; Rezende et al., 2006).

Table 4: Body Mass Index (BMI) standards adapted from the World Health Organisation (1995, 2000 and 2004, www.who.int).

Classification	BMI ($kg.m^{-2}$)
Underweight	Less than 18.5
Healthy weight	18.5 to 24.9
Overweight	25.0 to 29.9
Obese	30.0 or more
Obese, high risk	35.0 or higher

An observational study comparing women (aged 26-63 years) who performed twice weekly reformer Pilates classes for two years or less, with those who had been practicing for more than two years, found a significant difference in body mass and waist circumference ($p<0.002$). The more experienced group possessed lower figures, suggesting long term, sustainable weight management (Cristóbal et al., 2014). However, as this was a cross-sectional study without intervention, factors such as dietary habits or supplementary exercise programs may have impacted on these results

(Cristóbal et al., 2014). Lee et al., (2016) investigated stature and body mass measures in middle-aged women participating in three weekly Pilates sessions over 12 weeks (Lee, Oh, Han, Jin, & Roh, 2016). They used a body composition analyser (X-scan Plus II) and a three-dimensional (3D) scanner to show a statistically significant decrease in body mass ($p<0.05$) and increase ($p<0.01$) in stature (Lee, Oh, Han, Jin, & Roh, 2016). The increase in mean stature (0.5 cm) was unexpected and unexplained by the authors. Another study using middle-aged, sedentary women looked at the effects of three Pilates sessions (45 minutes duration) per week over eight weeks. They only found a significant decrease in body fat percentage ($p<0.05$, 3% decrease), while other measures such as body mass, BMI and waist-to-hip ratio did not change significantly (Arslanoğlu et al., 2011). Limitations of this study include the small sample sizes with only ten individuals per group. There was no mention of dietary control or a description of the low-intensity workout prescribed.

In contrast, an uncontrolled observational study by Segal et al., (2004), used bioelectrical impedance to measure truncal lean body mass in middle-aged Pilates practitioners at two, four and six month intervals (Segal et al., 2004). Their results showed that *once-weekly* Pilates over 6 months resulted in no significant changes in body composition, which was attributed to the fact that Pilates has no aerobic or cardiovascular exercise component (Segal et al., 2004). The low frequency of classes may have had an impact, similar to that found by Tolnai et al., (2016), although according to the researchers this was the frequency most likely to imitate real-life attendance (Segal et al., 2004). In a quasi-experimental study performed on healthy adults aged 20-60 years, twice weekly Pilates sessions over 12 weeks was not enough to elicit any change in body composition (Tsai et al., 2013). The large age range and lack of randomisation of the participants, as well as the fact that some were already moderately active, may have affected these results. Young girls, aged 11 years, participating in 20 sessions of Pilates over 4 weeks showed a significant reduction in BMI percentile (3.1 BMI percentile) compared to an increase in the control group (Jago et al., 2006). Yet BMI, body mass and waist circumference figures again showed no significant difference to pre-intervention measures (Jago et al., 2006). Only one other study has focused on young females and found no significant changes in BMI or waist circumference after two Pilates sessions per week over 8 weeks (Kibar et al., 2015). Interestingly, 12 weeks resistance training did not significantly affect body mass or BMI of young adult females (aged 25.3 ± 3.2 years) when participating in 3 sessions per week (Moghadasi & Siavashpour, 2013), suggesting that similar results may be expected from Pilates. Pilates may thus potentially serve as a form of weight maintenance, particularly in healthy adults. However, given the limited literature on young healthy females to date, this requires further investigation.

ii) Balance

Balance, or postural equilibrium, can either be maintained in a static position or while “moving a stable posture over a base of support”, termed dynamic balance (Browne & O’Hare, 2001; Johnson et al., 2007). Given that most Pilates matwork exercises are performed supine, prone or seated, it is interesting that it should be promoted as a means of improving balance. However, these enhancements are thought to result from increased core control and muscle strength, combined with improved motor control (Johnson et al., 2007).

While Pilates has been shown to be a suitable method for improving neuromotor fitness, including both static and dynamic balance, in elderly populations (Barker, Bird, & Talevski, 2015; Bird et al., 2012; Campos De Oliveira, Gonçalves De Oliveira, & De Almeida Pires-Oliveira, 2015; Cancela et al., 2014; de Siqueira Rodrigues et al., 2010; Irez et al., 2011; Lee, Hyun, & Kim, 2014; Newell et al., 2012; Vieira et al., 2016), the effect in healthy adults is not clear (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011). Elderly individuals are more susceptible to falling and risk serious injury (Irez et al., 2011), which necessitates finding techniques for improving their balance abilities. Fall rates in the elderly are understandably higher than those of younger adults (35% versus 18% respectively) (Talbot et al., 2005). However, it has been suggested that implementing balance improving techniques from early adulthood may assist in maintaining good balance ability into later life. This may be pertinent to females who show higher falling incidence rates (Talbot et al., 2005).

There is said to be a positive effect on balance in healthy adults through Pilates practice (Campos et al., 2016), however this claim comes from a review of just two papers. Uncertainty also stems from the variety of different measures of balance ability used to date (Kibar et al., 2015) (e.g. Timed Up and Go test, one legged stance test, Functional Reach Test, dynamic force platform), as well as the comparison of apparatus-based to matwork Pilates regimes. Middle-aged individuals (men and women) showed no changes in *static* balance ability after 24 sessions over 12 weeks (Kloubec, 2010). In contrast an observational study into single leg static balance suggested that middle-aged women (aged 35-50 years), who practiced Pilates twice weekly over the course of one year, showed markedly better balance results when compared to a sedentary matched group (Słupik et al., 2015). There is some evidence to suggest that *dynamic* balance in healthy adults (aged 23-31 years) can be improved by small, yet statistically significant margins ($p<0.01$) (Johnson et al., 2007), but the research remains inconclusive for this age group and younger individuals. In addition, this investigation was apparatus based and only consisted of 10 Pilates sessions over 5 weeks.

As far as the researcher is aware, there is no evidence to suggest that increased *sedentary* behaviour or lack of physical activity may alter balance ability in young, healthy females, but this has been found to be the case in postmenopausal women (Morales et al., 2012). However, research has suggested that maintaining physical activity levels and muscle tone may stave off decline in balance abilities (Gaerlan, Alpert, Cross, Louis, & Kowalski, 2012; Westlake & Culham, 2007). This suggests that improving balance ability at a younger age and maintaining this level would be beneficial in the long term. Previous research into the effects of Pilates in sedentary populations did not include balance measures (Sekendiz et al., 2007) and it therefore requires further investigation. Similarly, more research is needed to determine the frequency and exercise intensities needed to bring about any benefits (Gaerlan et al., 2012; Garber et al., 2011). Balance ability in younger individuals has not been well studied. However, it has been suggested that the visual system is the primary sensory system in balance regulation in young adults (aged 20-30 years), rather than the vestibular or somatosensory systems (Gaerlan et al., 2012). Since previous Pilates research on this cohort used *moderately-active* individuals, as well as balance-related exercises within the intervention protocol (Kibar et al., 2015; Tolnai et al., 2016), the effects of Pilates remain unclear. It is thus necessary to determine if static and dynamic balance ability of sedentary, young adult females is influenced by Pilates practice.

iii) Flexibility

Flexibility, or the ability to achieve extended range of motion, is essential for both performance and injury prevention (Booth et al., 2012; Kibar et al., 2015; Porcari, Bryant, & Comana, 2015). As a single, independent fitness measure, flexibility has even been shown to be a predictor of age-related arterial stiffness – a risk factor for cardiovascular disorders (Kao et al., 2014; Yamamoto et al., 2009).

Due to the attachment of the hamstrings on the ischial tuberosities of the pelvis, restriction through tight or inactive musculature can directly affect the lumbar spine through constrained pelvic tilting (Esola, McClure, Fitzgerald, & Siegler, 1996; Feldman, 2001). Improving flexibility, specifically in this region of the body, seems to be one of the more supported claims in the Pilates evidence base, however it is one of the most often studied (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011). Improvements are thought to develop from the static and dynamic stretching movements common in Pilates exercises (Campos et al., 2016; Phrompaet et al., 2011), such as the *Saw, Roll Over, Open Leg Rocker* and *Scissors*. Improved flexibility is a popular goal with individuals new to the Pilates method. In a survey of over 300 new Pilates enthusiasts, 32% listed improved flexibility as a desirable objective, with the most desirable being improved posture (38%) (von Sperling de Souza & Brum Vieira, 2006).

It is well known that stiffness increases, while muscle length decreases, with age (Youdas, Krause, Hollman, Harmsen, & Laskowski, 2005). Although women tend to have a greater range of motion than men throughout life, they are still affected by diminished movement as a result of age (Youdas et al., 2005). It is therefore understandable that middle-aged and older adult populations have been investigated with regards to the effects of the Pilates method on flexibility (similar to that of balance ability) (Cancela et al., 2014; Kao et al., 2014; Kloubec, 2010; Martins-Meneses et al., 2015; Phrompaet et al., 2011; Rogers & Gibson, 2009; Segal et al., 2004). Further, sedentarism and prolonged sitting results in less musculo-skeletal activity and an imbalanced musculature, leading to impaired function through stiffness (American College of Sports Medicine, 2013). Sekendiz and colleagues (2007) found that a 5-week Pilates exercise program with 3 sessions per week could improve posterior-trunk flexibility in middle-aged females with sedentary lifestyles (Sekendiz et al., 2007).

Although the support is cautious, most research has found evidence to suggest that Pilates does improve flexibility, yet support for this claim is still limited in healthy *young* women (Bernardo, 2007; Cruz-Ferreira, Fernandes, Laranjo, et al., 2011; Kloubec, 2011; Sinzato et al., 2013; Tolnai et al., 2016). While flexibility in this cohort has been examined (Table 3) (Kibar et al., 2015; Sinzato et al., 2013; Tolnai et al., 2016), the research is limited and the evidence not strong enough due to methodological discrepancies in each study. Healthy college-aged women (18-35 years) showed improved flexibility after a series of 'at home' Pilates sessions, performed 2-3 times a week over 10 weeks, however the same effect was found in the matched control (Donahoe-Fillmore et al., 2015). This suggests a learning effect. As mentioned, the limitations of a study using home-based sessions must be acknowledged.

It is clear that given their sedentarism and the fact that flexibility declines with age, establishing a means of maintaining, or potentially improving, flexibility from early adulthood is necessary for inactive women.

iv) Strength

The majority of strength investigations have been performed in elderly or middle-aged individuals (Arslanoğlu & Şenel, 2013; Bird et al., 2012; Campos De Oliveira et al., 2015; Irez et al., 2011; Kao et al., 2014; Sekendiz et al., 2007; Vieira et al., 2016). Various areas of the body have been investigated in these cohorts, such as lower back, abdominal, hip and lower limb strength, with a predominance of the focus being on the abdominal region (Donahoe-Fillmore et al., 2015; Emery, De Serres, McMillan, & Côté, 2010; Irez et al., 2011; Kao et al., 2014; Sekendiz et al., 2007; Vieira et al., 2016). This may be due to the variety of Pilates manoeuvres that target abdominal musculature, thus increasing the potential for improved strength through induced hypertrophy (Dorado, Calbet, Lopez-Gordillo, Alayon, & Sanchis-Moysi, 2012; Emery et al., 2010; Kloubec, 2011). However, due to varied populations, the multitude of measuring techniques and muscle fitness indicators, as well as conflicting results, the data remains inconclusive (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011).

Lower abdominal strength was assessed by Emery et al., (2010) by measuring the sagittal plane angle between the participants legs and floor whilst they lay supine having lowered the legs from 90° hip flexion. Participants were required to hold the legs in space for three seconds in order for the test to count. Significant improvement ($p<0.005$) was seen after 24 Pilates sessions conducted over 12 weeks. This test could potentially be used as a measure of abdominal and hip flexor endurance and this measure therefore gives ambiguous results for strength. Similarly, “strength” was used interchangeably with endurance when referring to core focused measures conducted by Donahoe-Fillmore et al., (2015). Participants with their lower body strapped to a plinth, were asked to raise their trunk to parallel with the floor, and to hold this position for as long as possible, thus requiring either flexion or extension of the torso. This timed test should thus indicate endurance, but has been used as a ‘strength’ measure within the published paper. No changes were seen between the intervention and the control group, however the researchers suggested that the test was not sensitive enough to identify between-group differences (Donahoe-Fillmore et al., 2015). In contrast, middle-aged women showed improvements in trunk flexor and extensor strength in as little as five weeks (15 sessions) (Sekendiz et al., 2007). The researchers used a Biodex isokinetic dynamometer at speeds of $60°s^{-1}$ and $120°s^{-1}$ as these were said to be similar to the velocity of Pilates movements. A significant difference ($p<0.05$) was found when comparing pre- and post-measures of peak torque for $60°s^{-1}$ flexion and extension as well as $120°s^{-1}$ flexion. These indicated a positive effect on abdominal and lower back strength (Sekendiz et al., 2007). Specifically selected Pilates exercises have similarly been shown to activate back musculature of healthy adult females. However, this investigation used EMG activation measures and involved once off measures only (Menacho et al., 2010).

Middle-aged females (aged 26-55 years), novice to the Pilates method, participated in 24 Pilates sessions over 12 weeks and showed significant improvements in lower limb strength both within groups ($p=0.001$) and between groups ($p<0.008$) (Kao et al., 2014). In similar research, healthy adults (men and women aged 20-40 years) showed no changes in lower limb strength after 12 weeks of Pilates (one session of either mat or reformer Pilates per week). Isokinetic dynamometry was used to measure dorsi and planter flexion peak torque, which the research suggested was a measure of foot strength. The number of heel raises to fatigue was described as lower limb muscular strength measure (Pumpa et al., 2015), but is ultimately more indicative of *endurance*, suggesting some ambiguity on the part of the researchers. The different populations, measures, frequency of sessions and Pilates type (matwork vs apparatus-based) used in these two investigations may be the reason for the contradictory results.

Investigations into strength improvements through Pilates for young, sedentary individuals are limited and inconclusive due to questionable methodologies (Kibar et al., 2015; Tolnai et al., 2016). An example was the measure of Transversus abdominis and multifidus activation as a measure of strength. The methodology and results, particularly for the latter, were unclear (Kibar et al., 2015). In addition, strength measures by Tolnai et al., (2016) were better suited as muscular endurance indicators and included curl ups within a 60 second period, as well as a timed static plank. There is thus a lack of evidence to support claims of improved strength in young adults, including that of upper and lower body strength.

v) Muscular endurance

There has been some research into the effects of Pilates on muscular endurance, however the evidence is to be considered as moderate at best, particularly in the case of healthy adults (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011). Justifiably, elderly populations have been investigated in an attempt to combat the decline in musculo-skeletal fitness and resultant sarcopenia associated with aging (Campos et al., 2016; Fourie, Gildenhuys, Shaw, Toriola, & Goon, 2012; Warburton et al., 2006). Similarly, given the numerous Pilates exercises involving flexion or isometric contractions of truncal musculature (Dorado et al., 2012), most endurance investigations have focused on abdominal musculature, with significant improvements seen in all instances (Donahoe-Fillmore et al., 2015; Kibar et al., 2015; Kloubec, 2010; Rogers & Gibson, 2009; Sekendiz et al., 2007). A recent systematic review of research on healthy Pilates practitioners found similar results and concluded that after 5-12 weeks of Pilates (at 2-3 sessions per week), abdominal muscular endurance improved by an additional 10 abdominal curls per 60-second sit up test when compared to non-exercising controls (Campos et al., 2016).

Arm or upper body muscular endurance has been less well studied with only two investigations focusing on this parameter. In a study investigating proximal upper body muscular endurance in university-level musicians (n=14), Pilates was shown to be as effective as a trunk-endurance focused exercise regime over 6 weeks (2 sessions weekly). However, given the small sample sizes, lack of randomisation and the lack of control group, these results should be interpreted with caution (Kava, Larson, Stiller, & Maher, 2010). Kloubec (2010) found that after 24 matwork Pilates sessions there was a significant improvement ($p<0.05$) in arm muscular endurance for the Pilates cohort ($n=25$) comprising of active, middle-aged men and women when compared to a matched control ($n=25$) (Kloubec, 2010).

Similarly, lower limb endurance has also only been examined in one instance, where the number of heel raises to fatigue was measured in a group of adults who were all new to the Pilates method (Pumpa et al., 2015). These volunteers participated in a mixture of matwork and equipment based classes and it was found that the change in lower limb endurance after 12 Pilates sessions (one per week) was not significant ($p=0.24$) (Pumpa et al., 2015).

vi) Blood pressure

While the research is limited, Pilates has been shown to have some beneficial effects on blood pressure (clinical and ambulatory) as well as combatting hypertension – particularly in older females (Cancela et al., 2014; Fourie et al., 2013) or those already on antihypertensive medication (Martins-Meneses et al., 2015). A 2015 systematic review suggested that Pilates exercises could result in some beneficial effects on blood pressure levels in populations with at least one cardiometabolic risk factor and sedentary lifestyles (Junges, Jacondino, & Gottlieb, 2015). Significant changes in blood pressure were seen in hypertensive participants who practiced Pilates five times per week – however, these individuals also followed a nutrition plan, along with a cardiovascular training element in their program (Wolkodoff, Andrick, Lazarus, Braunstein, & Patch, 2013). These additional factors may have contributed to the results. Sedentary middle-aged women (aged 38-41 years), categorised as overweight as per BMI classifications, showed a significant decrease in systolic blood pressure after 24 Pilates sessions over 8 weeks. Interestingly, the absolute change in their results was only 2 mm Hg. In addition, diastolic blood pressure levels dropped by 3 mm Hg post-intervention (Arslanoğlu & Şenel, 2013). While this change was not deemed to be significantly different to the control cohort it is possible that it may have had some clinical implications. In contrast, *young*, sedentary, overweight females showed no changes in blood pressure levels after 24 Pilates sessions in 8 weeks (Ali, Esfarjani, Bambaeichi, & Marandi, 2010). And young girls participating in 4 weeks of Pilates showed a non-significant decrease in systolic blood pressure over time (Jago et al., 2006). The effect of Pilates on blood pressure is thus still inconclusive, particularly in younger, healthy adult populations, and should be further researched (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011). Young women using oral contraceptives have not been investigated and, given that other similar exercises, such as yoga, provided *no* cardiovascular measure changes after 8 weeks (Tracy & Hart, 2013), it is necessary to determine if Pilates offers alternative results.

vii) Lung function

The breath pattern and technique in Pilates is one of the oldest principles from Joseph Pilates' original method. He focused much of his attention on using the breath to help cleanse the body and prevent illness (Latey, 2001). He is recorded as saying "True heart control follows correct breathing which simultaneously reduces heart strain, purifies the blood, and develops the lungs" (Latey, 2001). Pilates believed in maximal inhalation, and emptying the lungs as much as possible during exhalation whilst performing his exercises (Latey, 2001).

The breathing technique used in Pilates practice comprises of a deep inhale through the nose, with a 3-dimensional, lateral expansion of the ribcage, followed by an exhale through a pursed lip so as to create internal abdominal pressure and to thus 'squeeze the air out of the lungs' (Barbosa et al., 2015; Kloubec & Banks, 2004). This pattern is said to minimise the involvement of the abdominals – particularly during inhalation – which enables them to maintain contraction throughout (Cancelliero-Gaiad, Ike, Pantoni, Borghi-Silva, & Costa, 2013; Kloubec & Banks, 2004; Muscolino & Cipriani, 2004a). This is unlike diaphragmatic breathing which involves increased abdominal movement through the descending of the diaphragm, minimising the activity of the respiratory muscles within the ribcage region (Cancelliero-Gaiad et al., 2013). The Pilates breath pattern is also coordinated with movement and thereby assists with the timing and pace of the Pilates exercises (Latey, 2002).

Although the most frequently mentioned principle in the literature, this Pilates-specific method of breathing and its potential benefits for lung function or respiration, are neglected in the literature (Barbosa et al., 2015; Cancelliero-Gaiad et al., 2013; Giacomini et al., 2016; Tsai et al., 2013). Research comparing normal breathing, diaphragmatic breathing technique and the Pilates breath patterns suggested that the latter may increase respiratory volumes in healthy individuals, but not in those with chronic obstructive pulmonary disease (Cancelliero-Gaiad et al., 2013). An uncontrolled trial researching healthy, but previously sedentary middle-aged females undertaking 8 weeks of Pilates training (2 sessions per week) suggested that Peak Expiratory Flow may increase, but that spirometry measures including Forced Vital Capacity were not affected by the Pilates breathing technique (Giacomini et al., 2016).

2.4 SUMMARY OF THE LITERATURE

Physical inactivity levels, particularly in South African adult females, are extremely high and result in increased risk of a range of life-threatening diseases for these individuals (Joubert et al., 2007). In order to promote physical activity participation in adults, successful interventions are necessary. Not only should these interventions identify and address barriers to exercise, but should be implemented from early adulthood to increase the likelihood of continued participation throughout the individual's life (Bradshaw et al., 2007; Department of Health et al., 2007; Eyler et al., 2003; Foster, Hillsdon, Thorogood, Kaur, & Wedatilake, 2005). Long term adherence sets the platform for improved cardiovascular health and the decreased risk of non-communicable disease development over time, thus decreasing the burden on health care facilities and improving economic development (Ding et al., 2016; Mokabane et al., 2014; Mokdad et al., 2016; Warburton et al., 2006). Young adult females in South Africa have been identified as having high levels of physical inactivity and associated poor levels of fitness (Shisana et al., 2014). Increasing physical activity levels of this population should thus be a priority (Department of Health et al., 2007). Health status and physical fitness data for this group in the local Makana region of the Eastern Cape are limited. As such, more knowledge on the health and wellness of young women in the region is needed for the public health evidence base.

It is evident that Pilates may have some beneficial effects in terms of improving balance, muscular strength and endurance, as well as flexibility. However, research to date has focused primarily on elderly populations or symptomatic individuals. Little is known about the effects of Pilates for healthy adults. Pilates is highly popular with women of all ages, yet young females appear to be neglected in the literature. Healthy, young women may be considered low risk individuals for the development of cardiovascular and other non-communicable diseases, in addition to not yet experiencing age-related conditions, such as loss of balance. This makes them less ideal candidates for exercise interventions. However, given that the effects of Pilates on this specific demographic are unknown, it may be useful to identify any benefits that may exist. This lack of evidence applies to sedentary individuals as well (Bernardo, 2007; von Sperling de Souza & Brum Vieira, 2006). Pilates may offer a solution for implementing and maintaining a regular and enjoyable exercise schedule, particularly in sedentary young women (Tolnai et al., 2016). Further, the accompanying professional guidance and instruction may aid in a more effective, sustainable transition for these individuals (Foster et al., 2005). Given the paucity of data on the effects of Pilates on healthy, but sedentary young adult females, more research is required on this topic.

CHAPTER 3

METHODOLOGY

3.1 RESEARCH AIM

The aim of this research study was two-fold; firstly, to assess selected measures of health and fitness in females, aged 18-26 years, living in the Grahamstown/iRhini region of the Makana Municipality in the Eastern Cape Province of South Africa (Phase 1). The second aim was to investigate changes to these health and fitness parameters in a selected sub-sample of this group, following participation in an 8-week progressive Pilates intervention (Phase 2).

3.2 RESEARCH DESIGN

Phase 1: This phase was a semi-comparative, descriptive design. Since it was not possible to obtain normative data for all measures, or pertaining to the population and age range in question, similar data from recent national surveys or published texts were used. The surveys included two South African Demographic and Health Surveys (SADHS), conducted in 1998 and 2003, as well as the South African National Health and Nutrition Examination Survey (SANHANES-1) conducted in 2012. It should be noted that as the blood pressure data described in the SADHS 2003 is reportedly inaccurate it was excluded as a source of normative data. Similarly, while the SADHS surveys include standard error (SE) in their results this information is not available in the SANHANES-1 report. Spirometry norms consulted were those suggested for healthy adult females in general. Selected health and fitness measures from a cohort of healthy, young women (aged 18-26 years) were collected. Parameters investigated included anthropometric measures (stature, body mass, Body Mass Index (BMI) and waist circumference), musculo-skeletal measures (muscular strength and endurance), functional flexibility, lumbo-pelvic stability, balance (static and dynamic), as well as certain measures of health, specifically lung function and blood pressure (Table 5). This phase thus served as a point of reference with regards to aspects of health and fitness in these young women.

Table 5: Phase 1 Design Matrix.

	Physical Fitness and Health Parameters
Healthy, Young Adult Female Population	Anthropometry; Muscular Strength, Endurance; Static and Dynamic Balance; Lumbo-Pelvic Stability; Functional Flexibility, Blood Pressure; Lung Function

Phase 2: The second part of the study involved a progressive Pilates intervention implemented as a randomised controlled trial. Inactive, healthy females (aged 18-26 years) from the community, who formed part of the Phase 1 cohort and met the inclusion criteria for the intervention, were randomised into two homogenous groups, namely the *Pilates Exercise Group (PEx)* and the *Control Group (Con)*. Participants each selected a sealed, opaque envelope containing a group allocation from a shuffled pile. The intervention was run for an 8-week period with two Pilates classes per week. All sessions were conducted by the primary researcher; a certified STOTT Pilates® instructor with 3 years teaching experience. The study was thus not blinded. The same measures as those used in Phase 1 were used, with the additional measure of a Transversus abdominis isolation test. This measure was excluded from Phase 1 as it was only used for identifying the effect of Pilates on Transversus abdominis recruitment and so was not applicable to the participants of Phase 1. Measures taken at baseline were then repeated at 4-week intervals (Table 6). The control group were required to remain inactive, maintaining their same lifestyle on recruitment. This was controlled as far as possible.

Table 6: Phase 2 Design Matrix.

	Week 0	**Week 4**	**Week 8**
Pilates Exercise Group (PEx)	*Measures*	*Measures*	*Measures*
Control Group (Con)	*Measures*	*Measures*	*Measures*

3.3 ETHICS

The research procedures were reviewed and approved by the Ethical Standards Committee of the Human Kinetics and Ergonomics Department, Rhodes University, for research involving human participants (report reference HKE-2015-4; Appendix 1). The ethical approval application contained details on the methodology to be used in the research project as well as potential risks to participants and means of combatting these risks. Benefits to the volunteers were also highlighted. Means of maintaining participant confidentiality during and after testing were also outlined, along with the plans for feedback to participants regarding their personalised results. In accordance with ethical procedures, all participants were required to provide informed consent before participating in the research project.

3.4 PARTICIPANT RECRUITMENT AND CRITERIA FOR INCLUSION

Due to the age group of the population under investigation, social media and electronic communications were the primary tools used in recruitment. Young women from the community at large were invited to express interest, as well as those studying at Rhodes University. Community and Rhodes University related Facebook groups and other social media pages, as well as community newsletters, were used to advertise both phases of the research (Appendix 2). Posters were also placed on community notice boards (Appendix 6).

Once interest was expressed potential volunteers were sent an information form and email detailing various aspects of the project (Appendix 3) along with a list of the inclusion criteria (see 3.4.1). If they were eligible and still interested they were asked to confirm this with the primary researcher and to book a testing session.

At the testing sessions, the primary researcher welcomed the participants and explained the testing procedures in detail once again. All participants signed consent (Appendix 4) and completed the Participant Screening Questionnaire (Appendix 5). This screening form was signed and checked by the primary researcher and research assistants to ensure that the participant did indeed meet the criteria as previously claimed. Those who did not were excluded from participating (Figure 3). Those who were eligible were assigned a random participant code for data collection so as to keep their personal details and records confidential.

Before commencement of Phase 2, another introductory session was held for those eligible for participation in the Pilates intervention. This was done in order to explain the intervention time-period and exercise sessions, as well as testing procedures, pre-screening requirements, confidentiality of results, and the risks and benefits involved. This meeting presented the opportunity for the participants to voice any concerns or to ask questions. Those that remained interested and eligible were then asked to sign consent forms (Appendix 7). They also completed another Pilates-specific Participant Screening Form (Appendix 8), which served as a physical activity readiness predictor and was checked by the primary researcher before commencement of the intervention. After consent volunteers were randomised into the two intervention groups and assigned their unique codes for data collection purposes (Figure 3). It must be noted that the control group were offered the equivalent Pilates sessions at the end of the intervention period.

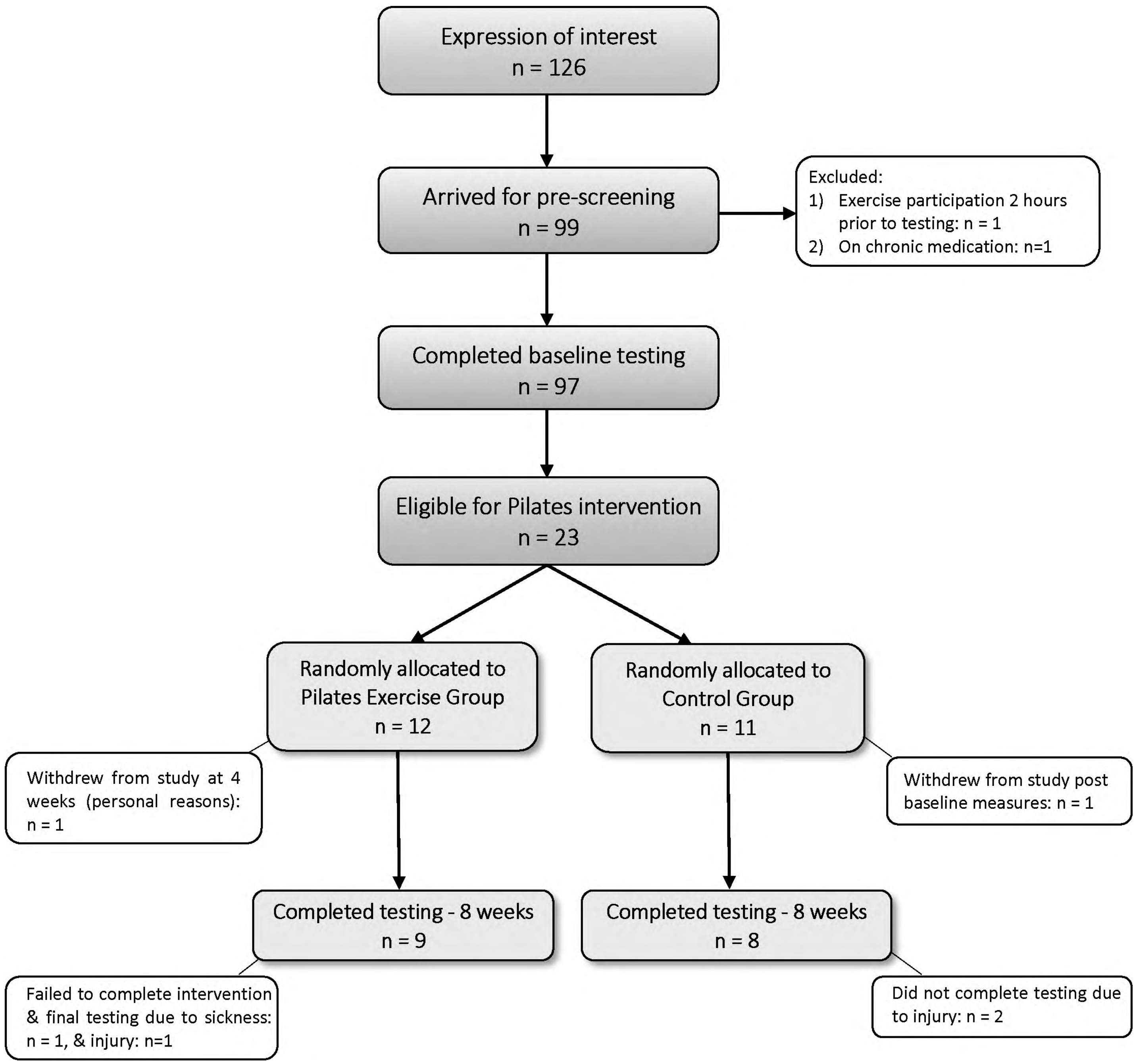

Figure 3: Consort flow diagram of Phase 1 and Phase 2 participants.

3.4.1 Phase 1: Inclusion Criteria

Inclusion criteria were broad so as to ensure that most young females from the age group were eligible to participate:

Female, age 18-26 years: Knowledge on the health and wellness of young adult females is restricted to national data collected during nation-wide surveys. Physical fitness and health data on this population, specifically in the local Grahamstown region is scarce, yet this group makes up the largest singular female group in the area (www.statssa.gov.za).

Race: Women from all races and ethnicities were eligible to participate in this study.

Not pregnant: It is well known that pregnancy alters various elements of physical fitness and health status. Balance, flexibility, VO_{2max}, blood pressure and tidal volume to name a few, are all affected as a result of pregnancy induced adaptions (Artal, 2003; Costantine, 2014; Melzer, Schutz, Boulvain, & Kayser, 2010; Mustafa, Ahmed, Gupta, & Venuto, 2012). From a practical point of view it would simply not be possible for pregnant females to accurately perform some of the tests involved, such as the curl up tests or the sit and reach flexibility test.

Good general health: Participants needed to be in good health (no head colds/influenza/chest infections or coughs) on the day of testing, as well as to confirm that they were not taking any additional chronic medication/s for heart, lung, kidney or liver ailments. Medication could cause severe side effects as a response to exercise, such as headaches, dizziness or hypotension, which thus presented a risk to participants (McArdle, Katch, & Katch, 2001). Health status was confirmed by self-reports, pre-screening and through direct communications with the participants.

No injuries: Injuries may have impaired physical abilities of participants leaving them unable to perform some of the tests and risking further injury. Injury status and risk were ratified through the pre-screening form and direct communications with the participants.

3.4.2 Phase 2: Intervention Inclusion Criteria

The inclusion criteria for the intervention phase were stringent and specific so as to limit confounding factors and to ensure a homogenous group of individuals. Hormonal control, Body Mass Index (BMI) range and physical activity levels were some of the restrictions imposed to control certain variables.

Female: Females typically show greater participation in Pilates (Aladro-Gonzalvo et al., 2012; von Sperling de Souza & Brum Vieira, 2006), yet the benefits of this exercise method for women is not well known. Young adult females show a higher level of inactivity when compared to their male counterparts (Owen et al., 2011). This behaviour has been shown to continue into later adulthood, leading to poor health and increased risk of NCD development (Hultquist et al., 2009). By encouraging females to become more physically active and to take ownership of their health earlier in their adult life, it may lead to healthier choices and possible prevention of illness and injury.

Age Range: 18-26 years of age. This age range is understudied in Pilates literature (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011). Young females may be considered a low risk, healthy population without the need for further exercise interventions. However, the rise in sedentary behaviour in this demographic, due to modern lifestyles, has resulted in the need for a novel exercise method that may encourage continued participation for sustained involvement in physical activity. Young females have been shown to have lower levels of physical activity when compared to their male counterparts (Buckworth & Nigg, 2010).

Race: Women from all races and ethnicities were eligible to participate in this study. As far as the author is aware, there is no evidence to suggest that race or ethnicity will influence the effect of strength and endurance training on musculo-skeletal adaptations or fitness levels in sedentary females from participation in any exercise type.

Activity Levels: Individuals with low physical activity levels were recruited i.e. prior to participation in the intervention they participated in less than 20 minutes organised activity on 3 or fewer days of the week, according to the recommended guidelines of the American College of Sports Medicine (ACSM) (Pollock et al., 1998). These participants also had no previous Pilates experience. Pilates has been investigated in different female populations, such as the aged, or those with lower back pain, however, limited knowledge is available on sedentary females (Sekendiz et al., 2007). In the event that these individuals may wish to become more active and remove themselves from a sedentary lifestyle, it is important to determine if Pilates serves as a useful mode of physical activity or not.

Overall Health: Participants were required to be in good health and not taking any additional chronic medication for heart, lung, and kidney or liver ailments. Medication could cause side effects in response to exercise, such as headaches, dizziness or hypotension, which presented a risk to participants (McArdle et al., 2001). Asthmatics were also excluded from the program due to the risk posed by exercise-induced bronchospasm, as well as to eliminate any potential effect on the lung function measures (McArdle et al., 2001). Participants had no musculo-skeletal disorders to report, particularly pertaining to lower back pain or cervical spine injuries, as these may have further increased their risk of injury. Participants presenting with lower back pain were excluded as it has been shown that this condition may be as a result of delayed Transversus abdominis activation recruitment (Herrington & Davies, 2005), which could directly affect specific measures. Participants who had undergone abdominal or spinal surgery were excluded, as muscular dysfunction is said to persist for more than 5 years post-surgery (Rantanen et al., 1993). Being a low risk group, as per the ACSM recommendations, participants were not required to obtain medical clearance prior to participation.

Body Mass Index (BMI): Since the intervention dealt with healthy adults and was not looking specifically at obese individuals, or those with metabolic disorders, participants were required to have a BMI within the normal to overweight ranges for adults, i.e. 18.5-29.9 $kg.m^{-2}$.

Blood Pressure: This research was not investigating hypertensive individuals, and as such participants' with a blood pressure in the healthy/normotensive or pre-hypertensive ranges were permitted.

Non-smokers: All participants were non-smokers (or had not smoked in one year or more before the beginning of the intervention). It is known that smoking cessation allows for an improvement in lung function and decreases further decline in FEV_1 (Willemse, Postma, Timens, & ten Hacken, 2004). Similarly, cardiovascular risk levels return to those of non-smokers within 12 months of smoking cessation (Gepner et al., 2011) .

