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EFFECT OF TWO DIFFERENT RESISTANCE TRAINING PROGRAMMES ON THE SPRINTING PERFORMANCE OF MEN AGED 18 TO 25

A thesis submitted to the Faculty of Health Sciences, University of Johannesburg, in fulfilment of the requirements for the degree Master of Sport Science.

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Johannesburg, 2014
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DECLARATION

I declare that this thesis is my own, unaided work. It is being submitted for the Degree of Master of Sport Science at the University of Johannesburg, Johannesburg. It has not been submitted before for any degree or examination at any other tertiary institution.

............................................................

............................................................ day of __________________2014
DEDICATION

This is dedicated to my parents, who
gave me the opportunities that I have today and for their love and support
and to my loving husband who supported me through it all.

ACKNOWLEDGEMENTS

I would like to express my sincere thanks and gratitude to the following persons and Institution for their guidance. Without their assistance, this study would not have been possible.

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- Richard Davies (Statistician, STATKON, University of Johannesburg) who assisted with my results, for his time and guidance.
- Jill Bishop (Independent Language Practitioner) who assisted with the language editing of my dissertation.
- Subjects who participated in this study, for their time, support, willingness and assistance.
- Institute for Sport Research, University of Pretoria for the use of their equipment to assess the subjects.
Resistance training (RT) is an essential element of fitness for most sports. Most athletic activities involve faster and more powerful movements than those found in maximal strength exercises. Thus athletes could be exceptionally strong but lack explosive power.

The aim of the study was to determine the possible effect of two different RT programmes on the sprinting performance of men aged 18–25. Body composition was assessed via anthropometrical measurements and lower extremity power was assessed via vertical jump and the Margaria Kalamen Power Test. Speed and acceleration will be assessed via a 40 meter, 60 meter, 80 meter and 100 meter sprint tests.

Thirty athletes were randomly divided into three groups (two experimental groups n=10 each and a control group n=10). Two different RT programmes (“General”, G and “Specialised”, SP) were applied for eight weeks in the two experimental groups, while the control group (C) had no form of strength training. Both training programmes included two sessions per week, each lasting 60 minutes.

Components that were tested included anthropometrical, body composition, lower extremity strength and 1RM measurements in regards to their 40m, 60m, 80m and 100m sprint time. Significant difference between SP, GP and C, at a P-value of 0.05, was determined by a dependant t-test. An independent t-test was used to determine significant difference between the three groups.

The results showed that there was a significant improvement on body fat (BF) % in SP (-1.71 ± 0.21), GP (-0.19 ± 0.57) and muscle mass (MM) % in SP (1.88 ± 3.23). There was a significant difference in explosive power (MK) for the specialised group (p=0.013) and the 60m sprint for the specialised group (p=0.047). One repetition maximum (1RM) bench press (p=0.005 SP and GP), 1RM deadlift (p=0.005 SP), 1RM power clean (p=0.005 SP) and 1RM squat (p=0.005 GP) improved in the relevant groups as indicated. There was a significant difference between the groups completing a 60m sprint (p=0.022), 80m sprint (p=0.057), 100m sprint (p=0.025) and 1RM bench strength test (p=0.007) at post-test. Positive correlations were found between MM% on 60m (p=0.021), 80m (p=0.01) and 100m (p=0.019) sprinting times and MK and 40m (p=0.015) sprinting time. The hypothesis was not supported in this study because it did not meet the set level of significance (p <0.05) as a predictor of training programme influence on sprint
performance. Based on the results, no significant difference was found between the two training groups’ mean change scores. However, both protocols over eight weeks of training resulted in an improvement in some of the pre- to post-test variables. It could be suggested that both training protocols can assist athletes to improve sprint performance.

KEY WORDS: resistance training; sprinting; explosive power; anthropometry; strength; 1RM; power.
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<th>Description</th>
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<tr>
<td>ATP</td>
<td>Adenosine-triphosphate-phosphagen</td>
</tr>
<tr>
<td>BF</td>
<td>Body fat</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
<tr>
<td>C</td>
<td>Control group</td>
</tr>
<tr>
<td>cm</td>
<td>Centimeter</td>
</tr>
<tr>
<td>CMJ</td>
<td>Countermovement jumps</td>
</tr>
<tr>
<td>CNS</td>
<td>Central nervous system</td>
</tr>
<tr>
<td>CSA</td>
<td>Cross-sectional area</td>
</tr>
<tr>
<td>CT</td>
<td>Complex training</td>
</tr>
<tr>
<td>D</td>
<td>Range of motion</td>
</tr>
<tr>
<td>EMG</td>
<td>Electromyogram</td>
</tr>
<tr>
<td>ES</td>
<td>Effects Size</td>
</tr>
<tr>
<td>f</td>
<td>Frequency</td>
</tr>
<tr>
<td>F</td>
<td>Muscular force</td>
</tr>
<tr>
<td>FG</td>
<td>Fast glycolytic</td>
</tr>
<tr>
<td>FOG</td>
<td>Fast oxidative glycolytic</td>
</tr>
<tr>
<td>GP</td>
<td>General training programme</td>
</tr>
<tr>
<td>GF</td>
<td>Gravitational force</td>
</tr>
<tr>
<td>GRF</td>
<td>Ground reaction force</td>
</tr>
<tr>
<td>i</td>
<td>Intensity</td>
</tr>
<tr>
<td>kg</td>
<td>Kilogrammes</td>
</tr>
<tr>
<td>LRT</td>
<td>Latent reaction time</td>
</tr>
<tr>
<td>m</td>
<td>Meter</td>
</tr>
<tr>
<td>m.s(^{-1})</td>
<td>Meters per second</td>
</tr>
<tr>
<td>MBT</td>
<td>Medicine ball throw</td>
</tr>
<tr>
<td>MK</td>
<td>Margaria Kalamen</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------</td>
</tr>
<tr>
<td>mm</td>
<td>Millimetres</td>
</tr>
<tr>
<td>MM</td>
<td>Muscle mass</td>
</tr>
<tr>
<td>MSF</td>
<td>Mass specific force</td>
</tr>
<tr>
<td>MU s</td>
<td>Motor units</td>
</tr>
<tr>
<td>N</td>
<td>Number</td>
</tr>
<tr>
<td>1RM</td>
<td>One repetition maximum</td>
</tr>
<tr>
<td>P</td>
<td>Power</td>
</tr>
<tr>
<td>p</td>
<td>Significant difference</td>
</tr>
<tr>
<td>PT</td>
<td>Plyometric training</td>
</tr>
<tr>
<td>RPI</td>
<td>Reciprocal index</td>
</tr>
<tr>
<td>RT</td>
<td>Resistance training</td>
</tr>
<tr>
<td>s</td>
<td>Total of exercises</td>
</tr>
<tr>
<td>SL</td>
<td>Stride length</td>
</tr>
<tr>
<td>SO</td>
<td>Slow oxidative</td>
</tr>
<tr>
<td>SP</td>
<td>Specialised training programme</td>
</tr>
<tr>
<td>SR</td>
<td>Stride rate</td>
</tr>
<tr>
<td>SSC</td>
<td>Stretch shortening cycle</td>
</tr>
<tr>
<td>t</td>
<td>Time (seconds)</td>
</tr>
<tr>
<td>T</td>
<td>Split Time</td>
</tr>
<tr>
<td>TMS</td>
<td>Trans-cranial magnetic stimulation</td>
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<tr>
<td>TU KS</td>
<td>University of Pretoria</td>
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<tr>
<td>V</td>
<td>Velocity</td>
</tr>
<tr>
<td>VJ</td>
<td>Vertical jump</td>
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<td>Wind resistance</td>
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CHAPTER ONE: RESEARCH PROBLEM AND GOAL OF STUDY

1.1 INTRODUCTION

The development of physical performance is influenced by anatomical, physiological and psychological heredity as well as by the response or adaptation shown to training. The performance capacity of a sprinter is a complicated function made up of morphological, functional, physiological, psychological and motor components; it can then be divided into primary and secondary capacities. For a sprinter, primary capacities are speed and power (explosiveness), while mobility and reaction time are regarded as secondary capacities (Kutsar, 1991).

Strength (also known as resistance) training can be defined as a method of improving muscular strength by gradually increasing the ability to resist force through the use of free weights, machines or the person’s own body weight. Strength training sessions are designed to impose increasingly greater resistance, which in turn stimulates development of muscle strength to meet the added demand (Baechle & Earle, 2000).

Considering the relationship between strength and other performance activities, it is reasonable to believe that when young people perform resistance training (RT) it could enhance their performance abilities. Programmes should consist of free weight training, which is one of the most common forms of strength training for youth with a frequency of twice per week for duration of eight weeks as the norm (Baechle & Earle, 2000).

The expectation that both groups will significantly enhance their fitness after adhering to eight weeks of training is further influenced by the existing body of literature. This literature seems to conclusively support the ability of adolescents to enhance their strength (Faigenbaum & Mediate, 2005; Cowan, Bolen, Weatherby & Foster, 2007; Szymanski, D.J. Szymanski, J.M. Bradford, Schade & Pascoe, 2007; Warburton, Bredin, Horita, Zbogar, Scott, Esch & Rhodes, 2007).
Studies by Weyand and Davis (2005) indicate that faster running speeds are achieved with greater ground forces and not with more rapid leg movements (cadence), bearing in mind that the traditional equation for running speed is as follows:

\[ \text{Running velocity} = \text{Stride length} \times \text{Stride rate} \] (Komi, 1983)

But this theory is challenged in Weyand, Sternlight, Bellizzi and Wright’s (2000) study which identified the two factors influencing faster running. These are mass specific force (MSF) and greater ground reaction forces. Strength training and training on the track must be geared to the MSF. Any form of training that does not affect improvement in one or both of the factors is considered unnecessary.

This all leads to the new ideas of strength training. The “M” in MSF, namely mass, is important to consider. To strive for mass in order to become stronger is a difficult phenomenon for a large number of athletes at all levels, and the main method is to use performance-enhancing drugs, which improve performance for some while destroying the careers of others (Ross, 2006).

The physiology involved in MSF to increase strength without increasing mass, requires a basic understanding of muscle physiology. Human muscle is made up of fast- and slow-twitch muscle fibres, divided into three groups.

The slow oxidative (SO) muscle fibres contain plenty of myoglobin and mitochondria, contract slowly, but are capable of working over a long period of time. The fast glycolytic (FG) muscle fibres synthesise adenosine-triphosphate-phosphagen (ATP) aerobically as well as anaerobically, contract reasonably fast, and tire more slowly than SO fibres. The world’s leading sprinters, for example, have 80 to 85% FG muscle fibres, while distance runners have 85 to 90% SO muscle fibres (Martini, 2004).

In Pavel Tsatouline’s book *Power to the People: Russian Strength Training Secrets for Every American* (2000), he states: “If you compare strength training to car racing, conventional bulking up is an unimaginative increase of the engine size.” Increasing the physical size of the engine neither automatically nor maximally increases the
horsepower. The same applies to running speed, as more bulk does not mean increased speed (Ross, 2006).

According to Ross (2006), adding body weight (the largest proportion of this increased body weight should be lean mass, and as such, while lean mass has to increase to increase the body weight, fat mass should decrease similarly) to the body will result in a proportional increase in the amount of force applied to the ground in order to maintain the same rate of speed.

1.2 PROBLEM STATEMENT

There is no consensus regarding how and to what extent sprinters should train to obtain optimal functional capacity with a minimum of weight gain or adding more bulk, but still become faster.

Unfortunately, research into the differences between different RT programmes is limited in terms of knowing whether certain RT exercises may add pure muscle mass but do not enhance the sprinting performance capacity of males. Therefore, it would be beneficial to compare the effects of two different RT programmes on the sprinting performance of men aged 18–25.

1.3 AIM OF THE STUDY

Primary aim: The primary aim is to determine the effect of two different RT programmes, namely specialised (SP) and general (GP), on the sprinting performance of men aged 18–25 and to compare the two different RT programmes.

Secondary aim: The secondary aim is to assess the correlation between different physical measurements and sprinting (40m, 60m, 80m and 100m) times.
1.4 HYPOTHESIS

There will be a statistically significant correlation (p≤0.05) between either of the following measurements during both RT interventions, but the SP will have a more significant correlation:

- Explosive power (Vertical Jump and Margaria Kalamen Power Test) (Gore, 2000)
- 1RM Strength test (Baechle & Earle, 2000)
- 40m, 60m, 80m and 100m speed (Gore, 2000)
- Anthropometrical measurements (Jones, Olds, Stewart & Carter, 2006)
CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this study is to investigate at the possible effect of an SP and a GP RT programme on sprinting performance in men aged 18–25. Sections included in this review of literature are factors contributing to sprinting performance (muscular, anthropometry, neuro-muscular adaptations and biomechanics); prediction of sprint speed through strength and power; and the effects of different training methods on sprinting performance.

2.2 FACTORS CONTRIBUTING TO SPRINTING PERFORMANCE

Sprinting has been studied from biomechanical and physiological perspectives to establish which muscles are the prime movers and what forces and angles are needed to produce the greatest sprinting performances (Nesser, Latin, Berg & Prentice, 1996; Majumbar & Robergs, 2011). This led to exceptionally advanced performances by today’s male athletes, which are the results of a multifaceted blend of many factors (MacDougall & Wenger, 1991). Kraaijenhof (1990) and Cronin and Blazevich (2009) identified the factors affecting the 100m sprint results, namely: muscular system, anthropometry, neuro-muscular adaptations and biomechanics.

2.2.1 The muscular system as a possible factor affecting speed

Researchers believe that muscle fibre composition (see Chapter 1 for muscles fibre composition) is genetically determined and minimally affected by training (Costill, Daniels, Evans, Fink, Krahenbuhl & Saltin, 1976; Kutsar, 1991). Although muscle fibre size is greatly affected by training and age, muscle fibre areas increase by 15–20-fold (hyperthropy) from birth to young adulthood (Kutsar, 1991). Significant improvements in muscle force output as a result of strength training have either been associated with or without specific increases in muscle fibre cross-sectional areas by MacDougall, Elder, Sale, Moroz and Sutton (1980); Coyle, Feiring, Rotkis, Cote, Roby, Lee and Wilmore.
De Lorne and Watkins (1951) report a relationship between strength gain and an increase in muscle girth or cross-sectional area (CSA). Rodahl and Horvath (1962) identify a strong relationship between absolute strength and cross-sectional area of the muscle. However, Ross, Leveritt and Riek (2001) acknowledge that an increased ability to generate force does not always occur with simultaneous increase in muscle cross-sectional area. Korhonen, Cristea, Alen, Hakkinen, Sipila, Mero, Viitasalo, Larsson and Suominen (2006) and Korhonen, Mero, Alen, Sipila, Hakkinen, Liikavainio, Viitasalo, Haverinen and Suominen (2009) indicate a possible relationship with 100m sprint performance and the CSA of FG fibres. In their study the authors note the decrease in the performance of sprinters from the ages of 18 to 84. The fibre type percentage did not change, but the CSA did change by between 6 and 11% per decade depending upon the fibre type. A recent study by Brännström, Rova and Yu (2013) showed that increased maximal muscular power after tapering also relies on higher neural drive and increased muscle fibre CSA, especially in FG muscle fibres. Complete rest is a special form of tapering and it usually leads to sustained maximal power.

This equates with changes in sprint performance, vertical jump performance, rate of force development, maximal force, stride length, stride frequency and even one repetition maximum (1RM) (half squat) (Korhonen et al., 2006; Korhonen et al., 2009). Leaner legs with relatively more FG fibres presumably increase stride frequency by allowing limbs to be repositioned more rapidly (Hill, 1950; Gray, 1959; Hildebrand, 1960; Jones & Lindstedt, 1993; Van Ingen, De Koning & De Groot 1994) and long limbs are believed to extend stride lengths by providing greater propulsion (Hill, 1950; Gray, 1959; Hildebrand, 1960; Jones & Lindstedt, 1993; Van Ingen et al., 1994). Cristea, Korohen, Hakkinen, Mero, Ale’n, Sipila, Viitasalo, Koljonen, Suominen and Larsson (2008) indicate that increasing the CSA of particularly the FG muscle fibres seems to increase the performance of a sprinter, although this would be limited by the genetic potential to develop FG muscle fibres.
Jaric and Markovic (2013) conclude that the optimum load in a maximum vertical jump is one’s own body mass, regardless of the strength of the lower limb muscles, because of the several neuro-mechanical mechanisms involved.

Councilman (1986) suggested that a 25–41 cm vertical jump indicates a predominance of SO muscle fibres and appropriateness for endurance events. When a vertical jump of 41–58 cm takes place there is an even scattering of SO and FG muscle fibres, and performances above 58 cm show a predominance of FG fibres. Explosive power exercises may not directly increase hypertrophy or muscle strength, although the muscular systems contribute force to accelerate the limbs.

Explosive exercises increase the recruitment of motor units (MUs) as well as the firing rate of the motor neuron. Increased power development yielded through explosive exercise training may also be attributed to the recoil action of the elastic muscle tissues. Eccentric muscle action immediately preceding concentric contraction (the mechanism in which most explosive exercises take place) will increase the concentric force generated due to stored elastic energy (Bosco, Luhthanen & Komi, 1983; Wilson, Newton, Murphy & Humphries, 1993; Komi, 1979; Bompa, 1994).

Cissik (2010) recommends that training should focus on both maximal strength and power (weightlifting and plyometrics) based on the importance of FG fibres in sprinting performance. The programme should focus on training the athletes to exert force against the ground (Cissik, 2010). Squats, deadlifts, romanian deadlifts, cleans, pulls, snatches and jerks should be prioritised ahead of exercises that do not train the athlete to exert force against the ground.

