A 12 week pre-season fitness training programme for senior male high school rugby players: The effect of supervision on anthropometric, physiological and physical performance variables.

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Abstract

The study comprises of two sections; i) a survey to determine the attitude towards fitness training for rugby and the current fitness training habits of elite high school rugby players in their penultimate year at school, ii) a training study on a sample of the same population group, to measure the effect of a 12 week fitness training programme, based on scientific principles, on anthropometric, physiological and performance variables. The training study also measured the efficacy of training supervision compared no supervision on these variables.

The survey was completed by 132 players (17.7 ± 1.1 years: mean ± S.D.) from 4 schools in the Western Cape and included players from all playing positions. A large percentage of the population (77%) had represented the school in another sport at the highest level and the majority of the players (90%) intended to play rugby after school. The majority of the players (99%) supported the concept of pre-season fitness training and the inclusion of resistance weight (99%) during this training period, however, relatively fewer players implemented either of these during the previous season. Only 65% of the sample began any form of fitness training in the two week period up to and including the start of the season, and 63% of the players included resistance weight training during the pre-season. Fewer players performed their own fitness training for each type of training during the previous playing season (in-season), than for the preceding pre-season; running 62% vs. 86% (in-season vs. pre-season) ($p<0.01$), weight training 48% vs. 63% ($p<0.05$), sprint training 31% vs. 57% ($p<0.001$) and circuit training 27% vs. 53% (NS). Fifty five percent of those players who trained on their own had designed their own programmes, and only 22% sought advice from a gymnasium instructor.

Each school that participated in the survey was randomly assigned to either a training group (n=2) or a control group (n=2). Eight forwards and 7 backline players were randomly assigned to the supervised training group (STG, n=15), the un-supervised training group (UTG, n=15) or the control group (CG, n=15). All players completed pre- and post intervention fitness testing which included;

i. anthropometric assessment to determine body fat, muscle mass and lean thigh volume,
ii. physiological tests to determine flexibility, functional leg strength, upper and lower body muscular strength, aerobic capacity and leg power and,
iii. performance tests to measure running speed and agility, upper body and abdominal strength endurance.

Results were reported back to players in the STG and UTG, who then underwent fitness training prescription which included resistance weight training instruction. The STG and UTG followed a prescribed fitness training programme for 12 weeks which included running, resistance weight training and flexibility training. The STG and UTG recorded all training in a log book and the STG trained under supervision in contrast to the UTG who trained without supervision. The STG had a significantly greater reduction in the sum of 4 skinfolds (16.8 ± 14.3 mm; $P<0.01$) than the UTG (6.6 ± 5.7 mm) and the CG (6.4 ± 5.4 mm). Both training groups had significantly ($p<0.03$) greater increases in absolute muscle mass (STG: 2.7 ± 2.0 kg and UTG: 2.1 ± 2.7 kg) than the CG (0.3 ± 1.8 kg). Bench press 1RM increased in the training groups (STG: 9.5 ± 7.0 kg and UTG: 9.4 ± 6.0 kg) by significantly ($P<0.01$) more than in the CG (2.3 ± 5.0 kg). Squat 1RM increased in the UTG (21.4 ± 18.0 kg) by significantly ($P<0.03$) more than both the STG (10.0 ± 12.6 kg) and the CG (0.9 ± 16.9 kg). The STG increased their training weight for all exercises combined, by significantly ($P<0.05$) more than the UTG over the 12 weeks (STG: 47.9 ± 36.3 kg vs. UTG: 20.3 ± 10.3 kg). The results suggest that senior male high school rugby players are aware of the need to perform individual fitness training based on scientific principles. A large percentage of players perform individual fitness training prior to the season and during the season. The training study data (supervised and unsupervised) indicate that a structured fitness training programme for senior male high school rugby players, that included resistance weight training, resulted in adaptations in anthropometry and muscular strength that would arguably enhance rugby playing performance. Supervision of training appears to increase the rate of progression of weight training intensity, however, the effect of supervision on the adaptation to training was not conclusive over this training duration.

Declaration

I, David Rodney Clark, hereby declare that:

i. The work in this thesis is my own original work and that neither the whole part, nor any part of it, has been or is being submitted for any other degree in this or any other university.
ii. The University of Cape Town may reproduce the thesis for purpose of research.