Oral Contraception: Hormonal fluctuations are known to impact on various physiological functions such as blood pressure, as well as fitness parameters including isometric strength and endurance and pulmonary function (Dubey, 2002; Harms, 2006; Lebrun, 1993). This therefore needed to be controlled, so as to negate any impacts on the investigated measures due to the regular menstural cycle and expected hormonal changes. All participants were thus required to be on some form of hormone based contraception – be it orally administered or via injection/implant. This allowed for the repeated monthly measures to be taken at approximately the same stage of a predictable menstrual cycle (Bale & Davies, 1983). By controlling for these fluctuations the effects of hormone levels at that specific point in time can be negated as having an influence on the results found. Likewise, it has been suggested that the use of hormonal contraceptives available today, and the lower dosages involved, would similarly have deminished effects on athletic performance (Lebrun, 1993)

Not Pregnant/Breastfeeding: While Pilates is considered a safe activity for pregnancy, exercises are substantially adapted for expectant as well as post-natal women participating in this exercise method (McNeill & Blandford, 2013). Pregnant females were therefore not permitted to participate in the progressive exercise program. Hypermobility and increased joint laxity caused by hormonal changes place the expectant mother at increased risk of injury (Robert-McComb & Stovall, 2008). Similarly the change in abdominal muscle elongation would make it difficult for pregnant females to participate in some of the planned tests, such as the curl ups (Lederman, 2010).

English Speaking (or good English language understanding): South Africa currently has eleven official languages (www.statssa.gov.za). While documentation could have been translated into other languages for participants, it was impossible to accommodate translation for instruction during the Pilates session. The instructor as well as research assistants were all first language English speakers and so, while a translator could potentially have been made available for testing sessions, it would not have been viable for the Pilates sessions due to time constraints. Participants were therefore required to have good English language skills in order to ably follow instruction in the exercise and testing sessions. This applied to the Control group members as well if they wished to participate in free Pilates classes offered after the exercise intervention period ceased.

3.5 MEASURES

Measures were the same for both Phase 1 and Phase 2 of the research, with the exception of the Transversus abdominis isolation test which was omitted in Phase 1 (see 3.5.2.6). To minimise any circadian factors, measures were taken in the late afternoon. This was also the time where most participants and research assistants were available for testing. Measures for Phase 1 were performed over 4 separate testing sessions within a 7 day period. The PEx and Con groups had their measures repeated at 4-week intervals in an effort to minimise the impact of monthly hormonal fluctuations. The same individual (primary researcher or assistant) was responsible for the same measure at each testing session when possible, in an attempt to reduce variability.

3.5.1 Anthropometry:

Anthropometric measures comprised of stature, body mass, Body Mass Index (BMI) and waist circumference.

3.5.1.1 Stature:
Stature of each participant was measured using a stadiometer (Harpenden Holtain® by Seritex Inc., United States of America) and measured to the nearest millimetre (mm). Participants were required to stand with their back towards the stadiometer, barefoot and with 3 points, namely the head, gluteus maximus and the heels, in contact with the stadiometer.

3.5.1.2 Body mass:
Participants were barefoot and minimally clothed at time of weighing. Body mass was recorded using a calibrated electronic scale (Toledo®, Cleveland, Ohio).

3.5.1.3 Body Mass Index/BMI:
This was calculated according to the standard formula:

$$BMI = \text{Body Mass (kg)} / \text{Stature (m)}^2$$

3.5.1.4 Waist Circumference

Girth measures at the level of umbilicus were taking using a standard dressmaker's tape measure, held against the skin with no compression. The measures were taken while the participant was standing and readings were taken at the end of normal expiration, read to the nearest 0.1 cm.

3.5.2 Physical Fitness

Warm up:

Participants were required to warm up prior to commencement of testing. This included briskly walking 4 lengths of the laboratory (22.5m long) alternating movements with each length (Table 7). This sequence, including the numerous stairs climbed to reach the laboratory, was considered sufficient enough to warm participants up without inducing fatigue of any kind.

Table 7: Basic warm up procedure.

	Length 1	Length 2	Length 3	Length 4
Warm Up Procedure	Brisk walking with arm swings	Brisk walking with hamstring curls, bringing heel to glute	Full leg flexion reaching opposite hand to up-swinging foot	Brisk backwards walking

Habituation:

Each measure was demonstrated to the participants by the research assistant in question, and participants were required to attempt the manoeuvres to ensure correct execution before commencing the actual test. Participants in the repeated measures sessions were reminded of the tests and allowed to attempt the manoeuvres each time they came in for their repeated tests.

Physical fitness measures were as follows:

3.5.2.1 Balance

a) Static Balance

Static balance was measured using the Stork Stand Test (Gladwell et al., 2006). Participants were required to stand on one leg, with their lifted foot in line with the knee of the supporting leg. Hands were placed on their hips, while maintaining a neutral head posture. They were required to close their eyes in order to commence the test. The test was a timed measure and was ceased when balance was lost, either as a result of a large postural sway or when the participant returned their raised foot down towards the ground or made contact with the stabilising surface. Timing was also ceased if the participant opened their eyes. The test was performed with both legs (alternating between trials), with three repetitions per leg and the scores averaged. A 30 second rest period was given between each of the trials. This is an easy test to perform with high reliability (0.87) and validity (0.99) values (Tritschler, 2000).

b) Dynamic Balance

Dynamic balance was measured using the Functional Reach Test (FRT) and a modified version of the Star Excursion Balance Test in the form of a Y-balance test.

b_1) Functional Reach Test (FRT)

The FRT, is generally used to measure dynamic balance while standing (Duncan, Weiner, Chandler, & Studenski, 1990; Johnson et al., 2007; Kim, Yuk, & Gak, 2013), therefore measuring *bilateral* dynamic balance. It required that participants stood barefoot at a particular reference point with feet hip width apart and shoulders flexed forward to 90°, palms facing the ground. Without bending the knees or allowing the pelvis to move backwards, the individual hinged forward by flexing at the hips, with straight arms remaining at shoulder height. The heels remained planted on the floor throughout and the pelvis remained square i.e. no rotation. The distance between the start and finish point of the third metacarpal was measured in centimetres. The participant was expected to hold their maximal reach point for 3 seconds before returning to the start position. The test was repeated three times and the average excursion recorded as the FRT score.

b2) Y-balance Test (Modified Star Excursion Balance Test)

The Star Excursion Balance Test has been used extensively in research and clinical practice settings and acts as a low cost alternative to laboratory equipment in assessing *unilateral* dynamic balance (Herrington, Hatcher, Hatcher, & McNicholas, 2009; Munro & Herrington, 2010). The individual performing the star excursion balance test is required to maximally reach their gesture leg in eight specified directions while maintaining their base of support through their stance leg (Gribble & Hertel, 2003). Intraclass correlation coefficients are said to be high at 0.84 (Munro & Herrington, 2010) as well as intra- and inter-tester reliability (Hertel, Miller, & Denegar, 2000).

Although a low-cost test, there are disadvantages to the star excursion balance test. Most notable being the considerable time taken to complete the test due to the number of reach-directions, and repetitions, per leg, as well as the redundancy resulting from repeated trails (Gribble, Hertel, & Plisky, 2012; Munro & Herrington, 2010). It has been shown that reach-distance in one direction strongly correlates with that of the other seven directions in the test (Hertel, Braham, Hale, & Olmsted-Kramer, 2006). The *modified* star excursion balance test, otherwise known as the Y-balance test, offers a suitable solution to circumvent these shortcomings. The Y-balance test involves only 3 reach directions – specifically anterior, posteromedial and posterolateral (Figure 4). This test has shown high intra- and interrater reliability and is substantially quicker to perform (Gribble et al., 2012; Gribble, Kelly, Refshauge, & Hiller, 2013).

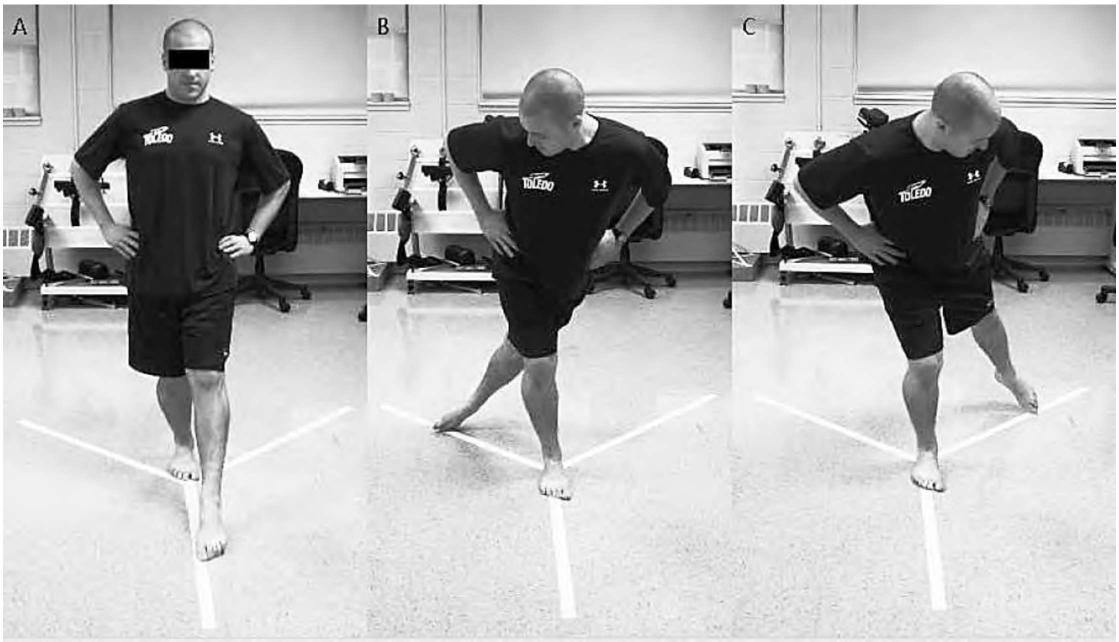

Figure 4: Y-balance test showing anterior (A), posteromedial (B) and posterolateral (C) reach directions. Image taken from Gribble, Hertel & Plisky, 2012.

Before commencement of the test, each participant was required to perform 4 practice rounds per leg, in order to eliminate any learning effects (Herrington et al., 2009; Munro & Herrington, 2010). They were then given 3 minutes recovery time before performing the test, along with one minute recovery time between legs. Direction of reach was randomised each time. The test was repeated 3 times per leg.

Participants were required to stand barefoot, hands on hips, with the stance leg on a centrally marked point in the middle of a grid with 3 lines extending out at 0°, 135° and 225° angle increments to form a Y-shape (Figure 4), each line being 120 cm long. The participant was then required to reach their non-stance leg out as far as possible along each of the demarcated lines and rest their toe on the ground without transferring any weight from the supporting leg. In the case of a posterior trial the participant's reaching leg moved behind that of the stance leg (Figure 4, B). The participant returned to bilateral stance in between the various trails. If balance was lost, significant weight transferred to the reaching leg, or the participant's heel of the supporting foot was lifted then the measure for that specific reach-direction was disregarded and the test for that specific direction was repeated.

The research assistants marked off each reach-point and measured the distance from the start position to this marked point using a tape measure (in centimetres). The test was performed three times per leg and the average distance per direction recorded (Herrington et al., 2009). Leg length of the participants was also measured from the anterior superior iliac spine to the distal tip of the medial malleolus (Gribble & Hertel, 2003). This was then used to normalise the data. Average reach distances per direction were normalised as a percentage of the *stance* leg length (Herrington et al., 2009; Hertel et al., 2000).

3.5.2.2 Flexibility

Posterior trunk and hamstring flexibility (functional flexibility) was measured using the Sit and Reach Test with a standard Sit and Reach box. This test has been shown to have high reliability values (0.94) (Jackson & Langford, 1989). The participants were required to remove their shoes sit in front of the Sit and Reach block with the ankles dorsiflexed and feet flat against the anterior board. They then extended their arms forward and placed their hands along the ruler with finger tips starting at 0 cm. To perform the test they were required to extend from the hips as far as possible during exhalation, reaching their hands as far as possible down the ruler. If their knees bent during the trial the result was excluded and the trial repeated. The test was repeated 3 times with 30 seconds recovery between tests, and the furthest measure recorded in millimetres.

3.5.2.3 Muscular Endurance

a) 60 Second Tests

In order to measure global or postural musculature endurance, a timed measure was used:

a_1) Abdominal musculature endurance

The number of curl ups (mini-crunches) performed within a 60 second period was used to measure global abdominal muscle endurance, with specific focus on the Rectus abdominis and the oblique groups (American College of Sports Medicine, 2013). Participants lay supine with legs bent to a comfortable 45° angle and approximately hip width apart, feet were placed flat on the mat and parallel. Arms were placed across the chest with each hand resting on the opposite shoulder. To successfully perform a curl up the participants were required to flex forward and lift their head, neck and scapulae off the mat, ideally avoiding any change in the pelvic position so as to avoid recruitment of the hip flexors. One mini-crunch or curl up involved lifting of the upper trunk followed by placement of the head back onto the mat. This manoeuvre was demonstrated to the participants by the research assistant before the test. Participants performed as many crunches as possible within a 60 second period, or to exhaustion (American College of Sports Medicine, 2013). The correct technique was required for the repetition to be counted and this was explained to participants beforehand and monitored by the research assistant at the station in question.

a2) Arm musculature endurance

To measure endurance of the arm musculature the number of push ups completed within a 60 second time limit was measured. The start position was a prone plank position with knees and feet in contact with the floor, legs parallel and hip-width apart or adducted. Arms were extended with hands approximately shoulder-width apart such that the participant's body formed a straight line from the apex of the head down to the knees when at the top of the push up. This is commonly referred to as a 'ladies' push up position'. One repetition involved the participants lowering their chest to just above the mat, followed by extension through the elbows bringing the chest up to the original start position. Accurate execution of each manoeuvre was observed by the research assistant to determine the push up could be counted. Correct form ensured that the head did not drop below the chest and that there was no flexion from the hips. The push up start position and technique was demonstrated to each participant before their trial/s. Participants then performed as many correct repetitions as possible within a 60 second period unless exhaustion was reached first. While the ACSM physical fitness guidelines suggest going to exhaustion (American College of Sports Medicine, 2013), it was assumed that a 60 second test would be a suitable amount of time to complete the possible number of reps for each participant.

b) Lower body (leg) musculature endurance: Wall squat hold (also known as a wall sit test)

In order to measure endurance of the global leg musculature, in particular the quadriceps muscles (rectus femoris, vastus medialis, vastus lateralis, vastus intermedius), participants were required to perform a static wall squat using a stability ball for as long as possible (without time limit). This served as a timed test of a submaximal contraction (American College of Sports Medicine, 2013). Participants began in a standing position with their back to a wall, whilst reclining on a stability ball placed between their thoracic and lumbar spine and the wall. Their feet were parallel, hip width apart and placed approximately 40 cm in front of them so that their weight was transferred back onto the stability ball, whilst ensuring that their trunk remained vertical. When ready, they alerted the research assistant and gradually moved down into a seated squat position, with knees flexed at a 90° angle with their trunk upright and supported by the ball (90° hip flexion). Arms remained resting alongside the body or with hands on hips. Participants then held this static position for as long as possible whilst being timed by the research assistant. Timing was stopped when the participant stood up or sat down on the ground signalling the end of the test.

3.5.2.4 Strength

In order to demonstrate the strength of the global musculature in the upper and lower extremities of the body, 1-repetition maximum (1RM) tests reflecting compound muscle recruitment were employed. The repetition maximum (RM) is a common test of muscle strength and describes the maximal amount of weight that can be moved through full range of motion and with correct postural form (American College of Sports Medicine, 2013). Three separate 1RM tests were used, focusing on back, chest and leg strength. The manoeuvres used for these tests are more commonly referred to as a 'lat pull down', 'chest press' and 'leg press'. The sequence was randomised each time with a sufficient rest period between each test. Each test was demonstrated to the participants by the research assistants at each station and participants were allowed to attempt the manoeuvres before commencing with each test.

a) Back Strength – "Lat" Pulldown

Participants sat facing a weighted stack attached to a bar via a pulley (Challenger series by Zest Fitness®, Cape Town, South Africa). They gripped the bar with arms extended overhead, with hands placed slightly wider than shoulder width apart. The bar was then pulled down in front of their body to a 90° position of the elbows, then released back to the start position with control. The load was initiated at 15 kg and was increased in 5 kg increments each time a repetition was performed correctly. When the participant was unable to perform the exercise correctly it was assumed that the 1RM had been reached at the previous weight. This exercise was selected as an evaluation of not only latissimus dorsi ("lat") strength, but as a compound measure including the deltoid musculature and the muscles of the arms and chest (triceps brachii, biceps brachii and pectoralis major).

b) Chest Strength - Chest Press

A common measure of upper body strength (American College of Sports Medicine, 2013), the chest press was performed using a machine ('Selection' Line, by Technogym®, Johannesburg, South Africa) while in a seated position. Participants placed their hands on the lateral hand grips of the movable weight stack bar, such that their hands were almost parallel with the edge of the machine's back rest. The weight stack was initially set to 5 kg. Participants were required to extend the elbows therefore lengthening the arms by pushing the lever arms forward away from their chest. Weights were increased by 2.5 kg after each successful chest press to determine their 1RM.

c) Lower Body - Leg Press

In order to evaluate the strength of the lower limbs a leg press machine (Element+ Line, by Technogym®, Johannesburg, South Africa) was used. Participants sat placing their feet on the foot-plate in front of them, ensuring feet were hip width apart, knees bent to 90°. The participant then pushed the foot-plate away from their body by extending the knees, whilst avoiding hyperextension, and then returned to the 90° start position to complete the manoeuvre. The load was initiated at 20 kg and increased incrementally (5 kg) to determine each participant's 1RM. This evaluation is considered a suitable measure of lower body strength (American College of Sports Medicine, 2013).

3.5.2.5 Lumbo-pelvic Stability

The Pilates method claims to promote improved lumbo-pelvic stability and control through the increased strength and endurance of the core musculature (Phrompaet et al., 2011). Stability of the lumbar spine and pelvic region during limb-loading was measured by observing the deviation in pressure of the region via means of a pressure biofeedback unit (PBU, Chattanooga Group, Inc.). The pressure biofeedback unit acts much like a blood pressure cuff and has been shown to be a useful tool for measurement of anterolateral abdominal function (Cairns, Harrison, & Wright, 2000). Part of the Sahrmann core stability test (Stanton, Reaburn, & Humpries, 2004), as described by

Herrington & Davies (2005) was used for this test. The deflated pad was placed under the lumbar spine, between L1 and S2 while the individual was lying supine with a neutral pelvic position and knees bent. The PBU was inflated to 40 mm Hg. The participant was required to perform unilateral hip flexion of 90° by lifting one foot from the mat in the sagittal plane, holding this position for a few seconds before returning the foot to the mat. No feedback, encouragement or instruction was given to the participants during testing other than commands to begin or complete the test. Any deviation in the pressure reading of ± 2 mm Hg on either side of the start measure during the manoeuvre indicated that lumbo-pelvic stability had been lost.

3.5.2.6 Transversus abdominis Isolation/recruitment

This measure was only tested in the intervention cohorts. Recruitment or activation of the deep abdominal muscles, specifically the Transversus abdominis, is a key feature of the Pilates 'core-focused' system. The ability of individuals to isolate and recruit this musculature was thus investigated through an isolation test (pass/fail), as per the tests standardised by Richardson, 1999 (described in Herrington & Davies, 2005). The PBU was employed once again and participants were required to lie in a prone position with arms by their side or with hands resting under their forehead for comfort. The PBU's inflatable pad was placed under the navel with the distal edge of the inflatable cells in line with the Anterior Superior Iliac Spines. When the participant was ready and relaxed the PBU was inflated to 70 mm Hg. During exhalation (through the Pilates breathing technique) the participants were required to activate through their Transversus abdominis and pelvic floor so as to draw the lower abdominal region away from the PBU, supporting their abdominal weight off the pad while avoiding movement of the pelvis or trunk. This movement was monitored by the primary researcher. They were required to maintain this activation for 10 seconds whilst breathing normally. Again, no feedback or instruction was given to the volunteers during the test itself. A decrease in the PBU pressure reading of 6-10 mm Hg identified a successful, localised contraction of the Transversus abdominis. Therefore, <6 mm Hg, no change or an increase in the pressure reading would suggest a failed test (Herrington & Davies, 2005).

It must be noted all participants in the intervention cohort were taught how to activate their Transversus abdominis in order to participate in this test. This was done separately for each group after randomisation and the first measurement was done at this time (less than 7 days after Phase 1 testing). During the explanation, the pelvic floor musculature was explained as being similar to a hammock at the base of the pelvis which lifts up and flattens during contraction. Participants were told that strengthening the muscles of this region form the basis of “Kegel exercises”, commonly prescribed to prevent or improve urinary incontinence. This musculature was also mentioned as being those which ‘help stop urine flow’ and this proved to be the best explanation for the participants. Identifying and recruiting pelvic floor musculature is important as this contraction happens in conjunction with Transversus abdominis recruitment (Critchley, 2002), another key muscle in Pilates training. The relationship between these two muscle groups was explained with the primary researcher explaining the difference between bracing the abdominal wall versus recruitment of the pelvic floor and Transversus abdominis. The accurate recruitment was described as being a lifting inwards and upwards, with focus being placed on recruiting from the area located between the umbilicus and the pubic bone, rather than focusing on drawing the umbilicus in towards the body.

3.5.3 Health Parameters

3.5.3.1 Blood Pressure:

Before blood pressure was measured, the participant was required to sit quietly for 5 minutes so as to make sure their blood pressure was taken at rest. This time was also used to minimise anxiety related to the blood pressure reading. A digital blood pressure cuff was used, specifically an OMRON M2 HEM-7121-E (Lodz, Poland). The same machine was used in all testing sessions so as to minimise variability in results.

Participants were seated with legs uncrossed for this measure. The blood pressure cuff was placed on the left arm while the arm was supported on a level surface or hanging next to the participant’s body. Using the Omron machine the RA initiated the inflation of the cuff, whilst the deflation was initiated by the machine and with the results displaying on the digital screen. The first reading (top number) showed systolic blood pressure (mm Hg) whilst the lower number showed diastolic pressure (mm Hg). Both these numbers were recorded and the cuff removed from the participants arm.

3.5.3.2 Lung Function

Breath and breathing pattern is a key principle of the Pilates method of exercise yet it is not known whether the practice of this slow and controlled breath pattern during exertion has any impact on lung function. Selected aspects of lung function were therefore investigated using a CORTEX MetaLyzer® 3B Stationary Ergospirometer (CORTEX Biophysik GmbH, Leipzig, Germany) and MetaSoft® Studio software. Prior to each session, the Metalyser system's flow sensor was calibrated. Gas concentrations were calibrated using the CORTEX Calibration Set every 2 weeks as per product recommendations. Gas analysers were calibrated using ambient air and secondly, a 16.10% oxygen, 4.90% carbon dioxide and 79% nitrogen mixture. After set up and calibration was completed, participants were required to sit while connected to the ergospirometer. During this time the research assistant explained the procedure to them and what was expected of them in order to gain accurate readings.

Lung function measures included the following:

- Minute Ventilation (V_E): Total volume of air moved in/out of the lungs over a period of 60 seconds during quiet breathing. This is calculated by multiplying the number of breaths per minute (an average of 12 breaths) by the TV. The average V_E for a healthy adult at rest is 6 $L.min^{-1}$ (Tortora & Derrickson, 2013).
- Tidal Volume (V_T): Volume of air moved in/out of the lungs during quiet inhalation/expiration. The average volume for healthy adult females is 0.5 L per breath (McArdle et al., 2001).
- Forced Vital Capacity (FVC): The maximal volume of air exhaled under force after a maximal inspiration. While FVC varies due to body size, body composition as well as position/posture during measuring, the average FVC for young adult females is 3.2 L (McArdle et al., 2001).
- Forced Expiratory Volume (FEV_1): This measure is a time-specific derivative of the FVC and indicates pulmonary airflow capacity. It is described as the volume of air expelled from the lungs during the first second of forced exhalation. Healthy individuals expel approximately 85% of their vital capacity within the first second (McArdle et al., 2001).
- Total Lung Capacity (TLC): The volume of air in the lungs at the point of maximal inflation or inspiration. For the purposes of this research, TLC was calculated by adding 1.1 L to the FVC reading, as per recommendations for healthy adult

female measures of residual volume during static lung function measures (Tortora & Derrickson, 2013).

In order to perform these measures participants were first asked to breathe normally for a period of 3 minutes, while their TV was monitored and measured and recorded during the 3rd minute. In order to measure FVC and FEV_1, they were then asked to inhale as quickly as possible and exhale as fast and as hard as possible on the command of the research assistant. The software allowed the research assistant to determine whether the data had been successfully captured or not, and if there were any errors the participants were asked to redo the FVC/FEV_1 test again.

3.5.4 Self-reports

Self-reports were restricted to those participants in Phase 2. In order to isolate the effects of the Pilates intervention, and limit the potential impact of external factors on the results obtained, certain elements needed to be controlled as much as possible. It was thus necessary to monitor dietary intake to determine whether this remained constant in both the PEx and Con groups over time. Similarly, physical activity levels in both groups were also monitored so as to ensure that the participants were not engaging in additional exercise regimes which could influence the results. Both aspects were monitored through participant self-reports via means of a dietary recall (3.5.4.1) and by the World Health Organisation (WHO) Global Physical Activity Questionnaire, version 2 (GPAQv2) (3.5.4.2), in the Self-Reports section below.

3.5.4.1 Diet

The documenting and analysis of caloric intake was performed to ensure that participants maintained their 'normal' dietary habits during the intervention period. This was so as to reduce the effects of diet on anthropometric measures, thus isolating any effects of the exercise intervention alone. In order to track participants' macro-nutrient intake over the intervention period, volunteers recorded all meals and drinks consumed over a 3-day (non-consecutive) period in a dietary recall (Appendix 9). Instructions on how to complete the dietary recall were given to the participants by the primary researcher at the beginning of the research period with reminders at each 4-week interval. Food diaries were completed during the week of their initial measurements (week 0) and again during the weeks of post-test measures (weeks 4 & 8). The data was analysed using licensed *FoodFinder 3™* software for Windows® - a product developed by the South African 'Medical Research Council' (MRC) in collaboration with 'WAMTechnology CC' for food intake analysis. Details of each participants' 3-day period intake were entered into the software program resulting in an average total caloric intake ($kj.day^{-1}$), as well as fat, protein and carbohydrate ($g.day^{-1}$) consumption per individual.

3.5.4.2 Physical Activity

As with dietary controls, physical activity levels outside the intervention were monitored and recorded (in $METmin.wk^{-1}$). This was to ensure that the PEx group did not add additional exercise programs to their routines, and that the Con group maintained their original activity levels pre-intervention, again, ensuring any effects found were from the intervention only. Participants completed a template of the World Health Organisation's *Global Physical Activity Questionnaire (version 2)* – the GPAQv2 (Appendix 10) – at baseline and again at weeks 4 and 8. The GPAQv2 is an adapted version of the original WHO GPAQ tool, developed to measure physical activity levels in developing countries, with an aim to improve chronic disease risk monitoring in these regions (Armstrong & Bull, 2006). The questionnaire examines energy expenditure in different facets of life, specifically activities at work, during travel or commuting, and leisure time. Energy expenditure was calculated in the form of METS (the energy cost of quiet sitting) and multiplying this by the recorded number of minutes per activity in a given week resulting in median $METmin^{-1}$ per week for each of the three domains. As per the GPAQv2 Analysis Guide (http://www.who.int/chp/steps/resources/GPAQ_Analysis_Guide.pdf?ua=1) moderate activities were calculated as being four times that of a person's resting metabolic rate, with vigorous activities being calculated as eight times as much. Thus, moderate activities listed were assigned 4 METs and vigorous activities were assigned 8 METs. Participants in Phase 2 were required to have 'low' levels of overall physical activity, and to keep their median $METmin^{-1}$ per week as consistent as possible throughout the research period.

3.6 EXERCISE INTERVENTION AND PILATES SESSIONS

Due to time constraints the intervention period was restricted to 8 weeks (from the originally planned 12 weeks). Most participants were unable to commit to a longer time period due to the short university term (7 weeks) followed by an examination and holiday period. Classes were available daily so that participants could attend two non-consecutive sessions per week. The primary researcher, a certified STOTT Pilates® instructor with 3 years teaching experience, conducted all classes so as to ensure that the various sessions on offer were similar in a given week, and that progression was incorporated over time. Due to the limited number of sessions in the intervention, participants were required to maintain an 85% attendance rate (≥14 sessions) for their participation to be deemed sufficient for analysis purposes. Classes were small (approximately six participants per session) to ensure individuals received adequate supervision and instruction and performed the exercises correctly. Most sessions took place in a private laboratory at the Human Kinetics and Ergonomics Department (Rhodes University, Grahamstown, South Africa), however some classes were held at a privately run, local studio – *Natural Affinity Wellness & Pilates Studio* (Stones Hill, Grahamstown, South Africa). Permission from the studio director was obtained so as to use the premises for this segment of the research project (Appendix 11). The private studio facilities enabled the instructor to incorporate the use of props which were not available within the university department.

While other international and local Pilates certifications are available in South Africa, including BASI Pilates® and Peak Pilates®, STOTT's contemporary approach and stringent instructor-training schedule, examination requirements and Continued Education program make it one of the leading instructor-training organisations in the world. The program, techniques and exercises used throughout the 8-week intervention followed those stipulated in the STOTT Pilates® Matwork Manual (© Merrithew Health and Fitness™, Canada). The exercises were progressive in nature moving from a basic essential level through to an intermediate/advanced level. The exercises encouraged movement in all planes, including flexion, extension, lateral flexion and rotation as well as working the upper and lower extremities. They also focused on isometric contractions as well as dynamic movements and importantly, allowed for adaptation as well as progression. Modifications to exercises were also made in accordance with recommendations from the manual, including the use of props. This is consistent with previous Pilates research protocols (Critchley et al., 2011; Sekendiz et al., 2007). The use of props was incorporated only when available and as such they were not used in every lesson.

3.6.1 The Pilates Intervention:

Participants in the Pilates exercise group (PEx) were first taken through an introductory session where they were given a brief history of Pilates as well as being taught the five basic principles, as per the STOTT Pilates® program. This was to ensure that they had an understanding of the background to the exercise method and could successfully incorporate the principles into their exercise routines. It should be noted that this introductory session was not immediately afforded to the Control (Con) group participants however they received the same information when attending the Pilates sessions made available to them at the end of the intervention.

The five basic principles taught to the intervention group were taken from the STOTT Pilates® teaching protocol and include breathing, head and cervical placement, scapular stabilisation, rib cage placement and pelvic placement. While the principles are not exercises themselves, they are necessary to aid in correct alignment and postural control during manoeuvres and transitions from one posture to the next, thus ensuring optimal (and safe) execution.

3.6.1.1 The five basic principles include:

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1) *The Pilates breath pattern*: This principle describes the 3-dimensional breathing pattern, with focus placed on lateral expansion within the ribcage region rather than expansion through the abdominals (Figure 5). Inhalation is through the nasal passage with exhalation through pursed lips. The breath is slow, controlled and deliberate with the aim of maximal inhalation and exhalation being reached in each breath.

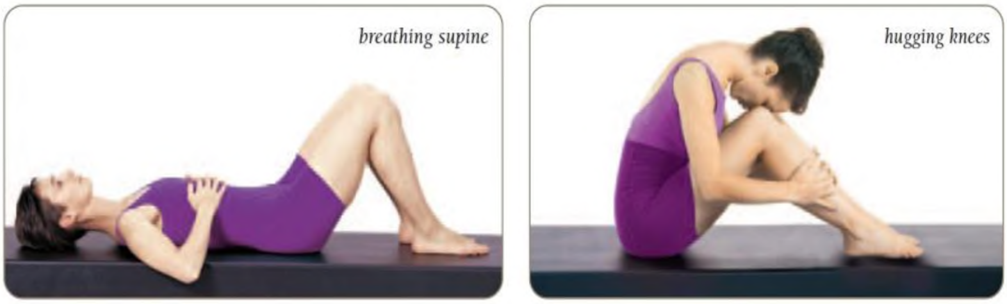

Figure 5: Pilates lateral breathing technique performed supine or flexed forward

2) *Head and cervical placement*: This principle describes the alignment of the neck and head during movements (Figure 6). It recommends that the cervical spine follow the line created by the thoracic spine in flexion, extension, lateral flexion or rotation, so as to avoid overworking or straining cervical musculature.

Figure 6: Head and cervical placement and alignment during flexion and extension.

3) *Scapular movement and stabilisation*: The large range of mobility of the scapulae requires stabilisation in this region in order to prevent the neck and upper back musculature from overworking. This principle encourages activation of the scapular

stabilisers by working through specific movements of the scapula (Figure 7), specifically protraction, retraction, elevation and depression.

Figure 7: Scapula isolation exercises.

4) *Rib cage placement*: The position of the ribcage will affect the curvature and alignment of the thoracic spine. Ribcage placement is therefore controlled via the abdominal connection on the ribs to avoid over extension of the thoracic spine (Figure 8). Correct positioning of the ribcage in certain positions is thus emphasised through this principle. Arm movement may affect ribcage placement (second panel of Figure 8, ribs popping) and the abdominals are then recruited to control this (first panel). This may result in a decreased range of arm movement, however this is considered appropriate when targeting stability, particularly of the spine.

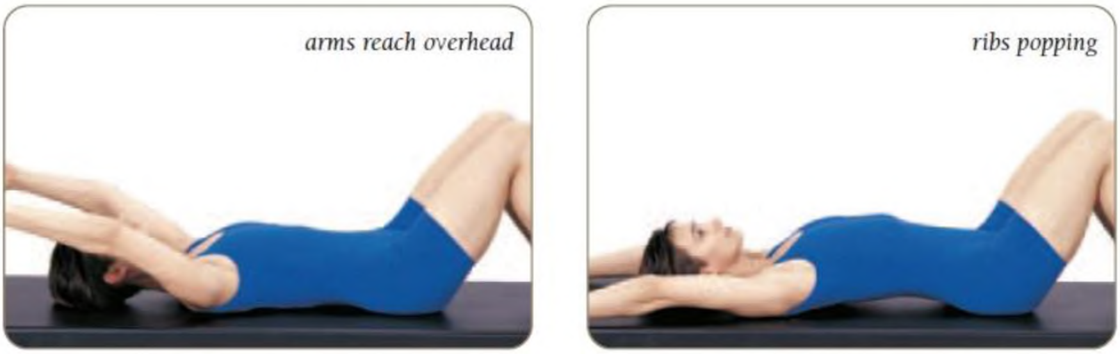

Figure 8: The impacts of arm movement on the rib cage placement shown with control via the abdominals (first image) and without control.

5) *Pelvic placement*: This principle focuses on identifying a neutral pelvic and lumbar spine alignment (Figure 9 and 10) and emphasises the importance of the relationship between these two regions and how they affect one another.

Figure 9: Neutral pelvis and Pilates imprint positions.

Participants were taught how to 'find' their neutral spine and pelvis. The neutral pelvis was explained using specific bony landmarks of the pelvis. It was described as a position where the Anterior Superior Iliac Spines (ASIS's) and the pubic symphysis were in the same coronal plane (Figure 10a). Alternatively, these bony landmarks were described as being parallel to the floor when in a supine position and the two ASIS's are in the same transverse plane (Figure 9, first panel).

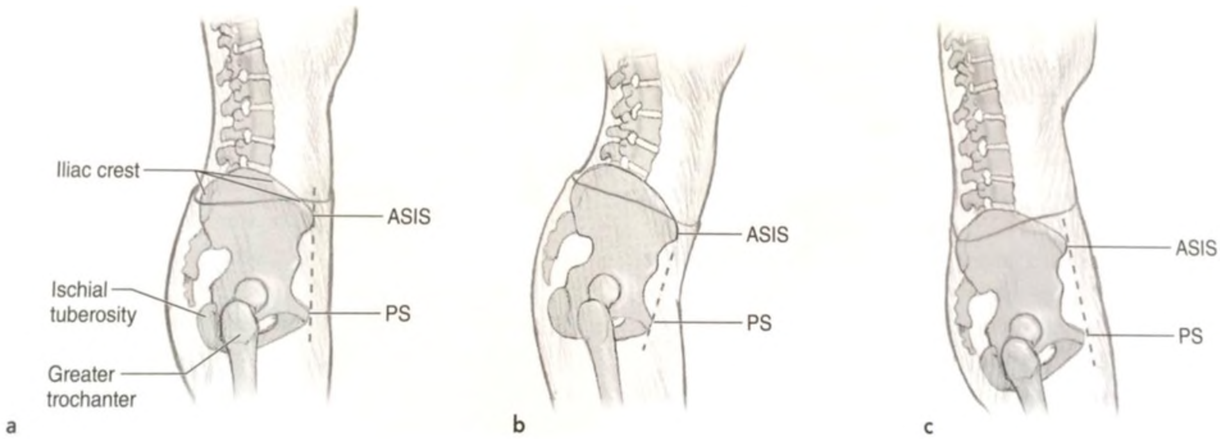

Figure 10: Bony landmarks of the pelvis showing a neutral pelvic position (a), an anterior pelvic tilt (b) and a posterior pelvic tilt (c).

To identify a neutral pelvic position, participants were instructed to place the base of one palm on each ASIS and then fold the fingertips down to meet at the point of the pubic symphysis while supine (knees bent). They were then encouraged to lift their head slightly to look at their hands and determine if their hands were parallel to the floor or not. This way, the hands acted as a guideline or reference point, allowing for a stronger visual guide. They were also taught the Pilates ‘imprint’ position, which involves a slight extension of the lumbar spine via contraction of the abdominals (Figure 9, panel 2). An ‘imprint’ is typically used when supine and in an open kinetic chain when abdominal strength and pelvic stability are too poor to maintain a neutral spine during manoeuvres with limb loading. The imprint thus aids in supporting the lumbar spine and preventing it from hyperflexion. Participants were encouraged not to force their lumbar spine into the mat by overemphasising a posterior pelvic tilt through use of the gluteal muscles. The principle researcher assessed each participant to ensure they could determine when they were in a neutral pelvic position, and to also confirm that they were only using abdominal recruitment to reach the imprint position rather than activating through the gluteal muscles.

Although not a principle on its own, activation of the Transverse abdominis in conjunction with pelvic floor recruitment was discussed at the time of discussing pelvic placement (as per details in section 3.5.2.6). Activation of these muscle groups is crucial to the basis of Pilates and its concept of core stability and control (Phrompaet et al., 2011).