Miller, Umberger and Caldwell (2012b) suggest that the force-velocity relationship of skeletal muscle plays a critical limiting role in the maximum speed at which humans can sprint. Results indicate that the force-velocity relationship is indeed the most important contractile property of muscle regarding limits to maximum sprinting speed, but that other muscular properties should be considered when explaining limits to maximal human performance. Miller et al. (2012b) also suggest that the shape parameters (Ar – a force velocity constant), which primarily determine the amount of
muscle force that can be produced at the moderate shortening velocities, play a role in limiting the maximum sprinting speed.

2.2.2 Anthropometry factors

The attention paid to body composition has increased since the early 1960s (Auckland, Elliott & Bloomfield, 2009). This interest is driven by the desire to maximally enhance athletes’ sprinting abilities (Docherty, Robbins & Hodgson, 2004). Athletes and coaches both recognise that success in a range of sports not only demands a certain physique but also a certain ratio of muscle mass to fat mass. Body size variables like height and mass have been incorporated into analyses of sprinters (Mann, Moran & Dougherty, 1986; Mero & Komi, 1985; Uth, 2005).

Sprinting demands fast reaction time, high movement speed and explosive strength, therefore the body type of sprinters is different from that of athletes in other events (Ansari, Paul & Sharma, 2012). Sprinters need to develop larger muscle mass and are capable of higher speeds and more rapid acceleration (Bohn, Shan, Attermeyer, Schutte & Nicol, 1998). Sprint performance depends on the capacity to generate power and to achieve a high ratio between body mass and power (Mero, Luhtanen, Viitasalo & Komi, 1981; Van Ingen et al., 1994; Weyand et al., 2000; Chelly & Denis, 2001; Cronin & Sleivert, 2005).

In past years, research was done in an attempt to provide additional insight into the degree that an athlete’s body elements and composition affect performance in different sports (Reilly, Secher, Snell & Williams, 1990). Anthropometric measurements were largely used to describe an athlete’s body composition within a specific sport (Larsen, Christensen, Nolan, Sondergaard, 2004; Slater, Rice, Mujika, Hahn, Sharpe & Jenkins, 2005); associate different disciplines and/or the sexes within a sport (Bourgeois, Claessens, Vrijens, Phillippaerts, van Renterghem & Thomis, 2000; Perez-Gomez, Rodriguez, Ara, Olmedillas, Javier & González Henriquez, 2008; Vicente-Rodriguez, Dorada, Ara, Perez-Gomez, Olmedillas & Delgado-Guerra, 2007); and relate key anthropometric variables to performance (Kerr, Spinks, Leicht & Sinclair, 2008; Knechtle, B, Knechtle, P, Schulze & Kohler, 2008; Slater et al., 2005). Stoggl, Enqvist,
Muller and Holmberg (2010) conclude that body dimensions do not seem to be predictors of pure speed, whereas some trainable parameters like body weight and lean mass indicate high correlations with performance.

Somatotyping illustrates trends in the human body shape and their appropriateness to particular sports. It has been used to assess the physical body shape and give a rating from 1 to 7 (least to most dominant) on the following characteristics: endomorph (roundness), mesomorph (muscularity) and ectomorph (leaness) (Heath & Carter, 1967). Somatotyping indicates a moderate to high musculoskeletal strength relative to height. Athletes are given a rating on all three. Pyke and Watson (1978) suggest that the average somatotype for sprinters in the 100m sprint event is 2:5.5:3 (high in mesomorphy, low in endmorphy and ectomorphy).

Male sprinters have values of 1.5:5:3 (Carter, 1984). For male as well as female sprinters, somatotypes are indicative of low relative fatness compared to normal populations (Abe, Fukashiro, Harada & Kawamoto, 2001; Kumagai, Abe, Brechue, Ryushi, Takano & Mizuno, 2000). Both male and female sprinters tend to be heavier than other runners (Radford, 1990), exhibiting a larger muscle mass (Cureton, Collins, Hill & McElhannon, 1998), which is consistent with capabilities of high speed and rapid acceleration.

Muscle mass is crucial in the acceleration phase due to an increase in the stride length and height in the second part of the sprint while the stride length is maintained (Kraaijenhof, 1990; Korchemny, 1994; Jarver, 2004) where it is important to overcome inertia and increase stride length (Brown, Kenwell, Maraj & Collins, 2008). Weyand and Davis (2005) assessed the maximum running speed of 18 athletic subjects. During fast running, ground and muscle support forces can exceed the body’s weight by as much as 2.5 and 5-fold, respectively (Weyand et al., 2000; Wright & Weyand, 2001).

The study proved that regardless of specialisation or sex, a single constant accurately links the ideal body mass for running performance to the ground support force required of the performer and concluded that there was a specific relationship between body weight, height and event-specific ground support force requirements that spans the
entire continuum of specialisations and applies to both male and female runners (body weight(kg) = mass specific support force x height$^2$ (m) x a constant; $N=16$ group means, $R^2=0.97$; where the ideal mass constant, D=10 kg m$^{-2}$) (Weyand & Davis, 2005).

Watts, Coleman and Nevill (2012) researched which anthropometric parameters characterised the most successful world-class sprinters. Results suggest that while body mass index is associated with success in both male and female world-class sprinters, which suggests an influence of muscle mass on sprinting performance, the reciprocal ponderal index has emerged as a more significant factor for success. Taller, more linear sprinters achieve greater success, measured by sprint speed.

Aerenhouts, Delecule, Hagman, Taeymans, Debaere, van Gheluwe and Clarys (2012) examined the physical characteristics and somatotype of junior and senior athletes in relation to sprint start and acceleration performance. Results indicate that greater muscularity in senior compared to junior athletes did not result in better sprint start dynamics, but the senior athletes did accelerate more quickly. Aerenhouts et al. (2012) suggest that strength training should be combined with sufficient attention to technical skills to allow a positive transfer.

2.2.3 Neuro-muscular adaptations

Performance in speed training has traditionally been believed to be largely dependent on genetic factors, with only minimal improvements occurring as a result of training (Miller, 1984). Muscle fibre type has been purported to be one of the principal factors underlying sprint performance (Mero et al., 1981), with enzymatic adaptations and hypertrophy of prime movers believed to be largely responsible for post-training improvements in sprint performance. Other mechanisms of adaptation are required and would likely include neural improvements. RT literature suggests that neural adaptation occurs after training involving repeated sessions of brief, intense exercise (Hakkinen & Komi, 1983; Hakkinen, Komi & Alen, 1985; Hakkinen & Komi, 1985).

Milner-Brown, Stein and Lee (1975) demonstrated improved synchronisation of motor unit firing in weightlifters. The reliable observations of improved muscle force
production in strength training studies, irrespective of whether muscle hypertrophy has occurred, includes neural adaptation as suggested previously (Coyle et al., 1981).

Moritani and De Vries (1979) propose a method to distinguish between the proportional contributions of neural factors and hypertrophy during strength training. If strength gain is brought about by “neural factors” such as learning to disinhibit muscular force, as suggested by Ikai and Steinhaus (1961) and Laycoe and Marteiniuk (1971), one would expect to see increases in maximal activation without any change in force per fibre or MUs innervated. However, if strength gain is entirely attributable to muscular hypertrophy, then the force of the fibre is increased by virtue of the hypertrophy with no change in maximal EMG.

The time frame in strength gain related to the contributions of neural factors and hypertrophy was studied in seven young males and eight young females during an eight-week isotonic strength training programme. The results indicate that as hypertrophy became the predominant source of strength gain after the first three to five weeks, a detraining of the neural adaptations occurred. The neural factors accounted for the larger proportion of the initial strength increment, and thereafter both neural factors and hypertrophy contributed to the further increase in strength. It is therefore advisable to train in such a manner as to elicit both neural and hypertrophy adaptations to achieve maximum strength gains. They conclude that early changes in strength may largely be attributed to neural factors with a gradual increased contribution of the hypertrophy factor as the training progressed (Moritani & De Vries, 1979).

Houston, Froese, Valeriote, Green and Ranney (1983) investigated biochemical, histochemical and contractile properties associated with strength training and detraining. The study tested six adult males during and after 10 weeks of dynamic strength training for the quadriceps muscle group of one leg, as well as during and after 12 subsequent weeks of detraining. Results showed that fibre area changes were only found in the trained leg. There were no changes in muscle enzyme activity and only modest changes in FG fibre areas in the trained leg. The significant changes in peak torque outputs in both legs suggest that neural adaptations play a prominent role in strength performance with training and detraining.
Past research used neurophysiological techniques such as trans-cranial magnetic stimulation (TMS), H-reflex and V-waves to study the neural adaptations resulting from strength training over a period of 3–14 weeks (Aagaard, Simonsen, Andersen, Magnusson & Dyhre-Poulsen, 2002; Adkins, Boychuk, Remple & Kleim, 2006; Beck, Taube, Gruber, Amtage, Gollhofer & Schubert, 2007; Carroll, Barton, Hsu & Lee, 2009; Carroll, Riek & Carson, 2000; Duclay, Martin, Robbe & Pousson, 2008; Falvo, Sirevaag, Rohrbaugh & Earhart, 2010; Folland & Williams, 2007; Gabriel, Kamen & Frost, 2006; Jensen, Marstrand & Nielsen, 2005; Hortobagyi, Richardson, Lomarev, Shamim, Meunier, Russman, Dang & Hallett, 2009; Griffin & Cafarelli, 2007; Griffin & Cafarelli, 2005; Van Vugt & Van Dijk, 2011; Lee, Gandevia & Carroll, 2009).

The central nervous system (CNS) responses to strength training might be similar to a process of “learning” to optimise muscle activation patterns to enhance torque production in the desired direction (Carroll et al., 2000; Carson, 2006). Selvanayagam, Riek and Carrol (2011) pursued this topic by testing the idea that strength training might share similar mechanisms with some forms of motor learning. Since ballistic motor learning is accompanied by a shift in muscle twitches induced by TMS toward the training direction, they investigated whether the changes also occurred after single isometric strength training sessions with various contraction durations and rate of force development. They suggest that early neural responses to strength training, which share similar cortico-spinal changes to motor learning, might reflect an important process that precedes more long-term neural adaptations that ultimately enhance strength. That is, if a change in the CNS is to enhance strength, it must act by increasing the activation of muscles that contribute to torque in the desired direction (i.e. agonists or synergists), or by reducing the activation of muscles that oppose torque in the desired direction (i.e. antagonists).

Choukou, Laffaye and Heugas-De Panafieu (2012) investigated human adaptations to fatigue induced by track sprint repetitions. Results show that velocity decreased during the second phase (30–80m) of the entire 100m due to neuro-muscular adaptations to fatigue used by skilled athletes.

Figure 2.1: Factors affecting both Stride Length (SL) and Stride Rate (SR), which are most influenced by the nervous system (Ross et al., 2001)
The review of literature by Ross et al. (2001) summarised (figure 2.1) that performance in sprint exercise is determined by the ability to accelerate, the magnitude of maximal velocity and the ability to maintain velocity against the onset of fatigue. These factors are strongly influenced by metabolic and anthropometric components. Improving the temporal sequencing of muscle activation and/or improving FG fibre recruitment may contribute to superior sprint performance.

Ultimately, training modalities and intensity will dictate the body’s neurological and muscular adaptations (Majumbar & Robergs, 2011).

2.2.4 Biomechanics of sprinting

The biomechanics of sprinting are complex, therefore a technical and analytical approach is needed to master sprinting skill and enable the athlete to successfully combine the actions of legs, arms and trunk in order to obtain smooth, coordinated movement (Ansari et al., 2012). The amount of interest in sprinting has encouraged a significant increase in research and assessment (Novacheck, 1998).

There are different interpretations of the correct methods to develop speed that have led to a variety of successful training systems; applying current scientific knowledge is a big challenge to most speed-training coaches (Alexander, 1992; Anderson, 1996; Cavanagh, 1987; Adelaar, 1986; Vaughan, 1984; Williams, 1985).

2.2.4.1 Kinesthesis of running

Sprinting at maximal speed, biomechanically and aerodynamically, requires an athlete to have a slightly forward lean in the upper body. This in return optimises the striking angle of the foot (Ross et al., 2001). Sprinting involves falling forward and recovering (kinesthesis), which can be discussed in two parts, namely the drive or flight phase and the recovery phase (McFarlane, 1987).
2.2.4.1.1 Drive (flight) phase

The first phase of sprinting (running) occurs when the foot applies a force to the ground in an attempt to accelerate the body’s centre of gravity forward. Impetus to the ground (force x time) is provided by the hip and knee extensors in combination with the ankle plantar flexors.

The support phase is the stage from when the foot makes contact with the ground until the hips are directly above the contact foot, and must be initiated and enhanced by plantar flexion of the ankle to lift the body and keep the hips high. Repositioning the limbs more quickly will result in a reduction of the impulse during this phase, which is required to maximise sprint speeds, ultimately having an adverse effect on the overall performance (Weyand, Sandell, Prime & Bundle, 2010).

Maximum torque (force) at the ankle joint is determined by the gastrocnemius, soleus and the flexor hallucis longus. This force needs to carry the support phase into the drive phase, where full extension of the hip, knee and ankle joints reveals that this has occurred. This thrust is originated by the contraction of the hip joint extensors (gluteus maximus and hamstrings) and knee extensors (quadriceps) in concurrence with the plantar flexors of the ankle. Strength in the rectus abdominus and rectae spinae greatly assists the ability to run upright with an erect posture. All force must go through the centre of the body (pillar) when running, and strength in this area is crucial (McFarlane, 1987).

2.2.4.1.2 Recovery phase

The foot is not in contact with the ground during this phase. It is inaugurated when the foot clears the ground, followed by a kick back and high knee lift with flexion at the hip, knee and ankle joints. The flexed joints shorten the whole lower limb complex, decreasing its moment of inertia about the hip joint, permitting maximum angular velocity. It must be realised that the entire sprinting action requires the total coordination of the driving leg and the recovery leg in each of the phases, which in turn
depends on the magnitude and timing of the torques applied to each of the hip, knee and ankle joints (McFarlane, 1987).

The heel is pulled to the gluteus as the driving foot leaves the ground and begins the recovery phase. At the high knee action and the advance of the lower leg through a swinging phase, the foot becomes dorsi-flexed. This action is generated by the hip flexors (iliopsoas, rectus femoris and pectineus), which decrease the moment of inertia while increasing angular velocity. It should be noted that the recovery foot is pulled through above the driving knee (McFarlane, 1987). Novacheck (1998) report that during sprinting, stance and flight phase durations are respectively about 40% and 60% of the step cycle, while in elite sprinters, duration can reach 20% and 80% respectively.

Due to the constraints (minimum swing times and maximum contact lengths that runners can use) of swing and support duration, Weyand et al. (2000) conclude that sprint speed is predominantly influenced by the ability to create greater muscular force toward the ground and to minimize ground contact time, using the transference of power down and back up the kinetic chain (Todd, Brown & Vescovi, 2012). In order to improve speed, athletes must therefore focus on training the ability to produce a higher power output during a shorter ground contact phase, rather than focusing on fast leg recovery during the flight/drive phase (Weyand et al., 2000).

2.2.4.2 Movement coordination

Improved movement coordination will have a greater impact on muscle force gains in more complex, multi-joint exercises (Daley, Felix & Biewener, 2007). Biomechanical research suggests that the muscles around the hip are more important than those around the knee for sprinting (Guskiewicz, Lephart & Burkholder, 1993). The power that is generated around the hip acts as a kinetic chain (the hip flexors assist in pulling the leg forward) and contributes to a faster stride frequency due to the faster flexion of the hip and leg recovery (Young & Elliot, 2001). The hip extensor drives the body forward and performs concentric and eccentric actions during the ground contact time (Guskiewicz et al., 1993; Faccioni, 1994). The lower body receives considerably more attention in
sprint running research than the upper body. The upper body, however, has the important role of counterbalancing the actions of the lower body.

There are different interpretations of the correct methods to develop speed, which have led to a variety of successful training systems. Sprint running is symptomatically a complex and multi-joint exercise (Majumdar & Robergs, 2011), but applying current scientific information is the greatest challenge to most training coaches. Komi (1983) suggests a formula to calculate speed:

\[
\text{Running velocity} = \text{Stride length} \times \text{Stride rate}
\]

Sprinting speed or running velocity, stride length multiplied by stride rate, is the ability to achieve high velocity (Paradisis & Cooke, 2006). To enhance an athlete’s speed, one or both parts of this equation must be improved (Ecker, 1996; Dintiman & Ward, 2003).

Stride length depends on the body height or leg length, while stride rate primarily depends on the CNS functioning at the cortical and subcortical level and it is strongly genetically determined (Mann & Herman, 1985; Mero, Komi & Gregor, 1992; Donati, 1995; Locatelli & Arsac, 1995; Coh, Mihajlovic & Praprotnik, 2001; Hunter, Marshall & McNair, 2004). When comparing faster athletes (sprinters) to slower athletes (sprinters), stride length is found to be greater for faster runners (Cowan, Bolen, Weatherby and Foster, 2007; Mackala, 2007).

Wdowski, Gittoes, Irwin, Nokes and Kerwin (2012) investigated the short-term biomechanical adaptations of maximum running in response to two sprint protocols, namely anticipated and unanticipated. Significant increases for the anticipated condition \((p \leq 0.05)\) were found in the step length \((0.03\text{m})\) and flight distance \((0.02\text{m})\) over the first 20m. These short-term technique adaptations indicate that sprint-training protocols for open skill sports may facilitate greater specificity in training by integrating unanticipated movement tasks.