3.6.1.2 Standard warm up (approximately 7-10 minutes)

The global muscle warm up was not a high intensity, aerobic warm up, but rather included working through the basic Pilates principles, such as the breath pattern, activating the deep abdominals and warming up the spinal musculature through flexion, and rotation based movements. Table 8 describes the movements and repetitions that were used begin each of the classes. This warm up sequence is in accordance with the STOTT Pilates® Comprehensive Matwork Manual.

Table 8: Pilates session warm up sequence.

The Warm Up	
Movement	**Repetitions**
Focused breathing	5
Head nods (cranio-vertebral flexion)	5
Imprint and release	6
Arm circles (clockwise and anticlockwise)	6
Hip release – medial rotation	4 per leg
Hip release – lateral rotation	4 per leg
Hip rolls	5
Scapular isolation (protraction and retraction)	6
Shoulder elevation and depression	5
Spinal rotation	3 per side
Cat stretch	5

3.6.1.3 Pilates Exercises/Conditioning (approximately 50 minutes):

The Pilates classes were planned so that exercises incorporated movement in all planes and directions. Given the participants' lack of Pilates experience it was necessary to repeat certain essential level exercises before progressing to more challenging manoeuvres. The primary researcher also judged the participants' overall ability to grasp the basic principles as well as the movements so as to determine the pace of the progression. The specific exercises used and number of repetitions per manoeuvre, including adaptions and use of props were in accordance with those listed in the STOTT Pilates® Comprehensive Matwork Manual and are tabulated below (Table 9). Modifications to the exercises are noted using an asterisked number in brackets immediately after the exercise in question. This number denotes the modification number as stipulated within the manual, therefore '*2' indicates that 'modification 2' from the manual was used. The use of props is also highlighted within Table 9. In-depth details on each exercise, highlighting difficulty level, the targeted musculature, and an image description of the movement, are tabulated in Appendix 12.

Table 9: List of exercises, repetitions per movement, modifications used and incorporation of props for each Pilates session held during the intervention.

Session 1 & 2		
Exercise	**Repetitions**	**Prop**
Ab Prep, Obliques Roll Back, Breast Stroke Prep 1 & 2	8	
One Leg Circles (clockwise & anticlockwise)	5/leg	
Swim Prep, Spine Stretch Forward	4	
Shoulder Bridge (*1), Leg Pull Front Prep, Half Roll Back	6	
Single Leg Stretch	10	
Side Bend Prep (*2)	5/side	
Push Up (*3)	3	
Session 3 & 4		
Exercise	**Repetitions**	**Prop**
Ab Prep, Double Leg Stretch, Rolling Like a Ball, Breast Stroke Prep 1 & 2, Side Leg Lift Series (1-4)	8	
Saw, Spine Stretch Forward	4	
Hundred (*2)	1	
Shoulder Bridge (*2), Swim Prep	5	
Breast Stroke	6	
Push Up (*6)	3	
Session 5		
Exercise	**Repetitions**	**Prop**
Shoulder Bridge	2	
Hundred (*3)	1	
Spine Twist, Spine Stretch Forward, Leg Pull Front Prep (*2)	4	
Breast Stroke Prep 1 & 3, Slow Double Leg Stretch	6	
Roll Up	7	
One Leg Circles (clockwise and anticlockwise)	5/leg	
Side Kick, Side Leg Series 1-4. Ab Prep (*1)	8	
Swim Prep	5	

Session 6		
Exercise	**Repetitions**	**Prop**
Shoulder Bridge	3	
Hundred (*3)	1	
Side Bend Prep	5/side	
Breast Stroke Prep 1 & 3, Swan Dive Prep, Swim Prep	6	
Roll Up	7	
Slow Double Leg Stretch, Side Kick, Side Leg Lift Series (1-4), Heel Squeeze Prone, Single Leg Extension, Ab Prep (*1)	8	
Obliques Roll Back	4/side	
Spine Stretch Forward	3	

Session 7 & 8		
Exercise	**Repetitions**	**Prop**
Breast Stroke Prep 3, Slow Double Leg Stretch, Heel Squeeze Prone, Leg Pull Prep (*2), Ab prep (*1)	8	
Hundred (*6)	1	
One Leg Circles (clockwise and anticlockwise)	5/leg	
Shoulder Bridge (*2)	5	
Spine Stretch Forward	3	
Teaser Prep (*1,)	4	
Spine Twist, Side Bend	4	
One Leg Kick	5/side	
Neck Pull Prep	6	

Session 9		
Exercise	**Repetitions**	**Prop**
Hundred (*6)	1	
Swan Dive Prep (*3), Push Up (*4), Leg Pull Front Prep (*2)	4	
Single Leg Stretch, Obliques Leg Stretch, Scissors, Single Leg Extension	10	
Half Roll Back, Seal, Side Leg Lift Series (1-4), Obliques Roll Back (*2)	8	
Swimming, Side Bend, Hip Twist	5	
Spine Stretch Forward	3	

Session 10		
Exercise	**Repetitions**	**Prop**
Hundred	1	
Slow Double Leg Stretch, Seal, Neck Pull Prep, Breast Stroke, Hip Twist (*1)	8	
Swim Prep, Twist, Side Bend	5	
Push Up (*4), Leg Pull Front	4	
One Leg Kick, Swan Dive Slow Rock, Rocking	6	
Teaser Prep (*2)	3/leg	
Leg Pull Prep (*1)	5	

Session 11 & 12 - with props		
Exercise	**Repetitions**	**Prop**
Hundred (*5)	1	Fitness Circle
Seal, Hip Twist (*1), Swan Dive Slow Rock, Single Leg Extension	8	
Teaser Prep (*3, feet resting on stability ball for support)	6	Swiss Ball
Push Up (from prone plank over stability ball)	8	Swiss Ball
Bicycle in the Air, Leg Pull Front, Breast Stroke Prep (*2)	6	
Obliques Roll Back (*2 & 3)	5	Fitness Circle
Spine Twist (*5)	5	Flex-band
Scissors (*8), Double Leg Stretch (*6)	10	Flex-band
One Leg Kick	4	
Side Bend	5/side	

Session 13		
Exercise	**Repetitions**	**Prop**
Swan Dive Slow Rock, Slow Double Leg Stretch, Neck Pull Prep, Single Leg Stretch, Obliques Leg Stretch, Scissors, Side Leg Lift Series 1-5, Breast Stroke	8	
Swim Prep, Shoulder Bridge	4	
Hip Twist, Teaser Prep (*3)	5	
Twist, Leg Pull	3/side	
Hundred	1	
Leg Pull Front	3	
Spine Stretch Forward	3	

Session 14		
Exercise	**Repetitions**	**Prop**
Ab Prep (*1), Half Roll Back, Obliques Roll Back, Rolling like a Ball, Heel Squeeze Prone, Spine Twist (*3)	8	
Hundred	1	
Rocking, Neck Pull, Teaser Prep (*3)	6	
Bicycle in the Air	10	
Hip Twist, Jack Knife	5	
Side Kick (*3)	6/side	
Twist	3/side	
One Leg Circle	5/side	
Push Up (*3)	3	

Session 15		
Exercise	**Repetitions**	**Prop**
Ab Prep (*1), Half Roll Back, Obliques Roll Back, Heel Squeeze Prone, Rolling like a Ball, Bicycle in the Air	8	
One Leg Circle	5/side	
Twist	3/side	
Hundred	1	
Side Kick (*3)	6/side	
Hip Twist, Jack Knife, Teaser Series 1	5	
Rocking, Neck Pull	6	
Push Up (*5)	2/side	
Session 16 - with props		
Exercise	**Repetitions**	**Prop**
Hundred (*5)	1	Fitness Circle
Breast Stroke Prep (*3), Side Leg Lift Series (1-5)	8	
Teaser Series 1	6	
Twist	3/side	
Heel Squeeze Prone (*1), Ab Prep (*3)	8	Fitness Circle
Swimming	5	
Roll Over (*6)	6	Fitness Circle
Shoulder Bridge, Spine Stretch Forward, Saw	3	
One Leg Circle (*7)	5/side	Fitness Circle
Swim Prep (prone over stability ball)	4	Swiss Ball
Double Leg Stretch (feet resting on stability ball)	8	Swiss Ball
Obliques Roll Back (*2 & 3), Single Leg Stretch	10	Fitness Circle
Roll Up	8	

3.6.1.4 Additional equipment/props:

Exercise mats (1850x1225x20 mm) were used with one mat per participant. As the exercise difficulty increased selected small props were introduced so as to add progressive resistance and challenge. These included burst proof Swiss exercise balls (65 cm diameter; one per participant), a Theraband^{TM} elasticised resistive band (blue colour code – medium resistance at 2.6 kg with 100% elongation; one per participant), and a fitness circles (Pilates Magical Circle; one per participant), as per Figure 11.

Figure 11: Stability ball, 65 cm (left), fitness circle, 14 inch (right) and blue (medium resistance) Theraband. Images taken from http://www.merrithew.com/shop/ProductDetail/ST06033_Stability-Ball--65cm-green, http://www.merrithew.com/shop/accessories/circles, and http://www.thera-band.com/faqs_consumer.php.

3.7 ADDITIONAL INFORMATION

3.7.1 Control Group Sessions

The Control group were required to stay sedentary during the intervention period which was, understandably, a deterrent from participation, as well as being an ethical concern. In order to offer compensation the Control group participants were offered a series of free Pilates sessions (16 in total) once the intervention period was complete. This afforded them the opportunity to derive similar benefits from participation to those experienced by the intervention group.

3.7.2 Emergency Protocol

While the risk of injury during the Pilates classes or monthly testing sessions was minimal it could not be ruled out and therefore precautions needed to be in place. A local medical practitioner agreed to be on standby for emergency situations and a trained first aid responder, with first aid kit, was on the premises during all sessions. All research assistants were trained, postgraduate Human Kinetics and Ergonomics students and had sufficient experience and knowledge to deal with minor injuries or muscle cramps etc.

3.7.3 Communication and Contact

Throughout the exercise intervention constant communication and contact was kept up via email, social media (Facebook) and text message services. Reminders and follow ups were critical to ensure that documentation was submitted timeously and to confirm individuals' participation in upcoming classes or testing sessions. Group texting services proved particularly useful and meant the participants got to communicate with each other directly which boosted morale. Since Pilates sessions were available everyday there was daily contact with the Pilates group to ensure attendance was kept up. The group was also motivated through Pilates-related cartoons or inspirational content posted periodically to their social media group. They were also encouraged to ask questions or to discuss their exercises before and after their sessions. This encouraged their participation, especially if they felt they understood the purpose of an exercise or saw progress in their individual abilities during the course of the intervention.

3.7.4 Feedback and Reporting to Participants

Participants from Phase 1 were each emailed a document reporting their individual measurements. They were encouraged to contact the primary investigator if they had any queries regarding their personal results.

Those involved in the exercise intervention were also provided with personalised feedback via email, and were also invited to a meeting where group results and overall findings were discussed. This debriefing was accompanied by a presentation and participants were encouraged to put forth any queries they had to the researcher.

3.8 STATISTICAL ANALYSES

Data analysis was carried out using Statistica software, versions 12 and 13 (©Statsoft Inc.).

Phase 1: After conducting descriptive statistics in order to determine means, standard deviations and standard error values, a single-sample t-test was used to compare data collected to existing population norms where possible. Significant differences were identified when $p<0.05$.

Phase 2: Descriptive statistics were again carried out so as to provide general information on each group. A repeated measures ANOVA was used to compare the two intervention groups to each other over time, with the response variable at each month as the repeated measure and group as a factor. The significance level was set at 5%. In the case of the pass-fail measures and the analysis of categorical data, a Chi-Square test was used to compare the results of the lumbo-pelvic stability and Transversus abdominis recruitment tests. Tukey Post-hoc analysis testing was used to identify time-points where significant differences were noted. Lastly, in the case of variables which demonstrated a trend with time, but were not statistically significant, effect sizes were investigated (Cohen's *d,* using pooled standard deviations) to assess the magnitude of difference over time (*d*: 0.2–0.49, small effect; 0.5–0.79, medium effect; ≥0.8, large effect) (Cohen, 1988, 1992; Cumming, 2014). Statistical tables are available in Appendix 13.

CHAPTER 4

RESULTS

An overview of the Phase 1 results are reported first and are followed by comparisons to available normative data where possible. Phase 2 results are reported thereafter. A reminder that the Phase 2 sample formed a subset of Phase 1. In both phases significant differences, utilising a 95% confidence interval, are indicated by an asterisk. Statistical tables are presented in Appendix 13.

4.1 PHASE 1: POPULATION STUDY

Mean results for all measures from Phase 1 are shown in Table 10 along with the most appropriate population-matched normative data. Comparisons to normative data from *all* surveys or recommended norms are graphically represented in Figures 12-18.

Anthropometry and blood pressure norms were taken from available national population surveys and include standard error (SE) bars (except in the case of SANHANES-1 data which did not report standard errors). Spirometry data was compared to suggested norms sourced from published text books and thus shows standard deviations within the Phase 1 results only. Significant differences ($p<0.05$) identified between the Phase 1 sample and normative figures for each measure are denoted with an asterisk.

Table 10: Mean (± standard deviation/SD) data and coefficient of variation (CV) for Phase 1 sample, and comparable existing norms where available.

†Relevant data sources: SANHANES-1 (2012), SADHS (1998), McArdle, Katch & Katch (2001), Tortora & Derrickson (2013)

Measure	Mean (±SD)	CV (%)	Normative Data†
Sample Size (n)	96		
Age (years)	21.7 (± 1.7)	7.8	-
Stature (cm)	165.2 (± 5.6)	3.4	158.2
Body Mass (kg)	63.0 (± 9.7)	15.4	63.0
Body Mass Index (kg.m^{-2})	23.1 (± 3.3)	14.2	26.2
Waist Circumference (cm)	72.4 (± 7.8)	10.8	82.0
Hours of exercise per week (n=96)	3.9 (± 3.8)	97.9	-
Hours of exercise per week (n=79)	4.6 (± 3.9)	85.6	-
HEALTH PARAMETERS			
Blood Pressure:			
Systolic (mm Hg)	121.5 (± 11.1)	9.2	106.0
Diastolic (mm Hg)	76.5 (± 8.4)	11.0	67.0
Lung Function:			
Minute Ventilation (L.min^{-1})	9.70 (± 2.4)	24.9	6.0
Tidal Volume (L)	0.66 (± 0.2)	35.3	0.5
Forced Vital Capacity (L)	2.95 (± 0.7)	24.3	3.2
Forced Expiratory Volume (L)	2.69 (± 0.6)	22.1	2.7
Total Lung Capacity (L)	4.05 (± 0.7)	17.6	4.3
PHYSICAL FITNESS PARAMETERS			
Static Balance:			
Stork Stand Left Leg (s)	14.1 (± 15.4)	109.1	-
Stork Stand Right Leg (s)	17.1 (± 19.5)	114.3	-
Bilateral Dynamic Balance:			
Functional Reach Test (mm)	21.3 (± 6.7)	31.3	-
Unilateral Dynamic Balance:			
Right: Anterior %	79.1 (± 7.1)	-	-
Right: Posteromedial %	84.6 (± 10.0)	-	-
Right: Posterolateral %	82.2 (± 11.6)	-	-
Left: Anterior %	79.6 (± 7.1)	-	-
Left: Posteromedial %	86.3 (± 9.8)	-	-
Left: Posterolateral %	81.8 (± 11.3)	-	-
Flexibility (mm)	137.4 (± 80.8)	-	-
Muscular Endurance:			
Abdominal (60s test)	34.1 (± 12.6)	36.9	-
Upper Body (60s test)	26.6 (± 13.0)	49.0	-
Lower Body (s)	66.1 (± 50.2)	75.9	-
Muscular Strength (1RM):			
Back (kg)	35.9 (± 8.2)	22.9	-
Chest (kg)	29.8 (± 8.0)	27.1	-
Leg (kg)	103.3 (± 32.7)	31.6	-
Lumbo-Pelvic Stability:			
Right Leg – Pass/Fail %	64.6/35.4	-	-
Left Leg – Pass/Fail %	61.5/37.5	-	-

Note that in Table 10 there are two figures relating to ‘hours of exercise’ per week. The first sample, n=96, is the complete Phase 1 cohort, while the second sample, n=79, excludes data of the sedentary participants from the Phase 2 groups.

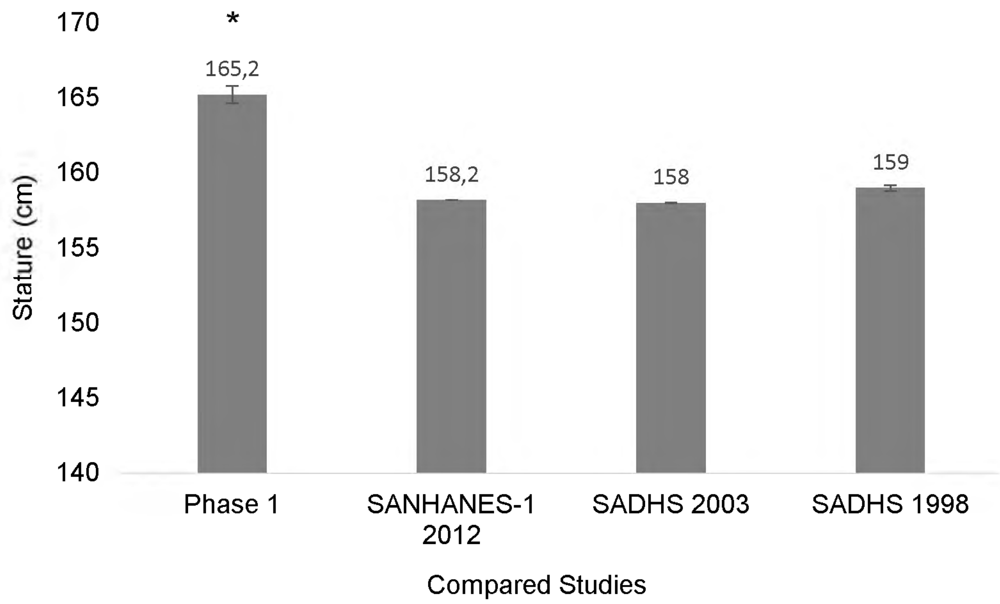

Figure 12: Comparison of mean stature values (±SE) of Phase 1 sample to those of other national survey values.

Participants (165.2 ±5.6 cm) were significantly taller ($p<0.000$ for all comparisons) than national population survey figures which ranged between 158-159 cm (Figure 12); a mean difference of between 5-6 cm.

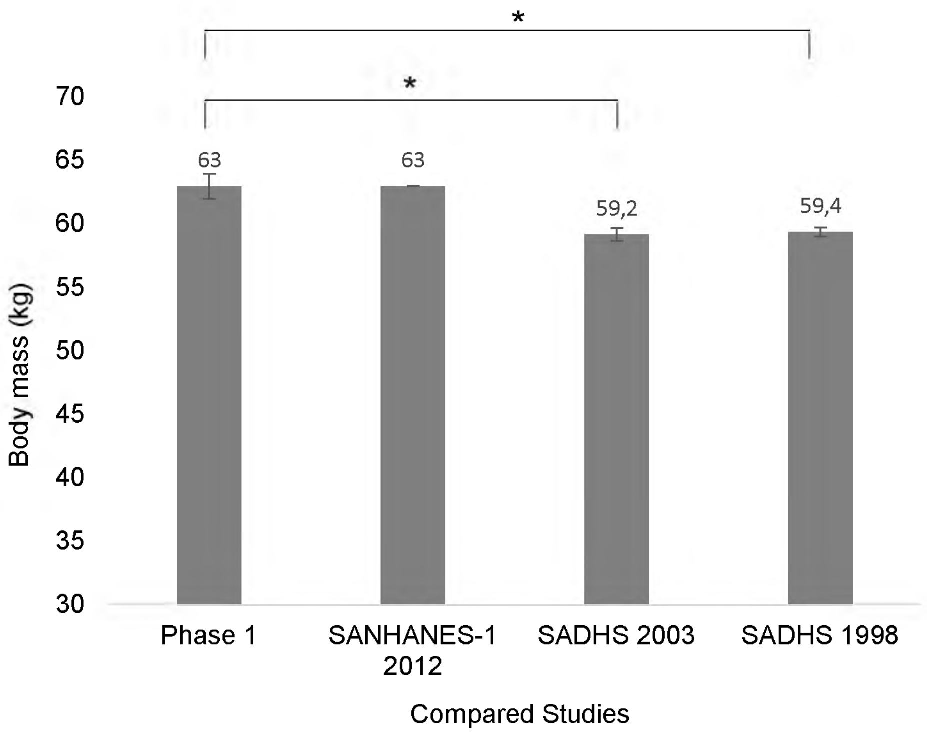

Figure 13: Comparison of mean Body Mass (±SE) of Phase 1 participants to those of other recent South African population surveys.

Mean body mass (63 ±0.99 kg) was significantly greater (p=0.000 for both) than the two South African Demographic and Health Surveys (2003: 59.2 ±0.51 kg; 1998: 59.4 ±0.35 kg), with no difference to the SANHANES-1 survey (63 kg) (Figure 13). The standard deviation of ±9.73 kg (Table 10) suggests large variations within the current sample.

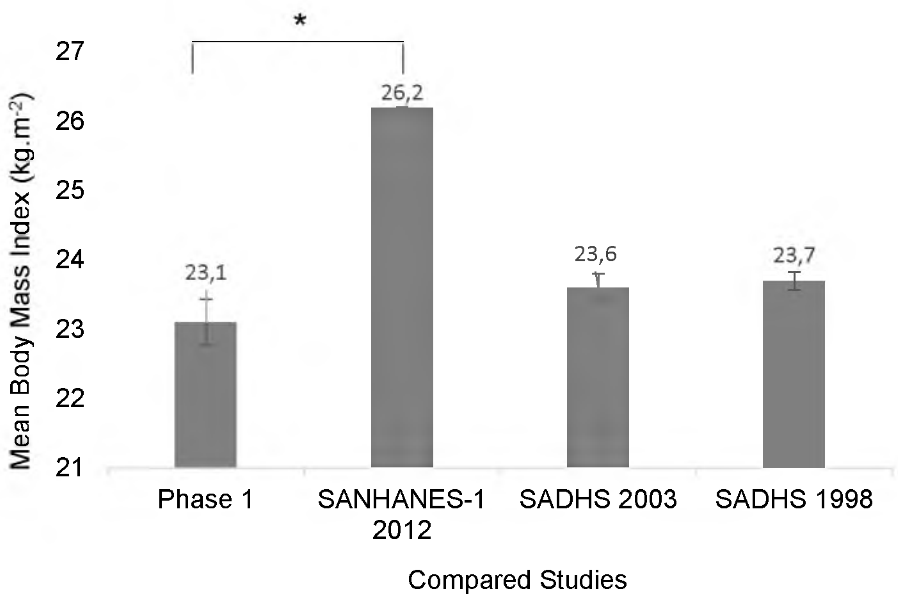

Figure 14: Comparison of mean BMI values (±SE) for Phase 1 cohort and national populations surveys.

The SANHANES-1 Body Mass Index data (26.2 kg.m^{-2}) was significantly greater ($p=0.000$) than the current sample (23.1 ±0.33 kg.m^{-2}) (Figure 14). No differences were found between Phase 1 and the SADHS BMI results (approximately 23 kg.m^{-2} for all). The SANHANES-1 cohort can be classified as 'overweight' (BMI between 25.0 to 29.9 kg.m^{-2}), while the other three samples, including the current group, fall within a 'healthy' BMI range (18.5 to 24.9 kg.m^{-2}).

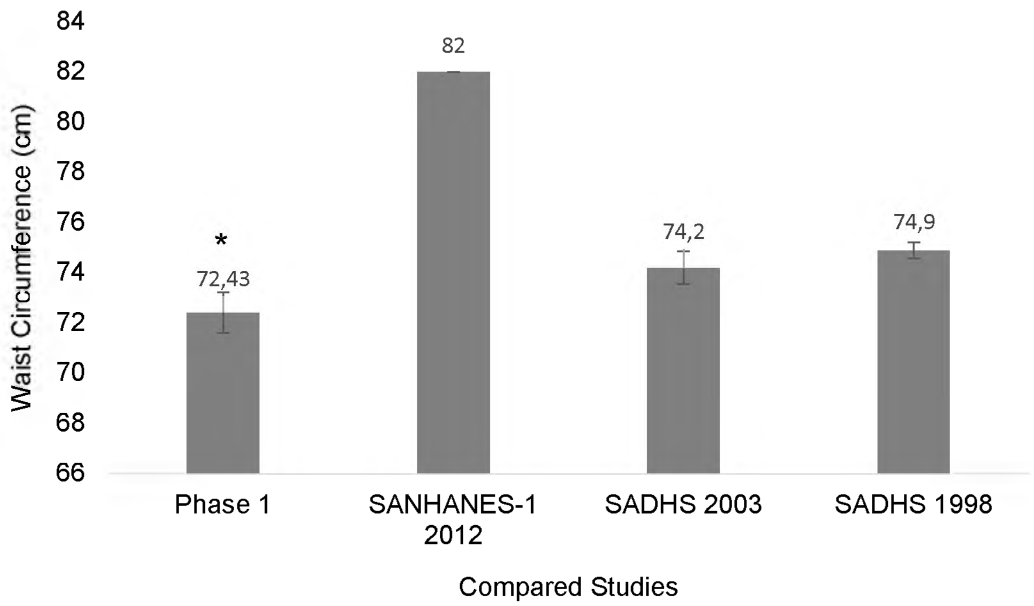

Figure 15: Comparison of mean waist circumference values (±SE) of Phase 1 participants to those of recent national survey values.

Mean waist circumference (72.3 ±0.80 cm) was significantly smaller (p<0.05) than all three reported national population means (Figure 15) and fell within the recommended healthy limits for adult women (<80 cm). The SADHS 2003 (p=0.029) and 1998 (p=0.0026) surveys had mean values of 74.2 (±0.65) cm and 74.9 (±0.31) cm respectively, and were also considered within a healthy range. The SANHANES-1 cohort was significantly greater (p<0.00) than the local sample. It had the largest average waist circumference of 82 cm and, as a result, can be categorised as being at increased risk of metabolic complications (>80 cm).

A reminder that SADHS 2003 blood pressure data has been omitted from these comparisons as the data was deemed inaccurate as a result of technical issues in the field as reported by the authors.

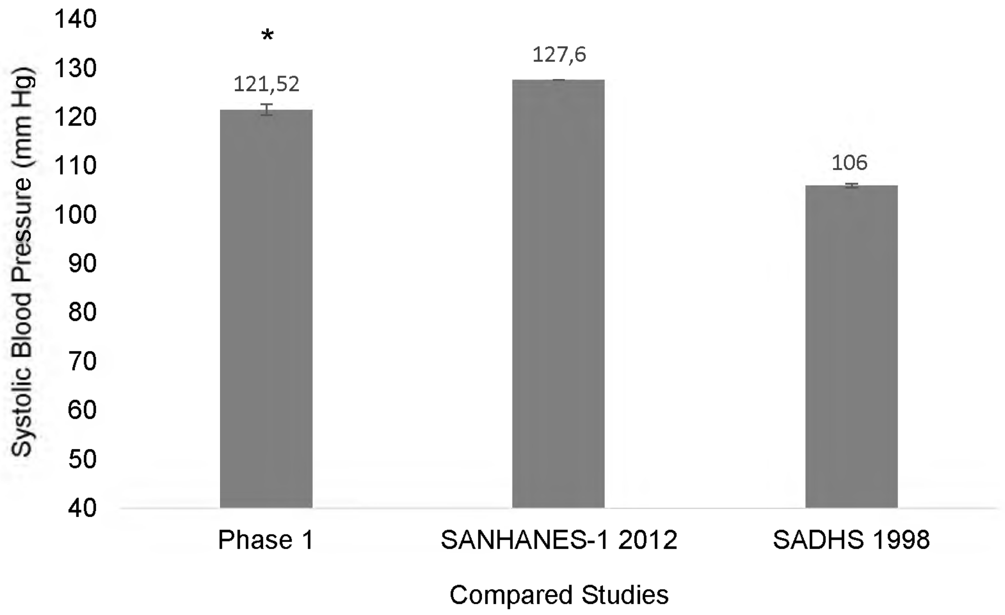

Figure 16: Mean systolic blood pressure (mm Hg ±SE) comparisons of Phase 1 participants to results from two recent national surveys.

Mean systolic blood pressure (121.52 ±1.14 mm Hg) was significantly lower ($p<0.000$) than the SANHANES-1 (127.6 mm Hg) data. Conversely it was significantly higher ($p<0.000$) than the SADHS 1998 data (106 ±0.38 mm Hg), (Figure 16). The large standard deviation for the study sample must be acknowledged at ±11.2 mm Hg.

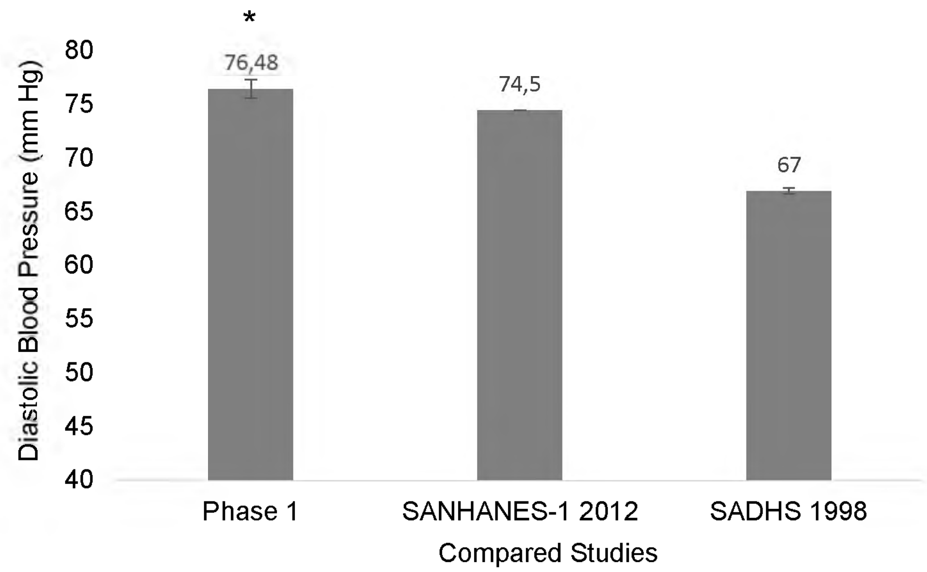

Figure 17: Comparison of mean diastolic blood pressure values (mm Hg ±SE) of Phase 1 participants to those of two other recent survey values.

Mean diastolic blood pressure (76.48 ±0.8 mm Hg) was the highest of the three readings (Figure 17) and was significantly greater ($p<0.05$) than the SANHANES-1 (74.5 mm Hg) and SADHS 1998 (67.0 ±0.29 mm Hg) data. Again, a large standard deviation of ±8.43 mm Hg, indicates the variance with the sample.

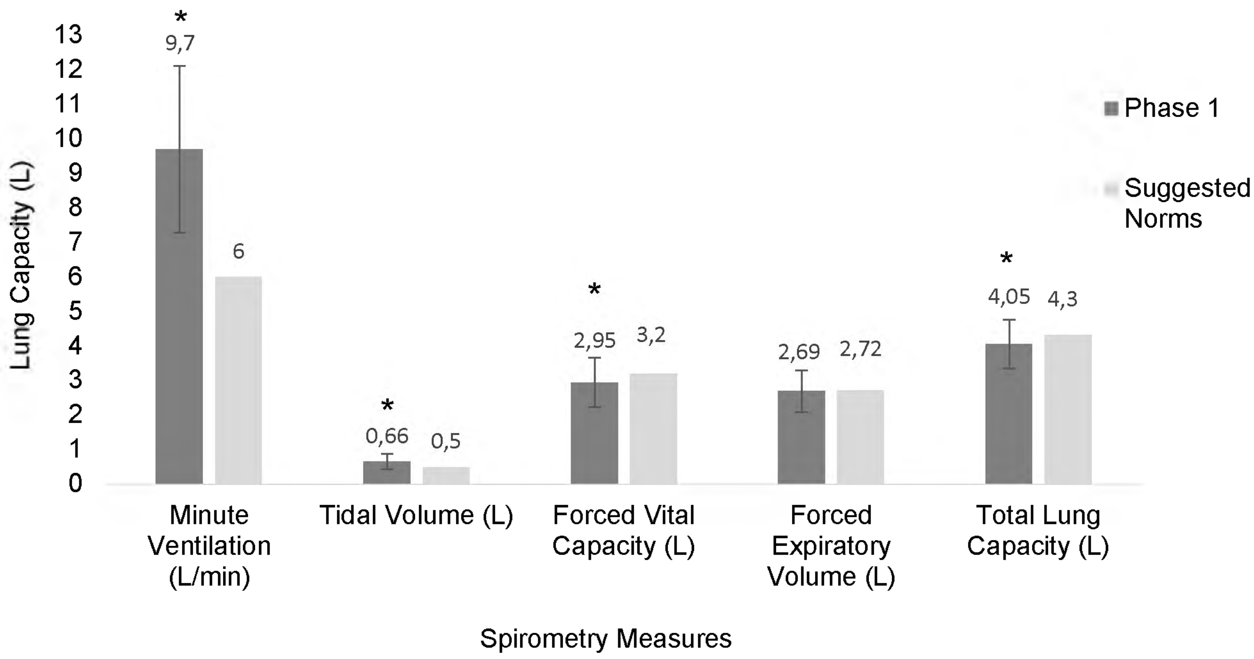

Figure 18: Phase 1 participants' spirometry means (±SD) and associated normative data for healthy adult women, as described in McArdle et al., 2001 & Tortora and Derrickson, 2013.

Minute Ventilation (9.7 ± 2.4 $L.min^{-1}$) and Tidal Volume (0.66 ± 0.23 L) were significantly larger (p=0.000 for both) than that of the suggested norms (6.0 $L.min^{-1}$ and 0.5 L respectively), (Figure 18). Both values had large standard deviations, indicating high variance. In contrast, Forced Vital Capacity (2.95 ±0.72 L) and Total Lung Capacity (4.05 ±0.71 L) were significantly lower (p=0.000 for both) than recommended normative data (3.2 L and 4.3 L respectively). The only value not significantly different (p=0.64) from normative data (2.72 L) was the mean Forced Expiratory Volume (FEV_1) at 2.69 ±0.72 L. The absolute difference between these volumes was 300 ml (or 1.1%).

4.2 PHASE 2: PILATES INTERVENTION STUDY

All participants in the PEx group of the intervention met the minimum class attendance requirement of 85% attendance (≥14 sessions). Only two participants (22%) managed to attend all sixteen of their intended sessions over the eight weeks, the majority (67%) attended fifteen sessions and one participant (11%) attended fourteen. It must be noted that the intervention phase included the same measures as those carried out in Phase 1, but with the additional evaluation of Transversus abdominis activation ability. The findings in this section need to be considered within the context of the small sample sizes (n=9 and 8 for PEx and Con groups respectively). Given these small groups this investigation could be considered as a pilot study.

4.2.1 Baseline Demographics

The groups were matched at baseline with no differences in age, stature, body mass or BMI (Table 11).

Table 11: Phase 2 intervention groups (PEx and Con) mean baseline data (±SD) and coefficient of variation (CV).

	Exercise Group (PEx)	CV (%)	Control Group (Con)	CV (%)
Sample Size (n)	9		8	
Age (years)	22 (± 0.9)	4.49	20 (± 1.2)	6.08
Stature (cm)	163.24 (± 6.7)	4.12	166.19 (± 4.5)	1.86
Body Mass (kg)	63.19 (± 8.7)	13.72	61.33 (± 7.9)	13.69
BMI ($kg.m^{-2}$)	23.71 (± 2.83)	11.92	22.18 (± 2.87)	12.05

4.2.2 Self-reports

Self-reports were used to monitor whether participants maintained their habitual dietary intake and physical activity levels (outside of the Pilates intervention in the case of those participants).

4.2.2.1 Dietary intake

Table 12: Mean caloric and macronutrient intake over time (with standard deviation & coefficient of variation (%)).

		Caloric Intake ($kj.day^{-1}$)	Carbohydrates ($g.day^{-1}$)	Protein ($g.day^{-1}$)	Fat ($g.day^{-1}$)
PEx	Week 0	7638 (± 2080) 27.23 %	192 (± 71) 37.19 %	75 (± 21) 28.53 %	70 (± 21) 29.99 %
	Week 4	7554 (± 1570) 20.78 %	198 (± 54) 27.31 %	68 (± 12) 17.68 %	74 (± 18) 24.78 %
	Week 8	8268 (± 2380) 28.79 %	217 (± 59) 21.13 %	77 (± 28) 36.57 %	75 (± 28) 36.86 %
Con	Week 0	6455 (± 1281) 19.86 %	189 (± 21) 11.27 %	53 (± 12) 23.75 %	60 (± 21) 34.91 %
	Week 4	7139 (± 1876) 26.29 %	186 (± 59) 31.83 %	64 (± 20) 31.39 %	65 (± 25) 39.79 %
	Week 8	6067 (± 2353) 38.78 %	168 (± 70) 41.72 %	55 (± 17) 31.69 %	53 (± 23) 45.22 %

No significant differences were found at baseline or over time for fat (p=0.11), carbohydrate (p=0.30) or total caloric intake (p=0.11). There was a significant group effect found for protein consumption (F=5.28, df=(2,30), p=0.036) with mean intake in the PEx group greater than that of the control group (Table 12). While Post Hoc analyses did not indicate at which time points these differences occurred, Cohen's *d* effect sizes showed a large between-group difference in protein intake at baseline (*d*=1.22) as well as week 8 (*d*=0.92). Further, large between-group effect sizes were also noted for PEx total fat (*d*=0.88) and caloric (*d*=0.93) intake, and a moderate effect size for carbohydrate intake (*d*=0.77) for PEx at week 8. The Con group decreases in total calorie and protein consumption between weeks 4-8 resulted in a between-group moderate effect size for both (*d*=0.5).

4.2.2.2 Physical activity

Table 13: Mean weekly physical activity levels (± standard deviation) in METmin.wk^{-1} with coefficient of variation for each group at baseline, week 4 and 8.

	Week 0 METmin.wk^{-1}	CV (%)	Week 4 METmin.wk^{-1}	CV (%)	Week 8 METmin.wk^{-1}	CV (%)
PEx	1357 (± 1351)	99.54	***1926 (± 1362)****	70.70	***1848 (± 1390)****	75.19
Con	1055 (± 927)	93.99	755 (± 616)	87.34	1075 (± 900)	89.54

** denotes significant difference to week 0 (baseline)*

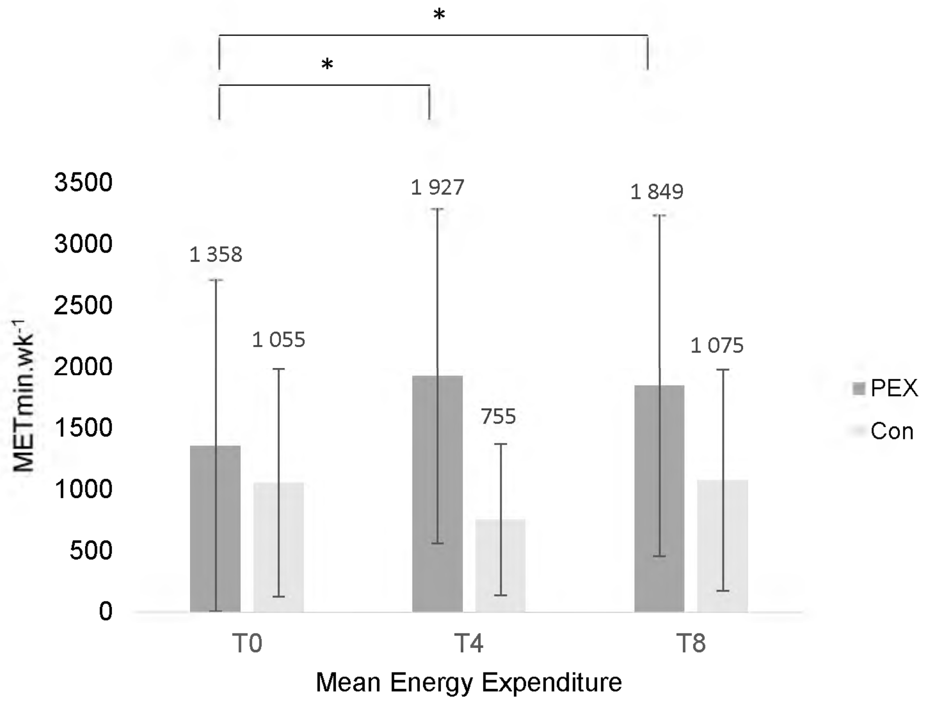

Figure 19: Mean weekly energy expenditure (±SD) expressed as METmin.wk^{-1} for participants in each group.

While no significant differences were seen between groups there was a significant interaction effect (F=8.07, df=(2,2), p=0.002). Post hoc analyses indicated that energy expenditure in the PEx group was significantly greater than baseline levels for both weeks 4, 1926 ± 1362 METmin.wk^{-1} (p=0.007), and week 8, 1848 ± 1390 (p=0.027) Table 13, Figure 19). A large effect size (*d*=1.07) was found between groups at week 4, where energy expenditure in the PEx group increased from baseline while, conversely, the Con group results decreased. Further, a moderate effect size (*d*=0.64) for between-group results was observed at week 8.

4.2.3 Anthropometry

Table 14: Phase 2 intervention groups (PEx and Con) mean anthropometric data (±SD and coefficient of variation (%)).

		Body Mass (kg)	CV (%)	BMI (kg.m^{-2})	CV (%)	Waist Circ. (cm)	CV (%)
PEx	Week 0	63.20 (± 8.67)	13.72	23.71 (± 2.83)	11.92	72.81 (± 7.84)	10.77
	Week 4	63.52 (± 8.90)	14.01	23.94 (± 2.97)	12.41	73.87 (± 7.54)	10.20
	Week 8	63.68 (± 8.78)	13.79	24.02 (± 2.89)	12.05	73.34 (± 7.66)	10.44
Con	Week 0	62.89 (± 8.61)	13.69	22.18 (± 2.87)	12.05	68.40 (± 6.27)	9.16
	Week 4	63.50 (± 9.33)	14.70	22.41 (± 2.91)	13.00	69.30 (± 6.62)	9.56
	Week 8	**63.98 (± 9.44)***	14.76	22.50 (± 2.83)	12.57	69.64 (± 7.04)	10.10

*Where BMI = Body Mass Index, CV = coefficient of variation, * denotes significant difference to week 0*

While there were no between group differences shown for body mass, a significant time effect was noted (F=6.77, df=(2,30), p=0.004). Further analysis suggested a time by group effect for the Con group only, with a significant increase (p=0.018) found between body mass at baseline (62.89 ± 8.61 kg) and week 8 (63.98 ± 9.44 kg) (Table 14). BMI similarly showed a time effect (F=5.7, df=(2,30), p=0.008), yet post hoc analysis only suggested an overall increase, with pooled BMI values at week 8 (23.31 kg.m^{-2}) significantly larger (p=0.007) than those at baseline (22.99 kg.m^{-2}). However, there was no group-specific interaction identified. Medium between-group effect sizes (d=0.5) were seen for the PEx group BMI results at all time points. Lastly waist circumference results also showed a significant increase over time (F=3.52, df=(2,30), p=0.042), although there was no difference between groups (p=0.24). Effect sizes between groups suggested a medium effect (with PEx being larger) at all three time points, with results of d=0.6 at baseline and week 4, with d=0.5 at week 8. Within group effect sizes were trivial.

4.2.4 Physical Fitness Measures

4.2.4.1 Static balance: Stork stand

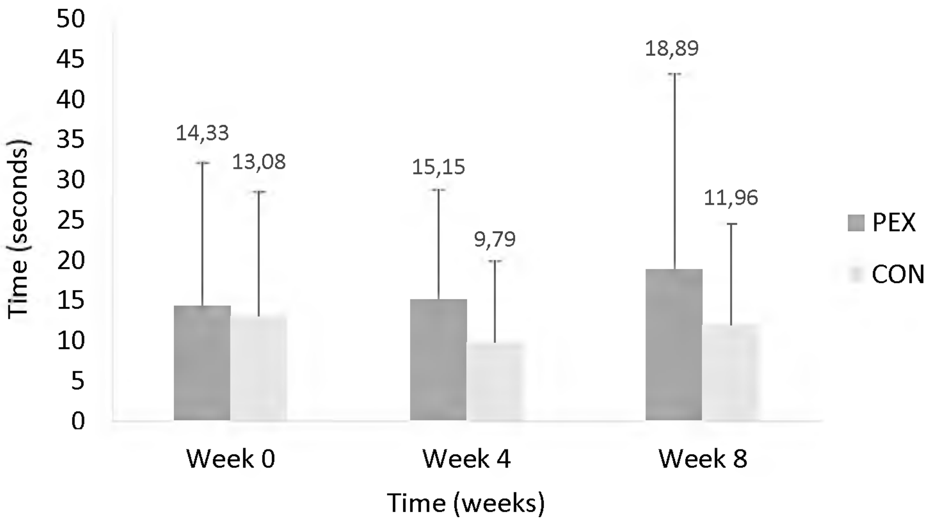

Figure 20: LEFT leg unilateral static balance means (±SD) for each group.

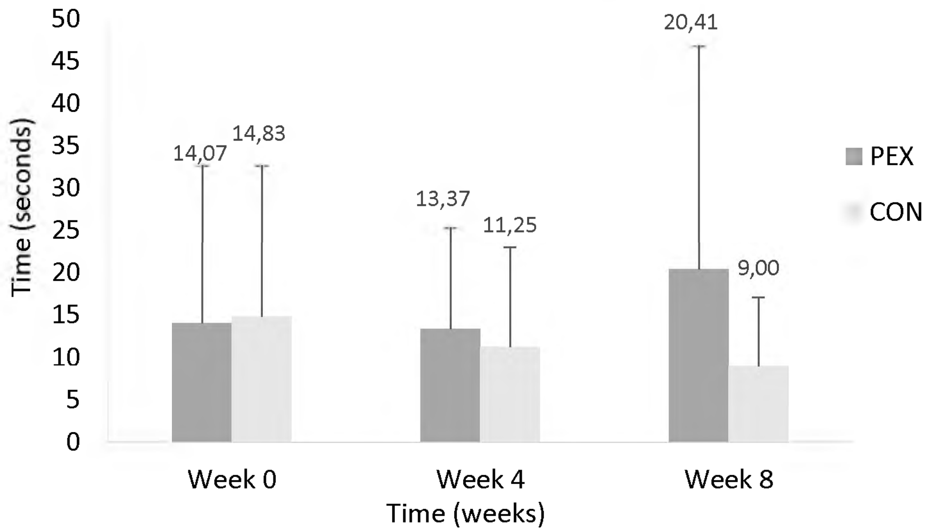

Figure 21: RIGHT leg unilateral static balance means (±SD) for each group.

Table 15: PEx and Con groups' timed single leg static balance means (±SD) and coefficient of variation (%).

		Left Leg (s)	CV (%)	Right Leg (s)	CV (%)
PEx	Week 0	14.33 (± 17.79)	124.09	14.07 (± 18.56)	131.84
	Week 4	15.15 (± 13.59)	89.67	13.37 (± 11.88)	88.83
	Week 8	18.89 (± 24.33)	128.83	20.41 (± 26.37)	129.20
Con	Week 0	13.08 (± 15.47)	118.21	14.83 (± 17.76)	119.76
	Week 4	9.79 (± 10.16)	103.77	11.25 (± 11.74)	104.38
	Week 8	11.96 (± 12.59)	105.32	9.00 (± 8.09)	89.88

No significant differences were found between groups for balance on either limb during the intervention. A medium between-group effect size was recorded for right limb balance at week 8, *d*=0.57, where the PEx group recorded a mean of 20 s (± 26.37) to the Con group's 9 s (± 8.09). The large standard deviations (and CV's) for all results (Table 15, Figure 20 and Figure 21) show the high degree of variability which must be acknowledged.

4.2.4.2 Bilateral dynamic balance: Functional Reach Test

The functional reach test results (Table 16) showed no significant differences between groups (p=0.79) or over time (p=0.058). Between group effect sizes were small, while a medium within group effect size was seen in the PEx cohort between weeks 4-8 (*d*=-0.7) where mean reach distances increased by 3 cm. The Con group results also showed medium effect sizes for increased mean reach distance between weeks 0-4 and weeks 0-8 (*d*=-0.5 and *d*=-0.6 respectively).

Table 16: Mean (±SD) reach results of the Functional Reach Test with coefficient of variation (%) for both PEx and Con groups.

	Bilateral Dynamic Balance Reach Distance (cm)					
	Week 0	CV (%)	Week 4	CV (%)	Week 8	CV (%)
PEx	22.3 (± 6.2)	28.24	21.4 (± 4.6)	21.53	24.4 (± 3.9)	16.12
Con	20.4 (± 5.9)	29.24	22.7 (± 3.8)	16.77	23.3 (± 3.6)	15.48

4.2.4.3 Unilateral dynamic balance: Y-balance Test

Table 17: Mean reach distance percentage (±SD) of normalised Left Leg data for both PEx and Con group Y-balance test.

		Left Ant %	Left PL %	Left PM %
PEx	Week 0	76.48 (± 5.10)	81.41 (± 11.88)	86.83 (± 8.90)
	Week 4	78.06 (± 7.11)	84.65 (± 10.41)	89.03 (± 9.59)
	Week 8	80.19 (± 4.11)	87.18 (± 10.24)	90.14 (± 9.25)
Con	Week 0	80.52 (± 9.75)	77.01 (± 22.36)	82.43 (± 15.83)
	Week 4	80.59 (± 7.18)	82.25 (± 13.63)	86.56 (± 13.75)
	Week 8	81.68 (± 5.02)	**86.66 (± 12.27)***	88.16 (± 11.27)

*Results reported as a percentage due to normalisation of recorded data to stance leg length, where Ant = Anterior, PL = Posterolateral and PM = Posteromedial *denotes significant difference to baseline*

No significant differences were found between groups for *left* leg reach distances (Table 17). However, a medium between-group effect size (*d*=0.5) was revealed for Left Anterior reach distances where the Con group results were greater than the PEx results at each time interval. A time effect was observed for the Left Posterolateral measures (p=0.00) with further analysis indicating a significant increase (p=0.01, *d*=-0.5) in the Con cohort between baseline (77.01 ± 22.36 %) and week 8 (86.66 ±12.27 %). Similarly, a significant time effect was found for the Left Posteromedial direction (p=0.042) and post hoc analysis indicated a general increase across both groups (p=0.041). No within-group differences were apparent however there was a large Cohen's d (*d*=-0.8) recorded for PEx Anterior reach between baseline and week 8.

Table 18: Mean reach distance percentage (±SD) of normalised Right Leg data for both PEx and Con group Y-balance test.

		Right Ant %	Right PL %	Right PM %
PEx	Week 0	77.67 (± 6.69)	81.24 (± 11.66)	86.09 (± 10.11)
	Week 4	79.87 (± 7.51)	85.17 (± 11.85)	88.28 (± 11.39)
	Week 8	80.64 (± 4.94)	85.18 (± 10.52)	87.44 (± 9.73)
Con	Week 0	79.05 (± 8.98)	77.86 (± 20.72)	80.06 (± 15.81)
	Week 4	79.56 (± 6.96)	83.45 (± 13.82)	85.72 (± 10.61)
	Week 8	81.27 (± 6.11)	85.56 (± 11.58)	86.26 (± 10.02)

Results reported as a percentage due to normalisation of recorded data to stance leg length where Ant = Anterior, PL = Posterolateral and PM = Posteromedial

Likewise, there were no differences observed between groups for *right* leg reach distances (Table 18). Similar to left leg results, there were significant time differences shown for the Right Posterolateral reach distance (p=0.014) and the Right Posteromedial (p=0.042). Post hoc analyses identified a general positive group effect regarding increases between baseline and week 8 (p=0.019) for posterolateral reach distance, but no group was identified. No meaningful effect sizes were recorded for these measures.

4.2.4.4 Flexibility

Table 19: Mean sit and reach (mm) results with standard deviation and coefficient of variation (%) for each group over time.

	Flexibility (mm)					
	Week 0	CV (%)	Week 4	CV (%)	Week 8	CV (%)
PEx	106.44 (± 97.67)	91.766	135.55 (± 93.72)	69.14	120 (± 92.03)	76.69
Con	170.13 (± 62.62)	36.80	133.13 (± 54.33)	45.32	144.25 (± 68.29)	47.32

While there were no differences between the two groups, there was a medium between group effect size seen at baseline (*d*=0.7) with the Con results (170.13 mm) greater than that of the PEx group (106.44 mm). A significant Time*Group interaction (F=6.91, df=(2,30), p=0.003) was identified, yet no specific time points were isolated as significantly different. This interaction effect could be as a result of the contrasting fluctuations seen in each cohort's results. Where the PEx cohort increased from base line at week 4 and then decreased again at week 8, the Con group decreased mean flexibility at week 4 (moderate within-group Cohen's *d*=0.6) only to increase at week 8 (Table 19). In addition to this, the large standard deviations in each group highlight the high degree of variability, with some individuals more flexible than others in each cohort.

4.2.4.5 Muscular endurance

Table 20: Phase 2 intervention groups (PEx and Con) mean (±SD) limb and trunk muscular endurance data and coefficient of variation (%) over 8 weeks.

		Arm Endurance[a]	Abdominal Endurance[b]	Leg Endurance[c] (s)
PEx	Week 0	17.56 (± 8.31) 47.33 %	22.78 (± 7.19) 31.57 %	46.06 (± 16.53) 35.90 %
	Week 4	**22.78 (± 9.38)* 41.17 %**	29.00 (± 8.65) 29.81 %	48.67 (± 11.73) 24.09 %
	Week 8	**25.22 (± 8.01)* 31.77 %**	**31.33 (± 7.40)* 23.61 %**	**64.78 (± 17.54)* 27.08 %**
Con	Week 0	17.75 (± 10.53) 59.30 %	23.35 (± 8.22) 35.37 %	65.88 (± 29.41) 44.64 %
	Week 4	18.75 (± 8.50) 45.14 %	30.38 (± 11.21) 36.91 %	56.13 (± 23.63) 42.10 %
	Week 8	21.13 (± 9.00) 42.60 %	29.75 (± 12.26) 41.20 %	52.75 (± 15.04) 28.51 %

a = push up repetitions, b = abdominal crunch repetitions, c = timed wall sit
**denotes significant difference to baseline*

There were no between-group differences identified for any muscular endurance measures (Table 20) however the PEx group showed significant within-group improvements for each measure.

Arm endurance results showed a significant time effect (F=11.64, df=(2,30), p=0.000). Post hoc analyses identified significant positive differences for the PEx cohort results between baseline and week 4 (p=0.02, *d*=-0.5) as well as baseline and week 8 (p=0.000, *d*=-0.9). In particular, the large effect size associated with the changes (+7.6 push ups) between week 0 and 8 suggests that these results are meaningful.
Abdominal muscular endurance demonstrated a significant time effect (F=8.8, df=(2,30), p=0.001). Further analysis again showed a significant increase and large effect size between PEx group measures at baseline and week 8 (p=0.037 *d*=-1.1). An absolute mean increase of 8.5 sit ups was recorded for this change. Again, the large

effect size supports the statistical analysis. A moderate within-group effect size was also observed between baseline and week 4 for the PEx cohort (d=-0.78). The Con group recorded moderate effect sizes between baseline and week 4 (*d*=-0.7), and baseline and week 8 (*d*=-0.62).

A significant time by group interaction effect was found for leg endurance (F=7.9, df=(2,30), p= 0.0017) where PEx results increased over time in contrast to the Con cohort's overall decrease. Cohen's *d* results showed a large between-group effect size of *d*=0.85 at baseline, with the Con group having the larger starting value. However, by week 8 the PEx group showed an average endurance time of 64.78 ± 17.54 s, compared to the Con cohort's 52.75 ± 15.04 s, resulting in a medium between-group effect for the PEx group (*d*=0.7). A significant increase (p=0.02, *d*=-1.1) for the PEx cohort results was observed between baseline (46.06 ± 16.53 s) and week 8 (64.78 ±17.54 s) with a mean increase of 18.72 s. Another large effect size was seen for the PEx group between weeks 4 and 8, *d*=-1.08. The large standard deviations in this measure and resulting variance in the sample must be acknowledged.

4.2.4.6 Muscular strength

Table 21: Mean muscular strength results (kg, ±SD and coefficient of variation (%)) for arm, back and legs of Phase 2 cohorts over 8 weeks.

		Arm Strength[a] (kg)	**Back Strength[b] (kg)**	**Leg Strength[c] (kg)**
PEx	**Week 0**	24.44 (± 4.10) 16.79 %	32.22 (± 3.63) 11.27 %	92.78 (± 24.63) 26.55 %
	Week 4	25.28 (± 4.58) 18.13 %	33.89 (± 4.86) 14.34 %	85.56 (± 26.03) 30.43 %
	Week 8	25.56 (± 6.10) 23.85 %	34.44 (± 6.82) 19.80 %	95.00 (± 28.50) 30.00 %
Con	**Week 0**	25.63 (± 6.09) 23.75 %	35.00 (± 6.55) 18.70 %	80.63 (± 24.12) 29.91 %
	Week 4	26.25 (± 4.23) 16.10 %	36.25 (± 5.82) 16.07 %	76.25 (± 11.88) 15.58 %
	Week 8	27.81 (± 4.90) 17.61 %	36.25 (± 4.43) 12.23 %	**101.88 (± 13.61)* 13.36 %**

*a = chest press, b = lat pull, c = leg press, *denotes significant difference to week 4*

There were no significant differences found between the PEx and Con groups for arm strength (p=0.52), back strength (p=0.35) or leg strength (p=0.61), with both groups showing overall increasing trends for each measure during the intervention. The large standard deviations highlight the large variance in results (Table 21). The only noteworthy effect size between cohorts was a moderate effect for baseline back strength, *d*=0.5, where Con results were greater than PEx. Leg strength results showed a significant general effect (F=6.6, df (2,30), p=0.004) and further analysis showed a significant increase (p=0.013, *d*=2.0) between weeks 4 (76.25 ± 11.88 kg) and week 8 (101.88 ± 13.61 kg) for the Con group. A large effect size was also seen between baseline and week 8 (*d*=-1.08) for this cohort and suggests meaningful changes.

4.2.4.7 Lumbo-pelvic stability/Sahrmann Core Stability Test

Table 22: Sahrmann core stability test results for lumbo-pelvic stability during LEFT leg movement for both PEx and Con groups, with resultant Chi-square values.

	Week 0		Week 4		Week 8	
Left Leg	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**
PEx	67%	33%	100%	0%	67%	33%
Con	38%	62%	38%	62%	75%	25%
Chi-square p-value	*p=0.229*		***p=0.0047****		*p=0.706*	

Table 23: Sahrmann core stability test results for lumbo-pelvic stability during RIGHT leg movement for both Phase 2 groups, with resultant Chi-square values.

	Week 0		Week 4		Week 8	
Right Leg	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**
PEx	56%	44%	100%	0%	100%	0%
Con	38%	62%	38%	62%	25%	75%
Chi-square p-value	*p=0.457*		***p=0.0047****		***p=0.0012****	

No differences in lumbo-pelvic stability were identified between the groups at baseline. Significant differences between groups were identified at week 4 with the PEx group showing improved loading with both the left and right legs (p=0.0047 for both). The PEx group progressed to a 100% pass rate for both limbs at week 4, from a 67% and 56% pass rate at baseline for left and right legs respectively. This, compared to 38% of the Con group which showed no changes (Table 22 and Table 23). At week 8, the PEx group showed a significantly greater pass rate (p=0.0012) for right limb loading than that of Con group. The pass rate remained at 100% for the PEx cohort and decreased to 25% for the Con group. While the Con group scored a 75% pass rate which was higher than the PEx results (67%), no difference (p=0.706) was found during left leg loading at week 8.

4.2.4.8 Transversus abdominis activation

Table 24: Pass/Fail scores and Chi-square results for the Transversus abdominis activation test for each group at baseline, weeks 4 and 8.

		Week 0	Week 4	Week 8
PEx	Pass	67%	67%	78%
	Fail	33%	33%	22%
Con	Pass	75%	50%	75%
	Fail	25%	50%	25%
Chi-square p-value		0.706	0.485	0.892

No significant differences were found between or within groups at any time intervals (Table 24) for the Transversus abdominis activation test.

4.2.5 Health Measures

4.2.5.1 Blood pressure (systolic and diastolic)

Table 25: Mean systolic and diastolic blood pressure results (mm Hg, ±SD) and coefficient of variation (%) for both groups over 8 weeks.

		Systolic (mm Hg)	CV (%)	Diastolic (mm Hg)	CV (%)
PEx	**Week 0**	117 (± 8.9)	7.57	79 (± 8.9)	11.33
	Week 4	123 (± 10.14)	8.24	78 (± 8.8)	11.30
	Week 8	126 (± 11.25)	8.92	77 (± 7.1)	9.09
Con	**Week 0**	119 (± 11.02)	9.25	75 (± 6.25)	8.29
	Week 4	125 (± 11.23)	8.96	78 (± 7.09)	8.90
	Week 8	124 (± 17.70)	14.22	75 (± 7.38)	9.81

There were no significant differences found in either systolic (p=0.84) or diastolic (p=0.51) blood pressure between or within groups (Table 25). Interestingly, PEx systolic blood pressure showed a medium within-group effect size (d=-0.57) between baseline and week 4, and a large effect size (d=-0.84) between baseline and week 8, where the difference in mean measures increased by 9 mm Hg. Only medium effect sizes were observed for the Con group's increases in systolic (*d*=-0.55) and diastolic (*d*=-0.51) blood pressures between baseline and week 4. A medium effect was similarly seen for the Con group's decrease in diastolic blood pressure between weeks 4 and 8 (*d*=0.50).

4.2.5.2 Lung function

Table 26: Spirometry measures results (mean ±SD, with coefficient of variation (%)) for both exercise and control groups, at baseline and each time interval.

		V_E (L.min^{-1})	V_T (L)	FVC (L)	FEV_1 (L)	TLC (L)
PEx	**Week 0**	9.67 (± 2.78) 28.78 %	0.65 (± 0.26) 39.75 %	2.60 (± 0.62) 23.95 %	2.52 (± 0.6) 23.76 %	3.70 (± 0.62) 16.83 %
	Week 4	11.77 (± 3.17) 26.90 %	0.76 (± 0.32) 42.43 %	2.45 (± 0.94) 38.59 %	2.33 (± 0.92) 39.32 %	3.55 (± 0.94) 26.62 %
	Week 8	**9.12 (± 2.35)* 25.77 %**	0.59 (± 0.20) 33.54 %	2.30 (± 0.71) 31.03 %	2.22 (± 0.71) 32.11 %	3.40 (± 0.71) 21.00 %
Con	**Week 0**	10.63 (± 3.76) 35.36 %	0.68 (± 0.26) 38.71 %	2.64 (± 1.10) 41.65 %	2.17 (± 0.34) 15.67 %	3.74 (± 1.10) 29.39 %
	Week 4	10.71 (± 2.39) 22.36 %	0.69 (± 0.20) 28.50 %	2.40 (± 0.78) 32.27 %	2.07 (± 0.63) 30.39 %	3.50 (± 0.78) 22.13 %
	Week 8	10.08 (± 2.81) 27.89 %	0.65 (± 0.22) 33.43 %	2.25 (± 0.53) 23.49 %	2.13 (± 0.53) 24.76 %	3.35 (± 0.53) 15.78 %

*V_E = Minute Ventilation, V_T = Tidal Volume, FVC = Forced Vital Capacity, FEV_1 = Forced Expiratory Volume, and TLC = Total Lung Capacity, *denotes significant difference to week 4*

There were no significant differences found between the groups for any spirometry measures (Table 26). There was however, a significant time effect for Minute Ventilation (F=5.38, df=(2,30), p=0.010). Further analysis showed a significant decrease (p=0.008, *d*=0.95) in the PEx Minute Ventilation from weeks 4 to 8, where mean results dropped from 11.77 (± 3.17) L.min^{-1} to below baseline at 9.12 (± 2.35) L.min^{-1}. The corresponding Cohen's *d* result suggests that the approximately 2 L.min^{-1} change in ventilation at these time points was meaningful. Further, a moderate between-group effect size (*d*=0.7) was observed for baseline FEV_1 results with PEx having the greater value. Finally, PEx Tidal Volume changes between weeks 4-8 resulted in a moderate effect size (*d*=0.62).

4.3 SUMMARY OF RESULTS

Phase 1:

Mean data for Phase 1 was significantly greater than all the comparative norms with respect to stature, diastolic blood pressure, Minute Ventilation and Tidal Volume. Conversely, the observed means for waist circumference, Forced Vital Capacity and Total Lung Capacity were significantly smaller than comparative data. Body mass was significantly greater when compared to the two SADHS figures, however not significantly different from the SANHANES-1 sample. BMI was similar to that of both SADHS studies, but was significantly smaller than that of the SANHANES-1 figure. Systolic blood pressure was significantly higher than the SADHS 1998 results, but conversely, significantly lower than the SANHANES-1 result. FEV_1 was the found to be similar to suggested norms.

Phase 2:

Lumbo-pelvic stability significantly improved in the PEx group at weeks 4 ($p<0.005$) and 8 ($p<0.002$). Similarly, abdominal ($p=0.00$), upper limb ($p=0.037$) and lower limb endurance ($p=0.02$) also improved in the PEx cohort over time. Protein consumption was also significantly higher ($p=0.036$, $d>0.8$ at baseline and week 8) in the PEx group than that of the Con cohort. Energy expenditure significantly increased from baseline in the PEx cohort at weeks 4 ($p=0.007$, $d=1.07$) and 8 ($p=0.027$, $d=0.64$). Minute Ventilation decreased in the PEx cohort ($p=0.010$, $d=0.95$) from weeks 4 to 8. The Control group showed a significant increase in body mass, leg strength (within-group Cohen's $d=-1.08$ between week 0-8 and $d=-2$ between weeks 4-8) and dynamic balance. General effects included significant increases in BMI (between-group effect size of $d=0.5$ indicated for PEx at all time points), waist circumference ($d\geq0.5$ for PEx at all time points) and dynamic balance. Significant interaction effects included an increase in lower limb endurance with the Con group initially having the larger mean (between-group effect size $d=0.85$), but by week 8 the PEx results were greater ($d=0.73$; (PEx within-group effect for weeks 4-8, $d=-1.1$)). Further, a significant interaction effect was observed for flexibility. Other measures that were not statistically different, but showed noteworthy between-group effect sizes, included total caloric intake ($d=0.93$, week 8) and total fat intake ($d=0.88$, week 8) which were greater in the PEx group. Table 27 presents a statistical summary.

Table 27: Statistical significances summary for all intervention measures.

	BETWEEN GROUP DIFFERENCES	GENERAL EFFECTS	INTERACTION EFFECTS	NONE
STATURE				X
BODY MASS		Con		
BODY MASS INDEX		X		
WAIST CIRCUMFERENCE		X		
TOTAL CALORIC INTAKE				X
TOTAL PROTEIN INTAKE	PEx			
TOTAL CARBOHYDRATE INTAKE				X
TOTAL FAT INTAKE				X
TOTAL ENERGY EXPENDITURE			PEx	
STORK STAND LEFT LEG				X
STORK STAND RIGHT LEG				X
FUNCTIONAL REACH TEST				X
RIGHT: ANTERIOR %				X
RIGHT: POSTEROMEDIAL %		X		
RIGHT: POSTEROLATERAL %		X		
LEFT: ANTERIOR %				X
LEFT: POSTEROMEDIAL %		X		
LEFT: POSTEROLATERAL %		Con		
FLEXIBILITY			X	
ABDOMINAL ENDURANCE		PEx		
UPPER BODY ENDURANCE		PEx		
LOWER BODY ENDURANCE			PEx	
BACK STRENGTH				X
CHEST STRENGTH				X
LEG STRENGTH		Con		
LUMBO-PELVIC STABILITY RIGHT	PEx			
LUMBO-PELVIC STABILITY LEFT	PEx			
TR. ABDOMINUS ACTIVATION				X
SYSTOLIC BLOOD PRESSURE				X
DIASTOLIC BLOOD PRESSURE				X
MINUTE VENTILATION		PEx		
TIDAL VOLUME				X
FORCED VITAL CAPACITY				X
FORCED EXPIRATORY VOLUME				X
TOTAL LUNG CAPACITY				X

Where PEx = Pilates group, Con = Control group and X = no group identified.

A summary of all large and medium effects sizes found for all measures are listed in Table 28 and Table 29 to show noteworthy effect sizes between and within groups.

Table 28: Time points and measures with medium (*d*=0.5-0.79) and large (*d*≥0.80) between group effect sizes, indicating cohort with larger variable.

Time Interval and Measure	Cohen's *d*	Group Improved
T0 Total Protein Intake	1,22	PEx
T4 Energy Expenditure	1,07	PEx
T8 Total Caloric Intake	0,93	PEx
T8 Total Protein Intake	0,92	PEx
T8 Total Fat Intake	0,88	PEx
T0 Leg Endurance	0,85	Con
T8 Total Carbohydrate Intake	0,77	PEx
T0 Sit & Reach	0,77	Con
T8 Leg Endurance	0,73	PEx
T0 FEV_1	0,70	PEx
T0 Total Caloric Intake	0,67	PEx
T4 Waist Circumference	0,64	PEx
T8 Energy Expenditure	0,64	PEx
T0 Waist Circumference	0,62	PEx
T8 Stork Stand (Right leg)	0,57	PEx
T0 Body Mass Index	0,56	PEx
T0 Back Strength	0,53	Con
T8 Body Mass Index	0,53	PEx
T0 Left Anterior Reach Distance	0,53	Con
T4 Body Mass Index	0,52	PEx
T8 Waist Circumference	0,50	PEx

Where T0 = baseline, T4 = week 4 and T8 = week 8, PEx = Pilates group, Con = Control group

Table 29: Medium (*d*=(-)0.5-0.79) and large (*d*≥ 0.80/≤-0.80) effect sizes identified within groups over time.

		Cohen's *d*		
Measure	Group	T0-T4	T0-T8	T4-T8
Systolic blood pressure	PEx	-0,57	-0,84	-0,29
	Con	-0,55	-0,36	0,06
Diastolic blood pressure	Con	-0,51	0,04	0,50
Abdominal endurance	PEx	-0,78	-1,17	-0,29
	Con	-0,72	-0,62	0,05
Arm Endurance	PEx	-0,59	-0,94	-0,28
Leg Endurance	PEx	-0,18	-1,10	-1,08
	Con	0,37	0,56	0,17
Functional Reach Test	PEx	0,15	-0,41	-0,69
	Con	-0,47	-0,58	-0,14
Leg Strength	Con	0,23	-1,09	-2,01
Sit and Reach	Con	0,60	0,39	-0,17
Minute Ventilation	PEx	-0,70	0,22	0,95
Tidal Volume	PEx	-0,36	0,27	0,62
Y-Balance: Left Anterior	PEx	-0,25	-0,80	-0,37
Y-Balance Right Anterior	PEx	-0,31	-0,50	-0,12
Y-Balance Left Posterolateral	PEx	-0,29	-0,52	-0,24
	Con	-0,28	-0,53	-0,34
Protein Intake	Con	-0,69	-0,13	0,52
Total Caloric Intake	Con	-0,43	0,20	0,50

Where T0 = baseline, T4 = week 4 and T8 = week 8, PEx = Pilates group, Con = Control group

CHAPTER 5

DISCUSSION

PHASE 1

Overall, the population in Phase 1 presented a healthy and relatively active group of young, adult females. This is in contrast to that found in national surveys where females have repeatedly been shown to have high levels of obesity, hypertension and physical inactivity (Department of Health et al., 2007; Joubert et al., 2007; Shisana et al., 2014). This difference can be attributed, in part, to the expected inherent good health of a young adult population, but similarly, to the voluntarily nature of participation. The passive recruitment process may have resulted in participants with intrinsic interests in their own health and wellness volunteering (Egli et al., 2011), resulting in a group of healthy individuals. The investigator noted some competitive individuals who were eager to push their limits during testing, and who were outwardly disappointed if they felt they did not do as well as they expected. In contrast, individuals less concerned with health status and fitness levels, or similarly those who knew they were not at an acceptable level of fitness, may have stayed away due to either a lack of interest or fear of embarrassment (Dishman, Sallis, & Orenstein, 1985). Although ethically preferable, passive recruitment was undoubtedly a limitation of this study.

Additional limitations impacted on the findings of this phase and the results should therefore be considered within the context of these. These limitations are as follows:

While care was taken to make the research available to the community at large, the final cohort consisted primarily of Rhodes University students. This resulted in a limitation in hindsight, in that this demographic (students) might only reside in the town for a limited period of time while attending the university. This makes parts of Grahamstown/iRhini transitory in nature and as a result, the young adult population is fluid. The ability to draw definitive conclusions or identify trends within this population group is therefore challenging. Similarly, while race did not influence inclusion criteria, almost three quarters (74%) of the participants were Caucasian, while only 21% of participants were Black. These findings therefore need to be taken into account during comparisons to national samples, which may have included more representative cohorts. The availability of normative data was limited and as such, only certain measures could be compared to these existing norms. Similarly, it was not always possible to match the normative data to that of the local sample (e.g. age range). While this is not ideal, these comparisons will nevertheless assist in presenting an approximation of the health status of this group. Finally, results relied heavily on the honesty of participants (Paulhus & Vazire, 2009), specifically regarding their activity levels before testing (they were required to refrain from exercise on the day of testing), as well as their use of chronic medications which may have impacted outcomes. It is well known that the accuracy of self-reports can be influenced by a multitude of factors (honesty, motivation, comprehension, memory) resulting in bias from participants (Kurtzman, 2009) and is thus a limitation of this study.

The average of 270 minutes (or 4.6 hours) of weekly exercise activity (when excluding the known sedentary Phase 2 cohort, therefore n=79, or 82%), exceeds the recommended target of at least 30 minutes of activity on 5 or more days of the week, as proposed by the American College of Sports Medicine (Garber et al., 2011). It must be noted that while the frequency and duration of exercise performed by this cohort is more than adequate, the intensity levels were not measured. Still, it can be suggested that these women are sufficiently active, which is in contrast to the SADHS (2003) report which found that 52% of females, aged 15-24 years, were insufficiently active (Department of Health et al., 2007). The SANHANES-1 sample, a more closely matched age cohort of 18-24 years, similarly recorded 50.2% of this population as unfit (Shisana et al., 2014).

In terms of anthropometric measures, the average height (165.2 ± 5.6 cm) of participants was significantly greater than that of the other recorded statures for young South African adult female cohorts (aged-matched, all races) (Department of Health et al., 2007; Shisana et al., 2014; South African Department of Health et al., 2002). National records however comprised of larger age ranges (15-24 years of age) and therefore included younger individuals who had not yet reached adult stature, allowing for greater variability and a reduced mean. Another explanation for these differences may be due to race. While no results on Caucasian females are available for the SANHANES-1 cohort, the SADHS surveys recorded the mean stature of Caucasian women (all ages) as 162-164 cm (Department of Health et al., 2007; South African Department of Health et al., 2002). This is more accurately matched to the current findings with a difference of only 1-3 cm. Given the predominance of Caucasian females in the current sample, it is likely that mean stature was influenced by this, as they appear to be taller than other races (Department of Health et al., 2007; South African Department of Health et al., 2002).