Stride frequency is directly related to the number of FG fibres in the muscle and involves selective recruitment of MUs to improve the firing frequency of the correct
MUs to give the greatest rate of force production. Sprinters will have more FG fibres (primarily in the flexors), which have a higher threshold for firing and will not fire under moderate workloads. Armstrong and Cooksey (1983) and Cavagna and Kaneko (1977) indicate that faster individuals take considerably longer strides than slower individuals. The same individual, running at increasingly faster speeds, will show increasingly greater stride lengths, as reported by Williams (2000). However in both scenarios, the duration of the support phase is reduced by approximately 45–50% (Mann et al., 1986).

Stride frequency seems to be greater in the faster athletes (Mackala, 2007) but not shown in the study by Cowan et al., (2007). Analysing the 2003 World Championships, Paruzel-Dyja, Walaszczyk and Iskra (2006) found statistically significant correlations ($r=-0.39$) between stride frequency and 100m time for female sprinters. There was a statistically significant correlation between stride length and 100m time for male sprinters ($r=-0.43$).

Babić, Čoh and Dizdar (2011) researched the possible differences among subjects of different sprinting abilities in the variables of running dynamics (latent reaction time (LRT) and split times (T) of running over 10m) in the 100m sprint event, as well as in the variables of kinematic indicators (stride frequency, stride length, foot-ground contact duration, airborne phase duration). The research was conducted on a sample of 133 male physical education teacher students, age 21.7 ± 1.08 years, body height 180.8 ± 6.98 cm and body mass 76.6 ± 7.62 kg. One significant discriminant function was obtained distinguishing the group of students who performed well from all the other groups of students with poorer sprint performance. The group that had the best running technique was characterised by the shortest foot-ground contact time in the phases of starting acceleration and maximum speed running, and a larger stride length in the phase of maximum speed running.

2.2.4.3 Ground reaction force (GRF)

The acceleration of the centre of mass of a sprinter is determined by three external forces, namely ground reaction force (GRF), gravitational force (GF) and wind
resistance (WR). Of these three forces, the athlete has the most control over GRF (Hunter, Marshall & McNair, 2005). Furthermore GRF can be divided into horizontal (anterior-posterior) and vertical components in the case of sprint running. The literature on sprint running contains a number of hypotheses regarding GRF components. A recommendation by Mero and Komi (1986); Wood (1987) and Mero et al. (1992) were that sprinters should minimise the braking GRF and maximise the propulsion GRF (Mero et al., 1992). In a study done by Weyand et al. (2000), the swing time and ground reaction forces were measured while sprinting at maximal speed on a level treadmill. Maximal sprint speed for the subjects averaged between 6.2 and 11.1 meters per second (m.s$^{-1}$). It was noted that the faster individuals were able to apply greater forces during a shorter support phase, whereas the slower individuals applied smaller ground forces with a longer support phase.

Brughelli, Cronin and Chaouachi (2010) recently demonstrated that as athletes approach top velocity, the horizontal propulsive ground forces produced increase. They conclude that the production of a horizontal force is central to peak maximal velocity running. This implies that the changes observed in running mechanics at 80% and 100% of top speed represent the same mechanical outcomes necessitated to improve maximal running speed by 25%.

When running at the velocities of maximal sprinting, the task of developing appropriate vertical impulse becomes a restrictive challenge for the athlete. This results in increasing braking and propulsive forces to allow velocity to be maintained by stalling the impending reduction in ground contact time (Goodwin, 2011). It seems that the inability of athletes to continue to increase peak vertical force production gradually reduces available vertical impulse until airtime reaches a practical minimum. The athletes cannot run any faster because they will not be able to generate sufficient airtime to recover their swing leg.

Nikooyan and Zadpoor (2011) studied the effects of fatigue on the GRF and the vibrations of the lower-extremity soft tissues. The outcome of the study was in line with the experimental studies (Santamaria & Webster, 2010), which found muscle fatigue
does not significantly change the GRF peaks but may increase the level of soft tissue vibrations.

The relationship between velocity, stride length (SL) and stride frequency (SF) was researched extensively by Bezodis, Irwin, Kuntze and Kerwin (2011); Bezodis, Salo and Kerwin (2009); Bezodis, Kerwin and Salo (2008a); Bezodis, Salo and Kerwin (2008b); Bezodis, Salo and Kerwin (2007) and Bezodis (2006). However, it could not be established which one had the dominant influence on elite sprint performance.

A recent study by Bezodis (2012), however, reveals that an elite sprinter’s velocity might be individually dependent on either SL or SF. The athlete’s training programme could also play an important role in determining SL and SF.

2.3 STRENGTH AND POWER PREDICTING SPRINT SPEED

2.3.1 Defining strength and power

Singh, Chengappa and Banerjee (2002) indicate that there are valuable reasons for testing strength and power, namely to determine the relevance and relative importance of strength and power to performance; to develop an athlete profile; to monitor progress of training and rehabilitation of injuries; and discover the implications for talent searching and allocation to sports disciplines. Explosive strength is an important factor in numerous athletic events (Olmo & Castilla, 2005).

Explosive strength is a very significant biomechanical factor when analysing performance of human gait. In opposing dynamics, the movement at each joint is determined by combining the segmental and joint kinematics, anthropometric measures and the external forces (Johnson & Buckley, 2001).
Table 2.1: Definitions of strength and power (Bauer, Thayer & Baras 1990)

<table>
<thead>
<tr>
<th>Strength</th>
<th>The maximal force developed by the contracting muscle or muscles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power (P)</strong></td>
<td>The rate of muscular force (F) production over the range of motion (D) in a specific time period (t). Velocity (V) = D/t i.e. PM = F.V.</td>
</tr>
<tr>
<td><strong>Functional strength, power and explosiveness</strong></td>
<td>The utilisation of muscular forces for the production of specific movements or events</td>
</tr>
<tr>
<td><strong>Explosive power &amp; relative versus absolute strength</strong></td>
<td>The nature of the movement or event will indicate whether the athlete requires high absolute strength or relative strength. Absolute strength is the total amount of force produced during the movement without consideration for the mass or weight of the body, e.g. explosive movements for throwing projectiles as in shot put or power lifting. Relative strength is the total amount of force produced relative to the mass or weight of the athlete, e.g. explosive movements involving displacing the entire body as in gymnastics, figure skating and mountain climbing.</td>
</tr>
</tbody>
</table>

2.3.2 Explosive power relationship to sprinting performances

It is widely recognised that explosive strength is firmly related to sprint performances. Optimal training techniques designed to maximise strength receive considerable interest from strength and conditioning specialists, strength coaches and researchers (MacDonald, Lamont & Garner, 2012).

The objective of the study by Olmo and Castilla (2005) was to identify isokinetic parameters that could be related to explosive strength in the context of knee flexion/extension in long-distance runners and high-level sprinters. The results showed that the parameters were significantly higher in sprinters than in long-distance runners, and higher in hamstrings than in quadriceps. Therefore the use of these parameters is
recommended for measuring explosive strength related to sprinting performances in athletes.

Nesser et al. (1996) indicate that sprinting is often used as an analyst of power and athletic potential. Their study tested 20 male athletes on various physiological variables that had an influence on a 40m sprint performance. The results indicated that the types of training founded in traditional conditioning programmes placed emphasis on sprint starts, plyometric jumps and general strength/power training.

Paruzel-Dyja et al. (2006) attempted to find optimal factors of sprint strides to increase running speed, and argue that stride factors (length or frequency) have the greatest impact on 100m results. One hundred and nine men and 79 women elite sprinters who participated in the 2003 World Championships in Paris were included in their study.

Results indicate that stride frequency significantly contributed to the performance of elite female sprinters, and stride length was the most significant parameter in male sprinters. Taller male sprinters obtained better 100m run results, Body mass and body height also significantly influenced the stride patterns. The greater the body weight and height, the longer the strides and the lower the stride frequency (Paruzel-Dyja et al., 2006).

2.3.3 Muscle power relationship to sprinting performance

Maximal power can be measured by a jump test (Bosco & Komi, 1979). Mero et al. (1981) demonstrate functional links between jumping and sprinting performance. Consequently the two main components (forward power and leg stiffness) involved in sprinting (Cavagna, Komarek & Mazzoleni, 1971) can be evaluated using two simple ergometric systems (ergometric treadmill and vertical jump).

Chelly and Denis (2000) indicate that muscle power is needed for acceleration and maintaining maximal velocity in sprint performance, while high leg stiffness (leg stiffness was calculated using the flight and contact times of the hopping test) may be needed for fast running. There is increased interest in muscle and tendon stiffness and
how it relates to strength and power production in many different ways. Wilson, Wood and Elliot (1991) demonstrate that muscle stiffness relates positively to power production during bench press.

Muscular power is a greater contributor during the acceleration phase of a race, while muscular resilience, the efficiency of the muscles to rebound, is inherent to top speed running (Majumdar & Robergs, 2011).

2.4 TRAINING METHODS AFFECTING SPRINTING PERFORMANCE

The main components necessary to achieve functional speed are strength, flexibility, endurance, coordination, balance and movement efficiency, which are integral to performance and sport-related skills (Cook, 2001; Mills, Taunton & Mills, 2005). The relationship between these variables has not been established, and the lack of evidence may be because definitions and testing methods are not available (Baker, 2000; Barry & Lawrence, 2005; Pope & Panjabi, 1985; Stanton, Reaburn & Humphries, 2004; Tse, McManus & Maters, 2005).

The advantages of having greater speed have led to a great deal of research focusing on the development of sprint performance using numerous forms of training including speed training, sprint drills, sprinting against resistance, weight or RT, combined resistance and speed training and PT (Delecluse, Coppenolle, Willems, Van Leemputte, Diels & Goris, 1995; Delecluse, 1997; Kukolj, Ropret, Ugarkovic & Jaric, 1999; Rimmer & Sleivert, 2000; De Villarreal, Requena, Izquierdo & Cronin, 2012b).

A meta-analysis by Bosquet, Berryman, Dupuy, Mekary, Arvisais, Bherer & Mujika (2013) indicates a detrimental effect of RT cessation on all components of muscular performance (submaximal force, maximal power and maximal force). The effect was also greater in inactive people for maximal force and maximal power when compared to recreational athletes.
2.4.1 Strength training methods

The aim of strength training is to increase the size of the muscle fibres and the strength of the athlete, which will improve the ability to generate more power (Behrens & Simonson, 2011). Strength training has been used for decades by a wide variety of athletes to improve their athletic performance. Strength training sessions are designed to impose increasingly greater resistance, which in turn stimulates development of muscle strength to meet the added demand (Baechle & Earle, 2000).

Strength alone can improve power by increasing force production capabilities (Kirby, Travis & McBride, 2010). Increasing intensity represents an increasing load, which will lead to a decrease in movement velocity in the squat and jump squat. So although it is very important to maintain or increase strength consecutively, there is also a need to increase velocity of movement as well by changing the quantity of training to power and speed.

Strength-training programmes for a sprinter have one fundamental purpose – to make the athlete run faster (Medlicott, 2006). Implementing a strength-training programme to develop athletes, Bompa (1994) implies that the aim of training is to stress the body in order to ensure that the response will facilitate and not counteract the adaptations.

High levels of performance are achieved after many years of systematic, well-designed and regular hard training. In addition, he suggests that superior performances are due to higher levels of adaptation.

Free weight training is one of the most common forms of strength training for young adults, with a frequency of twice per week for a duration of eight weeks as the norm (Baechle & Earle, 2000).

Research done by Aagaard et al. (2002) and Lee et al. (2009) focused on traditional strength training protocols that are known to result in large strength gains. The ability to produce high forces against large resistances (strength) and to produce a high work rate (power) is of utmost importance for various sports (Young, 2006). RT has become an
integral component of the physical preparation for enhancement of sport performances, and strength and conditioning training has become a specialisation within sport training (Young, 2006). Research has made it possible to train athletes more efficiently and prescribe training programmes focusing on muscles related to enhancing sport-specific speed. The principle still stands that for an exercise to be effective, it must have similar characteristics to the sport (Alcaraz, Palao & Elvira, 2009).

To improve speed, muscles and movements inherent to sprinting actions should be specifically targeted. Newton and Kraemer (1994) demonstrate that exercises emphasising speed and a full range of movements have a greater effect on sprinting performance than exercises that focus on absolute strength.

The intensity or percentage of a one-repetition maximum (1RM) of a given lift determines the level of force, power and velocity of performed repetitions at the given load; therefore these variables must be considered in the context of sports performance improvements. It is recommended by Kirby et al. (2010) that the selection of percentage of 1RM must be carefully considered based on exercise type and the phase of periodisation specific to various athlete populations.

Conventionally, the traditional squat (when the load attains a zero velocity at the end of the concentric phase) and ballistics squat (a loaded squat jump, where the load is projected vertically) movements have been incorporated as main exercises into strength programmes aimed to enhance maximal sprinting times or vertical jump performances in athletes (Newton, Kraemer, Hakkinen, K.W.J., & Hakkinen, K., 1996; Newton, Murphy, Humphries, Wilson, Kraemer & Hakkinen, 1997).

For ultimate transfer of movement, the characteristics of RT stimulus should be specific to activity in terms of muscles used, contraction type, contraction force and velocity, loading characteristics and range of movement (Sale, 2003). The maximal concentric actions of the lower-limb extensor muscles are important for jumping (Bobbert, Huijing & van Ingen, 1987) and sprinting (Mero et al., 1992), although it seems that the ballistic squat is more suitable than the traditional squat for the improvement of both functional activities, as each activity involves projection of body weight.
Wisloff, Castagna, Helgerud, Jones and Hoff (2004) report significant correlations ($r=0.71-0.94$ irrespectively) between 1RM in traditional squat and vertical jumping and sprint times at 10m and 30m in elite soccer players. Requena, B., García, Requena, F., De Villarreal, and Cronin (2011) indicate that traditional squat strength has little in common with counter-movement jumps and that relative 1RM and power outputs for both squat exercises (traditional and ballistic squat) are statistically correlated to most sprint distances, underlying the importance of strength and power in sprinting.

Okkonen and Häkkinen (2013) compared kinetics, kinematics and muscle activity among sprint start, sled-pulling and selected squat-type exercises, namely countermovement jumps (CMJs) and $\frac{1}{2}$ squats with various loads. The authors also examined how these exercises correlated with the performance time of the block start (10m). Nine male athletes volunteered as subjects. The comparisons were made with regard to the block phase (the phase of force production toward starting blocks) of the block start. In nearly all exercises, the activity of the gluteus maximus was significantly ($p \leq 0.05$) higher during the block phase. The angular velocity of the knee was significantly ($p \leq 0.05$) higher during the CMJs than during the block phase and, in general, the kinematic values of the sled-pulling and CMJs were closest to the values of the block start. Ground reaction forces were larger ($p \leq 0.05$) during the $\frac{1}{2}$ squats and CMJs. The highest correlation existed between the performance time in the block start (10m) and the take-off velocity during the CMJ without a load ($r = -0.950$, $p \leq 0.001$). They conclude that sled-pulling and CMJs can be recommended for use in the training of the block start because both velocity and movement specificity with regard to the block start and, hence good transfer of training adaptations to the block start, can be expected. It would be advisable to target force production and velocity of muscles in RT to maximise power performance, which will not be achieved by doing heavy resistance strength training (high force and low velocity).

Santos and Janeire (2012) evaluated the effects of a lower- and upper-body 10-week in-season RT programme on explosive strength development in young basketball players. Twenty-five adolescent male athletes were randomly assigned to an experimental group (EG; $n = 15$) and a control group (CG; $n = 10$). The subjects were assessed at baseline and after training for squat jump, counter movement jump, Abalakov test, drop jump
and seated medicine ball throw (MBT). Results of this study indicate that a 10-week in-season RT programme with moderate volume and intensity loads increases vertical jump and MBT performance in adolescent male basketball players.

Björk and Raask (2013) examined how the use of different loads of accommodating resistance influences peak power output in the bench-press exercise. They tested 14 subjects’ 1RM in bench press and after seven days performed a power test consisting of three repetitions with 30, 40, 50, 60 and 70% of 1RM and peak power using the MuscleLab Linear encoder. Results indicate that the use of accommodating resistance results in higher power output than using bar weight only when the total load is constant.

Smilios, Sotiropoulos, Christou, Douda, Spaias and Tokmakidis (2013) examined the changes in maximum strength, vertical jump performance and the load-velocity and load-power relationship after a RT period using a heavy load and an individual load that maximises mechanical power output with and without including body mass in power calculations in 43 moderately trained men. The subjects performed four to six sets of jump squats and the repeated-jump exercises for six weeks.

The researchers conclude that the inclusion or not of body mass to determine the load that maximises mechanical power output affects the long-term adaptations differently in the load-power relationship. Thus, training load selection will depend on the required adaptations. However, the use of heavy loads causes greater overall neuromuscular adaptations in moderately trained individuals.

Despite the research data on the effectiveness of short-term training programmes on athletic performance of adolescent athletes and non-athletes (Gorostiaga, Izquierdo, Ruesta & Ibanez, 1999; Faigenbaum, La Rosa, O’Connell, J., Glover, O’ Connell, J. & Westcott, 2001), the effects of specific training interventions still remain unknown (Bogdanis, Vaghelis, Anastasiadis & Maridaki, 2007).
2.4.2 Periodised resistance Training

The effect of periodised RT on accelerative sprint performance was studied by Moir, Sanders, Button and Glaister (2007). Sixteen subjects participated in their study; 10 engaged in an eight-week periodised RT intervention. Pre- and post-training measures were taken. The results show that despite the increase in measures of maximum and explosive strength, a period of RT does not improve the initial acceleration phase of sprinting (0–10m) immediately after the training period. However, the adaptations resulting from the RT exercises used in their study appear to be suitable for performance, as the subjects reached maximum speed sprinting (1–20m). These all contribute to current literature on the benefits of RT. Studies have not yet proven whether sprinters can improve their speed or power when RT exercises are performed at higher movement speeds, although some research suggests that there might be some benefits (Delecluse et al., 1995).