There was a similar finding in body mass as participants in this study (mean body mass of 63.0 ± 9.7 kg) were found to be significantly heavier than both SADHS samples (aged-matched, all races), which were on average 4 kg less, but again, the larger age ranges were confounding variables (Department of Health et al., 2007; South African Department of Health et al., 2002). In contrast there was no difference found between the local sample and the more recent SANHANES-1 results (aged-matched, all races) (Shisana et al., 2014). This suggests that while body mass in young adults showed increasing trends between the earliest and most recent national surveys, it has possibly stabilised since 2012, which is encouraging. Caucasian data in the SANHANES-1 survey was not specified due to too few measures obtained (Shisana et al., 2014). Race-specific results in the SADHS samples showed mean Caucasian body mass (all ages) to be greater than the current sample in both instances (71 kg in 1998 and 65 kg in 2003) (Department of Health et al., 2007; South African Department of Health et al., 2002). Given the lesser figures in the younger cohorts, this suggests an increase in weight with age.

Mean Body Mass Index (BMI) (23.1 ± 3.3 $kg.m^{-2}$) was within the recommended healthy range. A total of 22 (23%) participants had BMIs greater than 25 $kg.m^{-2}$. There were only 2 individuals (2.1%) with BMIs in the obese range of >30 $kg.m^{-2}$. This shows a 10-fold reduction compared to the SANHANES-1 suggested figure of 21.7% of females, aged 18-24 years (Shisana et al., 2014) which is promising. The current sample’s mean BMI was significantly smaller than that of the SANHANES-1 data, which comprised of all races, aged 18-24 years (Shisana et al., 2014) and is thus more accurately matched to the investigation cohort. As this is the most recent survey of the three, it suggests that the number of BMIs in the obese range may be decreasing in young women. While the SADHS 1998 and 2003 surveys also showed higher proportions (9.6% and 11% respectively) of obese young females than the current sample, they both recorded a healthy mean BMI for their cohorts (all races, aged 15-24 years) at 23.7 $kg.m^{-2}$ and 23.6 $kg.m^{-2}$ respectively (Department of Health et al., 2007; South African Department of Health et al., 2002). The decreased mean body mass of these samples resulted in lowering their BMI figures in comparison to that of the SANHANES-1 mean body mass (Department of Health et al., 2007; South African Department of Health et al., 2002). Again, the two SADHS samples are not as closely matched in age to the investigation group as the SANHANES-1 population (Shisana et al., 2014). Interestingly, BMI results for Caucasian females (all ages) in the SADHS surveys fell within the overweight category (Department of Health et al., 2007; South African Department of Health et al., 2002). Again, this suggests that this population may experience an increase in weight with age.

Mean waist circumference (72.4 ± 7.8 cm), was below that of the World Health Organisation recommended upper limit (80 cm) (World Health Organisation, 2008). This was significantly smaller than the SANHANES-1 sample average of 82 cm for females aged 20-24 years (all races) (Shisana et al., 2014), with a mean decrease of approximately 10 cm. In addition, over 50% of the SANHANES-1 group had a waist circumference of ≥80 cm (Shisana et al., 2014), whereas in the current sample only 11 individuals (11.5%) exceeded this recommended limit. The participant with the largest waist circumference of 106.2 cm places her at a substantially increased risk of metabolic complications (World Health Organisation, 2008). While also significantly smaller than results from the two SADHS samples (aged 15-24 years, all races), the absolute difference between these measures and the current sample was approximately 2 cm. As such, the SADHS samples were still considered to be within a healthy limit (Department of Health et al., 2007; South African Department of Health et al., 2002). As with body mass measures, waist circumference data for Caucasian groups (all ages) in the SADHS data were over the upper limit (>80 cm) in both reports, suggesting an increase in waist circumference with age (Department of Health et al., 2007; South African Department of Health et al., 2002). It should be noted that these recommended limits were derived and adapted for a Caucasian cohort (World Health Organisation, 2008). This makes them less applicable to the local sample since race and ethnicity were not examined or stipulated. As such, more research into norms for Sub-Saharan African populations is needed so as to identify accurate upper limits for different races in order to determine a more realistic level of risk.

Mean blood pressure of 121/76 mm Hg suggested a normotensive cohort (NHLBI Joint National Committee, 2004), however the large variations in both systolic and diastolic results must be acknowledged. For all race comparisons, systolic blood pressure was statistically lower than that of the SANHANES-1 findings (all ages), while significantly greater than the SADHS 1998 figures (aged 15-24 years) (Shisana et al., 2014; South African Department of Health et al., 2002). The comparison to the SANHANES-1 finding should be read within the context of the various age groups included. In contrast the diastolic pressure was greater than both the SANHANES-1 and SADHS 1998 mean figures, suggesting an increase in this measure over time (Shisana et al., 2014; South African Department of Health et al., 2002). Race specific data showed similarities between this sample and the SADHS Caucasian cohort (all ages, 121/74 mm Hg) while the SANHANES-1 Caucasian cohort (all ages and both sexes) was greater at 131/74 mm Hg (Shisana et al., 2014; South African Department of Health et al., 2002). The inclusion of both sexes in the SANHANES-1 sample was a confounding factor.

While it was not possible to draw accurate conclusions on the spirometry measures given the specific demographics of the Phase 1 cohort, general comparisons were made to data from healthy adult women (McArdle et al., 2001; Tortora & Derrickson, 2013). The significantly larger Minute Ventilation ($p=0.000$) was due to the larger average tidal volumes recorded (0.66 ± 0.2 L) (Tortora & Derrickson, 2013). More than two thirds (67.7%) of participants had a tidal volume of >0.5 L, however these were still within suggested resting norms (0.4-1.0 L) and may have been influenced by the greater stature and younger age of the cohort (McArdle et al., 2001; Tortora & Derrickson, 2013). In contrast, the significantly lower mean Forced Vital Capacity (FVC) was potentially impacted by the seated position used during testing (McArdle et al., 2001). Poor seated posture may have resulted in a collapsing of the thoracic region and is thus a limitation of this protocol (McArdle et al., 2001). Although significantly lower than normative data, mean Total Lung Capacity fell within a healthy range and was only 5.8% (0.25 L) smaller than that of the suggested norm (4.3 L) (Barreiro & Perrillo, 2004; Neder, Andreoni, Castelo-Filho, & Nery, 1999; Tortora & Derrickson, 2013). Only Forced Expiratory Volume (FEV_1) (2.69 ± 0.6 L) showed no significant differences to normative data (2.72 L) (McArdle et al., 2001). This normative FEV_1 is typically 85% of FVC (Mathur, Rastogi, Husain, & Gupta, 1998; McArdle et al., 2001; Neder et al., 1999), however a normal FEV_1/FVC ratio is said to range between 75-90% (Barreiro & Perrillo, 2004). In the case of the Phase 1 cohort the FEV_1 was 91.2% of FVC, suggesting healthy pulmonary airflow capacity (McArdle et al., 2001).

Additional considerations:

Education around the benefits of physical activity remains a necessity. Although not the aim of the study, it was noted that many participants were unaware of their capabilities, and over-estimated these. Many showed disbelief when their results were worse than they had expected. Given the inherent nature of humans to be motivated by actions of personal benefit and self-interest, it is possible that they could be influenced by their own results, particularly when these are not what they assume them to be. Unexpected poor performance may be a catalyst for improvement of behaviours and lifestyle, and as such, just the act of measuring may be useful in educating individuals. In addition, the national plans for further education and knowledge awareness as described in the *Strategic Plan for the Prevention and Control of Non-Communicable Diseases 2013-17* (www.hsrc.co.za) are appropriate and necessary if behavioural changes are to be made within any given population. The key is for these individuals to maintain these healthy lifestyles and high levels of physical activity going forward, avoiding factors that could interrupt this behaviour as they age (marriage, career, family planning, aging etc.).

PHASE 2

The intervention results suggest that Pilates significantly improves lumbo-pelvic stability and muscular endurance, as well as aiding in weight maintenance of healthy young females. Further it may provide some meaningful improvements in balance ability. However, as in Phase 1, there were limitations to this stage of the study. While overarching limitations are discussed here, more specific short-comings will be considered at relevant intervals within the discussion. It is also important to note that given the paucity of knowledge available on the effects of Pilates on the population in question, i.e. healthy, *young* adult females, comparisons have been drawn from investigations on 'healthy' adult female populations of various age groups where necessary.

General limitations:

The results from this controlled trial were undoubtedly influenced by the small cohort sample sizes as well as the reduced intervention period, and as such, should be read in context of these limitations.

Due to the stringent inclusion criteria and the small local community, finding suitable participants was challenging. While there were many interested volunteers, the vast majority did not comply with the inclusion criteria, and as a result, recruitment took considerable time. This resulted in the small sample sizes for each group, but also negatively impacted on the intervention time available, which was shortened from the originally planned 12 weeks to only 8 weeks. This similarly influenced the intended progression of exercises during the intervention. The intervention was therefore implemented during the months of May and June, causing many participants to be impacted on by both institutional examinations and the subsequent vacation period. This resulted in decreased commitment and availability for scheduled Pilates sessions, and the final round of testing, which has been found in other studies (Marcus et al., 2000; Rhodes & Pfaeffli, 2010; Vanden Auweele, Rzewnicki, & Van Mele, 1997; White et al., 2005). In addition, during the intervention period, three participants from each group left the project due to injury, illness and/or personal reasons (Figure 3), reducing the original samples even further. The dropout rate was 30%. These small cohorts resulted in poor statistical power and the potential inability to detect between-group differences (Christopher et al., 2006).

While an eight week duration has resulted in improvements in fitness parameters in previous Pilates studies, this has predominantly been shown in middle-aged or elderly populations (Arslanoğlu et al., 2011; de Siqueira Rodrigues et al., 2010; Giacomini et al., 2016; Phrompaet et al., 2011). Only one study in a young adult population has shown changes in this time period (Kibar et al., 2015). While the current study supports these findings regarding lumbo-pelvic stability and abdominal muscular endurance, it does not concur with evidence for improved flexibility, strength, or waist circumference. As such, it is still unclear as to whether this duration might induce beneficial effects for these measures in young adults. Further, it may be that frequency of sessions during the eight week period confounded the results, rather than the intervention duration itself.

Some researchers have recommended that between 900 and 1440 minutes of Pilates participation (15-24 hours in total) are needed in order to reveal true effects (Donahoe-Fillmore et al., 2015). The current study was a total of 960 minutes of Pilates (or 900 minutes for those participants who attended 15 sessions) which falls within this time frame, albeit at the lower end. It may be that participation at the upper end of this time bracket is necessary for the development of further benefits and a 3-session per week frequency should thus be considered for future research. Young to middle-aged adults as well as overweight females showed significant improvement in body composition, flexibility, and aerobic power after three sessions per week over 8 weeks (Ali et al., 2010; Rogers & Gibson, 2009). Similarly, muscular strength improved significantly in *elderly* females with the same frequency and duration (Fourie et al., 2012). Conversely, a lower frequency (once weekly) over a longer intervention (12 weeks) yielded no significant differences in fitness parameters of healthy adults (Pumpa et al., 2015).

The willingness of the individuals to participate in tests that they deemed as 'difficult' (e.g. the muscular endurance and strength tests) and to perform them to the best of their ability was questionable in some instances. Each participant's internal motivation may have influenced their effort during testing (Dishman & Ickes, 1981; Kilpatrick, Hebert, & Bartholomew, 2005; Wilson, Mack, & Grattan, 2008). This contrast was noted particularly when compared to some participants from Phase 1, where those keen sportswomen or athletes would push themselves for maximum results during testing.

Lastly, while the measures used in this study were minimalist as well as time and cost effective, certain tests may not have been sensitive enough to identify other changes. Possible alternatives that could be used for future research are presented later in this chapter.

Group comparison discussion:

5.1 Self-reports

While it was requested that participants continue with their habitual dietary intake, the consumption of calories and macronutrients was difficult to control. While the inferred honesty of participants (Schoeller, 1995) was stressed, this could not be guaranteed.

Even with reminders as to the importance of detailed completion, it was clear that certain respondents were more competent at completing these documents, while others noticeably omitted content. This is no doubt a limitation of this study. While it did not increase over the course of the intervention, protein consumption for the PEx group was significantly larger than intake for the Con group throughout. The corresponding large effect sizes suggest it was noticeably greater at baseline (d=1.2) and week 8 (d=0.9). In addition, while no differences were found between groups the moderate to large effect sizes at week 8 suggest there were some meaningful differences for total caloric intake (d=0.93), fat (d=0.88) and carbohydrate consumption (d=0.77), with the PEx group showing higher intake for all. Further, within-group effect sizes suggest a meaningful decrease in Con group protein and total calorie consumption in the second half of the intervention. The large variations between the participants were noteworthy, suggesting different dietary habits between participants (McArdle et al., 2001; Smith & Baghurst, 1992).

Participants were similarly asked to maintain their exercise habits throughout the intervention and no significant differences were seen between groups at any stage. While the PEx group were asked *not* to include their participation in Pilates sessions (two hours per week) in their GPAQv2 forms, the primary researcher suspects that some of them may have done so. The increase in mean energy expenditure from baseline to week 4, and the subsequent stabilisation of these results between weeks 4 and 8 (Table 13), resulted in a significant interaction effect (p=0.002) between baseline results and the week 4 and 8 measures. The large between-group Cohen's d at week 4 (d=1.1) suggests the PEx energy expenditure increase was clinically meaningful and there was similarly a moderate effect size (d=0.64) between groups at week 8 (with PEx results being greater). However, a more likely explanation is the occurrence of over-reporting at weeks 4 and 8 (Myers, Klesges, Eck, Hanson, & Klem, 1988), or similarly, initial under-reporting at baseline given the large standard deviations present for both groups throughout (Figure 19). Further, according to the SADHS 2003 report, results for both groups suggest that their mean activity levels throughout the intervention fell within the 'minimally active' range, or 600-<3000 METmin.wk^{-1} (Department of Health et al., 2007). Assuming participants were not including the intervention time in their reports, it could also suggests that some of them partook in additional activities after commencement, as has been documented in other research (Biddle & Mutrie, 2008; Dishman et al., 2004, 1985; Pedersen et al., 2013).

5.2 Anthropometry

The significant increase (p=0.01) for Con body mass between baseline and week 8 is noteworthy as similar results have not been observed in previous Pilates research. Body mass may have been influenced by dietary changes that were not adequately reflected in self-reports (as discussed in 5.1) (Schoeller, 1995). However, given the absolute increase of just 1 kg, this is more likely explained by typical daily weight fluctuations and persistent low physical activity levels.

Similarly, absolute changes in waist circumference (pooled for both groups) over the 8 weeks were between 0.5-1.2 cm and may have been influenced by inter-tester variability (Irez et al., 2011; Sekendiz et al., 2007) with different research assistants being present at different time intervals. However, the PEx cohort did show moderate between-group Cohen's *d* values at all intervals. This is in contrast to research using the same frequency and duration and a similar cohort to the current study, which found significant decreases in waist circumference (p=0.00) in their intervention group (Kibar et al., 2015).

While there were moderate within-group effect sizes observed for PEx BMI and waist circumference, both of which increased during the intervention, the PEx group showed no significant changes overall, which suggests that Pilates does not affect anthropometric measures, but is useful for weight maintenance (Prentice & Jebb, 2000). This finding corresponds with previous research in similar and other cohorts, including school-going girls as well as sedentary middle-aged men and women. After partaking in 1-5 sessions per week, no changes in body mass, BMI or other anthropometric measures were observed after 4-12 weeks (Arslanoğlu et al., 2011; Jago et al., 2006; Lee et al., 2016; Pumpa et al., 2015; Rogers & Gibson, 2009; Sekendiz et al., 2007; Tolnai et al., 2016). Results of the current research correspond with these findings to suggest there is no evidence that Pilates affects anthropometry in healthy adults, but that it may maintain body mass. While this lack of meaningful changes may be due to the short intervention durations used (between 4-12 weeks) and low frequency of weekly sessions, even extended time periods (six months), have shown no changes (Segal et al., 2004). An observational study suggested that experienced female practitioners who participated in twice-weekly Reformer Pilates for more than two years, showed significantly reduced body mass and waist circumferences to those who had only participated for one year or less (Vaquero-Cristóbal et al., 2016). However, the researchers acknowledged that other factors such as diet and additional exercise activities were not investigated in their study.

Ultimately, the lack of aerobic elements in Pilates and its predominance of isometric exercises, suggests body composition changes should not be expected (Segal et al., 2004). Unique research into the energy costs of a beginner, intermediate and advanced level Pilates matwork sequence suggested that energy expenditure of a beginner or essential level workout was equivalent to a low-moderate intensity workout at 3.5 METS (Olson et al., 2004). Intermediate and advanced level workouts were of a moderate intensity, suggesting benefits might only be observed with repeated performance at this level (Olson et al., 2004). Given that Pilates research too often involves novice participants, time is required for their safe progression to these advanced levels. Shorter interventions may thus not be sufficient for inducing effects on anthropometry or morphology. This may have been the case in the current study where participants only progressed to intermediate level exercises after approximately five sessions. As such, longitudinal studies involving experienced practitioners, with a higher frequency of sessions are required (Cristóbal et al., 2014; Segal et al., 2004). Further, the absence of dietary regulation in most Pilates studies, including the current research, will affect results. It is well established that restricted diets, or exercise programs performed in conjunction with a diet plan, yield greater results than a purely exercise-based program (Miller et al., 1997; Pollock et al., 1998; Stefanick, 1993) and should therefore be considered for inclusion in future studies.

5.3 Balance

The current study is not conclusive in terms of benefits of Pilates on static or dynamic balance in a group of previously sedentary young women. While statistically not different, there was a moderate between group effect size (d=0.57) for PEx static balance at week 8, as well as a moderate (d≥-0.50) to large (d=-0.80) within-group effect sizes for PEx dynamic balance (week 0-8) suggesting meaningful changes. The significant increase in the Con group dynamic balance (p=0.01, *d*=-0.5) is interesting and may have resulted from these volunteers participating in other activities or exercise which were not accurately documented in their self-reports. Alternatively this may have been a measurement error, as similar improvements on the same limb were not observed for other reach directions.

The meaningful increase in balance for the PEx cohort is encouraging, particularly as other research has found significant improvements (Kibar et al., 2015). However the lack of significance needs to be considered. The study by Kibar et al., (2015) used a Sport Kinesthetic Ability Trainer (KAT) 4000 device, which may have been more sensitive to changes in static balance ability. Further, Tolnai et al., (2016) showed improvements in dynamic balance using the Functional Reach Test after just 10 Pilates sessions (Tolnai et al., 2016). However, the findings of this latter study should be seen within the context of its design, as it employed specific balance-based exercises within its protocol. Another study also using the Functional Reach Test, found significant improvements in middle-aged men and women after just 10 sessions in 5 weeks (Johnson et al., 2007). The differences between groups however were not clear. The study by Johnson et al., (2007) was unique in that it used an apparatus based protocol, specifically a Reformer. This machine offers a range of leg-specific exercises, performed against spring-loaded resistance, as well as standing manoeuvres, which are not common in a matwork sequence. More importantly, the reformer carriage is mobile, resulting in the practitioner’s centre of mass being continuously challenged by the instability of the moving base. This may therefore have an alternative impact on balance and postural control to that of mat based Pilates. The comparison of effects on physical fitness parameters between matwork and apparatus based regimes need further investigation (Sinzato et al., 2013). However, as there was an effect, it may be that a larger sample size would have seen statistically significant improvements in the exercise cohort in this study and is something that needs to be explored further.

The American College of Sports Medicine suggests neuromotor exercises should be performed on 2-3 days of the week (Garber et al., 2011). It may be that in younger, healthy individuals, this recommendation would result in maintenance, with an increased frequency required for improvements. Therefore twice weekly classes, as per the current study, may not have been adequate. Moreover, it is also possible that the tests involved may not have been as suitable as originally thought. While they were both cost effective and easy to implement, these tests may have lacked the sensitivity required to detect balance changes in a healthy cohort. It was thought that the static single-leg balance test with eyes closed would identify differences between groups, since visual perception is said to be the principal sensory system of balance in young adults (Gaerlan et al., 2012). However, it may be that learning effects overruled this, and the differences were thus too small. Similarly, the Functional Reach Test has been recommended as a screening tool rather than a conclusive measure of balance ability (Browne & O'Hare, 2001). The Star Excursion Balance Test has not yet been used to investigate the impact of Pilates on dynamic balance, and it did not result in significant changes in the current study, except for a single direction using the left leg for the Con group. However, effect sizes suggest there were some meaningful improvements in the PEx group. It could be that the practice runs required before commencing the actual test (which itself was done in triplicate), as well as the repeated design, resulted in a learning effect for most participants. However, given the complexity of the task, these practice rounds could not be excluded as they are said to decrease individual variability and induce consistent results (Kinzey & Armstrong, 1998). Confusion remains as some researchers suggest that this test can serve as a measure of lower limb functionality in healthy adults (Gribble et al., 2012) while others suggest it may be better suited to rehabilitation environments (Kinzey & Armstrong, 1998). Indeed, the lack of major differences in the current study might indicate a lack of sensitivity when testing balance in healthy individuals. Further, it has been suggested that the varying measures used in Pilates research to date may be the reason for the inconclusive results (Donahoe-Fillmore et al., 2015). As such, more technologically advanced tools such as dynamic force platforms, which can detect small and subtle changes are said to be the most promising balance measures (Browne & O'Hare, 2001; Słupik et al., 2015) and should thus be used on these populations. The cost and availability of these however remains a challenge.

Finally, the long term effects of Pilates on neuromuscular adaptations are not known and should be investigated to determine if any long lasting improvements persist (Bird et al., 2012). Future studies could also investigate its effects on activities of daily living as more meaningful measures (Kinzey & Armstrong, 1998; Tolnai et al., 2016) - it is thought that even if changes are observed in healthy adults, they could be too small to positively affect these activities (Johnson et al., 2007).

5.4 Flexibility

The mean sit and reach results suggest that Pilates did not improve flexibility. While a significant interaction effect was observed, no specific time points were identified as being significantly different (between or within groups). Only medium effect sizes were observed for the Con group at baseline (between groups, *d*=0.77) and from baseline to week 4 (within group, *d*=0.66) following a decrease in their flexibility. The results of the current study therefore appear to challenge previous findings for this population (Kibar et al., 2015; Sinzato et al., 2013; Tolnai et al., 2016). One study showed significant improvement in as little as 10 sessions (Tolnai et al., 2016), however this intervention included focused stretching as part of each Pilates class. This may have confounded the effects of the intervention alone, as Pilates exercises do not typically involve end range stretches, but rather dynamic range of motion exercises (Campos et al., 2016). This is noteworthy as it has been suggested that static stretches (30s duration) will yield improved flexibility over dynamic stretch exercises (Bandy, Irion, & Briggler, 1998; Johnson et al., 2007). Another study reported a 19% improvement (+4 cm) in flexibility for their intervention group after 20 Pilates sessions (Sinzato et al., 2013), thus employing a longer intervention period. This suggests that had the current study progressed to 12 weeks duration, differences may have been identified between groups. Other investigations using the bi-weekly session model also showed improved flexibility in older cohorts after 12 weeks (Kao et al., 2014; Kloubec, 2010). Session frequency may also be important. Interventions lasting 8 weeks in duration appeared to elicit improved results when an increased frequency of 3 sessions per week was implemented (Arslanoğlu & Şenel, 2013; Rogers & Gibson, 2009).

While the Pilates literature to date appears to support the improvement of flexibility in healthy adults, these studies were of a lower methodological quality (Cancela et al., 2014; Cruz-Ferreira, Fernandes, Laranjo, et al., 2011). A systematic review with meta-analyses intimated that there is no evidence for any effect on flexibility between groups of healthy subjects, and that timed static stretches, as found in yoga (Lau, Yu, & Woo, 2015; Tracy & Hart, 2013) for example, would yield enhanced results over the dynamic movements found in Pilates (Campos et al., 2016). More evidence, particularly in young populations, is thus required in order to claim any effects that Pilates may have on flexibility.

5.5 Muscular Endurance

Within-group measures suggested that Pilates has positive effects on muscular endurance.

Leg endurance

Lower limb endurance associated with participation in Pilates is not well studied. This may be due to the majority of exercises being performed in supine, prone or seated positions. That said, many Pilates exercises incorporate leg musculature activity so, while not typically weight bearing, lower limb muscular endurance should improve. The PEx group significantly increased (p=0.02, *d*=-1.1) their wall sit test time by approximately 18 seconds in 8 weeks, while the Con group showed no improvement. In addition, the large within-group effect size (*d*=-1.08) suggests that the increase in PEx lower limb endurance between weeks 4-8 also had clinical relevance. In comparison, another investigation used the number of heel raises to fatigue as a measure of lower-limb endurance in healthy adults. They found that while their exercise group improved after 12 Pilates sessions this increase was not significant (Pumpa et al., 2015). Given the different tests used between this and the current study, as well as the general paucity on Pilates effects for this measure, it is difficult to compare and contrast the research.

Arm endurance

The significant improvement (p=0.00) and corresponding large Cohen's *d* result (*d*=-0.9) over time for the PEx group, suggests the increase (+7.5 push up reps) from baseline to week 8 was clinically relevant. Further, a significant increase was similarly found at week 4 for this group (within-group Cohen's *d*=-0.59) suggesting significant improvement after just 8 sessions. An anecdotal note was that all PEx participants could complete multiple full body push ups ("men's push-up" position) by the end of the intervention period, whereas most could not complete one repetition at the commencement of the intervention. Since no other Pilates investigations have considered upper limb endurance in young females, there are no comparative studies. It was noted that the 60s push up test was completed comfortably by most participants at all measurement intervals. As such, future research in young, healthy adults could potentially perform push ups to fatigue/failure in unlimited time, rather than restricting the test to a specific time interval.

Abdominal endurance

As with the push-up test, most participants managed to use the full allotted time when performing the timed curl-up test. As such, recommendations as per arm endurance tests apply, with a focus on 'continuation to fatigue' for future trials. While no statistically differences were found, moderate within-group effect sizes was observed for both groups between baseline and week 4 (*d*=-0.7) suggesting meaningful improvements in this time frame. In line with other endurance tests, the PEx cohort showed a significant increase with large effect size (p=0.037, *d*=-1.1) in abdominal endurance between weeks 0-8. This increase of approximately 8 additional curl ups suggests that Pilates positively affected abdominal endurance. These results concur with other findings in healthy adults (of various age ranges) (Kibar et al., 2015; Rogers & Gibson, 2009; Sekendiz et al., 2007; Tolnai et al., 2016), where abdominal muscular endurance improved significantly after 10-24 Pilates sessions. Interestingly, the investigation employing the lowest frequency of sessions (one per week) found a significant improvement (p=0.001), yet the absolute difference was a mean increase of just two additional curl ups (Tolnai et al., 2016). Further, the researchers referred to this test as a measure of abdominal *strength* rather than endurance (Tolnai et al., 2016). Kloubec (2011) suggests that a variety of abdominal exercises are required in a given workout to promote abdominal strength and endurance in healthy individuals (with less needed in clinical populations) (Kloubec, 2011). The assortment of abdominal exercises in the Pilates repertoire should thus be suitable for this sort of improvement (Kloubec, 2011) and the current study supports this theory.

In addition to the already suggested measurement modifications, a test which could receive attention in future studies is the 60° trunk flexor endurance test, as described in Evans et al., (2007), and used in research by Campos et al., (2016). This posture shares similarities with the half roll back position used in Pilates and may therefore prove better at highlighting Pilates specific endurance improvements (Campos et al., 2016; Evans, Refshauge, & Adams, 2007). However, since the focus on muscular endurance changes through Pilates practice has been predominantly on the abdominal region (Cruz-Ferreira, Fernandes, Laranjo, et al., 2011), more research is needed on other regions of the body. Push up tests could possibly be performed at a more advanced level, such as full-body push ups (with knees lifted from the floor), which might positively identify any differences between groups over time. A measure which may give a more accurate reflection of overall body stamina is a plank-hold endurance test. This would similarly be more accurate in highlighting core musculature endurance, than simply focusing on the global muscles of the trunk, as shown in the curl up test. Lateral planks could be used for lateral trunk musculature endurance, however, these tests only provide evidence for unilateral endurance (Evans et al., 2007). Similarly, multidirectional testing is needed to show any form of training effect on the trunk in all directions, as is a focus of the Pilates method, rather than focusing predominantly on forward flexion (Evans et al., 2007). Future research should thus focus on multidirectional testing rather than purely flexor or isometric endurance (Evans et al., 2007).

5.6 Strength

Pilates did not impact on strength measures. However, a significant time effect ($p=0.013$, $d=2.0$) was observed for the Con group leg strength, which increased by approximately 25 kg between weeks 4 and 8. While this increase could be due to a learning effect (Christopher et al., 2006), this was not seen in the exercise group. As such, this increase is possibly due to additional exercise participation that was not stipulated in the self-reports (similar to the balance results). Alternatively there may have been some internal motivation to perform maximally during the final testing session, which had been lacking at previous sessions (Dishman & Ickes, 1981). The significant increase in Con group leg strength, with lack of change within the intervention group, is in contrast to results found in middle aged women (±40 years) (Kao et al., 2014). Electric dynamometry results identified significant improvements in lower limb strength of their intervention cohort, with no changes occurring in their control group after 24 sessions (Kao et al., 2014). While this was a longer intervention period than the current study, the exercise repertoire also included standing work, which is not typical in the Pilates method, particularly matwork (Kao et al., 2014). In addition, the employment of measures that were less biased towards traditional strength training regimes may have aided in highlighting responses (Critchley et al., 2011). Back strength results concur with researchers who found no significant differences in young women (aged 20.8 ± 1.4 years) after 30 sessions (Christopher et al., 2006). While the use of an isokinetic dynamometer shows a fundamental difference in methodologies, the findings are in agreement with those of the current study and suggests that Pilates does not positively affect back strength. In contrast, sedentary females (aged ±30 years) showed a significant increase in trunk flexion strength ($p<0.05$) after just 15 sessions, also measured through isokinetic dynamometry (Sekendiz et al., 2007). Given the similar methodologies, but older age of this latter cohort it suggests that age may be a factor in these different responses.

Pilates workouts incorporate various facets of physical fitness, and focus on multiple muscle groups simultaneously in one session (Petrofsky et al., 2005; Posadzki et al., 2011). As such, measuring strength gains may be more complex, requiring a different approach to those used in traditional strength-targeted exercise regimes (LeMura et al., 2000). More responsive testing procedures, such as a Biodex (Sekendiz et al., 2007), may therefore be necessary. In addition the examination of musculature hypertrophy or thickness could be investigated using magnetic resonance imaging (MRI) and ultrasound, particularly in the case of abdominal muscles (Dorado et al., 2012; Endleman & Critchley, 2008). Of course these measures are more costly and as such are not always available.

A limitation of the strength measures was the weight increments used for measuring the 1 RM, particularly the back strength measures. The 5 kg increase in the back strength (lat pull down) measures appeared to be too great for highlighting any changes and as such, a 2.5 kg weight increase may have been more suitable. Similar amendments could have been made for the chest press exercise, where 2.5 kg increments appeared to be too great, and 1 kg increases may have been more appropriate for sedentary individuals. Alternatively, measures with varying free weights, such as arm curls with a dumbbell (Fourie et al., 2012), could be considered for future studies. However, these tests may not offer the same compound muscle recruitment as the tests employed in the current study, and might be too specified to an individual muscle group (e.g. Biceps brachii).

5.7 Lumbo-pelvic Stability

The significant improvement in the PEx cohort provides evidence to support the claim that Pilates improves lumbo-pelvic stability and that improvements may be seen in as little as 4 weeks. These findings are in agreement with previous research (Herrington & Davies, 2005; Phrompaet et al., 2011; Pumpa et al., 2015). The repeated focus on core control and stabilisation during Pilates manoeuvres is said to enhance local muscular control, particularly of the Transversus abdominis and internal obliques (Herrington & Davies, 2005; Phrompaet et al., 2011). While it has been shown that sixteen Pilates sessions over 8 weeks significantly improves lumbo-pelvic stability in women (Phrompaet et al., 2011), a study using once-weekly sessions (12 weeks) found improvements in their intervention cohort, but no statistical differences between groups (Pumpa et al., 2015). This suggests that an increased frequency of Pilates sessions is more beneficial.

While this improved lumbo-pelvic stability may be a benefit of Pilates participation it is noted that the crossover of this effect into activities of daily living is not well documented and thus warrants further investigation (Critchley et al., 2011; Herrington & Davies, 2005; Lamoth et al., 2006; Liebenson, 2012; McGalliard et al., 2010). It may be that improved stability has direct implications for the prevention of musculoskeletal injury and prevention of lower back pain, which could be clinically relevant.

5.8 Transversus abdominis Activation

The ability to activate the Transversus abdominis and maintain this contraction over ten seconds was not significantly different between groups at any stage, which is in contrast to previous studies (Herrington & Davies, 2005; Kibar et al., 2015). Earlier research has found significant improvements after 8 weeks, however, rather than conducting a pass-fail test, the researchers used a difference in pressure readings to identify changes (Kibar et al., 2015). Further, the details as to the exercises used in the intervention by Kibar et al. (2015) were not clear.

Evaluation of Transversus abdominis activity is difficult (Critchley & Coutts, 2002) and, as such, a limitation of this measure may have been the equipment used. While the pressure biofeedback unit has been shown to be a suitable tool for identifying abdominal function differences in symptomatic individuals (Cairns et al., 2000; Hodges & Richardson, 1996), this may not be the case in healthy adults due to lack of sensitivity (Herrington & Davies, 2005). Similarly, there appears to be discrepancies as to what a normal pressure reduction should be in asymptomatic adults (Herrington & Davies, 2005). This was highlighted in work conducted by Von Garnier et al., (2009), where a 1 mm Hg decrease over 4 seconds was considered a positive result (von Garnier et al., 2009). Therefore, while this method is both basic and cost effective, it may be more accurate to use alternatives, such as electromyography or ultrasound techniques (Segal et al., 2004). These can provide valid real-time thickness measures of the deeper abdominals (Endleman & Critchley, 2008; Hodges & Richardson, 1997). Unfortunately, these methods can be costly and in some cases, invasive (Mallin & Murphy, 2013). Further, it is known that individuals can find this kind of abdominal activation difficult to perform (Endleman & Critchley, 2008; Herrington & Davies, 2005), and a prone test might not be ideal given the added resistance from gravity. Some researchers have suggested that a supine position will yield more accurate results (Urquhart, Hodges, Allen, & Story, 2005), while others propose that standing tests produce increased abdominal activity (Jung, Kim, & Lee, 2014). They go on to recommend that stabilisation exercises for healthy adults should thus be done standing (Jung et al., 2014). This is in contrast to the Pilates method where exercises are generally done in the supine or prone position. As with lumbo-pelvic stability, research needs to determine if improved Transversus abdominis activity, as a result of a Pilates exercise regime, is transferred into functional tasks and activities of daily living (Critchley et al., 2011; McGalliard et al., 2010).

5.9 Health measures

5.9a Blood pressure

The Pilates intervention did not result in significant changes in blood pressure. However, it was noted that the PEx group experienced a mean increase of 9 mm Hg in systolic blood pressure from baseline to week 8, and the accompanying large effect size (*d*=-

0.84) suggests that this was clinically relevant. Still, PEx systolic blood pressure remained within a healthy range. While every effort was made to prevent this, it is possible that measurement errors may have occurred due to participants not being fully at rest during their readings. A 5 mm Hg increase in systolic blood pressure was also observed in the Con group, however the effect size was small (*d*=-0.3). Medium effect sizes (*d*=±0.5) were also observed in the Con diastolic blood pressure with an increase between baseline and week 4, followed by a decrease from weeks 4-8 with a mean different of just 3 mm Hg in each case. This lack of significant differences, concurs with results of other investigations on young populations, which have similarly shown no differences in blood pressure, even with an increased frequency of sessions (3-5 times per week) (Ali et al., 2010; Jago et al., 2006). These studies thus suggest that blood pressure in *younger* populations may not be affected by Pilates exercises. Conversely, where improvements in blood pressure have been observed, the populations appeared to be either middle-aged or elderly (±65 years of age) females (Arslanoğlu & Şenel, 2013; Fourie et al., 2013). Both studies used a 3-session per week protocol and the results showed decreases in systolic blood pressure only (Arslanoğlu & Şenel, 2013; Fourie et al., 2013).

It is evident that the already healthy blood pressure levels in the current sample may have buffered any exercise effects. In addition, the frequency and duration of the intervention may have not been long enough to elicit any significant or clinically relevant changes. Alternatively, given the inherent health of the population investigated, it may be that aerobic activities, rather than strength or core conditioning such as Pilates, would induce further benefits in these normotensive individuals (Whelton, Chin, Xin, & He, 2002). It has been suggested that more than 150 minutes of physical activity per week is needed to bring about a significant reduction in resting blood pressure (Whelton et al., 2002). This would not have been met by the 120 minutes per week included during the current intervention. Therefore, it could be suggested that at least three sessions per week, over a period greater than 8 weeks, may be required to induce a decrease in blood pressure in already healthy groups, and this warrants further investigation.

5.9b Lung function

A significant decrease in the PEx Minute Ventilation was observed between weeks 4 to 8 however this is largely unexplained. It may have been due to a decreased breathing frequency along with the accompanying decreased V_T (the moderate effect size for V_T between weeks 4-8 suggests clinical relevance). Similarly the seated posture may have influenced volumes as mentioned in Phase 1 (McArdle et al., 2001). It is interesting that the Minute Ventilation results at all three time intervals were larger than the suggested norms (6 $L.min^{-1}$) for healthy adults (Tortora & Derrickson, 2013) as was seen in Phase 1. This may have been due to participants not being fully at rest when the tests were performed. The remaining spirometry results suggested that 16 Pilates sessions were not sufficient to elicit any noteworthy changes in lung function or capacity. These findings correspond with the results of Giacomini et al., 2016. Their sample consisted of sedentary, but healthy middle aged women (aged 32.4 ± 10.4 years, n=16). Although an uncontrolled trial, they too, found no significant changes in FVC (p=0.8) or FEV_1 (p=0.5) results after an intervention of the same frequency and duration as the current study (Giacomini et al., 2016).

Since the current study is the only intervention to examine the effects of Pilates and its unique breathing pattern on various spirometry measures in young women, it cannot be compared. Research comparing normal breath patterns to diaphragmatic breathing technique and the Pilates breath pattern advocated that the latter may increase respiratory volumes in healthy individuals, however this research was conducted in elderly patients. (Cancelliero-Gaiad et al., 2013). As such, the effects of this breath pattern on younger individuals have not been adequately investigated. Furthermore, there is the opportunity for respiratory muscle strength to be examined, rather than lung function. As with other measures, a longer intervention period and an increased frequency (3 sessions/week) should be considered for future investigations.

5.10 Additional Limitations and Considerations

The Pilates program and its progression (Appendix 12), was designed as per the STOTT Pilates® recommendations and programming guidelines – and included flexion, extension, lateral flexion and rotation in each workout. Similarly, all sessions targeted various regions of the body and included facets of strength, endurance, flexibility and core control. Further, safety was of utmost importance and, given the short intervention period, the primary researcher could not safely progress the participants considerably in the limited time. The researcher had to adapt to the abilities of individual participants, and progression was thus implemented once the basics had been successfully achieved. Given the ‘whole-body’ focus in each session, it might be that a single class (60 minutes duration) does not offer adequate time to focus on musculature in a way that would elicit favourable responses for all the measures considered in this study (Posadzki et al., 2011), particularly in healthy groups. As a limitation of the current protocol, this ultimately advocates for an increased frequency of sessions as being more likely to yield improved results.

In addition to the above, the Pilates taught in a research program is not always taught as such in real-world applications, such as private studios or gyms. Classes may be altered each week so as to accommodate different apparatus or props and, as such, practitioners are unlikely to go through the matwork sequence for much longer than 8 weeks anyway. Individuals with poor body-awareness and co-ordination can often struggle with alignment or translation of the instructor’s cues into manoeuvres within their own body. This results in different abilities between volunteers and makes research challenging. Individual modifications are difficult to accommodate within research groups as it may result in certain individuals receiving easier or more challenging versions of an exercise, thus altering their exposure to the intervention. Private or individualised classes would be recommended for these participants in real-world scenarios, however, the cost of private classes must be acknowledged and is thus not always an option. Further, private sessions are not always a time-effective option in research settings.

Finally, education is a key factor, particularly when dealing with novice clients who are new to Pilates, or even to structured exercise in general. Given the fact that Pilates is based on key principles, a fundamental understanding of these is essential to ensure correct form during execution of the exercises. Similarly, ensuring correct activation and recruitment of core musculature is required, however activation can be more challenging for some individuals than others (Endleman & Critchley, 2008). Given the core-centric nature of Pilates, not being able to successfully recruit core musculature may decrease the effect of the exercises for that individual. The resulting abdominal bracing or poor lumbo-pelvic stability might lead to additional compression in the lumbar spine or increased risk of injury (McNeill, 2014). While the primary researcher used an introductory session to discuss and demonstrate core musculature activation to the participants, this may not have been sufficient.

5.11 Anecdotal Findings and Other Points of Interest

All participants in the intervention cohort mentioned feeling stronger and 'fitter' during the course of the 8-week program. Even though this was not evident from their strength results, they believed that a training effect had occurred. It may be that they mistook their improved endurance for strength gains in some instances. They mentioned upper and lower body strength, as well as abdominal endurance and lung function as particular areas they believed had improved. Their endurance remarks are clearly supported by the study, however their other suggestions were not. Further, all of them said they 'felt' better in general and most mentioned improved sleep patterns and reduced stress within a couple of weeks after commencement. This was noteworthy as many of the participants were entering a typically stressful examination period. These facets could inform future studies, with particular focus on stress management and mental health. Participants also expressed enjoyment during their sessions. This is important as a potential motivator for increased participation and long-term adherence (Ferrand, Perrin, & Nasarre, 2008; Huberty et al., 2013; Pescatello et al., 2004; Salmon et al., 2003; White et al., 2005). The primary investigator subsequently learnt that four participants from the exercise group and one from the control group continued with private Pilates classes (and even additional exercise regimes) post-intervention. What was interesting was that the four individuals from the intervention group were full-time employed individuals, thus having the financial means to support continued sessions at a private studio. This is noteworthy as it may explain why the remaining participants (mostly students) did not continue. This finding is however, merely anecdotal, but future studies could investigate the impact of financial status on exercise habits, particularly participation in instructor-led methods such as Pilates.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY OF PROCEDURES

The current study was divided into two phases. The first phase aimed to assess and compare selected physical fitness and health parameters of young adult females in the Makana area of the Eastern Cape to those of national surveys or norms (where possible). This population is poorly studied and this research thus contributes to our understanding of the health of this young cohort. Once-off measures were conducted on healthy females between the ages of 18-26 years, who met with specific inclusion criteria (section 3.4.1). Evaluations included anthropometric measures (stature, body mass, BMI and waist circumference) as well as health measures (spirometry measures as well as systolic and diastolic blood pressure). Physical fitness measures included static and dynamic balance, muscular strength and endurance, flexibility, and lastly lumbo-pelvic stability.

The second phase of the study comprised of randomised controlled trial. A subsample of inactive females from the Phase 1 cohort participated in an 8-week progressive Pilates (matwork) intervention, comprising of twice-weekly sessions (60 minutes duration each). The Pilates classes were conducted by the primary researcher and included progression from essential level exercises to an intermediate-advanced level by the final week (Appendix 12). Measurements were taken at baseline and repeated at weeks 4 and 8. Tests included those conducted in Phase 1 along with the additional evaluation of Transversus abdominis activation. Participants were asked to maintain their habitual diet and physical activity levels throughout the intervention period.

6.2 KEY FINDINGS AND RELATED LIMITATIONS

Phase 1

The population sample observed in the first phase was relatively healthy in all areas, although there was large variance in the measures obtained. This population was also healthier than those reported on in national surveys, which is promising. However, these findings must been seen in the context of certain limitations, including the small sample size and the predominance of Caucasian students within the sample. These factors were likely influenced by the recruitment procedures employed and may therefore warrant a different approach in future investigations. Similarly, the stringent inclusion criteria resulted in a unique cohort which was not easily matched to previous population data. This made comparisons to normative results challenging and limiting.

Phase 2

The intervention findings suggest that eight weeks of Pilates offers significant improvements in lumbo-pelvic stability and muscular endurance. The lumbo-pelvic stability changes indicate beneficial effects of the core-focused workout, resulting in improved core muscular control and resistance to perturbations. This could potentially translate into further gains – such as improved movement patterns or the prevention of lower back pain development (Herrington & Davies, 2005). This however, requires further investigation. In addition, the focus on various musculature during each Pilates session targeted musculature sufficiently enough to induce significant endurance improvements. The corresponding moderate and large within-group effect sizes support these muscular endurance findings. These benefits might similarly carry over into activities of daily living, reducing injury risk and increasing stamina during tasks. Spirometry measures showed significant decreases in PEx Minute Ventilation, with a moderate effect size for PEx tidal volume, between weeks 4-8. While not statistically significant to the Con group, moderate to large between-group effect sizes suggested that the increases in PEx fat, carbohydrate and protein consumption, energy expenditure, BMI and waist circumference may be clinically relevant. Despite this, the PEx group mean body mass did not change during the intervention, which suggests that Pilates may be useful as a weight management tool. Further, the large within-group effect size for PEx systolic blood pressure, and moderate effect size for static and dynamic balance, suggests that meaningful differences may have occurred in these measures, but were skewed by the small sample sizes. No difference in PEx flexibility and strength measures were observed. Noteworthy too, are the increases in body mass and improvements in leg strength and dynamic balance seen in the Control cohort. The increased body mass may have been as a result of increased caloric intake, which was not accurately documented in food diaries. Similarly, the improvements in fitness measures may have been as a result of additional exercise participation, or a learning effect. Within-group effect sizes for the Con cohort suggested a meaningful decrease in flexibility, and increases in blood pressure and dynamic balance. The small sample size, low session frequency and restricted intervention period were undoubtedly limitations of this study. Further, it is plausible that the population in question might require an extended intervention period along with highly sensitive tests to detect changes over and above those already observed. Ultimately, Pilates may prove to be a suitable option for the improvement of certain fitness measures in young, previously sedentary women over the short term. Longer term participation may offer additional benefits, however this remains unclear (Bird et al., 2012; Cristóbal et al., 2014; Segal et al., 2004). That said, it is clear that the paucity of information regarding Pilates – both in this population and others – still remains, and more investigations are required (Shedden & Kravitz, 2006). Given the popularity of Pilates with females both young and old (Aladro-Gonzalvo et al., 2012), these investigations are necessary.

6.3 RESPONSES TO STATISTICAL HYPOTHESES

Phase 1

The null hypothesis for the local sample comparisons is rejected for stature, waist circumference, systolic and diastolic blood pressure as differences were observed in all comparisons for these measures. It is similarly rejected for body mass with respect to the two SADHS (1998 & 2003) results, but accepted with respect to the SANHANES-1 study. Further, it is rejected for BMI with respect to SANHANES-1, but accepted with regards to the two SADHS comparisons. Lastly, the null hypothesis is rejected for all spirometry measures, except Forced Expiratory Volume (FEV_1). FEV_1 was the only measure which was statistically similar to related normative data.

Phase 2

i. The null hypothesis (anthropometric measures) is accepted for stature as no differences were observed. It is also accepted for group and interaction effects with respects to body mass, BMI and waist circumference. In contrast, the null hypothesis is rejected regarding time effects for body mass, due to the significant increase in the Con cohort over time. It is also rejected for BMI and waist circumference time effects, although no specific group was identified.

ii. The null hypothesis is accepted regarding group, time and interaction effects for static balance measures as no significant differences were observed.

iii. With regards to dynamic balance, the null hypothesis is accepted for all group and interaction effects. Conversely, time effects were identified for unilateral dynamic balance, specifically left and right posteromedial and right posterolateral measures. Further, the Con group's increase in left posterolateral reach distance resulted in a significant time effect, and the null hypothesis is thus rejected regarding time effects for dynamic balance.

iv. A significant interaction effect was observed for flexibility and as such this null hypothesis is rejected. The null hypotheses for group and time effects are conversely, accepted for flexibility.

v. The null hypothesis is accepted for all strength measures regarding group and interaction effects. However, a significant time effect was observed for the Con group leg strength results and as such the null hypothesis is rejected for this measure.

vi. The null hypothesis regarding group effects is accepted for all muscular endurance results. In contrast, it is rejected for both time (upper body and abdominal endurance only) and interaction effects (lower limb endurance only) due to significant increases observed in the PEx group in each instance.

vii. A significant group effect was observed for lumbo-pelvic stability which improved significantly in the PEx cohort, and as such the null hypothesis is rejected.

viii. The null hypothesis is accepted regarding Transversus abdominis recruitment as no differences between groups were observed.

ix. The null hypothesis is accepted for systolic blood pressure as no differences were observed over time or between groups.

x. Similarly, the null hypothesis is accepted for diastolic blood pressure.

xi. Finally, the null hypothesis is accepted for all spirometry measures regarding group or interaction effects. It is however rejected for time effects due to a significant time effect observed in the PEx cohort's Minute Ventilation measure only.

6.4 RECOMMENDATIONS FOR FUTURE STUDIES

Phase 1

Given the limited data available on population-health in the Eastern Cape, province-specific data is required in order to identify trends which could inform the development of health plans and policies. Focusing on young adult health may serve as a means of identifying long term trends over time, or by comparing their results to those of older cohorts. This could ideally assist in implementing prevention plans rather than treatment-based programs. Similarly, the dissemination of health knowledge is also key in improving individuals' responses to health status and their active uptake of tools/methods to improve this. While the population examined in Phase 1 was relatively healthy, this could be due to the voluntary nature of the recruitment process and the predominance of active students being assessed. The prevalence of Caucasian participants is also noteworthy and the research on young women in the Makana area is thus incomplete. Future studies could employ a more active recruitment protocol in order to include individuals from different regions of the town and surrounds, thus reducing the predominance of transitory students as found in the current sample. Sampling could be performed at local community centres in order to make it more accessible by decreasing logistical barriers. This would yield increasingly reliable results from a more permanent population, particularly for comparative or longitudinal studies. More sensitive tools could also be employed for more accurate assessments, particularly in healthy adults. Finally, future investigations could assess extrinsic and intrinsic motivating factors related to physical activity, and their influence on participation and adherence (Nazaruk, 2014). This will facilitate the understanding of factors promoting the uptake and maintenance of physical activity regimes in young women in the region.

Phase 2

While sample size was indeed a limitation of the current investigation, it is possible that the results were similarly affected by the low frequency of sessions and short duration of the intervention. Given the age range and overall good health of the cohort, it is possible that a longer Pilates intervention may have resulted in different findings. Future studies could thus focus on extended intervention periods, such as 3-6 months (Kibar et al., 2015; Sinzato et al., 2013; Tsai et al., 2013), providing insight into the time-progression of effects in a population that remains understudied.

Furthermore, the follow up after cessation of an intervention is also lacking and there is thus little evidence as to any enduring effects. To date the focus of research has been on predominantly novice practitioners over a short time period (Cristóbal et al., 2014). As a result, the effects of on-gong Pilates participation are not well known and similarly require investigation. Prolonged adherence may offer further benefits such as long-term weight maintenance or blood pressure management. Longitudinal studies on Pilates and indeed exercise in general are limited (Arikawa et al., 2011; Tsai et al., 2013) and few studies on healthy groups investigate maintenance and adherence six months post commencement (Marcus et al., 2000; Tsai et al., 2013). Further, studies tracking younger individuals may reveal whether the maintenance of core strength and stability is observed into later life, potentially serving as a preventative measure. This would be in contrast to interventions introduced at a later date in an attempt to recover lost functionality in older persons (Ott, 2015).

Given the Pilates approach to global movement and exercise with focus on the whole body, comparing this method to other forms of training, such as purely strength or endurance training, is challenging (Posadzki et al., 2011). Alternative measures geared to Pilates specific training may be recommended, rather than standard measures biased to other training regimes. In addition to alternative fitness measures, future Pilates investigations could also focus on changes in psychological aspects and functioning (Cruz-Ferreira, Fernandes, Gomes, et al., 2011). Elements such as “mindfulness”, personal autonomy, life satisfaction or perception of health status could be evaluated. The effect of Pilates on sleep and stress management is also an area that needs more attention (Caldwell, Harrison, Adams, Quin, & Greeson, 2010; Leopoldino et al., 2013).

With the promotion of Pilates as enhancing multiple facets of physical functioning, the transfer of these benefits into activities of daily living is not well documented. It has been suggested that the emphasis on improved movement patterns, coordination and balance should be easily transferred into functional tasks (Słupik et al., 2015), however other researchers have suggested that most Pilates exercises could be considered as non-functional (Akuthota & Nadler, 2004). Therefore the transfer of these benefits into activities of daily living deserves evaluation (Bernardo, 2007).

The total energy cost of Pilates is poorly understood (Olson et al., 2004). Given the lack of evidence to support claims that Pilates aids in weight loss, it is plausible that total energy expenditure is low, particularly at the beginner and intermediate levels. Advanced level practitioners may show increased energy expenditure as a result of a more demanding program (Olson et al., 2004), but this requires further investigation. In addition, the lack of a cardiovascular or aerobic component in Pilates training (Segal et al., 2004) may be the reason for this paucity in evidence pertaining to weight loss. This may also support the need for longer exposure time in younger, healthy individuals before changes in health or fitness present (Sinzato et al., 2013).

Lastly, the difference between benefits comparing matwork versus apparatus based Pilates is not clear and should be investigated. Unfortunately the apparatus is costly and thus not always accessible, hence the majority of investigations comprise of matwork only. However, given the differences in exercises and challenges presented by the two forms, this comparison warrants further attention particularly as both fall under the umbrella term of "Pilates".

6.5 CONCLUSIONS

According to this study, young women in the Makana area were shown to be in good health and exceeding recommended targets for weekly physical activity participation. This suggests decreased health risks and enhanced overall functioning, particularly into later life, provided these levels are maintained (Stenholm et al., 2015). In addition, it is hoped that this research project may have promoted interest in personal health for these volunteers, thus advocating for improved health and wellness in these young women (World Health Organisation, 2011). This research further showed that lumbo-pelvic stability as well as muscular endurance were significantly improved in a group of previously sedentary young women after participation in Pilates, indicating improvement in motor control and muscle fitness (Garber et al., 2011; Hodges & Moseley, 2003). Further, effect sizes suggested that Pilates may improve static and dynamic balance, but does not increase flexibility or muscular strength. Lastly, this exercise method may also assist in weight maintenance. Increases were observed in Con blood pressure, abdominal and leg endurance, with clinically relevant decreases in Con protein and total calorie intake, and flexibility. The two phases of this research are linked by the need to address physical inactivity levels in young women in South Africa. Activities that promote continued participation through perceived benefits, increased access and enjoyment are key (Kloubec, 2010). It is hoped that Pilates could perform this role given its lower intensity level, high enjoyment factor and popularity (Bernardo, 2007; Jago et al., 2006; White et al., 2005), however, it is clear that further quality investigations are required before accurate conclusions can be drawn.

Practical relevance:

In short, the practical significances of findings from the Pilates intervention are as follows:

- The significant improvement in lumbo-pelvic stability suggests that Pilates improves core muscular control and could thus serve as a measure of prevention against lower back injury or related conditions (Gladwell et al., 2006; Herrington & Davies, 2005; Izzo et al., 2013; Sherry et al., 2005).
- The significant improvements in all endurance measures (upper and lower limb as well as abdominal) supports suggestions that Pilates offers a ‘whole-body’ workout targeting all areas of the body.
- The combination of improved muscular endurance and lumbo-pelvic stability may translate into other facets of fitness and activities of daily living, such as improved balance in functional tasks or improved motor control, however this needs further investigation.
- Noteworthy effect sizes suggested meaningful increases in PEx waist circumference, BMI, energy expenditure, systolic blood pressure and balance.
- Body mass, BMI and waist circumference were not positively influenced and as such, Pilates should not be used as a weight-loss tool, however it could be used for weight maintenance.

- Pilates does not improve flexibility or strength parameters in younger cohorts as has been shown in elderly populations, and is thus potentially not as beneficial for improving these parameters in younger adults.
- Anecdotal evidence and good attendance rates (>85%) suggest that the participants responded well to a group setting and enjoyed the supervised classes.

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APPENDICES

APPENDIX 1: ETHICAL APPROVAL

Human Kinetics and Ergonomics

Application for Ethical Approval

RHODES UNIVERSITY
Where leaders learn

Student Name: Lara Proud

Type of Research: MSc

Project Title: **Effects of a 12-week progressive Pilates intervention on selected components of 'fitness' and health related parameters in inactive, young adult females.**

Supervisor: Dr Candice Christie, Dr Janet Viljoen

Application received: 16 March 2015

HKE Ethics Committee Comments

Reviewer	Date Received	Date processed	Comments
A	16-03-2015	21-03-2015	First I would like to comment the applicant on a very thorough ethics application – it made reading such an extensive document easy to read and I considered it very informative. I consider this study one of a low risk and the applicant has explained all ethical concerns that may arise from this intervention project to my satisfaction. In addition to some very minor spelling and formatting error, which I have corrected via track changes in the document, one aspect that considers probably just some rewording is the waivering of all responsibility on all three consent forms (pages 73, 75 and 77), rather than accepting joint responsibility. The research exposes individuals to an unfamiliar exercise, and although the risk are low and precautions have been taken, the Dept cannot ethically remove itself from all responsibility should injuries arise as a result of this intervention (but obviously not if the participants don't comply or injury is self-inflicted). Since reading the Natural Affinity agreement, there should probably also be a sentence in the consent relating to any injuries that may occur at the Natural Affinity Studio, indemnifying the owners. Under Privacy, Anonymity and Confidentiality section I recommend that you mention destruction of the master list (linking participant codes with personal identities) upon completion of your study. This is particularly important since you mentioned that your data will be made available for reuse. On that note, you would also need to inform the participants and get them to consent to reusing their data for projects other than your specific one (i.e. I'm referring to a future researcher using your raw data to answer a new research question, rather than making use of your overall results). As the two points raised above are merely formalities that need to be reflected in the final documentation, I am happy for the applicant to proceed in her experimentation.
B	16/03/2015	23/03/2015	A very well constructed application, covering a significantly detailed description of the study design. One or two issues may need to be cleared up. Please see the attached comments. The reviewer is happy to confirm that the review process has been a success and that ethical consent should be obtained.

Returned to HKE Ethics Committee Chairperson on: ___23/03/2015______________________

APPENDIX 2: ADVERTISEMENT

Women's health and wellness research at the Department of Human Kinetics & Ergonomics, Rhodes University:

[This research has received ethical approval from the Human Kinetics & Ergonomics University Ethical Standards Committee for research involving human participants]

Calling all **young ladies** between the ages of 18 and 26 years of age:

- Are you interested in obtaining an overall picture of your current health status?
- Would you be keen for once off, quick tests of your strength and endurance?
- How good is your balance, really?
- How flexible are you?
- Want to test your overall fitness?

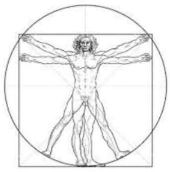
The Rhodes University Human Kinetics and Ergonomics Department is looking for young women to participate in a Masters research project investigating overall health and fitness in young females in Grahamstown and the Makana region. This research offers you the opportunity to learn more about your own health and wellness through **FREE ONCE OFF TESTS**. These tests are non-invasive and will require approximately 1 hour of you time.

We are therefore inviting all ladies who fit the following criteria to participate:

- ✓ 18-26 years of age
- ✓ Generally in good health (do you, or are you able to, participate in physical activity? No coughs, colds, chest infections?)
- ✓ No severe injuries in the last year (from a car accident etc, or injuries where surgery was required or where rehabilitation over more than a 2 month period was necessary)
- ✓ Not pregnant/breastfeeding
- ✓ Not using drugs or other agents (chronic medication such as blood pressure tablets, no illegal drugs such as marijuana or other prohibited chemical agents)
- ✓ Able to read and write in English (for information purposes and completion of forms)

If you are interested and are willing to participate in this research please contact Lara on
072 569 4490 (text/phone/whatsapp) or lara.proud@gmail.com
Please feel free to share this with anyone else you think might be willing to participate!

APPENDIX 3: INFORMATION FOR PARTICIPANTS



Human Kinetics & Ergonomics Department, Rhodes University
Pilates Research Information Session:
Population Baseline Measures Group

Welcome:

Thank you for expressing interest in the research being conducted by Ms Lara Proud, an MSc scholar in the Human Kinetics and Ergonomics Department (Rhodes University). The purpose of this letter is to give you a clearer understanding of the project as well as what to expect should you wish to participate. It will also offer a chance for you to ask questions prior signing up.

About the researcher and supervisors:

I (Lara Proud) am a Masters student and certified STOTT Pilates® instructor. I've been instructing Pilates at a local studio for 3 years and have actively participated in Pilates for more than 5 years. My interests lie in young womens' health, with a particular interest in the benefits of Pilates for young females.

My supervisors are Dr Candice Christie and Dr Janet Viljoen. Both supervisors are exercise scientists with a background in exercise physiology and physical activity for health.

About the research project – what's the point?

Studies in young women in the greater Makana region are limited and so little is known about the overall health and fitness of this population. This project is part of a 2-year Masters Project looking at the impact of Pilates on fitness and health in young women, specifically ages 18-26. We have therefore invited you to participate in the tests that will be applied to the intervention groups to gain an idea into the overall status if the health and fitness of young women in this region.

The tests we'll be using will look at muscular strength in the arms, legs and back, and muscular endurance tests will look at some of your abdominal (stomach) muscles as well as your legs and arms. We will also look at static and dynamic balance as well as flexibility. Lastly, we'll look at lung function and blood pressure. There are also some questionnaires to complete regarding your physical activity levels.

None of these tests of the procedures are invasive, however in the case of blood pressure and lung function we will be using specific machinery. As mentioned, you will be guided through each of the tests with a research assistant so you will not be expected to do anything on your own.

As with any exercise there are risks and benefits involved and this research project is no different. The risks are of course related to the potential for injury or the potential for embarrassment. During the testing you will be assisted and supervised by a research assistant at all times. Great care will be taken to make sure that your privacy is maintained and that your records are kept confidential. All measures will take place in a private lab in the department so you will not be in view of anyone except the research assistants.

There is a first aid kit available on the premises with medical assistance on standby in the case of an emergency. So if there is an injury of some kind you will be able to get help immediately.

The benefits include free testing of your health and wellness with the results given to you soon after the session. You may learn something about your health and gain interesting insight into your overall fitness. In terms of those who meet inclusion criteria, there is the chance to participate in the Pilates intervention, free of charge which could be seen as a monetary saving as you would not be paying the fees you would usually pay to join a gym or a private studio.

There is also the opportunity to learn about health and wellness from the primary researcher as well as the research assistants. Any questions you may have are welcome and encouraged. We want you to learn about your body and about health and wellness. Of course you'll be meeting new ladies and possibly making new friends too so we hope that you'll not only learn something but also have fun!

Introduction of research assistants:

I will require assistants to help me at each measuring interval and these are the ladies that will be helping me. They are fellow HKE students and so will be able to work with you in a professional and confidential manner and will ensure that your experience is a pleasant one. You will learn a lot from them so don't be afraid to ask them questions.

As mentioned, the measurements we're going to look at include some strength and endurance, flexibility, balance, and lung function. These will be set up at different stations so you'll simply move from station to station for each test where a research assistant will help you.

Remember that all your information will be kept confidential, so while we will share your results with you, we won't share them with anyone else.

Q & A Sessions:

Please feel free to ask me if you have any questions about this research, whether it be regarding the testing itself, or time commitments or anything more general. I'm happy to answer any question – no question is a silly question!!

<u>How to sign up:</u>

If you are still interested please do contact me so we can sign you up and book your testing session. We'd be thrilled to have you join in on this research.

Contact Lara Proud (primary researcher): 0725694490 or g03p3908@campus.ru.ac.za

Or Dr Candice Christie (supervisor): c.christie@ru.ac.za

Or Dr Janet Viljoen (co-supervisor): j.viljoen@ru.ac.za

APPENDIX 4: CONSENT FORM

CONSENT FORM

Population Baseline Measures Participants

RHODES UNIVERSITY
DEPARTMENT OF HUMAN KINETICS AND ERGONOMICS
Phone: 072 569 4490 • E-mail: g03p3908@campus.ru.ac.za

I, ______________________, willingly consent to participate in *Phase 1* of the following research study: **EFFECTS OF AN 8-WEEK PROGRESSIVE PILATES PROGRAMME ON SELECTED COMPONENTS OF 'FITNESS' AND HEALTH RELATED PARAMETERS OF INACTIVE, YOUNG ADULT FEMALES.** I have been informed as to the study's purpose as well as the possible risks involved and potential benefits. These have been explained to me by the primary researcher both verbally and in writing. I am aware of all procedures that I am expected to comply with and am still willing to participate in the above mentioned study.

By agreeing to partake in this study, I give up any legal action against the researcher, the Department of Human Kinetics and Ergonomics, and Rhodes University, should any injuries occur during testing. I understand that the Department of Human Kinetics and Ergonomics will take no responsibility if the injury is self-inflicted or as a result of lack of care by the participants. I will tell the researcher/research assistant immediately should I feel any discomfort or pain during testing or measurements. I am aware that at any point I may withdraw my consent and participation in the study.

I understand that my privacy will be protected and that confidentiality during the research period will be prioritised. I am aware of the different tests and measures that will be performed and recorded during the testing period by the principal researcher and female research assistants. I agree to allow the information collected to be used for scientific purposes and I am aware that should photographs be taken during the testing phase, my approval must first be obtained for this. I’m also aware that recognisable features will be hidden in the images and that these will only be used for illustration purposes.

I have read and understood the information above as well as the additional information about the study provided. Any queries concerning this study have been answered to my satisfaction.

Signed at ______________________________, Rhodes University

PARTICIPANT

________________	________________	________________
(Print name)	(Signed)	(Date)

RESEARCHER

________________	________________	________________
(Print name)	(Signed)	(Date)

WITNESS 1

________________	________________	________________
(Print name)	(Signed)	(Date)

WITNESS 2

________________	________________	________________
(Print name)	(Signed)	(Date)

APPENDIX 5: PARTICIPANT SCREENING FORM

PARTICIPANT SCREENING QUESTIONNAIRE

Name: Email address:

Cell number: Age (years & months):

Emergency Contact in G-town (name and number):

Local Doctor (Name & number, if applicable):

Home Province (or where you spend most of your time):

Please complete the questions below to the best of your ability. Please note that all included information will be kept strictly confidential! Your honesty is appreciated!

1)	a) How many hours of PLANNED, physical activity do you participate in during an average week? This refers to any activities that you do for exercise/health/fitness. b) Please list the activities you participate in most often	
2)	How would you rate your overall health? *Do you consider yourself a healthy person or do you feel like you get sick or injured often*? Please circle one option.	Poor Average Above Average Excellent
3)	Have you ever been told by your doctor or specialist to refrain from physical activity for a long period of time e.g. >3months? Yes/No If yes, please explain why.	
4)	Have you participated in Pilates or Pilates-based activities (at home or at a gym/studio) within the last 12 months?	
5)	Do you have any heart, liver or kidney disease? If so, please specify	
6)	Have you suffered from Lower Back Pain within the last 6 months? Yes/No If Yes, please elaborate.	
7)	Have you sustained any other spinal or back/neck injuries? Yes/No If Yes, please elaborate.	
8)	Have you had surgery of any kind within the last 12 months? If so, please explain what type of surgery it was.	

9)	Have you ever sustained an abdominal injury or have you ever had abdominal surgery? If Yes, please explain the type of injury or the reason for the surgery.	
10)	Have you had any other serious injuries within the last 12 months (e.g. injury resulting in you requiring physical therapy?)	
11)	Are you on any form of chronic medication (medication that you must take continuously)? If so, please list.	
12)	Do you suffer from asthma or any breathing/lung disorders? If so, please list	
13)	Do you/did you smoke (currently or during the past 12 months)? Yes/No	
14)	Are you currently or potentially pregnant? *(Your answer **will** remain 100% confidential!)*	
15)	Are you currently taking any form of hormone-based contraception, be it oral contraception (the pill), the injection or the patch? If yes, please state the make/brand.	
16)	Do you have any other physical conditions the researcher should be aware of e.g. Epilepsy, Rheumatoid Arthritis? *This can include anything that might make it difficult for you to do physical activities.*	
17)	Is there anything else you think the researcher should be made aware of regarding your health? *Remember your health and safety is the top priority!*	

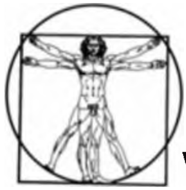
I [full name] ____ declare that the information that I have provided above is truthful and correct.

____________________ ____________________

Signed by participant Date

This research has been approved the Human Kinetics & Ergonomics Ethics Committee for research involving human participants

APPENDIX 6: INTERVENTION RESEARCH ADVERTISEMENT



PILATES FOR WOMEN: RESEARCH

Ladies, would you like to try Pilates as a form of exercise?

Would you be keen to participate in research on Pilates at Rhodes University?

Do you fit the following criteria?

- Female, aged 18-26 years
- Non-smoker, non-asthmatic
- Inactive (less than 20 minutes planned exercise on 3 days of the week)
- Generally in good health
- Using hormonal contraception
- No severe injuries in the last year
- Not pregnant/breastfeeding
- Not using drug or other agents
- Never practiced Pilates before
- Able to commit to Pilates classes on RU campus with a certified Instructor
- Able to read and write English

Interested and want to know more???

Contact Lara Proud

(HKE Department)

lara.proud@gmail.com

WhatsApp or phone:

0725694490

KEEP CALM AND DO PILATES

Free Offer

Benefits to you:

1. **Free** instruction and classes
2. Improved health and wellness
3. Detailed reports on your own progress throughout
4. Learn more about exercise in group educational sessions
5. Be part of important research
6. Make new friends

This research has been cleared by the by the Rhodes University Ethical Standards Committee for research on human subjects

APPENDIX 7: CONSENT FORM FOR INTERVENTION GROUPS

CONSENT FORM

RHODES UNIVERSITY

DEPARTMENT OF HUMAN KINETICS AND ERGONOMICS

Phone: 072 569 4490 • E-mail: g03p3908@campus.ru.ac.za

I, ______________________, willingly consent to participate in *Phase 2* of the following research study: **EFFECTS OF AN 8-WEEK PROGRESSIVE PILATES PROGRAMME ON SELECTED COMPONENTS OF 'FITNESS' AND HEALTH RELATED PARAMETERS IN HEALTY, INACTIVE, YOUNG ADULT FEMALES.** I have been informed as to the study's purpose as well as the possible risks involved and potential benefits. These have been explained to me by the primary researcher both verbally and in writing. I am aware of all procedures that I am expected to comply with and am still willing to participate in the above mentioned study.

By agreeing to partake in this study, I give up any legal action against the researcher, the Department of Human Kinetics and Ergonomics, and Rhodes University, the Rhodes University Health Suite and its affiliates, as well as *Natural Affinity Pilates and Wellness Studio*, should any injuries occur during testing. I understand that the Department of Human Kinetics and Ergonomics will take no responsibility if the injury is self-inflicted or as a result of lack of care by the participants. I understand that the department in question, as well as the primary researcher and research assistants will do all in their power to assist and act promptly should injury occur. I will tell the researcher/research assistant immediately should I feel any discomfort or pain during the Pilates sessions or during testing. I am aware that at any point I may withdraw my consent and participation in the study.

I understand that my privacy will be protected and that confidentiality during the research period will be prioritised. I am aware of the different tests and measures that will be performed and recorded during the testing period by the principal researcher and female research assistants. I agree to allow the information collected to be used for scientific purposes and I am aware that should photographs be taken during the testing phase, my approval must first be obtained for this. I'm also aware that recognisable features will be hidden in the images and that these will only be used for illustration purposes.

I have read and understood the information above as well as the additional information about the study provided. Any queries concerning this study have been answered to my satisfaction.

Signed at ________________________________, Rhodes University

PARTICIPANT

____________________	____________________	____________________
(Print name)	(Signed)	(Date)

RESEARCHER

____________________	____________________	____________________
(Print name)	(Signed)	(Date)

WITNESS 1

____________________	____________________	____________________
(Print name)	(Signed)	(Date)

WITNESS 2

____________________	____________________	____________________
(Print name)	(Signed)	(Date)

APPENDIX 8: SCREENING FORM FOR INTERVENTION VOLUNTEERS

PARTICIPANT SCREENING QUESTIONNAIRE

Name: Email address:

Cell number: Age (years & months):

Emergency Contact Person (name and number) – Ideally someone in Grahamstown:

Home Province:

*Please complete the questions below to the best of your ability. Please note that all included information will be kept strictly confidential! So be as **honest** as possible…*

1)	How many hours of PLANNED, physical activity do you participate in during an average week? This refers to any activities that you do for exercise/health/fitness. *A sedentary lifestyle comprises of <30 minutes light activity, 5 days a week.*	
2)	How would you rate your overall health? *Do you consider yourself a healthy person or do you feel like you get sick or injured often*? Please circle one option.	Poor Average Above Average Excellent
3)	Have you ever been told by your doctor or specialist to refrain from physical activity for a long period of time e.g. >3months? Yes/No (If yes, please explain why)	
4)	Have you participated in Pilates or Pilates-based activities (at home or at a gym/studio) within the last 12 months?	
5)	Do you have any heart, liver or kidney disease? If so, please specify	
6)	Have you suffered from Lower Back Pain within the last 6 months? Yes/No If Yes, please elaborate.	
7)	Have you sustained any other spinal or back/neck injuries? Yes/No If Yes, please elaborate.	

8)	Have you had surgery of any kind within the last 12 months? If so, please explain what type of surgery it was.	
9)	Have you ever sustained an abdominal injury or have you ever had abdominal surgery? If Yes, please explain the type of injury or the reason for the surgery.	
10)	Have you had any other serious injuries within the last 12 months (e.g. injury resulting in you requiring physical therapy?)	
11)	Are you on any form of chronic medication (medication that you must take continuously)? If so, please list.	
12)	Do you suffer from asthma or any breathing/lung disorders? If so, please list	
13)	Do you/did you smoke (currently or during the past 12 months)? Yes/No	
14)	Are you currently or potentially pregnant? *(Your answer **will** remain 100% confidential!)*	
15)	Are you currently taking any form of hormone-based contraception, be it oral contraception (the pill), the injection or the patch?	
16)	Do you have any other physical conditions the researcher should be aware of e.g. Epilepsy, Rheumatoid Arthritis? *This can include anything that might make it difficult for you to do physical activities.*	
17)	Is there anything else you think the researcher should be made aware of regarding your health? *Remember your health and safety is the top priority!*	

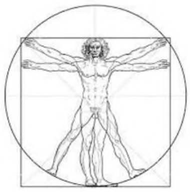
I [full name] ____ declare that the information that I have provided above is truthful and correct.