The aim of the study carried out by Blazevich and Jenkins (2002) was to examine potential changes in strength and sprint times in national ranked junior (u/21) sprint athletes during seven weeks of concurrent speed and RT. Results show that velocity-specific strength adaptations can occur rapidly in untrained and non-concurrently training individuals.

The study by Edge, Eynon, McKenna, Goodman, Harris and Bishop (2013) was to prove that exercise-induced changes in metabolites and ions are crucial in the adaptations of contracting muscles. The authors tested 12 females by comparing adaptations to two different interval-training protocols (only differing in resting duration between intervals). Results showed that there was no significant difference between the groups regarding their VO2 Peak, repeated sprint performance or muscle NA+, K+ and ATPase content; however, following training both groups had a significant decrease in post-exercise muscle (H+) and lactate content.
The majority of research suggests that PT improves maximal power performance, measured as 1RM (De Villarreal, Requena & Newton, 2010), but muscular strength and power are considered critical elements for successful athletic performance (Kraemer et al., 2001; De Villarreal, Kellis, Kraemer and Izquierdo, 2009). Research evidence supports that PT is also effective for maximal strength (Clutch, Wilton, Mc Gown & Bryce, 1983; Blakey & Southard, 1987; Fatouros, Jamurtas, Leontsini, Taxidaris, Aggelousis & Kostopoulos, 2000; Buckley, Brinkworth & Abbott, 2003). Research also indicates that PT improves strength, power output, coordination and athletic performances (Bedi, Cresswell, Engel & Nicol, 1987; Bobbert et al., 1987; Adams, O'Shea, J., O'Shea, K. & Climstein, 1992; Baker, 1996; Holcomb, Lander, Rutland & Wilson, 1996).

Changes in performance were monitored through jumping ability (measuring countermovement and squat jumping) and strength performance (assessed through isometric and isokinetic testing of knee extensors) to determine the time frame of performance responses after an acute bout of plyometric exercises combined with high- and low-intensity weight training (Beneka, Malliou, Missailidou, Chatzinikolaou, Fatouros, Gourgoulis, & Georgiadis, 2013). The results suggest that an acute bout of intense plyometric exercise combined with weight training exercise induces time-dependent changes in performance, which means a decline in jumping performance for as long as 72 hours, but not in other forms of muscle strength (Beneka et al., 2013).

Campillo, Andrade and Izquierdo (2013) examined the effects of different training volumes and training surfaces during a short-term PT programme on neuromuscular performance. Twenty-nine subjects were assigned to different groups (control, moderate volume, moderate volume and hard surface, and high volume groups). The results show that high training volumes lead to a significant increase in explosive performance that requires fast-stretch shortening cycle (SSC) actions in comparison to what was observed after a moderate training regimen. Secondly, when PT is performed on a hard surface, a moderate training volume induces optimal stimulus to increase explosive performance.
requiring fast SSC, maximal dynamic strength enhancement and higher training efficiency.

2.4.4 Core training

Training the core muscles is also important for a sprinter. The core muscle group includes large muscle areas at the trunk and hip region. These muscles provide the basis of strength for production of forces during an explosive movement (Martini, 2004).

Anatomical components of core can be described as a box consisting of 29 pairs of muscles, forming front (abdominals), back (paraspinals and gluteals), top (diaphragm) and bottom (pelvic floor and hip girdle) areas (Richardson, Jull, Hodges & Hides, 1999).

Muscle groups include the following (Martini, 2004):

- **Upper trunk** – chest and upper back – pectoralis major and minor, latissimus dorsi, trapezius and rhomboids major and minor;
- **Lower trunk** – abdominals and erector spinea muscle group – rectus abdominus, external and internal oblique and transversus abdominus; and
- **Thigh/hip** – gluteal maximus, medius and minimus, quadriceps (rectus femoris, vastus intermedius, vastus lateralis, vastus medialis), hamstrings (bicep femoris, semimembranousus, semitendinousis, sartorius and popliteus), adductor group (adductor brevis, adductor longus, adductor magnus pectines and gracilis), abductor group (obturator externus and internus, piriformis, gemelli superior and inferior).

Power is not produced by the core but rather in the hips and then transferred through a stable or hardened core (McGill, 2010). Kibler, Press and Sciascia (2006) established that core stability is the ability to control the trunk to allow the greatest transfer of torque to the external segments. Therefore the ability to stabilise the anatomical box “core” could have a significant influence on athletic propulsion performance by avoiding bending and loosing. Therefore, it is necessary to encourage the transfer of
torque to the extremities. This led to evidence supporting the positive influence that incorporating core exercises has on performance measures (Cosio-Lima, Reynolds, Winter, Paolone & Jones, 2003; Sato & Mokha, 2009).

Core stability can be achieved through stabilisation of the torso, therefore allowing optimal production, transfer and control of force and motion to the segment throughout a kinetic chain movement (Panjabi, 1992; Cook, 2001; Liemohn, Baumgartner & Gagnon, 2005; Kibler et al., 2006). Research has shown the importance and contribution of core stability in everyday human movements, while producing efficient trunk and limb actions for the generation, transfer and control of forces or energy during integrated kinetic chain activities (Hodges & Richardson, 1997; Cook, 2001; Cissik, 2002; McGill, 2004; Behm, Leonard, Young, Bonsey & Mackinnon, 2005; Kibler et al., 2006). Okada, Huxel and Nesser (2011) determined the relationship between core stability, functional movement and performance. Twenty-eight healthy individuals (age = 24.4 ± 3.9 years, height = 168.8 ± 12.5 cm, mass = 70.2 ± 14.9 kg) performed several tests in three categories: core stability, functional movement screen and performance tests. Results prove that it is important to include core and functional movement training in a fitness programme, especially for injury prevention; however they should not be the primary emphasis of any training programme.

2.4.5 Combined training methods

In order to understand the athlete’s training response, coaches/strength and conditioning trainers need to understand the relationship between strength and power (Bauer et al., 1990). Perceptions of explosive power training have been the focus of debate among sports scientists and trainers in recent years. Improvement of sport performance is built on the use of a diversity of training approaches, for instance some form of resistance exercise involving near-maximal efforts with improvement of power output.

The power an athlete can exert often determines success or at least aids muscular function and motor performances. Improving muscular function through resistance
strength training necessitates an understanding of how specific techniques affect power output (Cronin, McNair & Marshall, 2001).

Complex training is a form of combined training and can be described as training that alternates between traditional (heavy resistance) training and plyometric exercise within a single session (Chu, 1996; Ebben & Blackard, 1997; Ebben, 2002; Masamoto, Gates & Faigenbaum, 2003). Various training methods including weight-training (Wilson, Murphy, Giorgi, 1996; Wilson et al., 1993) and RT (Newton, Hakkinen, K., Hankkinen, A., McCormick, Volek & Kraemer, 2002) have successfully been used to enhance strength performances.

Results from various studies related to complex training indicate that it may improve measures of athletic ability (will demonstrate no decrement to athlete) compared with more conventional training programmes (Fatouros et al., 2000; Adams et al., 1992; Duthie, Young & Aitken, 2002; Mihalik, Libby, Battaglini & McMurray, 2008). To achieve maximal strength (Blakey and Southard, 1987; Fatourus et al., 2000; De Villarreal et al., 2008), a combination of training modalities is recommended rather than using a single modality. This is in accordance with previous studies that demonstrated that the combination of heavy and explosive weight training method is an efficient strategy to improve strength performance in youth (Harris, Stone, O’Bryant, Proulx & Johnson, 2000; Newton et al., 2002). The studies conclude that RT is an effective method for developing muscular strength (Hakkinen & Komi, 1981).

The use of plyometric exercises with athletic populations which enhance performance is a well-accepted practice among sport performance professionals (Durell, Pujol & Barnes, 2003; Ebben, Hintz & Simens, 2004; Ebben, Hintz & Simenz, 2005). Cristea et al. (2008) indicate that incorporating weight training exercises in the conditioning programme leads to improvements in maximal and explosive strength in world-class master sprinters. Part of the clarification for substantial improvements in muscular strength may be due to the specific form of strength training used, in which heavy resistance exercises were combined with explosive-type weight training and plyometric exercises.
De Villarreal *et al.* (2010) examined 26 studies with a total of 56 effect sizes (ES) which met the inclusion criteria. Analysis of ES demonstrates that the strategies that seem to maximise the probability of obtaining significantly (p < 0.05) greater improvement in sprint performance include training volume for more than 10 weeks, a minimum of 15 sessions, and high-intensity programmes with less than 80 combined jumps per session.

To optimise sprint enhancement, the combination of different types of plyometrics and the use of training programmes that incorporate greater horizontal acceleration is recommended, rather than using only one form of jump training (De Villarreal *et al.*, 2010). The studies conclude that resisted jump training in the form of weighted jump squats increases vertical jump height but is not more effective than plyometric depth jump after training. Resisted sprint training is superior in increasing speed in the initial acceleration phase of sprinting (Hrysomallis, 2012).

Haghighi, A., Moghadasi, Nikseresht, Torkfar & Haghighi, M., (2012) investigated the effect of plyometric versus RT on sprint and skill performance in young soccer players. Results indicate that the times of the sprint running test and dribbling improved after PT and RT (p < 0.05). De Villarreal, Requena, Izquierdo and Gonzalez-Badillo (2012b) compared the effects of five different training stimuli on sprinting ability and strength production. Sixty students were tested and trained three times a week for seven weeks. Training comprised a full squat, parallel squat, loaded countermovement jumping and PT. Testing was done before and after seven weeks and consisted of sprinting performance (30m), maximal dynamic strength (1RM) and velocity displacement in the concentric phase of the full squat (m.s\(^{-1}\)). Results showed that the combined training approach results in a slight improvement in maximal strength, velocity of displacement and sprint performances and the resemblance between movement patterns and velocity of displacement common to the training and testing methods. Harries, Lubans and Callister (2012) evaluated the efficiency of RT programmes on muscular power and sports performances in an adolescent athlete population and found positive correlations.

MacDonald *et al.* (2012) compared the effects of RT, PT and combined training on lower body strength and anthropometrics. Thirty-one active college-aged men trained using one of the three methods twice weekly for six weeks. Testing was done pre-, mid-
and post-training to assess back squat strength, Romanian deadlift strength and standing calf raises strength, quadriceps girth, triceps girth, body mass and body fat percentage. Results suggest that combined training mirrors the benefits seen with traditional RT or PT. Additionally, combined training proved to have no decremented influence on strength and anthropometric values and can also be used as a training method.

Tsimachidis, Patikas, Galazoulas, Bassa and Kotzamanidis (2013) examined the effect of a 10-week combined resistance/sprint training programme on the post activation potentiation (the mechanism which causes enhanced muscular performance after a high intensity stimulus) of sprint performance before, between and after RT sets. The intervention increased both strength and sprint performance. It also illustrated that post-activation potentiation effects on sprint performance, which did not previously manifest as a result of systematic RT, became noticeable after a 10-week resistance/sprint combined training programme.

Paradisis, Bissas and Cooke (2013) researched the effects of an eight-week uphill-downhill sprint training programme on the force generation capacity of leg muscles. Twenty-four university students were randomly allocated to one of two training groups (combined uphill-downhill and horizontal) and a control group (did not train). The combined training was significantly more effective in improving the maximum sprinting speed by 5.9%, \( p < 0.05 \) and associated kinematic variables.

In particular, the propulsive phase of contact decreased significantly by 17% \( p < 0.05 \), indicating a link between the improved rate of force production during the isometric test and the rate of production of propulsive forces during sprinting. The increased capacity of the leg flexor muscles to generate force appears to contribute to the improvement of sprinting speed, perhaps due to a more efficient muscle function during the support phase of the stride.

The above-mentioned research indicates that a combination of speed and explosive strength training is needed to improve peak running speed and jump height (Durell et al., 2003; Ebben, Carroll & Simenz, 2004; Ebben et al., 2005; Christou, Smilios, Sotiropoulos, Volakilis, Pilianidis & Tokmakidis, 2006; Cristea et al., 2008; Chelly,
2.5 SUMMARY

Specific strength and power assessments can assist in predicting sprinting performance (speed) over short distances (40m) and maximum speed phase of the 100m sprint. To increase power and sprint performance, RT must be conducted at a high speed.

The training methods used to achieve power and strength output can also counteract a person’s performance (ground contact time or biomechanical faulty running), which can increase sprinting times or injuries if not trained by a professional.

Recent studies (Moir et al., 2007; De Villarreal et al., 2008; Mihalik et al., 2008; De Villarreal et al., 2009; Sato & Mokha, 2009; MacDonald et al., 2012) of different training methods have been conducted to determine which training method is the most advantageous to elite male professional athletes (Durell et al., 2003; Ebben et al., 2004; Ebben et al., 2005) and young boys (Harris et al., 2000; Newton et al., 2002). Unfortunately few studies relate to recreational males (Gorostiaga et al., 1999; Faigenbaum et al., 2001).

There was sufficient evidence to conclude that general RT interferences can improve muscular power in males and younger athletes, which will help coaches and athletes improve performance and conduct proper training programmes. RT, PT, speed training or a combination of these training methods all have the potential to improve muscular power. However, it has not yet been established which type of programme is more advantageous in improving muscular power, resulting in improved sprinting performances in various adolescents.
CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

It has been well established by Fry, Kreamer, Weseman and Conroy (1991) and Wilson et al. (1993) that RT is a good indicator of increased sprinting performance. The aim of this study is to determine the possible effect of two different RT programmes on sprinting performance. This chapter explains and describes the assessments used in this study, namely selective anthropometrical assessments, one repetition maximum (1RM) strength test, 7-stage abdominal test, vertical jump, Margaria Kalamen power test and 40m, 60m, 80m and 100m speed test.

Existing literature on sprint training suggests various tests to estimate the specific physical abilities of sprinters (Clutch et al., 1983; Blakey & Southard, 1987; Wilson et al., 1993; Wilson, Murphy et al., 1996; Kraemer, Mazzetti, Nindl, Gotshalk, Volek & Bush, 2001; Maffiuletti, Dugnani, Folz & DiPierno, 2002; MalATESTA, Cattaneo, Dugnani & Maffiuletti, 2003; De Villarreal et al., 2009). The popular tests are sprinting and jumping tests. Misjuk and Mehis (2007) observed the relationship between jumping tests, running acceleration and maximal speed of the sprinter; results proved that jumping tests provide valuable information for training sprinters. Other studies have shown that strength can improve sprinting speed in young adult athletes (Cadefau, Casademont, Grau, Fernandez, Balaguer, Vernet, Cusso & Urbano-Marquez, 1990; Andersen, Klitgaard & Saltin, 1994; Delecluse et al., 1995; Harris et al., 2000).

Vertical jumps seem to be a compatible model for studying the maximal dynamic productivity of lower-limb muscles (McBride, Triplett-McBride, Davie & Newton, 1999; Baker, Nance & Moore, 2001; Driss, Vandewalle, Quièvre, Miller & Monod, 2001; Harris, Cronin & Hopkins, 2007; Cormie, McCaulley, Triplett & McBride, 2007; Markovic & Jaric, 2007). The performances of maximal vertical jump correlate exceedingly with maximal performances of other rapid and explosive movement tasks (e.g. running) (Kukolj et al., 1999).
Measuring functional power of the lower body, the vertical squat jump (Young, 1995; Arteaga, Dorado, Chavarren & Calbet, 2000; Knudson, Bennet, Corn, Leick & Smith, 2001; Young & Elliot, 2001; Cornwell, Nelson & Sidaway, 2002;), among numerous other jump protocols, seems to be the most widely used assessment method. Which jump test is the prognostic one preferred by the clinician or conditioning coach (Maulder & Cronin, 2005)?

Results show that no single strength/power measure or assessments protocol can explain all the variances related to performance measure, but horizontal leg power (for instance Margaria Kalamen) assessments appear to be inexpensive, easy-to-administer tests that are reliable and valid in assessing unilateral leg power. The ability to jump is a fundamental skill that is required in many different sports (Davis, Briscoe, Markowski, Saville & Taylor, 2003).

Several studies examined the correlations between vertical jump and muscular strength. Positive results have been found between vertical jump displacement and the strength of the lower extremity musculature (Hakkinen, 1989; Young, Warren & Bilby, 1993; Ashley & Weiss, 1994; Blackburn & Morrissey, 1998). The objective of a study done by Davis et al. (2003) was to determine the relationship between vertical jump performance and anthropometric and physical characteristics in recreational males.

3.1.1 Profile of subjects

Thirty male members of the University of Pretoria (TUKS) Gymnasium between the ages of 18–25 were randomly recruited to participate in the study. Permission to approach these students was obtained from the manager of the TUKS Student Gymnasium.

The subjects all signed an informed consent form before participating in the study. The data collection occurred during an eight-week period. Subjects had to comply with the following inclusion and exclusion criteria.
**Inclusion criteria**

Subjects:
- had to be males between the ages of 18 and 25
- who had not been participating in any specific sporting activity
- who willingly completed the Informed Consent Form (Appendix A)
- who willingly completed the Par-Q Form (Appendix B)
- who willingly completed the Medical Screening questionnaire to assess exclusion criteria (Appendix C)

**Exclusion criteria**

Subjects:
- who were not males between the ages of 18–25
- who were participating in any specific sporting activity
- who did not willingly complete the Informed Consent Form (Appendix A)
- who did not willingly complete the Par-Q Form (Appendix B)
- who did not willingly complete the Medical Screening questionnaire to assess injuries (Appendix C)

Table 3.1 indicates the descriptive statistics of the subjects that participated in the study.