______________________ ________________________

Signed by participant Date

This research has been approved the Human Kinetics & Ergonomics Ethics Committee for research involving human participants

APPENDIX 9: DIETARY RECALL TEMPLATE



DIETARY RECALL_BASELINE MEASURES

Participant Name/Code: _(017)_______________

Date:_07 May 2015________________

Instructions:

- Please record everything you eat and drink over a three-day period on the following days of the week: Tuesday, Thursday and Saturday. For each day, please note **everything** you consume from waking until going to sleep that night (effectively 24 hours).
- This information is required as it allows me to determine whether the diets of the participants did not change dramatically over time. The diet itself will not be analysed, but I will be merely using this data for results and statistical correlations.
- There are no "good" or "bad" foods – please do not feel embarrassed about recording, truthfully, what you have consumed.
- Please give your best estimate of portion sizes, and quantities. Amounts may be given in numbers, volume, or weight. Please consider one "portion" to be ½ cup or 'a handful'.
- Please specify when referring to spoons: teaspoon/table spoon/serving spoon.
- Be as specific as possible about substances (such as milk: was it full cream or 2%?).
- Record ALL alcoholic beverages (and please state how many glasses, or quantity, if possible).
- Record all non-alcoholic beverages: tea (was it rooibos or ordinary? How many sugars? Did you use brown or white sugar?), cool drinks (coke light 330ml; Fanta orange 330ml; iced tea, peach, 250ml), flavoured water etc.
- Record all distinct components of a meal: fillet steak, grilled (250g); brown rice; green beans...
- Please also record all "snacks" eaten between meals, no matter how big or small.

e.g. Day 1: Tuesday

Example: **7AM: 1x small cup filter coffee (plunger) with 50ml milk (2%)** **1 x large buttermilk rusk (Ouma Brand)**	**Example:** **1PM: Two thick-cut slices white bread,** **1 tsp. butter spread (Flora light), peanut butter (two Tbsp.).** **One small yoghurt (plain, low fat, 250ml).** **1 large glass of water (approximately 400ml)**
Example: **5PM: 1 apple** **1 small cup of 5-Roses tea, 1 tsp. white sugar, 50ml milk (2%)**	**Example:** **7:3PM:330ml Coke Light** **1x Single Rack Steers Ribs with small chips**
Day 1 Friday 8 May 2015	
7:05 French toast: 1 egg, 2 slices wholewheat bread Golden syrup – 20ml Cinnamon – 2 ml 1 small granny smith apple (fried) 1 tsp oil 240 ml coffee: 20ml low fat milk ½ tsp sugar	
12:30 Coucous salad: 1 cup couscous 50g feta cheese 1 ½ granny smith apple (small) Spices (sodium free) Balsamic vinegar reduction (5ml) Water 1 L during the day	
13:00 180ml coffee ½ tsp sugar 1 nutticrust biscuit, 1 cream biscuit (chocolate filling, size of a lemon cream) 1 strawberry swirl biscuit	
14:00 1 lemon cream biscuit	
17:15	

2 corn thins: flora light margarine – 7ml Oxo spread, cheddar cheese, 6 thin slices	
19:30 220 ml (1/2 tin) pea soup 2 slices wholewheat bread 10ml flora light margarine Coffee, 20ml low fat milk, ½ tsp sugar	
Day 2 Sunday 10 May 2015	
10:00 Breakfast: ½ cup coffee With long life low fat milk (20ml) Buttermilk rusk, one small (30g) Water: 400 ml	
13:15 Lunch: Steers toasted sandwich: 2 slices white bread, bacon, cheese, tomato Steers chips: 8-10 chips Barbeque sauce, ½ sachet Bottle water: 500ml	
14:45 Brutal fruit, peach	
17:15 Biltong, beef, lean - 100g Bottle beetroot, grated: 2 fork fulls Water – 240 ml	
20:30 2 small glasses sherry Pizza, large (rat and parrot) 4 slices regina (tomato base, ham, mushrooms, cheese), 1 slice Mexicana (mince, avo, peppers, pickled jalapeno, cheese) 15 ml amarula on ice	
Day 3 Tuesday 12 May 2015	
7:00 1 slice wholewheat toast 7 ml flora light margarine 2 tsp apricot jam	

5 slices white cheddar cheese	
7:45 Coffee 240 ml 25ml low fat milk	
10:30 100 ml yoghurt, sweetened	
11:10 1 soft citrus	
12:30 1 slice wholewheat bread 1 tsp basil pesto 2 tbsp jalapeno hummus 1 slice ham 3 slices white cheddar cheese Rocket, 3 leaves 1 cup coffee – 240ml 25ml low fat milk Malva pudding – 1 piece: 5x10cm Ultramel custard – 2 tbsp	
17:10 1 corn thin 300 ml water 18:15 4 sour worms	
20:00 Roast chicken – thigh and breast (cooked with skin, did not eat skin) 1 medium potato, roasted with chicken 3 small roasted carrots 6 large asparagus spears, with butter Coffee, ¼ tsp sugar, 25 ml low fat milk 21:30 3 sourworms	

Please email/give this document to Lara as soon as it is completed.
Thank you for your time!

APPENDIX 10: GPAQV2

World Health Organisation (WHO) Global Physical Activity Questionnaire (version 2) – GPAQv2

Participant Code: 017 **Date: 07/05/2015**

This questionnaire asks about the time you spend doing different types of physical activity in a typical week. Please answer these questions to the best of your ability, even if you do not consider yourself to be a physically active person.

Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/going to lectures, household chores, seeking employment, grocery shopping or running errands.

In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increase in breathing or heart rate, 'moderate-intensity activities' are those that require moderate physical effort and cause small increase in breathing or heart rate.

	QUESTIONS	RESPONSE	CODE
	Activity at work		
1	Does your work involve vigorous-intensity activity that causes large increases in breathing or HR (such as carrying or lifting heavy loads, digging or construction work) for at least 10 mins continuously?	Yes 1 No 2 *If No, go to P4*	P1
2	In a typical week, on how many days do you do vigorous-intensity activities as part of your work?	Number of days ____	P2
3	How much time do you spend doing vigorous-intensity activities at work on a typical day?	Hours ____ Minutes ____	P3 (a-b)
4	Does your work involve moderate-intensity activity that causes small increases in breathing or HR such as brisk walking (or carrying light loads) for at least 10 mins continuously?	Yes 1 No 2 *If No, go to P7*	P4
5	In a typical week, on how many days do you do moderate-intensity activities as part of your work?	Number of days __5__	P5
6	How much time do you spend doing moderate-intensity activities at work on a typical day?	Hours __3_ Minutes _30_	P6 (a-b)

The next questions exclude the physical activities at work that you have already mentioned. The following questions refer to the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship.			
QUESTIONS		RESPONSE	CODE
Travel to and from places			
7	Do you walk or use a bicycle for at least 10 mins continuously to get to and from places?	Yes 1 No 2 *If No, go to P10*	P7
8	In a typical week, on how many days do you walk or bicycle for at least 10 mins continuously to get to and from places?	Number of days ____	P8
9	How much time do you spend walking or bicycling for travel on a typical day?	Hours ____ Minutes ____	P9 (a-b)

The next questions exclude the work and transport activities that you have already mentioned. These next questions focus on your sports participation, fitness and recreational (leisure) activities.			
QUESTIONS		RESPONSE	CODE
Recreational activities			
10	Do you do any vigorous-intensity sports, fitness or leisure activities that cause large increases in breathing or HR, like running, for at least 10 mins continuously?	Yes 1 No 2 *If No, go to P13*	P10
11	In a typical week, on how many days do you do vigorous-intensity sports, fitness, or leisure activities?	Number of days _1___	P11
12	How much time do you spend doing vigorous-intensity sports, fitness or leisure activities on a typical day?	Hours ____ Minutes _20_	P12 (a-b)
13	Do you do any moderate-intensity sports, fitness or leisure activities that cause small increases in breathing or HR such as brisk walking (cycling, swimming, volleyball) for at least 10 mins continuously?	Yes 1 No 2 *If No, go to P16*	P13

14	In a typical week, on how many days do you do moderate-intensity sports, fitness or leisure activities?	Number of days ____	P14
15	How much time do you spend doing moderate-intensity sports, fitness or leisure activities on a typical day?	Hours ____ Minutes ____	P15 (a-b)

The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching TV, but DO NOT include time spent sleeping.			
QUESTIONS		**RESPONSE**	**CODE**
Sedentary behaviour			
16	How much time do you usually spend sitting or reclining on a typical day?	Hours _9__ Minutes ____	P16 (a-b)

Please email/give this document to Lara as soon as it is completed.

Thank you for your time!

APPENDIX 11: PERMISSION FOR USE OF PRIVATE FACILITY

Natural Affinity
WELLNESS & PILATES STUDIO

I, Lindsay Davy, hereby give permission for Ms Lara Proud (student number: g03p3908) to conduct Pilates classes at the Natural Affinity Wellness & Pilates Studio (Grahamstown) as part of her Master research investigation. Classes may be conducted by her (the primary researcher) as well as other certified instructors from the Natural Affinity Studio in accordance with the research protocol.

Participants of the research must consent to indemnify and waive their rights against Natural Affinity and its employees, for any damages sustained, loss and/or the similar that they may suffer (to themselves or to their property), by participating in any of the research sessions based at the studio. Natural Affinity is indemnified against any injury or damages sustained by participants during classes related to this research project.

The researcher hereby also agrees to hold classes at a time that is suitable according to the existing studio timetable and that will not interfere with any of the regular, scheduled Natural Affinity Studio classes on offer.

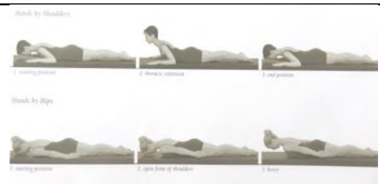
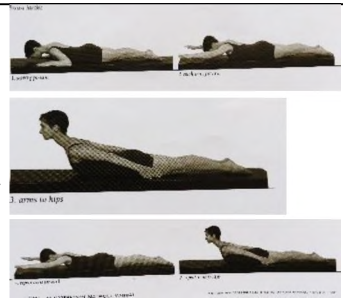
As these classes are part of a local research project, Natural Affinity or its owners will not require any monetary income for use of the property, but will offer the space as a sign of goodwill.

Yours in Pilates,

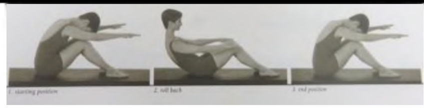
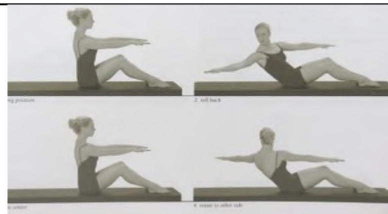
Lindsay Davy

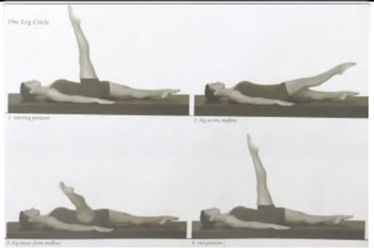
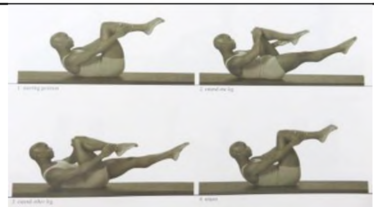
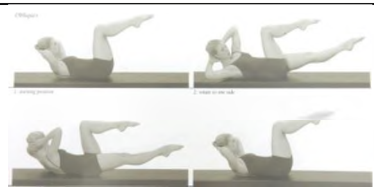
083 465 9869 • thenaturalaffinity@gmail.com

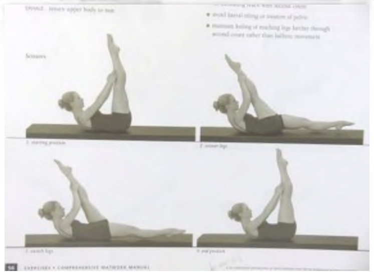
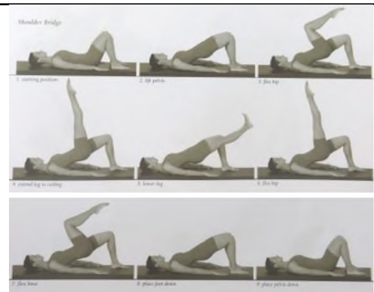
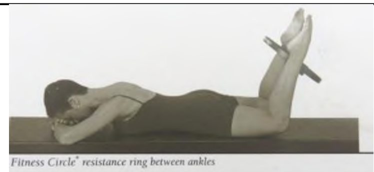
APPENDIX 12: PILATES INTERVENTION EXERCISE DETAILS AND MUSCULAR FOCUS

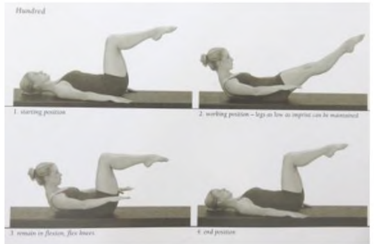
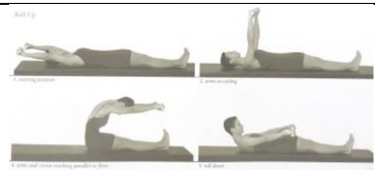
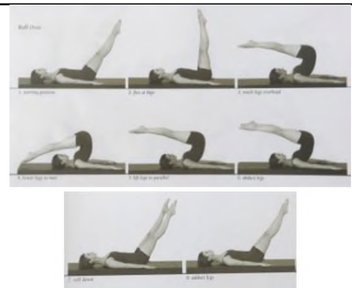
EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Ab Prep •	Transversus abdominis and pelvic floor musculature (TrA), Rectus abdominis (RA), obliques	Supine, knees bent: Lift head, neck and shoulders into thoracic flexion with no change in lumbo-pelvic region (neutral spine). Lift arms in line with shoulders. Return to start position		• *1 Hands behind head to challenge abdominal strength • *3 Fitness ring between knees for lower body resistance
Breast Stroke Preps 1, 2, 3 •	TrA, upper and mid-back erector spinae, scapula stabilisers, obliques and hip extensors	Prone, legs parallel: Lift into thoracic extension, maintaining neutral spine, before returning to start position BSP_1: Hands resting in line with shoulders BSP_2: Hands long by sides of body BSP_3: Hands folded under forehead		
Breast Stroke •	TrA, erector spinae, hip extensors, scapular stabilisers, deltoids, latissimus dorsi and teres major	Prone, neutral spine, leg long and adducted. Arms bend, hands by shoulders. Reach arms forward, palms down, upper body hovering off mat, circle arms out to side and then long against the side of the body whilst extending thoracic and cervical spine lifting into slightly higher extension. Flex elbows, leading with hands to reach forward again without returning head to the mat. On last repetition place hands on the mat in start position and lower head.		

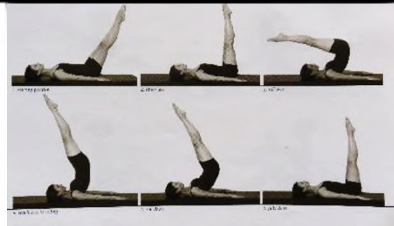
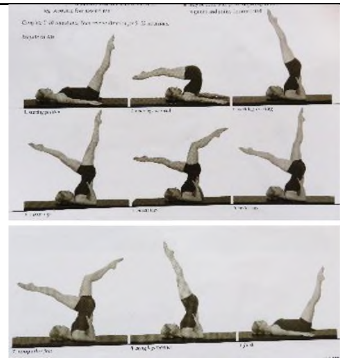
Where: TrA = Transversus abdominis and deep pelvic floor musculature, RA = Rectus abdominis,
TT = Table Top (90° hip and knee flexion)
•=essential level exercise; †= intermediate level, †† = advanced level

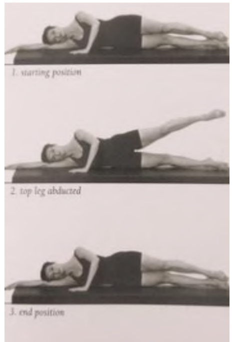
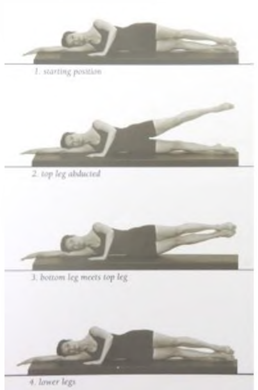
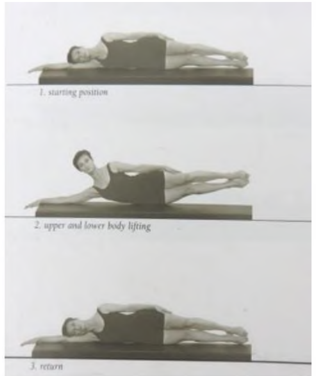
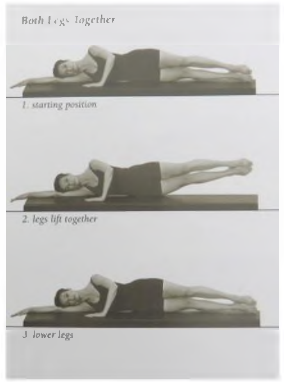
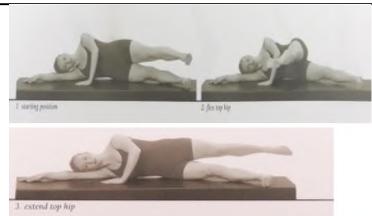
EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Half Roll Back •	TrA, Rectus abdominis and obliques, hip flexors and extensors	Seated, legs long or bent slightly, spine flexed forward over legs, arms reaching and parallel to floor. Articulate pelvis away from legs without straightening the spine, return to start position.		
Obliques Roll Back •	TrA, Rectus abdominis, contralateral internal and external obliques, hip flexors, and hip extensors, erector spinae	Seated in neutral spine, legs slightly bent, abducted at hip width apart, feet flat on the mat. Arms out in front at shoulder height, palms down. Ross ASIS away from femurs and flex lumbar spine, simultaneously rotate torso to reach outside arm back. Sweep the arm back to the start position as rolling torso up back to start.		• *2 Hands resting behind head and eliminate arm reach • *3 Fitness circle squeezed between knees
Rolling like a Ball •	TrA, obliques, RA, hip adductors, hip flexors, scapular stabilisers	Seated with weight back of ischial tuberosities, ASIS rolled away from femurs, spine in flexion to create a 'C-curve', legs adducted with hips and knees flexed, hands reaching for side of knees. Maintaining 'ball' shape throughout and deepen lumbar flexion to roll back along spine onto upper thoracic, then roll up to seated position maintaining balance at the top.		
Seal •	TrA, obliques, RA, hip adductors, hip flexors, scapular stabilisers, lateral hip rotators	Seated with weight back of ischial tuberosities, ASIS rolled away from femurs, spine in flexion to create a 'C-curve', legs abducted with hips and knees flexed, toes together and hands reaching through legs to hold onto ankles. Maintaining 'ball' shape throughout and deepen lumbar flexion to roll back along spine onto upper thoracic, clapping feet together 3 times at the furthest point and again at the top once rolled up to seated position.		

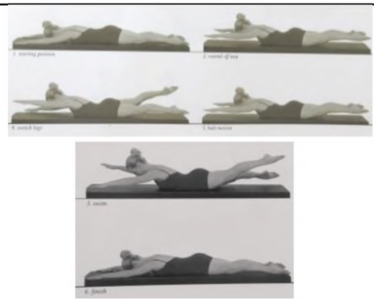
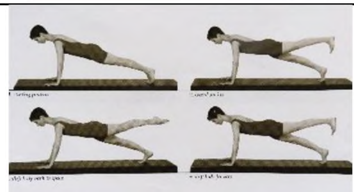
EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
One leg circle •	TrA, oblique groups, multifidis, and hip flexors, adductors and abductors	Supine, neutral spine, one leg extended with hip flexed at 90°. Arms on the mat. Circumduct extended leg whilst maintaining neutral spine and pelvis. Minimise pelvic rotation.		• *7 Hold fitness circle above chest to add torso stabilisation challenge
Spine Twist •	TrA, contralateral internal and external obliques, scapular stabilisers	Seated, legs long and adducted in front, arms reaching out to sides at shoulder height. Rotate to one side maintaining arm position about the body. Rotate maximally 3 times releasing slightly between rotations and maintaining tall seated position. Return to forward facing after 3 rotation. Then repeat on opposite side.		• *3 Flex back elbow on rotation *5 Add flex band to add resistance
Single Leg Stretch •	TrA, Rectus abdominis, obliques, hip flexors	Supine, thoracic flexion, spine imprinted, hips and knees flexed to 90°. Hands reaching to knees. Extend one leg at a time out on the diagonal then switching legs to alternate reaching legs.		
Obliques Leg Stretch •	TrA, Rectus abdominis, contralateral internal and external obliques, hip flexors	As above, but with hands behind the head. On leg extension rotate upper torso towards incoming flexed knee.		

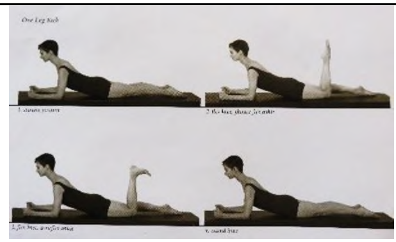
EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Scissors •	TrA, Rectus abdominis, obliques, hip flexors	As above but with legs fully extended and hands reaching to knees. Two beat count to reach one leg into extension and flex the other leg further for one repetition, then repeat with the other leg.		• *8 Flex band: wrapping band around one foot and holding with corresponding hand. Bicep curl as leg reaches away. Swap sides.
Shoulder Bridge ✝	TrA, Rectus abdominis, obliques, hip extensors, hip flexors, multifidis	Supine, legs bent, arms by side of the body, neutral spine. Extend hips to lift pelvis up maintaining a neutral spine and creating a straight line from should through to knee. Maintain level pelvis and lift one leg up, foot planter flex. Dorsiflex the foot while lowering the gesture leg through hip extension while maintaining neutral spine before bringing the leg back up. Repeat twice more, lower the leg to the mat and repeat on the other side, then, flex hips to lower pelvis back to start position.		• *1 Prep: Lift and lower pelvis • *2 Whilst in bridge, lift and lower each foot alternatively (a few cm from the mat) to increase challenge on hip/pelvic stability
Heel Squeeze Prone •	TrA hamstrings, gluteus maximus and lateral rotators of the hip.	Prone, pelvic and spine neutral, knees flexed and abducted wider than hip width apart, with heels together, ankles dorsiflexed. Hands under forehead. Squeeze heels together, then release.		• *1 Place fitness circle between ankles for added resistance
Single Leg Extension •	TrA, Unilateral Gluteus maximus and hamstrings, obliques and multifidis	Prone, neutral spine and pelvis. Legs long and abducted at hip width apart, hands under forehead. Extend one leg into the air without rotation or anterior tilt of pelvis.		

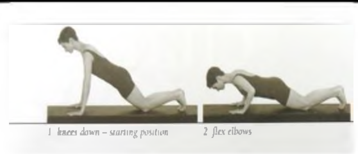
EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Hundred •	TrA, RA, obliques, scapula stabilizers and hip flexors, adductors, quadricep group	Supine, imprinted, legs parallel and adducted, extended out on the diagonal. Flex upper thoracic spine bringing arms parallel to floor. Pulse arms gently for 100 beats (10 breaths) maintaining upper and lower body in position and minimising effect of pulsing arms on trunk.	 	• *2 Feet remain on the mat, neutral pelvis • *3 Hips and knees flexed at 90° throughout • *5 Fitness circle between ankles • *6 Legs TT, extend out on the diagonal for 5 beats, return to TT for 5 beats
Spine Stretch Forward •	TrA, RA, obliques, erector spinae	Seated upright with legs long and abducted hip width apart, feet dorsiflexed. Hands resting on mat inside legs. Articulate spine to flex forward whilst keeping pelvic neutral, sliding hands forward. Return to vertical seated position.		
Roll Up •	TrA, RA, obliques, hip flexors, hip extensors	Supine, legs long, arms reaching overhead: Articulate from head through spine to roll torso up off the mat and reach over legs keeping pelvis neutral. Roll back down on to mat articulating through spine.		• Perform with knees slightly bent
Roll Over †	TrA, RA, obliques, hip flexors, adductors	Supine, imprinted spine with legs extended on the diagonal. Flex hips to bring legs towards torso, articulate spine off mat from the tailbone as legs move overhead till parallel with mat. Control lower of body and release of legs back out to start position with imprinted spine.		• *6 Fitness circle in ankles for lower body resistance

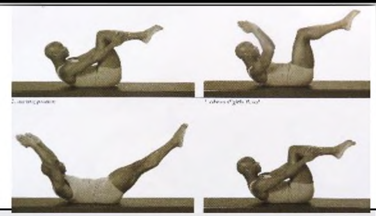
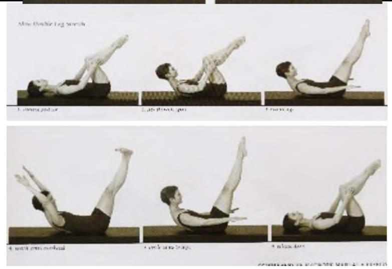
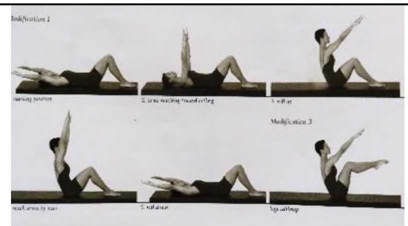
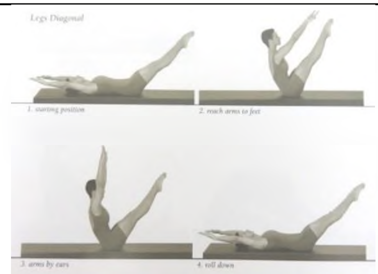
EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Jack Knife †	TrA, RA, obliques, hip flexors, hip extensors, leg adductors	Start position as above. Flex hips to bring legs towards torso, articulate spine off mat from the pelvis as legs move overhead till parallel with mat. Use hip extensors to lift legs up overhead, maintaining trunk stability and weight over upper thoracic. Keeping legs extended as extended as possible, control lowering of body back down onto the mat and release the legs back out to start position with imprinted spine.		
Bicycle in the Air ††	TrA, RA, obliques, multifidus, hip flexors, hip extensors, leg adductors	Supine, imprinted spine, legs extended on the diagonal. Flex hips to bring legs towards torso, articulate spine off mat from the pelvis moving legs overhead till parallel with mat. Use hip extensors to lift legs up overhead whilst maintaining trunk stability & weight over upper thoracic. Place hands on lumbar spine to support pelvis in space. Split legs in sagittal plane: bring one leg into extension & one into flexion. Flex knee of extended leg, scoop the foot towards the mat & bring knee towards the chest, then straighten the leg into flexion whilst other leg reaches into extension. Repeat, swapping legs each time. Bring legs together in the air. Keeping legs extended, place hands back on the mat & control lowering of body back down and release the legs back out to start position with imprinted spine.		

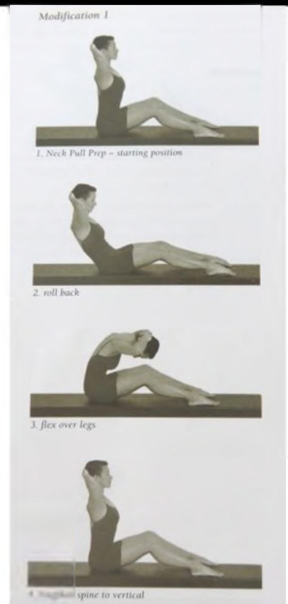
EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Side Leg Lift Series – performed as a sequence •	TrA, obliques, erector spinae, multifidis, hip adductors and abductors, flexors and extensors.	Side lying, pelvic in neutral, hips stacked and legs extended in like with torso. Bottom arm supporting head, other hand resting on the mat in front of chest. 1) Lift and lower top leg. 2) Use top leg and circle to the front then to the back. 3) Lift the top leg, follow with the bottom leg to meet it before lowering both to the mat simultaneously. 4) Lift both legs together, keeping them adducted. 5) Add lateral torso flexion as the double leg lift happens.	*Sequence described in row below*	
Top leg abduction: 	*Top leg circles:* 	*Staggered legs:* 	*Lateral flexion:* 	*Double leg lift:* 
Side Kick •	TrA, Obliques, Erector spinae, multifidis, top leg abductors, hip flexors and extensors	Side lying, pelvis in neutral, hips stacked and legs hinged slightly forward. Feet dorsiflexed. Head supported by bottom arm, free hand resting on the mat in front of chest. Lift top leg to parallel with mat, pulse forward for two counts before reaching top leg back for one count. Maintain neutral spine throughout.		• *3 Both hands on head – resting on elbows.

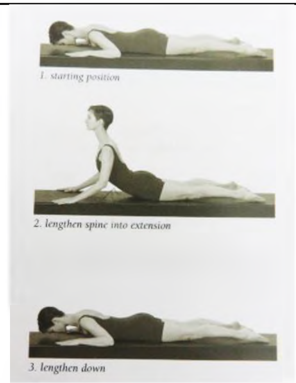
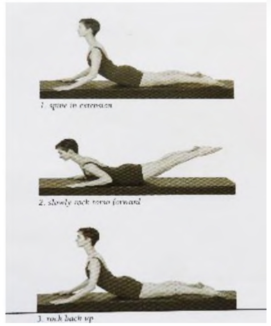
EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Swimming Prep •	TrA, obliques and multifidis, Gluteus maximus and deltoids	Start in a 4-point kneeling position, neutral spine. Reach one arm and opposite leg to parallel with the mat before returning to 4-point kneeling position. Keep neutral spine throughout		• Perform over stability ball for balance challenge
Swimming †	TrA, Unilateral Gluteus maximus and hamstrings, erector spinae, deltoids, obliques and multifidis	Prone, neutral spine and pelvis. Legs long and abducted at hip width apart, arms reaching ahead, palms down. Extend thoracic spine and hips to hover arms and legs over the mat. Pulse opposite arm and leg for 10 beats to perform one set. Repeat 5 times and then lower legs and arms back to the mat.		
Leg Pull Front Prep •	TrA, obliques and multifidis, Pectoralis major and scapular stabilisers, leg adductors	Four-point kneeling, neutral spine. Without losing neutral spine position, lift knees 2 cm off the mat before placing them down again		• *2 Add alternating lift of one foot off the mat then the other whilst holding knees off the mat
Leg Pull Front †	TrA, obliques, multifidus, pectoralis major, serratus anterior, hip extensors	Prone plank or full push up position, extend one leg with ankle dorsiflexed whilst maintaining a neutral spine, shift weight back through supporting leg to increase dorsiflexion in that food whilst planter flexing lifted foot. Shift body weight forward to plank position, dorsiflex lift foot and then return it to the mat. Repeat on the other side.		

EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Side Bend Prep •	TrA, obliques, adductors of top leg and abductors of bottom leg, multifidis	Side seated, supporting knee resting on mat, top leg laterally rotated, feet together. Push through supporting knee and hand to lift hips up and reach top arm overhead. Lower hips to the mat.		• *2 Keep both knees together, with top leg closed over bottom leg
Side Bend †	TrA, Obliques, adductors of top leg and abductors of bottom leg, multifidis	Side seated, supporting knee resting on mat, top leg laterally rotated, feet together. Push through feet and supporting hand to lift hips up and reach top arm overhead. Lower hips to the mat.		
One Leg Kick †	TrA, RA, Obliques, hip extensor and hamstrings, scapular stabilisers (serratus anterior)	Prone, supported on elbows, spine as neutral as possible with ASIS just off mat. Flex knee twice through two pulses, one with plantar flexed and one with dorsiflexed foot. Return to mat and flex other knee.		

EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Push Up **•/†**	TrA, RA, obliques, Pectoralis major, Triceps, Serratus anterior, Biceps, hip adductors	*Prep*: Hands and knees on the mat, spine and pelvis neutral, with legs adducted and parallel, hips extended to form straight line from head to knees. Lower chest to the mat through controlled elbow flexion and push back up to return to start position *Full exercise*: Start standing and roll body down to floor articulating through spine until hands reach the mat. Walk body out to full plank, neutral spine, (extending one leg out behind into arabesque position for modification). Lower chest to the mat through controlled elbow flexion and push back up returning to start whilst maintaining leg in extended position. Perform 3 push ups and then push back through hands whilst keeping extended leg lifted as moving to bottom of roll down, and roll up through spine flexion placing foot back on the mat only once at full standing position. Repeat with other leg in extension (*†)*	 	• *3 Elbows flex straight back to brush along rip cage on lowering to mat • *4 Hands together – fingers and thumbs form diamond shape • *5 One leg extended into arabesque position (as per graphical depiction) • *6 Roll up to standing and add bend through knees followed by rise onto toes
Rocking **††**	Prone, neutral spine, legs adducted, parallel, knees flexed. Hands reaching back to grip the feet, scapular stabilised.	Maintain grip on feet and allow upper body to lift up through spinal extension as feet are pressed into hands. Reach legs away by extending knees and hips to lift femurs up slightly. Allow legs to abduct. Control the return back to start position.		

EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Double leg stretch •	TrA, Rectus abdominis, obliques, hip flexors, scapular stabilisers	Supine, thoracic flexion, spine imprinted, hips & knees flexed to 90°. Hands reaching to knees. Extend both legs out on the diagonal simultaneous reaching both arms out overhead, maintaining flexion. Return knees to start whilst circumducting arms out & back to start.		• *6 With flex-band
Slow Double Leg Stretch †	TrA, RA, Obliques, Hip flexors and extensors, lateral and medial rotators of the hip	As above, but no flexion and legs laterally rotated at hips (toes together). Hands pressed to outside of knees. Flex thoracic spine. Then extend legs on diagonal, adducted and parallel. Hover arms parallel to floor alongside body. Maintain position and circumduct arms to complete a full arm circle whilst rotating legs laterally and dorsiflexing feet. Return to start position to complete the repetition.		
Teaser Prep •	TrA, RA, obliques, hip flexors	Supine, legs bent with one/both feet on the mat, arms reaching back. Lift arms to ceiling then bring them in front of the shoulders, articulating spine up off the mat, until weight is back of ischial tuberosities. Hold this position and reach arms overhead. Keep this arm position and roll back down to start position. Legs remain in start position throughout.		• *1 Both feet on mat • *2 Start with 1 foot remaining on the mat, other leg at 90° • *3 Progress to both legs at 90° and resting on stability ball before straightening out
Teaser †	TrA, RA, obliques, hip flexors	As above, but with hips flexed with legs extended on the diagonal throughout. Lift arms to ceiling then bring them in front of the shoulders, articulating spine up off the mat, until weight is back of ischial tuberosities. Hold this position and reach arms overhead. Keep this arm position whilst rolling back down to start position.		

EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Neck Pull Prep •	TrA, RA, hip flexors, erector spinae, scapula stabilisers	Seated with legs bent slightly, hands behind head. Articulate through lumbar spine to roll pelvis away from knees to half roll back position, then flex torso over the legs with weight on the ischial tuberosities before articulating back to vertical spine and start position.		
Neck Pull †	TrA, RA, hip flexors, erector spinae, scapula stabilisers, rectus abdominals, obliques	Supine, legs bent, hands behind head. Articulate through lumbar spine to roll torso up off the mat and then fold forward over legs, but keeping pelvic vertical. Extend spine to a vernicle sitting position then roll pelvis away from legs and roll down back to start position.		

EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Saw •	TrA, RA contralateral internal and external obliques, erector spinae	Seated, neutral spine, legs abducted wider than hip width, ankles dorsiflexed, arms reaching out to sides. Rotate torso to face one leg, arms reach forward & back. Articulate into flexion, reach forward facing arm to toes, back arm medially rotates. Articulate back to a vertical spine & return to start, repeat in other direction.		
Swan Dive (Prep) **•/†**	TrA, erector spinae, hip extensors, obliques, scapular stabilisers	Prone, legs abducted wider than hip width apart with lateral rotation. Arms resting next to body with hands in line with face. Extend spine to lift torso up into extension, pushing through arms. Keep pelvis and lumbar spine supported through abdominal contraction. Lower body to mat. *Slow rock*: whilst lowering torso to mat maintain extension by bringing the legs up behind as body lowers. Return to extended position by lifting torso and lowering legs.	 	*3 Swan dive prep with slow rock

EXERCISE	TARGET MUSCLE	DESCRIPTION	GRAPHICAL DEPICTION	MODIFICATION
Hip Twist †	TrA, RA, obliques, hip flexors, rhomboids, trapezius group, latissimus dorsi, teres major	Seated with weight back of ischial tuberosities, lumbar spine slightly flexed, arms extended behind with palms on mat to support trunk. Legs extended in the air and adducted. Keeping both legs together preform a leg circle changing direction to alternate through each manoeuvre.	 	*1 rest on elbows
Twist ††	TrA, obliques (contralateral), hip extensors, adductors of top leg and abductors of bottom leg, multifidis	Side seated, supporting knee resting on mat, top leg laterally rotated, feet together. Push through feet and supporting hand to lift hips up and reach top arm straight up, with eye-line ahead. Take free arm down and sweep under torso, flexing through spine, rounding lumbar region to ceiling. Return back to forward facing and take gesture arm slightly back so as to extend slightly through spine whilst resisting pelvic rotation. Bring arm back and reach it overhead increasing lateral flexion through the body. Flex knees to lower hips to the mat.	   	• Can be performed resting on forearm if wrist discomfort is felt.