**Table 3.1: Descriptive statistics of the subjects.**

<table>
<thead>
<tr>
<th></th>
<th>Specialised Group (n=10)</th>
<th>General Group (n=10)</th>
<th>Control Group (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (yrs)</strong></td>
<td>20.84 (±2.34)</td>
<td>21.10 (±2.35)</td>
<td>21.58 (±2.39)</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>177.49 (±8.65)</td>
<td>177.41 (±9.58)</td>
<td>177.11 (±7.69)</td>
</tr>
<tr>
<td><strong>Body mass (kg)</strong></td>
<td>74.16 (±10.89)</td>
<td>73.29 (±11.82)</td>
<td>76.13 (±11.74)</td>
</tr>
</tbody>
</table>
Thirty athletes were randomly divided into three groups (two experimental groups, n=10 each and a control group, n=10). Two different RT programmes, namely GP and SP, were implemented for the duration of eight weeks in the case of the two experimental groups, while the control group (C) had no form of strength training. Both training programmes included two sessions per week, each lasting 60 minutes.

3.2 PROCEDURES

Each subject was evaluated twice throughout the study, before the onset of the exercise intervention and at the end of the intervention (eight weeks).

3.2.1 Pre-screening

The volunteer subjects were informed of the benefits and risks associated with the study (Appendix A). Written consent was obtained to ensure compliance with criteria for participation in the study, after which biographical data was collected.

3.2.2 Test session

Information gathered included the following:

- Par-Q
- Medical Screening Questionnaire
- Anthropometrical Assessment and Somatotyping, height (The Leicester Height Measure, SECA, Birmingham), weight (Tanita Body Composition Analyzer, Japan), skinfolds (Harpenden Skinfold Calliper, Baty International, England), circumferences (Cescorf Measure Tape, Brazil) and breadths (Sliding Calliper, Germany)
- Vertical jump (Vertec, Questtek Corp, Northridge, CA)
- Seven-Stage abdominal test
- One Repetition Maximum (1-RM) strength tests
- Margaria Kalamen Power Test
- Speed tests: 40m, 60m, 80m and 100m
3.2.2.1 Questionnaires

See Appendix B for Par-Q and Appendix C for Medical Screening questionnaires.

3.2.2.2 Anthropometrical assessment

The following anthropometric measurements were taken:

- standing height (cm) (Jones et al., 2006)
- mass (kg) (Jones et al., 2006)
- skinfolds (mm) (Jones et al., 2006) (tricep, bicep, subscapularis, supra-iliac supraspinale, abdominal, front thigh and calf)
- circumferences (cm) (Jones et al., 2006) (relaxed arm, contracted arm, forearm, waist, gluteal (hip), mid-thigh and calf)
- Humerus and femur breadth (cm) (Jones et al., 2006)

3.2.2.2.1 Standing height

Standing height was measured with a portable Leicester Height Measure (Seca, Birmingham, UK) (figure 3.1). Height was measured with the subject standing upright, barefoot with heels together and gluteus maximus, upper spine and head in contact with the wall. The direction of vision is horizontal, with the corner of the eye and the superior ear orifice in a horizontal plane (Frankfort plane). Measurements were made in duplicate, to the nearest millimetre, and the mean value was recorded (Jones et al., 2006).

**Figure 3.1: Leicester Height Measure**
3.2.2.2.2 Mass

Mass was measured using the Tanita Body Composition Analyzer (Tanita Corporation, Tokyo, Japan) (maximum: 180kg) as seen in figure 3.2. Subjects were weighed wearing gym shorts of which the mass was known. Mass was registered to the nearest 0.1kg (Jones et al., 2006).

![Tanita Body Composition Analyzer](image)

**Figure 3.2: Tanita Body Compositioning Analyzer**

3.2.2.2.3 Skinfolds

The tricep, bicep, subscapular, supra-iliac, supraspinale, abdominal, mid-thigh and calf skinfold were taken using a Harpenden Skinfold Calliper (Baty International, England) (figure 3.3) and measurements were taken to the nearest mm (Jones et al., 2006).

![Harpenden Skinfold Calliper](image)

**Figure 3.3: Harpenden Skinfold Calliper**
3.2.2.2.4 Circumferences

The circumferences of the contracted arm, waist, gluteal (hip), mid-thigh and calf were measured using the Cescorf Type Measure (CESCORF Sports Equipment Ltda, Porto Alegre, Brazil) (figure 3.4) in cm, according to Jones et al. (2006).

![Figure 3.4: Cescorf Type Measure](image1.png)

3.2.2.2.5 Widths

Humerus and femur widths were measured using a large sliding calliper (Georg Hommel, Aldingen, Germany) (figure 3.5). The widths were then measured in cm according to Jones et al. (2006).

![Figure 3.5: Sliding calliper](image2.png)
3.2.2.3 Vertical jump

Vertical jump was performed using a Vertec device (Questtek Corp, Northridge, California) (figure 3.6). The subject stands side-on to the Vertex jumping device. Keeping heels on the floor, the subject reaches upward as high as possible, fully elevating the shoulder to displace the zero reference vane. An arm swing and countermovement is used to jump as high as possible with the subject displacing the vane at the height of the jump. The take-off must be from both feet, with no preliminary steps or shuffling. The distance between the reach height and jump height is recorded to the nearest cm. The subject performs a maximum of three trials. The best of the trials is recorded and converted to power output (Average Power (Watts) = $\sqrt{4.9 \times \text{body mass (kg)} \times \sqrt{\text{jump-reach score (m)}} \times 9.81}$) (Gore, 2000).

Figure 3.6: Vertec device

3.2.2.4 Seven-Stage Abdominal Test

The abdominal seven-stage test is a graded test for abdominal strength. Each of the seven stages becomes progressively more difficult as the positions of the hands and arms are modified. These modifications, plus the use of 2.5 kg and 5 kg discs, places increasing stress on the abdominal musculature. The aim of the test is to accomplish as many of these stages as possible, with three attempts to complete a stage before going to the next (see Appendix E for stages) (Gore, 2000).
3.2.2.5 Margaria Kalamen (MK) Power Test

The test requires the subject to sprint up a flight of stairs. The tester marks a starting line with cones six metres in front of the first stair and also places a cone on and to one side of the third, sixth and ninth stairs. The vertical distance is then measured from the third to the ninth stair (metres). The athlete starts at the six-metre line.

The subject sprints to the steps and up the flight of stairs, three at a time, landing on the third, sixth and ninth stairs. The time starts when the subject’s foot lands on the third step and stops when the subject’s foot lands on the ninth step; and the time is then recorded. The athlete’s power (Watts) is calculated as follows: $P \text{ (Power)} = (M – \text{athletes weight} \times D – \text{vertical distance}) \times 9.8 \div t \text{ (time)}$ (Fox, Bowers & Foss, 1989).

3.2.2.6 Speed test: 40m, 60m, 80m and 100m

Speed was assessed with timing gates (Swift Performance Equipment, Australia) placed at 40m, 60m, 80m and 100m. The test starts with the initial movement of the subject from a crouched position. The best attempt of four was recorded (Gore, 2000).

3.2.2.7 One Repetition Maximum (1RM) Strength Tests

The following 1RM tests were conducted: bench press, deadlift, power clean, bent-over row and squat (Heyward, 2002). The 1RM strength value is obtained through the protocol for 1RM testing as set out by the National Strength and Conditioning Association (see Table 3.2).
Table 3.2: Protocol for 1RM testing (Baechle & Earle, 2000).

<table>
<thead>
<tr>
<th>1-RM TESTING PROTOCOL</th>
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<tbody>
<tr>
<td>1. Instruct the athlete to warm up with a light resistance that easily allows 5-10 repetitions.</td>
</tr>
<tr>
<td>2. Provide a 1-min rest period.</td>
</tr>
<tr>
<td>3. Establish a warm-up load that will allow the athlete to complete 3-5 repetitions by adding:</td>
</tr>
<tr>
<td>- 10-20 lb (4.5-9 kg) or 5-10% for upper-body exercise or</td>
</tr>
<tr>
<td>- 30-40 lb (14-16 kg) or 10-20% for lower-body exercise</td>
</tr>
<tr>
<td>4. Provide a 2-min rest period.</td>
</tr>
<tr>
<td>5. Establish a conservative, near-maximal load that will allow the athlete to complete 2-3 repetitions by adding:</td>
</tr>
<tr>
<td>- 10-20 lb (4.5-9 kg) or 5-10% for upper-body exercise or</td>
</tr>
<tr>
<td>- 30-40 lb (14-16 kg) or 10-20% for lower-body exercise</td>
</tr>
<tr>
<td>6. Provide a 2-4 min rest period.</td>
</tr>
<tr>
<td>7. Make a load increase:</td>
</tr>
<tr>
<td>- 10-20 lb (4.5-9 kg) or 5-10% for upper-body exercise or</td>
</tr>
<tr>
<td>- 30-40 lb (14-16 kg) or 10-20% for lower-body exercise</td>
</tr>
<tr>
<td>8. Instruct the athlete to attempt a 1-RM.</td>
</tr>
<tr>
<td>9. If the athlete was successful, provide a 2-4 min rest period and go back to step 7.</td>
</tr>
<tr>
<td>If the athlete failed, provide a 2-4 min rest period, decrease the load by subtracting:</td>
</tr>
<tr>
<td>- 5-10 lb (2.5-4.5 kg) or 2.5-5% for upper-body exercises or</td>
</tr>
<tr>
<td>- 15-20 lb (7-9 kg) or 5-10% for lower-body exercises</td>
</tr>
<tr>
<td>AND then go back to step 8.</td>
</tr>
<tr>
<td>Continue increasing or decreasing the load until the athlete can complete one repetition with proper exercise technique. Ideally, the athlete’s 1-RM will be measured within 5 testing sets.</td>
</tr>
</tbody>
</table>

3.3 INTERVENTION PROGRAMME

Subjects were randomly divided into two experimental groups (n=10) and a control group (n=10). When the baseline assessments were completed a GP and an SP resistance programme were applied for eight weeks in the two experimental groups, while the control group (C) did not follow any form of RT programme in the designated time.

Both training programmes included two sessions per week (training sessions had to be kept to fixed days with a resting day in between), lasting 60 minutes each. A familiarisation session was held before commencement of the training programmes, where the exercises were explained and subjects had to chance to do the exercises to
make sure their technique was correct. The two groups were trained by the same head coaches and assistants, who were present during each training session. Motivation was similar and consistent for both resistance programmes.

The strength training programme prescription for the GP and SP groups was similar regarding frequency (f) and time (t), but differed in terms of their modality specific intensity (i) prescriptions, type (e) and total (s) number of exercises.

3.3.1 General Strength Training Programme (GP)

According to Behringer, vom Heede, Yue, and Mester (2010) the typical strength-training programme design consists of two to three sets, eight to 15 repetitions and loads between 60 percent (%) and 80 % of the 1RM for six to eight exercises. Training loads were determined by either taking a specific percentage of the 1RM or performing a multiple-RM testing (e.g. 10RM). The GP was performed twice a week in the gymnasium; subjects did dynamic stretching before each session and static stretching after each session. Exercises included the following:

**Session 1**

1. Overhead squat  
2. Push-up tuck jumps  
3. Medicine ball shoulder press side bend  
4. Leg medicine ball throw  
5. Seated medicine ball throws with rotation  
6. Barbell deep front squat shoulder press  
7. Hanging hip flexion  
8. Barbell reverse grip bent-over row

**Session 2**

1. Overhead squat  
2. Push-up tuck jumps
3. Deep back squat
4. Single leg medicine ball throw
5. Seated medicine ball throws with rotation
6. Barbell deep front squat shoulder press
7. Bench press
8. Reverse grip pull-up

3.3.2 Specialised Strength Training Programme (SP)

The specialised SP was performed twice a week in the gymnasium. Exercises were the following:

Dynamic stretch before each session, static stretch after each session

1. Deadlift every session, three sets of three reps @ 85–95% of 1RM
   a. Plyometrics at the end of each set, within one minute of set completion
   b. Usually depth jumps from varying heights, generally six jumps or fewer. The focus is on delivering maximum strength in minimum time.

2. Bench press at each session, three sets of three reps,
3. Power clean at each session, three sets of three reps,
4. Abdominal exercises each session, three sets of 10 reps
   a. Vertical leg crunches
   b. Side medicine ball throws against wall
   c. Sit-ups medicine ball throws against wall

3.4 RESEARCH DESIGN

The research design is a true experimental group design, namely the Pre-test–Post-test Randomised Group Design as seen in Table 3.3 (Thomas & Nelson, 2001).

This design made use of three randomly assigned groups. The three groups were tested before and after an intervention. Two different SPs were used by two of the three groups.
and the third group, being the control, did not participate in a programme. In both instances differences between the groups exposed to the intervention and those not exposed, allow one to conclude that such changes are attributable to the intervention (Thomas & Nelson, 2001).

The purpose of the research design was to determine the possible improvement in sprinting performance as a result of following the different RT programmes.

**Table 3.3: Research design**

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>T1</th>
<th>RT1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>T1</td>
<td>RT2</td>
<td>T2</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>T1</td>
<td>–</td>
<td>T2</td>
</tr>
</tbody>
</table>

R: Random assignment of subjects to groups  
T1: Pre-testing of all three groups  
RT: RT programmes being executed for eight weeks (the terms RT1 and RT2 refer to different RT programmes, a blank space means that the group is a control group)  
T2: Post-testing of all three groups

### 3.5 DESCRIPTIVE STATISTICS

Descriptive data were used to describe data. Means, standard deviation, minimum and maximum scores and effect sizes for all variables measured were determined. An indication of explosive power and anthropometrical assessment on sprinting performance can be indicated through descriptive data.

Non-parametric statistics were used in this study, since there was no normal distribution and it did not meet the assumptions of the parametric techniques (Thomas & Nelson, 2001).
3.5.1 Wilcoxon Singed Ranked Test and Kruskal-Wallis test

When data was collected twice on the same subjects, an analysis was done with the Wilcoxon Singed Ranked Test and Kruskal-Wallis test to determine whether a significant difference existed between the mean two sets of scores (Thomas & Nelson, 2001). In this study the test was used to determine the significant difference between pre- and post-testing for the different variables measured.

3.5.2 Spearman’s Rho Correlation Test (Non-Parametric)

This correlation was used to determine if there was a significant relationship between two variables (Thomas & Nelson, 2001). In this study it was used to determine whether significant differences (p < 0.05) with specialised and general programmes exist to indicate differences.

All significant differences were reported at the ninety five percent level of significance (p ≤ 0.05), with all graphs presenting the mean values based on the statistical analysis that was used.
CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 INTRODUCTION

The purpose of this study was to determine the possible effects of two different RT programmes on sprinting performance. The primary aim was to determine the possible effect of two different RT programmes (SP and GP) on sprinting performance, to compare the two different training programmes with each other and to assess the possible correlations between different physical measurements and sprinting (40m, 60m, 80m and 100m) times.

Male subjects with limited strength training experience and non-sprinters were randomly selected from students enrolled at the TUKS Student Gymnasium. Subjects (N=30) aged 18–25 (21.4 ± 2.33) years were randomly assigned to three groups: SP (n=10), GP (n=10) and C (n=10), as described in Chapter Three. All subjects had some form of strength training experience, but none were participating in any sport.

The pre- and post-test scores were computed for every subject. Significant difference was determined by dependant-t test with significant difference set at p-value of lower than 0.05.

4.2 AGE AND SELECTIVE ANTHROPOMETRICAL VARIABLES

Table 4.1 depicts the physical characteristics and anthropometrical variables of the subjects in the research undertaken prior to and after the 12 weeks of intervention programme.

Recent literature supports the fact that a decrease in body fat percentage (BF%) and increase in muscle mass percentage (MM%) contributes to faster sprinting times (Mero et al., 1981; Van Ingen et al., 1994; Weyand et al., 2000; Chelly & Denis, 2001; Cronin & Sleivert, 2005), although the current study’s results are not significant (due to small sample size).
### Table 4.1: Physical characteristics (age) and anthropometrical variables during pre- and post-test within groups

<table>
<thead>
<tr>
<th>Physical Measurement</th>
<th>Group</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Change Score (Pre-post)</th>
<th>Sig Diff</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>20.84 ± 2.37</td>
<td>20.98 ± 2.37</td>
<td>0.14 ± 0.00</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>21.10 ± 2.53</td>
<td>21.40 ± 2.53</td>
<td>0.30 ± 0.00</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>21.58 ± 2.26</td>
<td>21.86 ± 2.26</td>
<td>0.28 ± 0.00</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>177.49 ± 9.01</td>
<td>179.22 ± 09.26</td>
<td>1.73 ± 0.25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>177.41 ± 11.63</td>
<td>176.05 ± 11.56</td>
<td>-1.36 ± 0.01</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>177.11 ± 6.62</td>
<td>180.02 ± 6.63</td>
<td>2.91 ± 0.94</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>74.16 ± 8.28</td>
<td>72.79 ± 9.22</td>
<td>-1.37 ± 0.94</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>73.29 ± 14.72</td>
<td>73.39 ± 15.21</td>
<td>1.00 ± 0.49</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>76.13 ± 10.61</td>
<td>78.82 ± 10.05</td>
<td>2.69 ± -0.56</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>BMI (body mass index)</strong></td>
<td>SP</td>
<td>22.32 ± 1.76</td>
<td>22.63± 1.85</td>
<td>0.31 ± 0.09</td>
<td>0.740</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>23.51 ± 3.79</td>
<td>23.57 ± 3.88</td>
<td>0.06 ± -0.09</td>
<td>0.646</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>24.39 ± 2.34</td>
<td>24.23 ± 1.91</td>
<td>-0.16 ± -0.43</td>
<td>0.508</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>% Body fat (BF)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>12.9 ± 4.07</td>
<td>14.61 ± 3.86</td>
<td>-1.71 ± 0.21</td>
<td>0.210</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>17.21 ± 7.50</td>
<td>17.4 ± 6.93</td>
<td>-0.19 ± 0.57</td>
<td>0.878</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>14.14 ± 2.90</td>
<td>14.23 ± 2.84</td>
<td>-0.09 ± 0.06</td>
<td>0.074</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>% Muscle mass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>62.31 ± 3.61</td>
<td>64.19 ± 6.84</td>
<td>1.88 ± 3.23</td>
<td>0.508</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>61.42 ± 11.67</td>
<td>58.45 ± 7.69</td>
<td>-2.97 ± -3.98</td>
<td>0.959</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>57.44 ± 5.97</td>
<td>58.72 ± 7.86</td>
<td>1.28 ± 1.89</td>
<td>0.169</td>
<td>0.31</td>
</tr>
</tbody>
</table>

*Note: All statistics are noted as mean ± standard deviation, negative scores represent a greater score for BMI and BF% (sig. diff. within groups, p = 0.05).*

Body mass index (BMI), BF% and MM% were analysed pre- and post-test for all three groups. BF% was determined according to Lukaski & Bolonchuk's (1988) formula for...
total body water (TBW) which is: \( TBW = 0.372(S^2/R) + 3.05(Sex) + 0.142(W) - 0.069(age) \). [\( S = \) Height in centimetres, \( R = \) Resistance, \( W = \) Weight in Kg, \( Sex \) Male = 1 Female = 0 , Age in years].

Watts et al. (2012) investigated which anthropometric parameters characterise the most successful world-class sprinters. Results suggest that while body mass index (BMI = kg.m\(^{-2}\)) is associated with success in both male and female world-class sprinters, which suggests an influence of muscle mass on sprinting performance, the reciprocal ponderal (RPI = cm.kg\(^{-0.333}\)) index has emerged as a more significant factor for success. BMI is a recognised substitute for adiposity in non-athletic populations (Watts et al., 2012); however there was no significant difference between any of the three groups at pre- and post-test scores (SP = 0.31 ± 0.09, GP = 0.06 ± 0.09, C = -0.16 ± 0.43). However, between 1910 and 2009, a high BMI positively correlated with sprinting success in world-class male sprinters (23.79 ± 1.75). The RPI shows that taller, leaner sprinters achieve greater success, measured by sprint speed in the last decade (2000-2009) (Watts et al., 2012).

According to the literature, sprinting demands fast reaction time, high movement speed and explosive strength; therefore the body types of sprinters are different from those in other events (Ansari et al., 2012). Aerenhouts et al. (2012) examined the physical characteristics and somatotypes of junior and senior athletes in relation to sprint start and acceleration performance. Results showed that greater muscularity of senior compared to junior athletes did not result in better sprint start dynamics, but seniors did accelerate more quickly. The researchers suggest that strength training should be combined with sufficient attention to technical skills to allow a positive transfer.

The current study results showed that MM\% in SP (1.88 ± 3.23) did improve; however, there were no significant differences found between the mean change score for the two training protocols. Bohn et al. (1998) discovered that sprinters with larger muscle mass are capable of higher speeds and more rapid accelerations. Sprint performance depends on the capacity to generate power and to achieve a high ratio between body weight and power (Mero et al., 1981; Van Ingen et al., 1994; Weyand et al., 2000; Chelly & Denis, 2001; Cronin & Sleivert, 2005). Muscle mass is crucial in the acceleration phase due to
increasing the stride length and height in the second part of the sprint, while maintaining the stride length (Kraaijenhof, 1990; Korchemny, 1994; Jarver, 2004), where it is important to overcome inertia and increase stride length (Brown et al., 2008).

The acceleration of the centre of mass of a sprinter is determined by three external forces: GRF, GF and wind resistance. Of these three forces, the athlete has the most control over the GRF (Hunter et al., 2005). Furthermore, GRF can be divided into horizontal (anterior-posterior) and vertical components in the case of sprint running. The literature on sprint running contains a number of hypotheses regarding GRF components. A recommendation that has been made was that sprinters should minimise the braking GRF (Mero & Komi, 1986; Wood, 1987; Mero et al., 1992) and maximise the propulsion GRF (Mero et al., 1992). In a study done by Weyand et al. (2000), the swing time and GRF were measured while sprinting at maximal speed on a level treadmill. Maximal sprint speed for the subject averaged between 6.2 m.s$^{-1}$ and 11.1 m.s$^{-1}$. It was noted that the faster individuals were able to apply greater forces during a shorter support phase, whereas the slower individuals applied smaller ground forces with a longer support phase.

Brughelli et al. (2010) recently demonstrated that as athletes approach top velocity, the horizontal propulsive ground forces produced by them increase. They concluded that the production of a horizontal force was central to peak, maximal velocity running. This implies that the changes observed in running mechanics at 80% and 100% of top speed represent the same mechanical outcomes necessary to improve maximal running speed by 25%.

When running at the velocities of maximal sprinting, the task of developing appropriate vertical impulse becomes a restrictive challenge for the athlete. This results in increasing braking and propulsive forces to allow velocity to be maintained by stalling the impending reduction in ground contact time (Goodwin, 2011).

It seems that the inability of athletes to continue to increase peak vertical force production gradually reduces available vertical impulse until airtime reaches a practical minimum. The athletes cannot run any faster because they will not be able to generate
sufficient airtime to recover their swing leg. Weyand and Davis (2005) assessed the maximum running speed of 18 athletes. During fast running, ground and muscle support forces can exceed the body’s weight by as much as 2.5 and 5-fold respectively (Weyand et al., 2000; Wright & Weyand, 2001).

The study proved that regardless of specialisation or sex, a single mass constant accurately links the ideal body mass for running performance to the ground support force required of the performer, and concluded that there was a specific relationship between mass, stature and event-specific ground support force requirements that spans the entire continuum of specialisations and applies to both male and female sprinters (Weyand & Davis, 2005). This supports the fact that a decrease in BF% and increase in MM% enhances sprinting performance.

4.3 EXPLOSIVE POWER VARIABLES

Optimal training techniques designed to maximise strength have received considerable interest from strength and conditioning specialists, strength coaches and researchers (MacDonald et al., 2012). It has however been recognised that explosive strength/power is firmly related to sprint performances (MacDonald et al., 2012).

Maximal power can be measured by a jump test (Bosco & Komi, 1979). Mero et al. (1981) demonstrated functional links between jumping and sprinting performance. Consequently the two main components (forward power and leg stiffness) involved in sprinting (Cavagna et al., 1971) can be evaluated using two simple ergometric systems (ergometric treadmill and vertical jump).

Counselman (1986) suggests that a 25–41cm vertical jump result indicates a predominance of slow-twitch muscle fibres and appropriateness for endurance events. A vertical jump of 41–58 cm is indicative of an even distribution of slow- and fast-twitch muscle fibres, and vertical jump results above 58 cm indicate a predominance of fast-twitch fibres. Explosive power exercises may not directly increase hypertrophy or muscle strength, although the muscular systems contribute force to accelerate the limbs.
Table 4.2 presents the pre- and post-test explosive power variables within the groups. In this study there was no significant difference between the SP and GP groups on pre- and post-test for any of the explosive power variables assessed (p > 0.05), which can be explained by Jaric and Markovic (2013), with the exception of MK for the specialised group (p=0.013).

The reported effect size for this group was large, at 0.56. This could be due to the fact that explosive power exercises were incorporated into the SP (see Chapter Three: Methodology). There was however an improvement from pre- to post-test in SP and GP groups, they were just not significant enough to report on.

**Table 4.2: Pre- and post-explosive variables within the groups**

<table>
<thead>
<tr>
<th>Physical Measurement</th>
<th>Group</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Change Score (Pre-post)</th>
<th>Sig Diff</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explosive Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Margaria Kaalamen)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute (Watts)</td>
<td>SP</td>
<td>1196.31 ± 193.58</td>
<td>1339.95 ± 239.33</td>
<td>143.64 ± 45.75</td>
<td>0.013*</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>1143.76 ± 310.61</td>
<td>1203.20 ± 403.85</td>
<td>59.44 ± 93.24</td>
<td>0.241</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1321.43 ± 353.60</td>
<td>1294.22 ± 330.47</td>
<td>-27.21 ± 23.13</td>
<td>0.169</td>
<td>0.31</td>
</tr>
<tr>
<td>Explosive Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Vertical Jump)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff (cm)</td>
<td>SP</td>
<td>68.50 ± 10.3670</td>
<td>70 ± 35.52</td>
<td>2.2 ± 25.16</td>
<td>0.333</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>54.80 ± 9.94</td>
<td>56.30 ± 16.99</td>
<td>1.5 ± 7.05</td>
<td>0.858</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>56.50 ± 11.22</td>
<td>56.70 ± 11.12</td>
<td>0.20 ± 0.10</td>
<td>0.776</td>
<td>0.06</td>
</tr>
<tr>
<td>Explosive Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Vertical Jump)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute (Watts)</td>
<td>SP</td>
<td>1273.34 ± 267.27</td>
<td>1292.75 ± 78.16</td>
<td>19.41 ± 189.11</td>
<td>0.333</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>1160.17 ± 234.23</td>
<td>1179.54 ± 335.43</td>
<td>19.37 ± 101.2</td>
<td>0.878</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1276.69 ± 178.95</td>
<td>1277.17 ± 176.82</td>
<td>0.48 ± -2.13</td>
<td>0.285</td>
<td>0.24</td>
</tr>
<tr>
<td>Explosive Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Vertical Jump)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative (watt/kg)</td>
<td>SP</td>
<td>17.88 ± 3.77</td>
<td>17.90 ± 1.38</td>
<td>0.02 ± 2.39</td>
<td>0.333</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>16.00 ± 1.40</td>
<td>16.08 ± 2.61</td>
<td>0.08 ± 1.21</td>
<td>0.959</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>16.22 ± 1.64</td>
<td>16.26 ± 1.59</td>
<td>0.04 ± 0.05</td>
<td>0.678</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Note: All statistics are noted as mean ± standard deviation, negative scores represent a decrease in power output (sig. diff. within groups, p ≤ 0.05*).
Jaric and Markovic’s (2013) review of the optimum external load that maximises the mechanical power output of particular muscle(s) or neuro-musculo-skeletal system corresponding to a certain percentage of maximum strength concluded that the optimum load in a maximum vertical jump is one’s own body mass, regardless of the strength of the lower limb muscles. The authors also believed that several neuro-mechanical mechanisms were involved, which among these are a long-term adaptation of the muscular force–velocity relationship to the body weight and inertia, alteration of the jumping technique, load-specific muscle activation and jumping skills.

In this study the difference in cm for the SP vertical jump (pre: 70.70 ± 35.52 and post: 65.50 ± 10.36) was higher than the suggested 58cm of Counsilman (1986). This could be due to the fact that plyometrics have been incorporated with strength training repetitions in the SP, which helps with explosive power.

Santos and Janeira (2012) also evaluated the effects of a lower- and upper-body 10-week in-season RT programme on explosive strength development in young basketball players. Results showed that a 10-week in-season RT programme, with moderate volume and intensity loads, increased vertical jump and MBT performance in adolescent male basketball players.

Smilios et al. (2013) examined the changes in maximum strength, vertical jump performance and the load-velocity and load-power relationship after a RT period using a heavy load and an individual load that maximises mechanical power output with and without including body mass in power calculations in 43 moderately trained men (age: 22.7 ± 2.5 years). Subjects were separated into four groups; two groups of maximum power, one where body mass was not included in the calculations of the load that maximises mechanical power (Pmax - bw, n = 11) and one where body mass was included in the calculations (Pmax + bw, n = 9); a high-load group (HL-90%, n = 12); and a control group (C, n = 11). The subjects performed four to six sets of jump squats and the repeated-jump exercises for six weeks.

They concluded that the inclusion or not of body mass to determine the load that maximises mechanical power output, affects the long-term adaptations differently in the
load-power relationship (The high load group-90% and the maximised mechanical power minus body weight group increased (p < 0.05) power output at loads of 20, 35, 50, 65, and 80% of 1RM. The maximal mechanical power plus body weight group increased (p < 0.05) at loads of 20 and 35% of 1RM). Thus, training load selection depends on the necessary adaptations that maximise mechanical power output. However, the use of heavy loads causes greater overall neuro-muscular adaptations in moderately trained individuals (Smilos et al., 2013).

A recent study by Campillo et al. (2013) examined the effects of different training volume and training surfaces during a short-term PT programme on neuromuscular performance. The results showed that high training volumes lead to a significant increase in explosive performance that requires fast SSC actions in comparison to what is observed after a moderate training regimen. Secondly, when PT is performed on a hard surface, a moderate training volume induces optimal stimulus to increase explosive performance requiring fast SSC, maximal dynamic strength enhancement and higher training efficiency. This supports the current study intervention, SP, which included PT to have a significant improvement of p < 0.13 (Campillo et al., 2013).

4.4 SPRINTING VARIABLES

As seen in Table 4.3 there was no significant difference between the SP and GP groups from pre- and post-test for any of the sprinting variables assessed (p > 0.05), with the exception of the 60m sprint for the specialised group (p=0.047). The reported effect size for this group was large, at 0.44. All sprinting variables improved (decrease in time) from pre- to post-test in the SP; however as mentioned only 60m sprint time was significant.

The review of literature by Ross et al. (2001) summarised that performance in sprint exercise is determined by the ability to accelerate, the magnitude of maximal velocity and the ability to maintain velocity against the onset of fatigue. These factors are strongly influenced by metabolic and anthropometric components. Improving the temporal sequencing of muscle activation and/or improving FG fibre recruitment may contribute to superior sprint performance. This can explain why there was a significant
improvement in 60m sprinting time, due to the significant improvement of MM. However all sprinting times did improve while no sprinting activities has been included in the program, it could be due to the anthropometrical, explosive power and strength improvements.

To summarise, if speed needs to be improved, muscles and movements inherent to sprinting actions should be specifically targeted. The principle still stands that for an exercise to be effective, it must contain similar characteristics to the sport (Alcaraz et al., 2009).

**Table 4.3: Sprinting variables during the pre- and post-test within the groups**

<table>
<thead>
<tr>
<th>Physical Measurement</th>
<th>Group</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Change Score (Pre-post)</th>
<th>Sig Diff</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>40m Sprint (sec)</strong></td>
<td>SP</td>
<td>5.41 ± 0.33</td>
<td>5.40 ± 0.38</td>
<td>-0.01 ± 0.05</td>
<td>0.878</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>5.80 ± 0.58</td>
<td>5.86 ± 0.47</td>
<td>-0.06 ± 0.11</td>
<td>0.959</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>5.62 ± 0.37</td>
<td>5.59 ± 0.39</td>
<td>-0.03 ± 0.02</td>
<td>0.221</td>
<td>0.27</td>
</tr>
<tr>
<td><strong>60m Sprint (sec)</strong></td>
<td>SP</td>
<td>7.85 ± 0.48</td>
<td>7.66 ± 0.41</td>
<td>-0.19 ± 0.07</td>
<td>0.047*</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>8.22 ± 0.78</td>
<td>8.45 ± 0.67</td>
<td>0.23 ± 0.11</td>
<td>0.878</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7.80 ± 0.59</td>
<td>7.83 ± 0.58</td>
<td>0.03 ± 0.01</td>
<td>0.262</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>80m Sprint (sec)</strong></td>
<td>SP</td>
<td>10.24 ± 0.64</td>
<td>10.16 ± 0.73</td>
<td>-0.08 ± 0.09</td>
<td>0.575</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>10.86 ± 1.12</td>
<td>11.04 ± 0.83</td>
<td>0.18 ± 0.29</td>
<td>0.721</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>10.44 ± 0.78</td>
<td>10.51 ± 0.73</td>
<td>0.07 ± 0.05</td>
<td>0.444</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>100m Sprint (sec)</strong></td>
<td>SP</td>
<td>12.65 ± 0.78</td>
<td>12.55 ± 0.68</td>
<td>-0.1 ± 0.1</td>
<td>0.285</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>13.51 ± 1.63</td>
<td>13.51 ± 1.06</td>
<td>0.0 ± 0.57</td>
<td>0.646</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>12.25 ± 0.80</td>
<td>12.38 ± 0.65</td>
<td>0.13 ± 0.15</td>
<td>0.139</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Note: All statistics are noted as mean ± standard deviation, negative scores represent a decrease in sprinting time (sig. diff. within groups, p = 0.05*).
4.5 STRENGTH VARIABLES (1RM)

Cissik (2010) recommends that training should focus on both maximal strength and power (weightlifting and plyometrics), based on the importance of FG fibres in sprinting performance. The intensity or percentage of 1RM of a given lift determines the level of force, power and velocity of performed repetitions at this given load; therefore these variables must be considered in the context of sports performance enhancements.

It is recommended by Kirby et al. (2010) that the selection of percentage 1RM be carefully considered based on exercise type and the phase of periodisation specific to various athlete populations.