APPENDIX 13: STATISTICAL ANALYSES

PHASE 1: POPULATION STUDY – SINGLE SAMPLE T-TESTS

STATURE

SANHANES-1 (2012)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Stature (cm)	165,2146	5,583245	96	0,569838	158,2000	12,30979	95	0,000000

SADHS (2003)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Stature (cm)	165,2146	5,583245	96	0,569838	158,0000	12,66077	95	0,000000

SADHS (1998)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Stature (cm)	165,2146	5,583245	96	0,569838	159,0000	10,90589	95	0,000000

MASS

SANHANES-1 (2012)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Mass (kg)	63,04063	9,728062	96	0,992866	63,00000	0,040917	95	0,967448

SADHS (2003)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Mass (kg)	63,04063	9,728062	96	0,992866	59,20000	3,868220	95	0,000201

SADHS (1998)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
Mass (kg)	63,04063	9,728062	96	0,992866	59,40000	3,666783	95	0,000405

BODY MASS INDEX

SANHANES-1 (2012)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
BMI	23,07506	3,276558	96	0,334412	26,20000	-9,34457	95	0,000000

SADHS (2003)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
BMI	23,07506	3,276558	96	0,334412	23,60000	-1,56973	95	0,119802

SADHS (1998)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
BMI	23,07506	3,276558	96	0,334412	23,70000	-1,86876	95	0,064737

WAIST CIRCUMFERENCE

SANHANES-1 (2012)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
WCavg (cm)	72,42601	7,840093	96	0,800176	82,00000	-11,9649	95	0,000000

SADHS (2003)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
WCavg (cm)	72,42601	7,840093	96	0,800176	74,20000	-2,21700	95	0,029008

SADHS (1998)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
WCavg (cm)	72,42601	7,840093	96	0,800176	74,90000	-3,09181	95	0,002611

SYSTOLIC BLOOD PRESSURE

SANHANES-1 (2012)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
BP (Sys)	121,5208	11,16006	96	1,139019	127,6000	-5,33720	95	0,000001

SADHS (1998): Young Females Nationally

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
BP (Sys)	121,5208	11,16006	96	1,139019	106,0000	13,62649	95	0,000000

SADHS (1998): All Eastern Cape Females

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
BP (Sys)	121,5208	11,16006	96	1,139019	121,0000	0,457265	95	0,648525

DIASTOLIC BLOOD PRESSURE

SANHANES-1 (2012)

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
BP (Dia)	76,47917	8,429246	96	0,860306	74,50000	2,300537	95	0,023605

SADHS (1998): Young Females Nationally

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
BP (Dia)	76,47917	8,429246	96	0,860306	67,00000	11,01836	95	0,000000

SADHS (1998): All Eastern Cape Females

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
BP (Dia)	76,47917	8,429246	96	0,860306	77,00000	-0,605404	95	0,546354

MINUTE VENTILATION

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
MV (L/Min)	9,695611	2,412565	96	0,246231	6,000000	15,00869	95	0,000000

TOTAL LUNG CAPACITY

Variable	Test of means against reference constant (value) (Spreadsheet1_(Recovered))							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
TLC (L)	4,048958	0,714347	96	0,072908	4,300000	-3,44328	95	0,000857

TIDAL VOLUME

Variable	Test of means against reference constant (value) (Spreadsheet1_(Recovered))							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
VT (L)	0,664163	0,234214	96	0,023904	0,500000	6,867493	95	0,000000

FEV$_1$

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
FEV1 (L)	2,691875	0,595554	96	0,060784	2,720000	-0,462708	95	0,644632

FORCED VITAL CAPACITY

Variable	Test of means against reference constant (value) (Young Female Population Study and Norms)							
	Mean	Std.Dv.	N	Std.Err.	Reference Constant	t-value	df	p
FVC (L)	2,946875	0,716371	96	0,073114	3,200000	-3,46204	95	0,000805

PHASE 2: INTERVENTION STUDY – REPEATED MEASURES ANALYSIS OF VARIANCE

STATURE

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 9,3200				
	SS	Degr. of Freedom	MS	F	p
Intercept	1394262	1	1394262	16051,26	0,000000
Group	357	1	357	4,11	0,060916
Error	1303	15	87		
TIME	0	2	0	0,66	0,525553
TIME*Group	1	2	0	1,23	0,307170
Error	9	30	0		

MASS

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 15,4786				
	SS	Degr. of Freedom	MS	F	p
Intercept	204685,5	1	204685,5	854,3316	0,000000
Group	0,0	1	0,0	0,0000	0,997908
Error	3593,8	15	239,6		
TIME	5,3	2	2,7	6,7688	0,003749
TIME*Group	0,8	2	0,4	0,9754	0,388698
Error	11,8	30	0,4		

BMI

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 4,9292				
	SS	Degr. of Freedom	MS	F	p
Intercept	27184,72	1	27184,72	1118,839	0,000000
Group	29,76	1	29,76	1,225	0,285836
Error	364,46	15	24,30		
TIME	0,92	2	0,46	5,709	0,007925
TIME*Group	0,00	2	0,00	0,005	0,995413
Error	2,43	30	0,08		

WAIST CIRCUMFERENCE

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 12,3895				
	SS	Degr. of Freedom	MS	F	p
Intercept	257839,5	1	257839,5	1679,750	0,000000
Group	227,2	1	227,2	1,480	0,242593
Error	2302,5	15	153,5		
TIME	9,9	2	4,9	3,523	0,042230
TIME*Group	1,8	2	0,9	0,639	0,534611
Error	42,1	30	1,4		

SYSTOLIC BLOOD PRESSURE

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 12,8607				
	SS	Degr. of Freedom	MS	F	p
Intercept	765007,1	1	765007,1	4625,272	0,000000
Group	6,4	1	6,4	0,039	0,846991
Error	2481,0	15	165,4		
TIME	465,1	2	232,5	1,779	0,186102
TIME*Group	38,5	2	19,3	0,147	0,863627
Error	3920,9	30	130,7		

DIASTOLIC BLOOD PRESSURE

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 9,6147				
	SS	Degr. of Freedom	MS	F	p
Intercept	304766,7	1	304766,7	3296,854	0,000000
Group	40,8	1	40,8	0,441	0,516617
Error	1386,6	15	92,4		
TIME	33,6	2	16,8	0,394	0,677596
TIME*Group	44,0	2	22,0	0,516	0,602276
Error	1279,1	30	42,6		

ABDOMINAL ENDURANCE

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 13,8410				
	SS	Degr. of Freedom	MS	F	p
Intercept	39130,76	1	39130,76	204,2608	0,000000
Group	0,10	1	0,10	0,0005	0,982225
Error	2873,59	15	191,57		
TIME	575,63	2	287,81	8,8031	0,000981
TIME*Group	19,47	2	9,74	0,2978	0,744640
Error	980,84	30	32,69		

ARM ENDURANCE

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 14,7844				
	SS	Degr. of Freedom	MS	F	p
Intercept	21421,34	1	21421,34	98,00232	0,000000
Group	88,79	1	88,79	0,40622	0,533504
Error	3278,70	15	218,58		
TIME	259,57	2	129,78	11,63955	0,000181
TIME*Group	51,18	2	25,59	2,29487	0,118198
Error	334,51	30	11,15		

LEG ENDURANCE

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 29,6095				
	SS	Degr. of Freedom	MS	F	p
Intercept	157726,7	1	157726,7	179,9050	0,000000
Group	328,3	1	328,3	0,3745	0,549731
Error	13150,8	15	876,7		
TIME	345,2	2	172,6	1,2497	0,301090
TIME*Group	2183,6	2	1091,8	7,9057	0,001747
Error	4143,2	30	138,1		

FUNCTIONAL REACH TEST

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 7,2303				
	SS	Degr. of Freedom	MS	F	p
Intercept	25590,36	1	25590,36	489,5172	0,000000
Group	3,66	1	3,66	0,0700	0,794970
Error	784,15	15	52,28		
TIME	56,28	2	28,14	3,1317	0,058184
TIME*Group	23,11	2	11,55	1,2858	0,291236
Error	269,59	30	8,99		

STORK STAND (LEFT LEG)

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 27,1969				
	SS	Degr. of Freedom	MS	F	p
Intercept	9773,44	1	9773,444	13,21323	0,002444
Group	258,71	1	258,708	0,34976	0,563056
Error	11095,07	15	739,671		
TIME	74,54	2	37,271	0,96698	0,391765
TIME*Group	72,86	2	36,430	0,94517	0,399884
Error	1156,32	30	38,544		

STORK STAND (RIGHT LEG)

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 26,7854				
	SS	Degr. of Freedom	MS	F	p
Intercept	9710,46	1	9710,463	13,53457	0,002233
Group	230,17	1	230,167	0,32081	0,579498
Error	10761,84	15	717,456		
TIME	58,65	2	29,325	0,38003	0,687087
TIME*Group	342,45	2	171,225	2,21891	0,126265
Error	2314,99	30	77,166		

ARM STRENGTH

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 7,9910				
	SS	Degr. of Freedom	MS	F	p
Intercept	33902,45	1	33902,45	530,9196	0,000000
Group	27,45	1	27,45	0,4299	0,521961
Error	957,84	15	63,86		
TIME	23,14	2	11,57	1,7849	0,185174
TIME*Group	4,03	2	2,01	0,3106	0,735358
Error	194,50	30	6,48		

BACK STRENGTH

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 8,6567				
	SS	Degr. of Freedom	MS	F	p
Intercept	61111,22	1	61111,22	815,4875	0,000000
Group	68,08	1	68,08	0,9085	0,355616
Error	1124,07	15	74,94		
TIME	29,47	2	14,73	2,0313	0,148818
TIME*Group	2,02	2	1,01	0,1389	0,870851
Error	217,59	30	7,25		

LEG STRENGTH

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 33,6939				
	SS	Degr. of Freedom	MS	F	p
Intercept	399688,5	1	399688,5	352,0623	0,000000
Group	300,2	1	300,2	0,2645	0,614560
Error	17029,2	15	1135,3		
TIME	2704,0	2	1352,0	6,6438	0,004087
TIME*Group	892,2	2	446,1	2,1922	0,129242
Error	6104,9	30	203,5		

FLEXIBILITY

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 136,5274				
	SS	Degr. of Freedom	MS	F	p
Intercept	925115,6	1	925115,6	49,63138	0,000004
Group	10320,4	1	10320,4	0,55367	0,468317
Error	279596,0	15	18639,7		
TIME	329,8	2	164,9	0,24329	0,785574
TIME*Group	9370,3	2	4685,2	6,91172	0,003398
Error	20335,7	30	677,9		

MINUTE VENTILATION

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 4,5796				
	SS	Degr. of Freedom	MS	F	p
Intercept	5421,604	1	5421,604	258,5037	0,000000
Group	1,056	1	1,056	0,0503	0,825491
Error	314,595	15	20,973		
TIME	23,674	2	11,837	5,3830	0,010054
TIME*Group	11,449	2	5,725	2,6033	0,090666
Error	65,968	30	2,199		

TIDAL VOLUME

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 0,3906				
	SS	Degr. of Freedom	MS	F	p
Intercept	22,65180	1	22,65180	148,4411	0,000000
Group	0,00020	1	0,00020	0,0013	0,971662
Error	2,28897	15	0,15260		
TIME	0,09204	2	0,04602	3,0239	0,063625
TIME*Group	0,03486	2	0,01743	1,1454	0,331625
Error	0,45655	30	0,01522		

FORCED VITAL CAPACITY

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 1,2049				
	SS	Degr. of Freedom	MS	F	p
Intercept	302,4796	1	302,4796	208,3539	0,000000
Group	0,0055	1	0,0055	0,0038	0,951669
Error	21,7764	15	1,4518		
TIME	0,9970	2	0,4985	2,0933	0,140920
TIME*Group	0,0209	2	0,0105	0,0439	0,957064
Error	7,1438	30	0,2381		

FEV_1

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 1,0209				
	SS	Degr. of Freedom	MS	F	p
Intercept	255,3548	1	255,3548	244,9941	0,000000
Group	0,7047	1	0,7047	0,6761	0,423800
Error	15,6343	15	1,0423		
TIME	0,2854	2	0,1427	1,1993	0,315457
TIME*Group	0,1454	2	0,0727	0,6109	0,549462
Error	3,5700	30	0,1190		

TOTAL LUNG CAPACITY

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 1,2049				
	SS	Degr. of Freedom	MS	F	p
Intercept	636,7502	1	636,7502	438,6060	0,000000
Group	0,0055	1	0,0055	0,0038	0,951669
Error	21,7764	15	1,4518		
TIME	0,9970	2	0,4985	2,0933	0,140920
TIME*Group	0,0209	2	0,0105	0,0439	0,957064
Error	7,1438	30	0,2381		

Y-BALANCE: LEFT ANTERIOR

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 10,2843				
	SS	Degr. of Freedom	MS	F	p
Intercept	321920,3	1	321920,3	3043,657	0,000000
Group	91,7	1	91,7	0,867	0,366476
Error	1586,5	15	105,8		
TIME	52,1	2	26,0	2,165	0,132360
TIME*Group	13,9	2	6,9	0,577	0,567618
Error	360,7	30	12,0		

Y-BALANCE: RIGHT ANTERIOR

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 11,0963				
	SS	Degr. of Freedom	MS	F	p
Intercept	322630,4	1	322630,4	2620,300	0,000000
Group	4,1	1	4,1	0,033	0,857968
Error	1846,9	15	123,1		
TIME	57,0	2	28,5	2,649	0,087176
TIME*Group	6,0	2	3,0	0,281	0,756954
Error	322,5	30	10,8		

Y-BALANCE: LEFT POSTEROMEDIAL

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 18,7035				
	SS	Degr. of Freedom	MS	F	p
Intercept	386359,7	1	386359,7	1104,446	0,000000
Group	110,7	1	110,7	0,316	0,582070
Error	5247,3	15	349,8		
TIME	182,1	2	91,0	3,532	0,041918
TIME*Group	14,0	2	7,0	0,271	0,764573
Error	773,1	30	25,8		

Y-BALANCE: RIGHT POSTEROMEDIAL

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 18,6637				
	SS	Degr. of Freedom	MS	F	p
Intercept	372774,2	1	372774,2	1070,161	0,000000
Group	134,7	1	134,7	0,387	0,543344
Error	5225,0	15	348,3		
TIME	168,0	2	84,0	4,008	0,028668
TIME*Group	53,0	2	26,5	1,263	0,297286
Error	628,8	30	21,0		

Y-BALANCE: LEFT POSTEROLATERAL

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 22,8979				
	SS	Degr. of Freedom	MS	F	p
Intercept	351774,0	1	351774,0	670,9249	0,000000
Group	75,5	1	75,5	0,1441	0,709577
Error	7864,7	15	524,3		
TIME	504,6	2	252,3	9,1896	0,000771
TIME*Group	32,0	2	16,0	0,5823	0,564779
Error	823,7	30	27,5		

Y-BALANCE: RIGHT POSTEROLATERAL

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 22,1783				
	SS	Degr. of Freedom	MS	F	p
Intercept	350754,5	1	350754,5	713,0921	0,000000
Group	31,6	1	31,6	0,0642	0,803413
Error	7378,2	15	491,9		
TIME	325,3	2	162,7	4,8888	0,014529
TIME*Group	30,2	2	15,1	0,4535	0,639659
Error	998,2	30	33,3		

CARBOHYDRATE INTAKE

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 78,5708				
	SS	Degr. of Freedom	MS	F	p
Intercept	1874175	1	1874175	303,5902	0,000000
Group	5827	1	5827	0,9440	0,346668
Error	92601	15	6173		
TIME	62	2	31	0,0149	0,985198
TIME*Group	5174	2	2587	1,2519	0,300485
Error	61993	30	2066		

PROTEIN INTAKE

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 24,2456				
	SS	Degr. of Freedom	MS	F	p
Intercept	218536,0	1	218536,0	371,7547	0,000000
Group	3104,2	1	3104,2	5,2806	0,036367
Error	8817,8	15	587,9		
TIME	54,7	2	27,3	0,0961	0,908631
TIME*Group	1005,7	2	502,8	1,7676	0,188059
Error	8534,1	30	284,5		

FAT INTAKE

Effect	Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 29,9169				
	SS	Degr. of Freedom	MS	F	p
Intercept	225175,5	1	225175,5	251,5862	0,000000
Group	2448,9	1	2448,9	2,7361	0,118874
Error	13425,3	15	895,0		
TIME	249,3	2	124,6	0,3401	0,714402
TIME*Group	527,7	2	263,8	0,7199	0,495005
Error	10994,2	30	366,5		

TOTAL CALORIC INTAKE

Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention)
Sigma-restricted parameterization
Effective hypothesis decomposition; Std. Error of Estimate: 2723,7724

Effect	SS	Degr. of Freedom	MS	F	p
Intercept	2,625468E+09	1	2,625468E+09	353,8874	0,000000
Group	2,038013E+07	1	2,038013E+07	2,7470	0,118196
Error	1,112840E+08	15	7,418936E+06		
TIME	7,735108E+05	2	3,867554E+05	0,1833	0,833427
TIME*Group	6,795575E+06	2	3,397788E+06	1,6105	0,216578
Error	6,329183E+07	30	2,109728E+06		

METMIN.WEEK^{-1}

Repeated Measures Analysis of Variance (Phase 2 Pilates Intervention)
Sigma-restricted parameterization
Effective hypothesis decomposition; Std. Error of Estimate: 1972,3635

Effect	SS	Degr. of Freedom	MS	F	p
Intercept	90767533	1	90767533	23,33225	0,000220
Group	7136475	1	7136475	1,83447	0,195653
Error	58353267	15	3890218		
TIME	553705	2	276852	2,78918	0,077451
TIME*Group	1602552	2	801276	8,07255	0,001567
Error	2977778	30	99259		

CHI-SQUARE TESTS – CATEGORICAL MEASURES

Lumbo-Pelvic Stability

LEFT LEG

2-Way Summary Table: Observed Frequencies (Lumbo-pelvic stability)
Marked cells have counts > 10

Group	T0 LPS Left Pass	T0 LPS Left Fail	Row Totals
PEx	6	3	9
Con	3	5	8
Totals	9	8	17

Statistics: Group(2) x T0 LPS Left(2) (Lumbo-pelvic stability)

Statistic	Chi-square	df	p
Pearson Chi-square	1,446181	df=1	p=,22914
M-L Chi-square	1,465880	df=1	p=,22600

Group	2-Way Summary Table: Observed Frequencies (Lumbo-pelvic stability) Marked cells have counts > 10		
	T4 LPS Left Pass	T4 LPS Left Fail	Row Totals
PEx	9	0	9
Con	3	5	8
Totals	12	5	17

Statistic	Statistics: Group(2) x T4 LPS Left(2) (Lumbo-pelvic stability)		
	Chi-square	df	p
Pearson Chi-square	7,968750	df=1	p=,00476
M-L Chi-square	10,01210	df=1	p=,00156

Group	2-Way Summary Table: Observed Frequencies (Lumbo-pelvic stability) Marked cells have counts > 10		
	T8 LPS Left Pass	T8 LPS Left Fail	Row Totals
PEx	6	3	9
Con	6	2	8
Totals	12	5	17

Statistic	Statistics: Group(2) x T8 LPS Left(2) (Lumbo-pelvic stability)		
	Chi-square	df	p
Pearson Chi-square	,1416667	df=1	p=,70663
M-L Chi-square	,1424976	df=1	p=,70581

RIGHT LEG

Group	2-Way Summary Table: Observed Frequencies (Lumbo-pelvic stability) Marked cells have counts > 10		
	T0 LPS Right Pass	T0 LPS Right Fail	Row Totals
PEx	5	4	9
Con	3	5	8
Totals	8	9	17

Statistic	Statistics: Group(2) x T0 LPS Right(2) (Lumbo-pelvic stability)		
	Chi-square	df	p
Pearson Chi-square	,5542052	df=1	p=,45660
M-L Chi-square	,5578265	df=1	p=,45514

Group	2-Way Summary Table: Observed Frequencies (Lumbo-pelvic stability) Marked cells have counts > 10		
	T4 LPS Right Pass	T4 LPS Right Fail	Row Totals
PEx	9	0	9
Con	3	5	8
Totals	12	5	17

Statistic	Statistics: Group(2) x T4 LPS Right(2) (Lumbo-pelvic stability)		
	Chi-square	df	p
Pearson Chi-square	7,968750	df=1	p=,00476
M-L Chi-square	10,01210	df=1	p=,00156

Group	2-Way Summary Table: Observed Frequencies (Lumbo-pelvic stability) Marked cells have counts > 10		
	T8 LPS Right Pass	T8 LPS Right Fail	Row Totals
PEx	8	1	9
Con	2	6	8
Totals	10	7	17

Statistic	Statistics: Group(2) x T8 LPS Right(2) (Lumbo-pelvic stability)		
	Chi-square	df	p
Pearson Chi-square	7,137301	df=1	p=,00755
M-L Chi-square	7,758470	df=1	p=,00535

Transversus Abdominis Activation

Group	2-Way Summary Table: Observed Frequencies (Tra Activation Test) Marked cells have counts > 10		
	T0 Fail	T0 Pass	Row Totals
PEx	3	6	9
Con	2	6	8
Totals	5	12	17

Statistic	Statistics: Group(2) x T0(2) (Tra Activation Test)		
	Chi-square	df	p
Pearson Chi-square	,1416667	df=1	p=,70663
M-L Chi-square	,1424976	df=1	p=,70581

Group	2-Way Summary Table: Observed Frequencies (Tra Activation Test) Marked cells have counts > 10		
	T4 pass	T4 Fail	Row Totals
PEx	6	3	9
Con	4	4	8
Totals	10	7	17

Statistic	Statistics: Group(2) x T4(2) (Tra Activation Test)		
	Chi-square	df	p
Pearson Chi-square	,4857143	df=1	p=,48585
M-L Chi-square	,4871998	df=1	p=,48518

Group	2-Way Summary Table: Observed Frequencies (Tra Activation Test) Marked cells have counts > 10		
	T8 pass	T8 Fail	Row Totals
PEx	7	2	9
Con	6	2	8
Totals	13	4	17

Statistic	Statistics: Group(2) x T8(2) (Tra Activation Test)		
	Chi-square	df	p
Pearson Chi-square	,0181624	df=1	p=,89280
M-L Chi-square	,0181416	df=1	p=,89286

POST HOC ANALYSES

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = ,39243, df = 30,000

Cell No.	TIME	{1} 63,052	{2} 63,513	{3} 63,821
1	T0 Mass (kg)		0,097570	0,003405
2	T4 Mass (kg)	0,097570		0,336573
3	T8 Mass (kg)	0,003405	0,336573	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Between; Within; Pooled MSE = 80,123, df = 15,098

Cell No.	Group	TIME	{1} 63,196	{2} 63,524	{3} 63,682	{4} 62,890	{5} 63,500	{6} 63,978
1	PEx	T0 Mass (kg)		0,871908	0,574901	1,000000	1,000000	0,999969
2	PEx	T4 Mass (kg)	0,871908		0,994341	0,999989	1,000000	0,999998
3	PEx	T8 Mass (kg)	0,574901	0,994341		0,999967	1,000000	1,000000
4	Con	T0 Mass (kg)	1,000000	0,999989	0,999967		0,394833	0,018113
5	Con	T4 Mass (kg)	1,000000	1,000000	1,000000	0,394833		0,651885
6	Con	T8 Mass (kg)	0,999969	0,999998	1,000000	0,018113	0,651885	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = ,08088, df = 30,000

Cell No.	TIME	{1} 22,989	{2} 23,220	{3} 23,308
1	T0 BMI (kg.m-2)		0,061351	0,007405
2	T4 BMI (kg.m-2)	0,061351		0,642354
3	T8 BMI (kg.m-2)	0,007405	0,642354	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Between; Within; Pooled MSE = 8,1530, df = 15,200

Cell No.	Group	TIME	{1} 23,710	{2} 23,945	{3} 24,024	{4} 22,178	{5} 22,405	{6} 22,503
1	PEx	T0 BMI (kg.m-2)		0,510842	0,208972	0,872409	0,929658	0,948321
2	PEx	T4 BMI (kg.m-2)	0,510842		0,990843	0,794568	0,870259	0,897533
3	PEx	T8 BMI (kg.m-2)	0,208972	0,990843		0,764742	0,845691	0,875701
4	Con	T0 BMI (kg.m-2)	0,872409	0,794568	0,764742		0,605236	0,230075
5	Con	T4 BMI (kg.m-2)	0,929658	0,870259	0,845691	0,605236		0,981860
6	Con	T8 BMI (kg.m-2)	0,948321	0,897533	0,875701	0,230075	0,981860	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 1,4032, df = 30,000

Cell No.	TIME	{1} 70,735	{2} 71,720	{3} 71,598
1	T0 Waist Circumference (cm)		0,054963	0,102114
2	T4 Waist Circumference (cm)	0,054963		0,952014
3	T8 Waist Circumference (cm)	0,102114	0,952014	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Between; Within; Pooled MSE = 52,102, df = 15,551

Cell No.	Group	TIME	{1} 72,815	{2} 73,867	{3} 73,341	{4} 68,396	{5} 69,304	{6} 69,638
1	PEx	T0 Waist Circumference (cm)		0,431248	0,932237	0,801393	0,910817	0,93928
2	PEx	T4 Waist Circumference (cm)	0,431248		0,932237	0,634156	0,780449	0,82775
3	PEx	T8 Waist Circumference (cm)	0,932237	0,932237		0,721140	0,852766	0,89137
4	Con	T0 Waist Circumference (cm)	0,801393	0,634156	0,721140		0,646252	0,31618
5	Con	T4 Waist Circumference (cm)	0,910817	0,780449	0,852766	0,646252		0,99276
6	Con	T8 Waist Circumference (cm)	0,939282	0,827751	0,891379	0,316181	0,992769	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Between MSE = 153,50, df = 15,000

Cell No.	Group	{1} 73,341	{2} 69,112
1	PEx		0,242716
2	Con	0,242716	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 32,695, df = 30,000

Cell No.	TIME	{1} 23,000	{2} 29,647	{3} 30,588
1	T0 Ab Endurance		0,005552	0,001637
2	T4 Ab Endurance	0,005552		0,881361
3	T8 Ab Endurance	0,001637	0,881361	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Between; Within; Pooled MSE = 85,654, df = 25,502

Cell No.	Group	TIME	{1} 22,778	{2} 29,000	{3} 31,333	{4} 23,250	{5} 30,375	{6} 29,750
1	PEx	T0 Ab Endurance		0,222245	0,036946	0,999998	0,550721	0,636599
2	PEx	T4 Ab Endurance	0,222245		0,951825	0,793623	0,999621	0,999981
3	PEx	T8 Ab Endurance	0,036946	0,951825		0,484914	0,999936	0,999248
4	Con	T0 Ab Endurance	0,999998	0,793623	0,484914		0,158600	0,236157
5	Con	T4 Ab Endurance	0,550721	0,999621	0,999936	0,158600		0,999929
6	Con	T8 Ab Endurance	0,636599	0,999981	0,999248	0,236157	0,999929	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Between; Within; Pooled MSE = 80,294, df = 18,123

Cell No.	Group	TIME	{1} 17,556	{2} 22,778	{3} 25,222	{4} 17,750	{5} 18,750	{6} 21,125
1	PEx	T0 Arm Endurance		0,026322	0,000557	1,000000	0,999763	0,960048
2	PEx	T4 Arm Endurance	0,026322		0,634295	0,851971	0,934889	0,998828
3	PEx	T8 Arm Endurance	0,000557	0,634295		0,539118	0,676610	0,930369
4	Con	T0 Arm Endurance	1,000000	0,851971	0,539118		0,990355	0,354537
5	Con	T4 Arm Endurance	0,999763	0,934889	0,676610	0,990355		0,713556
6	Con	T8 Arm Endurance	0,960048	0,998828	0,930369	0,354537	0,713556	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 11,150, df = 30,000

Cell No.	TIME	{1} 17,647	{2} 20,882	{3} 23,294
1	T0 Arm Endurance		0,022144	0,000198
2	T4 Arm Endurance	0,022144		0,105734
3	T8 Arm Endurance	0,000198	0,105734	

Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 203,50, df = 30,000

Cell No.	TIME	{1} 87,059	{2} 81,176	{3} 98,235
1	T0 Leg Strength (kg)		0,461194	0,073686
2	T4 Leg Strength (kg)	0,461194		0,004335
3	T8 Leg Strength (kg)	0,073686	0,004335	

Cell No.	Group	TIME	{1} 92,778	{2} 85,556	{3} 95,000	{4} 80,625	{5} 76,250	{6} 101,88
	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 514,09, df = 26,011							
1	PEx	T0 Leg Strength (kg)		0,887838	0,999460	0,875721	0,667215	0,960038
2	PEx	T4 Leg Strength (kg)	0,887838		0,724142	0,997524	0,956087	0,678654
3	PEx	T8 Leg Strength (kg)	0,999460	0,724142		0,779852	0,542795	0,988229
4	Con	T0 Leg Strength (kg)	0,875721	0,997524	0,779852		0,989249	0,057611
5	Con	T4 Leg Strength (kg)	0,667215	0,956087	0,542795	0,989249		0,013431
6	Con	T8 Leg Strength (kg)	0,960038	0,678654	0,988229	0,057611	0,013431	

Cell No.	TIME	{1} 10,120	{2} 11,271	{3} 9,5688
	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 2,1989, df = 30,000			
1	T0 Minute Ventilation (L/Min)		0,077203	0,531158
2	T4 Minute Ventilation (L/Min)	0,077203		0,006201
3	T8 Minute Ventilation (L/Min)	0,531158	0,006201	

Cell No.	Group	TIME	{1} 9,6705	{2} 11,767	{3} 9,1156	{4} 10,626	{5} 10,713	{6} 10,079
	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 8,4570, df = 21,478							
1	PEx	T0 Minute Ventilation (L/Min		0,055162	0,966471	0,982804	0,974895	0,999704
2	PEx	T4 Minute Ventilation (L/Min)	0,055162		0,008112	0,963143	0,973615	0,834683
3	PEx	T8 Minute Ventilation (L/Min)	0,966471	0,008112		0,888250	0,863543	0,982197
4	Con	T0 Minute Ventilation (L/Min)	0,982804	0,963143	0,888250		0,999997	0,975442
5	Con	T4 Minute Ventilation (L/Min)	0,974895	0,973615	0,863543	0,999997		0,954276
6	Con	T8 Minute Ventilation (L/Min)	0,999704	0,834683	0,982197	0,975442	0,954276	

Cell No.	TIME	{1} 84,759	{2} 87,866	{3} 89,204
	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 25,769, df = 30,000			
1	T0 L PM (%)		0,192064	0,041296
2	T4 L PM (%)	0,192064		0,724946
3	T8 L PM (%)	0,041296	0,724946	

Cell No.	Group	TIME	{1} 86,833	{2} 89,027	{3} 90,136	{4} 82,426	{5} 86,560	{6} 88,155
	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 133,79, df = 19,533							
1	PEx	T0 L PM (%)		0,939132	0,738068	0,967067	1,000000	0,999890
2	PEx	T4 L PM (%)	0,939132		0,997092	0,843482	0,997668	0,999986
3	PEx	T8 L PM (%)	0,738068	0,997092		0,742540	0,986750	0,999209
4	Con	T0 L PM (%)	0,967067	0,843482	0,742540		0,586948	0,242800
5	Con	T4 L PM (%)	1,000000	0,997668	0,986750	0,586948		0,987982
6	Con	T8 L PM (%)	0,999890	0,999986	0,999209	0,242800	0,987982	

Cell No.	TIME	{1} 83,250	{2} 87,079	{3} 86,886
	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 20,961, df = 30,000			
1	T0 R PM (%)		0,053138	0,069069
2	T4 R PM (%)	0,053138		0,991784
3	T8 R PM (%)	0,069069	0,991784	

Cell No.	Group	TIME	{1} 86,089	{2} 88,284	{3} 87,440	{4} 80,057	{5} 85,724	{6} 86,263
	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 130,09, df = 18,692							
1	PEx	T0 R PM (%)		0,908560	0,988187	0,880030	1,000000	1,000000
2	PEx	T4 R PM (%)	0,908560		0,998737	0,677738	0,996989	0,999048
3	PEx	T8 R PM (%)	0,988187	0,998737		0,764318	0,999574	0,999933
4	Con	T0 R PM (%)	0,880030	0,677738	0,764318		0,163740	0,102691
5	Con	T4 R PM (%)	1,000000	0,996989	0,999574	0,163740		0,999898
6	Con	T8 R PM (%)	1,000000	0,999048	0,999933	0,102691	0,999898	

Cell No.	TIME	{1} 79,344	{2} 83,523	{3} 86,935
	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 27,456, df = 30,000			
1	T0 L PL (%)		0,067639	0,000686
2	T4 L PL (%)	0,067639		0,156672
3	T8 L PL (%)	0,000686	0,156672	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 193,07, df = 18,207							
	Group	TIME	{1} 81,415	{2} 84,651	{3} 87,178	{4} 77,014	{5} 82,253	{6} 86,662
1	PEx	T0 L PL (%)		0,777297	0,212761	0,985119	0,999995	0,968079
2	PEx	T4 L PL (%)	0,777297		0,906562	0,862220	0,999168	0,999646
3	PEx	T8 L PL (%)	0,212761	0,906562		0,665388	0,975647	1,000000
4	Con	T0 L PL (%)	0,985119	0,862220	0,665388		0,365992	0,010730
5	Con	T4 L PL (%)	0,999995	0,999168	0,975647	0,365992		0,553231
6	Con	T8 L PL (%)	0,968079	0,999646	1,000000	0,010730	0,553231	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 33,272, df = 30,000			
	TIME	{1} 79,649	{2} 84,360	{3} 85,355
1	T0 R PL (%)		0,060053	0,019239
2	T4 R PL (%)	0,060053		0,870681
3	T8 R PL (%)	0,019239	0,870681	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 186,14, df = 19,158							
	Group	TIME	{1} 81,242	{2} 85,171	{3} 85,176	{4} 77,856	{5} 83,448	{6} 85,556
1	PEx	T0 R PL (%)		0,700288	0,699279	0,995156	0,999399	0,985334
2	PEx	T4 R PL (%)	0,700288		1,000000	0,874067	0,999820	1,000000
3	PEx	T8 R PL (%)	0,699279	1,000000		0,873785	0,999817	1,000000
4	Con	T0 R PL (%)	0,995156	0,874067	0,873785		0,399658	0,111686
5	Con	T4 R PL (%)	0,999399	0,999820	0,999817	0,399658		0,976511
6	Con	T8 R PL (%)	0,985334	1,000000	1,000000	0,111686	0,976511	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between MSE = 587,85, df = 15,000		
	Group	{1} 73,389	{2} 57,758
1	PEx		0,036493
2	Con	0,036493	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 284,47, df = 30,000 TIME	{1} 64,765	{2} 66,573	{3} 66,763
1	T0 Protein (g.day-1		0,947778	0,936583
2	T4 Protein (g.day-1	0,947778		0,999484
3	T8 Protein (g.day-1	0,936583	0,999484	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 385,60, df = 39,558 Group	TIME	{1} 75,048	{2} 68,007	{3} 77,111	{4} 53,196	{5} 64,958	{6} 55,121
1	PEx	T0 Protein (g.day-1		0,94712	0,99983	0,22225	0,89506	0,31401
2	PEx	T4 Protein (g.day-1	0,94712		0,85854	0,63361	0,99955	0,75532
3	PEx	T8 Protein (g.day-1	0,99983	0,85854		0,14687	0,79731	0,21647
4	Con	T0 Protein (g.day-1	0,22225	0,63361	0,14687		0,72975	0,99991
5	Con	T4 Protein (g.day-1	0,89506	0,99955	0,79731	0,72975		0,84894
6	Con	T8 Protein (g.day-1	0,31401	0,75532	0,21647	0,99991	0,84894	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 138,11, df = 30,000 TIME	{1} 55,382	{2} 52,176	{3} 59,118
1	T0 Leg Endurance (sec)		0,708805	0,628036
2	T4 Leg Endurance (sec)	0,708805		0,213787
3	T8 Leg Endurance (sec)	0,628036	0,213787	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 384,31, df = 24,714 Group	TIME	{1} 46,056	{2} 48,667	{3} 64,778	{4} 65,875	{5} 56,125	{6} 52,750
1	PEx	T0 Leg Endurance (sec)		0,99685	0,02267	0,32919	0,89346	0,97989
2	PEx	T4 Leg Endurance (se	0,99685		0,06740	0,48003	0,96793	0,99798
3	PEx	T8 Leg Endurance (se	0,02267	0,06740		0,99999	0,94072	0,80177
4	Con	T0 Leg Endurance (se	0,32919	0,48003	0,99999		0,56781	0,25280
5	Con	T4 Leg Endurance (se	0,89346	0,96793	0,94072	0,56781		0,99204
6	Con	T8 Leg Endurance (se	0,97989	0,99798	0,80177	0,25280	0,99204	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between MSE = 18640,, df = 15,000		
	Group	{1} 120,67	{2} 149,17
1	PEx		0,468498
2	Con	0,468498	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 677,86, df = 30,000			
	TIME	{1} 136,41	{2} 134,41	{3} 131,41
1	T0 Sit & Reach (mm)		0,972833	0,842282
2	T4 Sit & Reach (mm)	0,972833		0,939904
3	T8 Sit & Reach (mm)	0,842282	0,939904	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 6665,1, df = 17,216							
	Group	TIME	{1} 106,44	{2} 135,56	{3} 120,00	{4} 170,13	{5} 133,13	{6} 144,25
1	PEx	T0 Sit & Reach (mm)		0,198379	0,875715	0,606147	0,982794	0,926576
2	PEx	T4 Sit & Reach (mm)	0,198379		0,799888	0,948469	1,000000	0,999920
3	PEx	T8 Sit & Reach (mm)	0,875715	0,799888		0,799996	0,999402	0,988763
4	Con	T0 Sit & Reach (mm)	0,606147	0,948469	0,799996		0,077790	0,372645
5	Con	T4 Sit & Reach (mm)	0,982794	1,000000	0,999402	0,077790		0,954311
6	Con	T8 Sit & Reach (mm)	0,926576	0,999920	0,988763	0,372645	0,954311	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 99259,, df = 30,000			
	TIME	{1} 1215,3	{2} 1375,3	{3} 1484,7
1	T0 METmin.wk-1		0,314385	0,047140
2	T4 METmin.wk-1	0,314385		0,574947
3	T8 METmin.wk-1	0,047140	0,574947	

Cell No.	Tukey HSD test; variable DV_1 (Phase 2 Pilates Intervention) Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 1363E3, df = 16,548 Group	TIME	{1} 1357,8	{2} 1926,7	{3} 1848,9	{4} 1055,0	{5} 755,00	{6} 1075,0
1	PEx	T0 METmin.wk-1		0,007362	0,027017	0,993930	0,889242	0,995578
2	PEx	T4 METmin.wk-1	0,007362		0,994844	0,647427	0,350154	0,668238
3	PEx	T8 METmin.wk-1	0,027017	0,994844		0,726958	0,420323	0,746587
4	Con	T0 METmin.wk-1	0,993930	0,647427	0,726958		0,419232	0,999995
5	Con	T4 METmin.wk-1	0,889242	0,350154	0,420323	0,419232		0,349296
6	Con	T8 METmin.wk-1	0,995578	0,668238	0,746587	0,999995	0,349296	