Table 4.4: Pre- and post-strength (1RM) variables within the groups

<table>
<thead>
<tr>
<th>Physical Measurement 1 RM</th>
<th>Group</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Change Score (Pre-post)</th>
<th>Sig Diff</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Press (kg)</td>
<td>SP</td>
<td>77.90 ± 11.63</td>
<td>95.40 ± 14.60</td>
<td>17.5 ± 2.97</td>
<td>0.005*</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>70.20 ± 14.16</td>
<td>80.40 ± 14.22</td>
<td>10.2 ± 0.06</td>
<td>0.005*</td>
<td>0.63</td>
</tr>
<tr>
<td>Deadlift (kg)</td>
<td>SP</td>
<td>122.60 ± 14.60</td>
<td>149.20 ± 20.05</td>
<td>26.6 ± 5.45</td>
<td>0.005*</td>
<td>0.63</td>
</tr>
<tr>
<td>Power Clean (kg)</td>
<td>SP</td>
<td>77.40 ± 20.05</td>
<td>88.10 ± 11.44</td>
<td>10.7 ± 8.61</td>
<td>0.005*</td>
<td>0.63</td>
</tr>
<tr>
<td>Squat (kg)</td>
<td>GP</td>
<td>81.00 ± 24.37</td>
<td>82.10 ± 13.03</td>
<td>1.1 ± 11.34</td>
<td>0.005*</td>
<td>0.40</td>
</tr>
<tr>
<td>Bent over row (kg)</td>
<td>GP</td>
<td>65.60 ± 13.09</td>
<td>76.50 ± 12.63</td>
<td>10.9 ± 0.46</td>
<td>0.073*</td>
<td>0.63</td>
</tr>
</tbody>
</table>

*Note: All statistics are noted as mean ± standard deviation, negative scores represent a decrease in 1 RM strength (sig. diff. within groups, p = 0.05*).

De Villarreal et al. (2010) suggest that PT improves maximal power performance as measured in the 1RM, but muscular strength and power are considered critical elements for successful athletic performance (Kraemer et al., 2001; De Villarreal et al. 2009). Research evidence indicates that PT is also effective for maximal strength (Clutch et al., 1983; Blakey & Southard, 1987; Fatouros et al., 2000; Buckley et al., 2003).
As Table 4.4 indicates, there was a significant difference between the specialised and general groups on pre- and post-test for the 1RM variables assessed (p > 0.05) in the current study: 1RM bench press (p=0.005 SP and GP), 1RM deadlift (p=0.005 SP), 1RM power clean (p=0.005 SP) and 1RM squat (p=0.005 GP), with the exception of 1RM bent-over row (p=0.073 GP). The reported effect size (0.63) for these groups was large. The above-mentioned research supports the selection of exercise intensity in the training protocols of SP and GP, due to the significant increase in pre- and post-test. Cissik’s (2010) study proves that programmes should focus on training athletes to exert force against the ground. He suggests that squats, deadlifts, romanian deadlifts, cleans, pulls, snatches and jerks should be prioritised ahead of exercises that do not train the athlete to exert force against the ground.

The effect of RT cessation on strength performance through a meta-analysis by Bosquet et al. (2013) indicated that RT cessation had a detrimental effect on all components of muscular performance (sub-maximal force, maximal power and maximal force). The effect was also larger in inactive people for maximal force and maximal power when compared with recreational athletes.

Newton and Kraemer (1994) demonstrated that exercises emphasising speed and full range of movement have a greater effect on sprinting performance than exercises focusing on absolute strength. In the SP, deadlifts were performed first, followed by plyometrics, bench press and cleans.

Brännström et al. (2013) showed that increased maximal muscular power after tapering also relies on higher neural drive and increased muscle fibre CSA, especially in type 2A muscle fibres. Complete rest is a special form of tapering and it usually leads to sustained maximal power. This also correlates with the current study’s resting intervals in the two interventions programmes between sets, which can also lead to improvements in strength (1RM).

Results from various studies related to complex training indicate that it may improve measures of athletic ability (will demonstrate no decrement to athlete) compared with more conventional training programmes (Fatouros et al., 2000; Adams et al., 2001;
Duthie et al., 2002; Mihalik et al., 2008;). Blakey and Southard (1987), and Fatouros et al. (2000) suggest that to achieve maximal strength, a combination of training modalities is recommended instead of a single modality. This is in accordance with previous studies, which indicate that the combination of a heavy and explosive weight training method is an efficient strategy to improve strength performance in youth (Harris et al., 2000; Newton et al., 2002). The use of plyometric exercises within athletic populations to enhance performance is a well-accepted practice among sport scientists (Durell et al., 2003; Ebben et al., 2004; Ebben et al., 2005). Cristea et al. (2008) indicate that incorporating weight training exercises in the conditioning programme leads to improvements in maximal and explosive strength in world-class master sprinters. Part of the reason for substantial improvements in muscular strength may be the specific form of strength training used, in which heavy resistance exercises where combined with explosive-type weight training and plyometric exercises. The same was seen with the current study, where heavy RT was incorporated with plyometric jumps in the SP group and resulted in a significant correlation of MK on 40m (p=0.015) sprinting time.

Strength alone can improve power by increasing force production capabilities (Kirby et al., 2010). Increasing intensity represents an increasing load, which leads to a decrease in movement velocity in the squat and jump squat. So although it is very important to maintain or increase strength consistently, there is also a need to increase velocity of movement by changing the quantity of training to power and speed. Research done by Aagaard et al. (2002) and Lee et al. (2009) resemble traditional strength-training protocols that are known to result in large strength gains. The ability to produce high forces against large resistances (strength) and to produce a high work rate (power) is of utmost importance for various sports (Young, 2006).

In the current study, the GP consisted of more general types of exercise, e.g. squats (deep squats, front squats and back squats) followed by plyometrics and bench press. A significant difference between the general group on pre- and post-test for the 1RM variables were seen: 1RM bench press (p=0.005, SP and GP) and 1RM squat (p=0.005 GP). The reported effect size for this group was large, at 0.63. Conventionally, the traditional squat (when the load attains a zero velocity at the end of the concentric
phase) and ballistics squat (a loaded squat jump, where the load is projected vertically) movements have been incorporated as main exercises into strength programmes aimed at enhancing maximal sprinting times or vertical jump performances in athletes (Newton et al., 1996; Newton et al., 1997). For ultimate transfer of movement, the characteristics of RT stimulus should be specific to the activity in terms of muscles used, contraction type, contraction force and velocity, loading characteristics and range of movement (Sale, 2003). The maximal concentric actions of the lower-limb extensor muscles are important for jumping (Bobbert et al., 1987) and sprinting (Mero et al., 1992), although it seems that ballistic squats are more suitable than the traditional squat for the improvement of both functional activities, because each activity involves projection of body weight. Wisloff et al. (2004) report significant correlations (r=0.71-0.94) between 1RM in traditional squat and vertical jumping and sprinting times at 10m and 30m, in elite soccer players.

Requena et al. (2011) indicate that traditional squat strength has little in common with counter-movement jumps and that relative 1RM and power outputs for both squat exercises (traditional and ballistic squat) are statistically correlated to most sprint distances, underlying the importance of strength and power in sprinting. This correlates with the results of the current study. Results for the 1RM squat in GP were significant pre- and post-test (p = 0.005), but showed no significant correlation when compared to sprinting times (40m, 60m, 80m and 100m).

Björk and Raask (2013) examined how the application of different loads of accommodating resistance influences peak power output in the bench press. They tested 14 subjects’ 1RM in bench press and after seven days performed a power test consisting of three repetitions with 30, 40, 50, 60 and 70% of 1RM and peak power using a MuscleLab Linear encoder. Results indicated that the use of accommodating resistance results in greater power output than using bar weight when the load is constant. This can be implemented in future studies to give even more significant results.
4.6 DIFFERENT VARIABLES AND CORRELATIONS WITH SPRINTING PERFORMANCES

At post-test, it was also concluded that there was no significant difference between groups in BMI, BF%, MM %, MK and VJ and 40m sprint. However, there was a significant difference between the groups in the 60m sprint (p=0.022), 80m sprint (p=0.057), 100m sprint (p=0.025) and 1RM bench strength test (p=0.007) (the general group differed from specialised and control).

As shown in Table 4.5, there was no significant difference between the specialised, general and control groups at pre-test, based on any of the variables assessed (p > 0.05).

Table 4.5: Variables within groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-Test</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chi-Square</td>
<td>df</td>
</tr>
<tr>
<td>BMI</td>
<td>3.920</td>
<td>2</td>
</tr>
<tr>
<td>Body Fat % (BF %)</td>
<td>3.231</td>
<td>2</td>
</tr>
<tr>
<td>Muscle Mass % (MM %)</td>
<td>4.049</td>
<td>2</td>
</tr>
<tr>
<td>Explosive Power (MK)</td>
<td>1.551</td>
<td>2</td>
</tr>
<tr>
<td>Explosive Power (VJ)</td>
<td>2.945</td>
<td>2</td>
</tr>
<tr>
<td>40m sprint</td>
<td>3.420</td>
<td>2</td>
</tr>
<tr>
<td>60m sprint</td>
<td>2.309</td>
<td>2</td>
</tr>
<tr>
<td>80m sprint</td>
<td>2.017</td>
<td>2</td>
</tr>
<tr>
<td>100m sprint</td>
<td>4.452</td>
<td>2</td>
</tr>
</tbody>
</table>

*Note: All significant statistics are noted as * (p<0.05)*

It was hypothesised that SP and GP would result in improvement of anthropometrical measurements, explosive power (vertical jump and Margaria Kalamen Power Test),
1RM strength and sprinting times (40m, 60m, 80m and 100m), but SP would result in a greater improvement in sprinting times compared to the GP for males aged 18–25 years. It was also hypothesised that there would be a correlation between either anthropometrical measurements, explosive power, 1RM strength or sprinting times (40m, 60m, 80m and 100m). In contrast to the hypothesis, the results indicated that there was no significant difference between any of the three groups with any of the variables tested at pre-test.

**Table 4.6: Post-test correlation between anthropometrical variables and sprinting performance within the groups**

<table>
<thead>
<tr>
<th>Physical Measurement</th>
<th>Spearman’s Rho</th>
<th>40 metre (sec)</th>
<th>60 metre (sec)</th>
<th>80 metre (sec)</th>
<th>100 metre (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Body Mass index (BMI)</td>
<td>Correlation</td>
<td>0.039</td>
<td>0.176</td>
<td>0.176</td>
<td>0.131</td>
</tr>
<tr>
<td></td>
<td>Sig diff.</td>
<td>0.838</td>
<td>0.353</td>
<td>0.354</td>
<td>0.489</td>
</tr>
<tr>
<td>% Body Fat (BF)</td>
<td>Correlation</td>
<td>0.170</td>
<td>0.210</td>
<td>0.156</td>
<td>0.304</td>
</tr>
<tr>
<td></td>
<td>Sig diff.</td>
<td>0.370</td>
<td>0.264</td>
<td>0.411</td>
<td>0.102</td>
</tr>
<tr>
<td>% Muscle Mass (MM)</td>
<td>Correlation</td>
<td>-0.285</td>
<td>-0.418</td>
<td>-0.463</td>
<td>-0.427</td>
</tr>
<tr>
<td></td>
<td>Sig diff.</td>
<td>0.127</td>
<td>0.021*</td>
<td>0.010*</td>
<td>0.019*</td>
</tr>
</tbody>
</table>

*Note: All significant statistics are noted as * (p=0.05)*

Based on the results shown in Table 4.6, it was concluded that there was no significant correlation between BMI and BF% and sprinting times, with the exception of MM% on 60m (p=0.021), 80m (p=0.01) and 100m (p=0.019) sprinting times. Neither SP nor GP was more significant. Based on the results in Table 4.7, it was concluded that there was no significant correlation between explosive power and sprinting times, with the exception of MK on 40m (p=0.015) sprinting time.
### Table 4.7: Post-test correlation between explosive power variables and sprinting performance within the groups

<table>
<thead>
<tr>
<th>Physical Measurement</th>
<th>Spearman’s Rho 40 metre (seconds)</th>
<th>Spearman’s Rho 60 metre (seconds)</th>
<th>Spearman’s Rho 80 metre (seconds)</th>
<th>Spearman’s Rho 100 metre (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explosive Power (MK)</td>
<td>Correlation</td>
<td>-0.440</td>
<td>-0.241</td>
<td>-0.285</td>
</tr>
<tr>
<td></td>
<td>Sig diff.</td>
<td>0.015*</td>
<td>0.200</td>
<td>0.127</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Explosive Power (VJ)</td>
<td>Correlation</td>
<td>-0.237</td>
<td>-0.249</td>
<td>-0.273</td>
</tr>
<tr>
<td></td>
<td>Sig diff.</td>
<td>0.207</td>
<td>0.184</td>
<td>0.144</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

*Note: All significant statistics are noted as * (p=0.05)*

A successful 100m sprinter must be able to produce a great deal of force in order to get a good start, must have a high maximum velocity, and must be able to sustain that maximum velocity for a long period of time (Kale, Asci, Bayrak & Acikada, 2009). With the 100m sprinting tests, one must be able to generate enough force to start quickly and reach maximum velocity early in the sprint in order to post a good time (Cronin & Hansen 2005). MK is a measure of force and power production and a better performance seems to be more related to shorter distances. Ultimately the subjects were never required to sprint more than 100m, and therefore their physiological adaptations have made them more prone to have good results in shorter sprints with greater force and power production and they will lose speed as they proceed to a full 100m. From the results of past studies and the current study, it is clear that there is some relationship between jumping and sprinting among many different types of athlete. De Villarreal et al. (2012b) compared the effects of five different training stimuli on sprinting ability and strength production. Sixty students were tested and trained three times a week for seven weeks. Training comprised a full squat, parallel squat, loaded countermovement jumping and PT. Testing was done before and after seven weeks of consisted sprinting.
performance (30m), maximal dynamic strength (1RM) and velocity displacement in the
centric phase of the full squat (m/s). Results show that the combined training
approach results in a slight improvement in maximal strength, velocity of displacement
and sprinting performances and the resemblance between movement patterns and
velocity of displacement common to the training and testing methods.

Table 4.8: Post-test correlation between 1RM variables and sprinting
performance within the groups

<table>
<thead>
<tr>
<th>Physical Measurement 1RM</th>
<th>Spearman’s Rho</th>
<th>40 metre (seconds)</th>
<th>60 metre (seconds)</th>
<th>80 metre (seconds)</th>
<th>100 metre (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Press (kg)</td>
<td>Correlation</td>
<td>-0.142</td>
<td>-0.212</td>
<td>-0.231</td>
<td>-0.159</td>
</tr>
<tr>
<td></td>
<td>Sig diff.</td>
<td>0.550</td>
<td>0.369</td>
<td>0.327</td>
<td>0.502</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Deadlift (kg)</td>
<td>Correlation</td>
<td>0.143</td>
<td>0.212</td>
<td>0.292</td>
<td>0.255</td>
</tr>
<tr>
<td></td>
<td>Sig diff.</td>
<td>0.694</td>
<td>0.557</td>
<td>0.413</td>
<td>0.478</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Power Clean (kg)</td>
<td>Correlation</td>
<td>-0.239</td>
<td>-0.142</td>
<td>0.006</td>
<td>-0.301</td>
</tr>
<tr>
<td></td>
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<td>Bent over row (kg)</td>
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Note: All significant statistics are noted as * (p≤0.05)
Table 4.8 shows that there is no significant correlation between 1RM strength test variables and sprinting times.

Neither the SP nor the GP was more significant in explosive power and 1RM strength. The effect of periodised RT on acceleration sprint performance was studied by Moir et al. (2007). Sixteen subjects participated in the authors study, and 10 engaged in eight weeks of periodised RT intervention. The results of the pre- and post-test showed that despite the increase in measurements of maximum and explosive strength, a period of RT did not improve the initial acceleration phase of sprinting (0–10m) immediately after the training period. However, the adaptations resultant from the RT exercises used in their study appeared to be suitable for performance, as the subjects reached maximum speed sprinting (1–20m). These findings contribute to current literature regarding the benefits of RT. In the current study there is only a significant correlation with MK on 40m (p=0.015) sprinting time.

Chelly et al. (2010) performed a sequence of exercises including jumps and counter movement jumps to assess the leg power of male soccer players. The subjects completed the training for eight weeks during their regular season and it was found that PT induced a significant increase in thigh muscle volume, a significant increase in squat jump and counter movement jump heights, and a significant increase in running velocities over 5m and 40m respectively.

MacDonald et al. (2012) compared the effects of RT, PT and complex training on lower-body strength and anthropometrics. Their study used 31 trained college-age males who were trained using one of those three methods twice weekly for six weeks. Testing was done pre-, mid- and post-training to assess back squat strength, Romanian deadlift strength, standing calf raises strength, quadriceps girth, triceps girth, BMI and BF%. Results suggest that complex training mirrors benefits seen with traditional RT or PT. Additionally, complex proved to have no decremented influence on strength and anthropometric values and can also be used as a training method.

Faigenbaum, Kraemer, Blimkie, Jeffereys, Micheli, Nitka and Rowland (2009) compared the effects of a six-week training period of combined plyometric and RT and
RT alone on fitness performance in boys between the ages of 12 and 15 years. The study found that 31 combined exercises of plyometric and RT significantly improved the vertical jump, long jump and 9.1m shuttle run, whereas the resistance-training-only protocol did not show significant differences in the performance areas assessed. This suggests that a combination of high volume and high RT programmes will significantly improve sprint time performance.

Hrysomallis (2012) did research on the effectiveness of resisted movement training on sprinting and jumping performance, and concluded that resisted jump training in the form of weighted jump squats indicates an increased vertical jump height but is not more effective than plyometric depth jump training. Hrysomallis (2012) concludes that resisted sprint training is superior in increasing speed in the initial acceleration phase of sprinting. This supports the current study’s incorporation of plyometric jumps in the intervention programmes.

Haghighi et al. (2012) investigated the effect of plyometric versus RT on sprint and skill performance in young soccer players. Thirty elite players participated in the study. They were divided into three groups: control, PT (eight weeks of lower extremities) and RT (two to four sets of weight training for four stations, intensity 60-90% of 1RM, and 6-12 repetitions). Results showed that times in the sprint and dribbling test improved after PT and RT (p < 0.05). The same effect can be seen with the significant correlation on MK on 40m sprint time (p < 0.015) in the current study.

Tsimachidis et al. (2013) examined the effect of a 10-week combined resistance/sprint training programme on sprint performance before, between and after RT sets. The combined training programme consisted of five sets at five to eight RM half-squats with sprints performed between each set. The intervention increased both strength and sprint performance. It also illustrated that post-activation potentiating effects on sprint performance, in subjects who did not previously follow systematic RT, emerge after a 10-week resistance/sprint combined training programme.

In the current study, RT had no significant effect on sprinting performance, but could have had a significant effect if combined with sprint training. This is also seen in the
Paradisis et al. (2013) study, where they examined the effects of an eight-week uphill-downhill sprint training programme on the force generation capacity of leg muscles. The combined training was significantly more effective in improving the maximum sprinting speed (5.9%, p<0.05)

The results of this study show an overall improvement in the subjects’ sprint performance for both training protocols. These improvements are significant between the two training groups but when comparing the pre- and post-test times, the change is not significant.
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

The main objective of this study was to determine the possible effect of two different resisting training programmes on the sprinting performance on men aged 18–25. The hypothesis of the study was that there would be a statistically significant correlation (p < 0.05) between anthropometrical and explosive power measurements in regards to the 40m, 60m, 80m and 100m sprinting time as a result of both intervention programmes.

The hypothesis was not supported in this study because it did not meet the set level of significance (p < 0.05) as a predictor of training programme influence on sprint performance. Based on the results, no significant difference was found between the two training groups’ mean change scores. However, both protocols over eight weeks of training resulted in an improvement in some of the pre- to post-test variables. It could be suggested that both training protocols can in some manner assist athletes to improve sprint performance.

Based on the information from this study it may be important for people involved in sprint coaching to understand that general RT interventions can improve muscular power in males and younger athletes. The length of a training programme (i.e. number of weeks) may show a significant change, if other external factors are taken into account.

Research indicates that a minimum of eight weeks is needed to determine training adaptations in performance; however, the optimal amount of time required is likely to be greater than ten weeks (Coffey & Hawley, 2007). Free weight training is one of the most common forms of strength training for young athletes, with a frequency of twice per week for a duration of eight weeks as the norm (Baechle & Earle, 2000).

The results of this study suggest that a training period of eight weeks may induce a significant change between the pre- and post-test sprint times. Both training protocols produced an improvement from the pre- to post-test trial sprint time; however, other factors may have influenced the outcome of the trials. The change in sprint time performance between the pre- and post-test trials could be due to a familiarity with the
researcher and the subjects being more comfortable with performing the running trials and the training protocols. RT, PT, speed training or a combination of these methods all have the potential to improve muscular power and can produce an improvement in sprint time.

This study used specific training exercises to determine if any change in sprinting time would occur. There are some limitations to the study. The sample size used in the study could have been bigger. Another consideration would be to change the sets, repetitions and exercises used in the protocols and combine them with sprint training to see which combination of exercise induces a greater change in the sprint time performance.

Although there was no significant improvement in sprinting times in both the SP and GP intervention programmes, there are some significant changes pre- and post- test and correlations in some of the variables related to sprinting time that can be taken into consideration when designing strength training programmes for the athletic population, focusing on improving sprinting times. These changes are as follow:

Changes in SP:
- MM% increased
- Explosive power increased (MK and VJ)
- 40m, 60m, 80m and 100m sprint times decreased (positive, meaning times got faster)
- All 1RM strength increased

Changes in GP:
- Explosive power increased (MK and VJ)
- All 1RM strength increased

These changes indicates that SP is more effective as there was more changes in certain variables namely sprinting times and MM% than in GP.
REFERENCES


APPENDICES

Appendix A: Research Authorisation and Consent form

Appendix B: Physical Active Readiness Questionnaire (PAR-Q & You)

Appendix C: Medical Screening Questionnaire

Appendix D: Description of Anthropometric measurements

Appendix E: Description of 7-Stage abdominal test
Research Authorisation and Consent Form

Researcher: Licinda Pienaar (Research for completion of Masters)

Supervisors:
Dr A.J.J. Lombard (Department of Sport and Movement Studies, UJ)
Prof. E. Kruger (Department of Sport and Movement Studies, TUKS)

Subject information and consent

Dear Subject

The University of Johannesburg Department of Sport and Movement Science would appreciate it if we can use the data and information obtained from your test scores for possible research purposes.

Please read through the following carefully before you sign the form.

Aim of the research

The aim of this research is to determine the effect of two different RT programmes on the sprinting performance of males aged 18–25. The study will analyse laboratory and field physical test results and look into physiological variables.

Research protocol

The following tests will be included in the test protocol:
• **Questionnaires**

Completing of the following questionnaires: Par-Q and Medical Screening Questionnaire

• **Laboratory**

**Anthropometry**: Height (The Leicester Height Measure, SECA, Birmingham), weight (Tanita Body Composition Analyzer, Japan), skinfolds (Harpenden Skinfold Calliper, Baty International, England), circumferences (Body Care Type Measure, West Germany) and breadths (Sliding Calliper, Germany) will be tested.

**Vertical Jump**: Take-off must be from two feet, with no preliminary steps or shuffling. The distance between the reach height and jump height is recorded to the nearest cm. The subject performs a maximum of three trails (Gore, 2000) using the Vertex vertical jump.

**Margaria-Kalamen Test**: The subject needs to sprint up a flight of stairs. The tester marks a starting line with cones six metres in front of the first stair and also places a cone on and to one side of the third, sixth and ninth stairs. The vertical distance is then measured from the third to the ninth stair (metres). The athlete starts at the six-metre line.

**1-RM Strength test**: The maximum weight that can be lifted for one complete repetition of the movement will be tested. The following 1-RM test will be conducted: Bench press, Deadlift, Power Clean, Bent over row and squat. The 1-RM strength value is obtained through trial and error (Heyward, 2002).

**7 Stage Abdominal test**: The abdominal stage test is a graded test for abdominal strength. Each of the seven stages becomes progressively more difficult as the positions of the hands and arms are modified. These modifications plus the use of 2.5 and 5 kg disks places increasing stress on the abdominal musculature. The aim of the test is to
accomplish as many of these stages as possible (See Appendix A for stages) (Core, 2000).

The following field tests will be conducted after a warm up to prepare your body for physical activity:

**Speed and acceleration**: The test measures running speed over 40, 60, 80 and 100m distances using the speed gates (Swift Performance Equipment, Australia).

- **Strength Training Programme**

**Specialised Strength Training Programme (SP)**

The specialised strength training programme will be performed twice a week in the gymnasium for duration of 12 weeks.

Exercises will include the following:

- Dynamic stretch before each session, static stretch after each session

1. Deadlift every session, 2-3 sets of 2-3 reps @ 85-95% 1RM

   a. Plyometrics at the end of each set, within 1 minute of set completion.
      i. Usually depth jumps from varying heights generally 6 jumps or less. The focus is on delivering maximum strength in minimum time.

2. Bench Press at each session, 2-3 sets of 2-3 reps,
3. Power Clean at each session, 2-3 sets of 2-3 reps,
4. Abdominal exercises each session, 3-5 sets of 3-5 reps.
   a. Vertical Leg Crunches
   b. Side Medicine Ball throws against wall
   c. Sit ups Medicine Ball throws against wall
General Strength Training Programme (G)

The general strength training programme will be performed twice a week in the gymnasium for duration of 12 weeks.

Exercises will include the following:

Dynamic stretch before each session, static stretch after each session

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<tr>
<td>Overhead squat</td>
<td>Overhead squat</td>
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<tr>
<td>Push up tuck jumps</td>
<td>Push up tuck jumps</td>
</tr>
<tr>
<td>Medicine ball shoulder press side bend</td>
<td>Deep back squat</td>
</tr>
<tr>
<td>Leg medicine ball throw</td>
<td>Single leg medicine ball throw</td>
</tr>
<tr>
<td>Seated medicine ball throws with rotation</td>
<td>Seated medicine ball throws with rotation</td>
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<tr>
<td>Barbell deep front squat shoulder press</td>
<td>Barbell deep front squat shoulder press</td>
</tr>
<tr>
<td>Hanging hip flexion</td>
<td>Bench press</td>
</tr>
<tr>
<td>Barbell reverse grip bent over row</td>
<td>Reverse grip pull up</td>
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</table>

Risk, freedom from harm and inconveniences

The risks in the testing will be limited by performing a good warm up and the tester will use all the recommended techniques to ensure that there are no additional risks in performing the tests. As a subject you may withdraw from performing any of the tests if you consider any test dangerous.

Please disclose information with regards to your health status or any previous experiences of discomfort during periods of physical exertion.
Please disclose any information that may prevent you from doing the tests.
Do you have any injury that would prohibit you from being tested?

The research team assumes no liability for persons who undertake in physical activity.

Therefore this document may be used for legal and administrative purposes.

Benefits and economic considerations

You will not receive any monetary benefit from participating in this research. You will receive feedback on your current physical fitness. You will also receive feedback on the conclusions of the study.

Confidentiality

All identifiable information that is obtained in connection with the test and injury feedback-form will remain confidential. When the results of the research are published or discussed in conferences, no personal information, other than the details mentioned above will be included.

Voluntary Participation and Withdrawal

You can withdraw your participation at any stage of the testing procedure. You are free not to make your data available for research.

Questions

Please feel free to ask about anything you don’t understand and take as long as you feel it is necessary before you make a decision.
Privacy rights

All reasonable efforts will be made to protect the confidentiality of your data, which may be shared with others to support this research.

Authorisation

I have read, (or someone has read to me) the Authorisation and have decided to make my test data results available to the University of Johannesburg Institute for Biokinetics and Sport Science for research. Its general purpose, the particulars of my involvement and possible risks and inconveniences has been explained to my satisfaction. By signing below, I give permission for the described uses and disclosure of information. My signature indicates that I have received a copy of the consent/authorisation form. I do not give up any of my legal rights by signing this form.

________________________________________
Name of subject

________________________________________
Signature of Person Obtaining     Consent Date

If you have any queries about the study please contact Licinda Pienaar (Researcher) on 082 214 4931 or Mr A.J.J. Lombard (Supervisor) on 011 559 2748.
APPENDIX B

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q & YOU)
# Medical Screening Questionnaire

## Subject Information

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## Medical Screening

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### Orthopedic Injury

History & onset of signs and symptoms:
APPENDIX D

DESCRIPTION OF ANTHROPOMETRIC MEASUREMENTS

Standing Height

Standing height will be measured using the Leicester Height Measure (Seca, Bimingham) portable height measure. Height will be measured with the subject stretching up and barefoot with heels together, gluteus maximus, upper spine and head in contact with the wall. The direction of vision is horizontal, with the corner of the eye and the superior ear orifice in a horizontal plane (Frankfort plane). All hair will be removed from underneath the measuring arm. Measurements will be made in duplicate, to the nearest millimetre, and the mean value will be recorded (Jones et al., 2006).

Mass

Mass will be measured using the Tanita Body Composition Analyzer (maximum: 180kg). Subjects will be weighed wearing gym shorts of which the mass is known. Mass will be registered to the nearest 0.1kg (Smit, 1979). (Jones et al., 2006).

Tricep Skinfold

Tricep skinfold will be taken using a Harpenden Skinfold Calliper (Baty International, England). The subject assumes a relaxed standing position. The right arm should be relaxed with the shoulder joint externally rotated to the mids-prone position and elbow extended by the side of the body. Measurement will be taken to the nearest mm (Jones et al., 2006).

Bicep Skinfold

Bicep skinfold will be taken using a Harpenden Skinfold Calliper (Baty International, England). The subject assumes a relaxed standing position. The right arm should be relaxed with the shoulder joint externally rotated and elbow extended by the side of the body. Measurement will be taken to the nearest mm (Jones et al., 2006).
Subscapular Skinfold

Subscapular skinfold will be taken using a Harpenden Skinfold Calliper (Baty International, England). The subject assumes a relaxed standing position with the arms hanging by the sides. Measurement will be taken by the natural fold lines of the skin in mm (Jones et al., 2006).

Supra-Iliac Skinfold

Supra-Iliac skinfold will be taken using a Harpenden Skinfold Calliper (Baty International, England). The subject assumes a relaxed standing position with the right arm either abducted or placed across the trunk. The line of the skinfold generally runs slightly downward posterior-anterior as determined by the natural folds of the line (Jones et al., 2006).

Supraspinale Skinfold

Supraspinale skinfold will be taken using a Harpenden Skinfold Calliper (Baty International, England). The subject assumes a relaxed standing position with the right arm either abducted or placed across the trunk. The line of the skinfold generally runs medially and anteriorly at a 45 degrees angle as determined by the natural fold of the skin (Jones et al., 2006).

Abdominal Skinfold

Abdominal skinfold will be taken using a Harpenden Skinfold Calliper (Baty International, England). The subject assumes a relaxed standing position with the arms hanging by the sides. The site is identified by a horizontal measure of 5 cm, to the subject’s right, form the omphalion. The skinfold is then taken as a vertical fold. (Jones et al., 2006).
Mid-thigh Skinfold

Mid-thigh skinfold will be taken using a Harpenden Skinfold Calliper (Baty International, England). The subject assumes a seated position at the front edge of the box with the torso erect, the arms supporting the hamstring and the leg extended. The skinfold then gets taken by raising the fold at the marked site (Jones et al., 2006).

Calf Skinfold

Calf skinfold will be taken using a Harpenden Skinfold Calliper (Baty International, England). The subject assumes a relaxed standing position with the right foot placed on the box. The right knee is bent at about 90°. The fold is parallel to the long axis of the leg (Jones et al., 2006).

Contracted arm circumference

Contracted arm circumference will be measured using the Body Care Type Measure, (West Germany). The subject assumes a relaxed standing position with left arm hanging by the side. The subject’s right arm is raised anteriorly to the horizontal with the forearm supinated and flexed at about 45-90° to the arm. The measurer stands to the side of the subject and with the type loosely applied the subject is asked to contract the arm muscles as strongly as possible and hold it while the measurement is taken in cm (Jones et al., 2006).

Waist circumference

Waist circumference will be measured using the Body Care Type Measure, (West Germany). Circumference will be taken with arms folded across the thorax. Place the type around the abdomen from the front. Adjust the level of the type at the back to the adjudged level of the mid-point between die lower costal (10th rib) border and the ilia crest. Waist circumference will then be measured at the end of a normal expiration (end tidal) in cm (Jones et al., 2006).
Gluteal (hip) circumference

Gluteal (hip) circumference will be measured using the Body Care Type Measure, (West Germany). Circumference will be taken with arms folded across the thorax. Subject’s feet should be together and the gluteal muscle relaxed. Place the type around the hips from the side. Adjust the level of the type at the back to the adjudged level of the greatest posterior protuberance of the buttocks. Gluteal circumference will then be measured in cm (Jones et al., 2006).

Mid-thigh circumference

Mid-thigh circumference will be measured using the Body Care Type Measure, (West Germany). Circumference will be taken with arms folded across the thorax. Subject’s feet should be slightly apart and mass equally distributed on both feet. Pass the type between the lower thighs and then slide the type up to the correct plane (mid-thigh). Thigh circumference will then be measured in cm (Jones et al., 2006).

Calf circumference

Calf circumference will be measured using the Body Care Type Measure, (West Germany). Circumference will be taken with arms relaxed next to the body. Subject’s feet should be slightly apart and mass equally distributed on both feet. Pass the type around the calf and then slide the type to the correct plane (mid-thigh). The type should be held in a plane perpendicular to the axis of the leg. Calf circumference will then be measured in cm (Jones et al., 2006).

Humerus Breadth

Humerus Breadth will be measured using a large sliding calliper (Germany). Breadth will be taken while subject assumes a relaxed standing or seated position. The right arm is raised anteriorly to the horizontal and the forearm is flexed at the right angles to the arm. The breadth will then be measured in cm (Jones et al., 2006).
**Femur Breadth**

Femur Breadth will be measured using a large sliding calliper (Germany) and a box. Breadth will be taken while subject assumes a relaxed seated position with the hand clear of the knee region. The right leg is flexed at the knee to form right angle with the thigh. The breadth will then be measured in cm (Jones *et al.*, 2006).
APPENDIX E

DESCRIPTION OF SEVEN-STAGE ABDOMINAL TEST

The starting position for all stages is lying supine on the floor with a 90° bend at the knee. The feet-without shoes-should be comfortably apart, in contact with the floor, and not held. The subject is allowed up to three attempts to pass each stage. Each of the stages is completed successively. All movements are to be conducted in a smooth, controlled manner. The subject’s score is the last stage completed successfully. Any attempt is unsuccessful if the subject:

- Lifts either foot partially or totally from the floor.
- Throws the arms and or head forward in a jerky manner.
- Moves the arms form the nominated position.
- Lifts the hips off the floor.
- Fails to maintain a 90° angle at the knee.
- Is unable to complete the nominated sit-up.

Stages:

- Stage 1: Palms over knees
- Stage 2: Elbows over knees
- Stage 3: Forearms to thighs
- Stage 4: Elbows to mid-thighs
- Stage 5: Chest to thighs
- Stage 6: Chest to thighs with 2.6 kg mass
- Stage 7: Chest to thighs with 5 kg mass