Signed by candidate

Signature: Signature removed

Date: 5 August 1998

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1. Motivation for the study

The traditional attitudes of rugby union players, coaches and administrators towards rugby training have, until the last decade, remained uninfluenced by science. This can be attributed to rugby union administrators who actively protected traditional training methods, passed on from generation to generation, by encouraging only successful rugby players to become coaches. Furthermore, the coaches task included aspects of fitness training for which they were not specifically qualified. In contrast, American football coaches, in their quest for success, have used scientific training techniques from other sports, such as power lifting and track and field athletics. As a result, fitness training for American football has become refined with most teams employing a strength and conditioning specialist to assist with the players physical preparation.

However, increased international competition and the introduction of the Rugby World Cup in 1987, created an awareness which brought about a fresh approach to fitness training by the leading international rugby unions. This approach included the increased application of scientific fitness training principles. For example, in 1986 the England Rugby Football Union invited Tom McNab, a former national athletics coach, to be part of the National Fitness Programme which was brought about to prepare an ongoing squad of players for the Rugby World Cup (Hazeldine and McNab 1991). Furthermore, in Australia from 1989, talented youth players were given scholarships to attend the Australian Institute of Sport, where they were taught, amongst other things, a scientific approach to fitness training. It is tempting to conclude that these two teams reached the final of the 1991 World Cup as a result of their scientific approach to fitness training.

In addition, in the last decade, many studies into the game of rugby have been conducted in different parts of the world (Reilly 1993). As consequence, an international congress (World Congress of Science and Football) was established in 1987 to be held every four years. This congress was established for the presentation of research data from rugby and the other football codes.

At present, despite an increase in the application of scientific training methods by most national representative teams, it is not known to what extent this approach to fitness training is applied at other levels of proficiency and age groups of rugby. Specific questions for the general rugby playing population therefore arise;

i) To what extent are players aware of scientific fitness training methods?
ii) What are players attitudes towards this approach to training?
iii) To what extent are players performing individual fitness training according to scientific principles?
iv) Would a pre-season fitness training programme, based on scientific principles, improve the recognised components of rugby fitness?

2. Literature review

2.1 Introduction

Brooke and Knowles (1974) proposed, in a review of the physiological adaptation to physical training in rugby union, that four factors determined the training methods predominantly used by rugby coaches;

i) the imitation of successful training techniques used in other sports,

ii) the imitation of other successful rugby teams,

iii) tradition, and

iv) pure acts of faith.

However, more recently it appears that an increasing number of representative rugby unions are applying scientific training principles (Hazeldine and Holmyard 1991, Turnbull 1991, McLean 1992). However, there is still no consensus on the efficacy of these scientifically based training programmes in improving the fitness components important for rugby.

The following review of the literature will attempt to address the question of whether a scientifically based fitness training programme is effective in improving the fitness components important for rugby. The review will analyze studies describing the physical demands of rugby union in an attempt to identify the fitness components important for rugby. In addition, studies of the physiological and anthropometric characteristics of rugby players will be reviewed. Furthermore, studies of the incidence and nature of injuries in rugby and weight training will also be analyzed.

2.2 Physical demands of rugby

2.2.1 Subjective analysis

Evans (1973), in a subjective analysis of the demands of the game of rugby, identified muscular strength or power, muscular and cardiorespiratory endurance, flexibility and anaerobic capacity as the important fitness components for rugby. He established a battery of 9 exercise tests to measure these fitness components and collected data, for junior and adult Welsh rugby players, over a period of 6 years, and published a set of normative data for this rugby population (Evans 1973).

Reid and Williams (1974), however, argued that rugby was an endurance event and based this conclusion on a study that reported that rugby players ran between 5 and 10 kilometers in a game. They consequently placed great emphasis on the measurement of maximal oxygen consumption in rugby players and suggested that this measurement could discriminate between players at different levels of playing proficiency. However, these researchers failed to consider that players ran this distance intermittently over a period of 70 minutes and also that the distance differed greatly according to the players playing position.

It is evident from the research by Reid and Williams (1974) and Evans (1973) that in early 1970 there was little consensus regarding the nature and physiological demands of rugby. It is reasonable to therefore assume that the same lack of consensus on fitness training methods for rugby should have applied. But this was not the case, probably because fitness training methods in rugby union were not based on scientific principles or research, but had developed from the imitation of methods applied in other sports and teams (Brooke and Knowles 1974).

The intermittent nature of the game of rugby was generally recognized and accepted by early 1980 (Morton 1978, Maud 1982, Maud 1983, Maud and Schultz 1984). Maud (1982) reported a ratio of 1:2 for playing time to recovery time. The mean playing time during a match was 12 seconds followed by 26 seconds recovery. In a review of early game analysis data, Morton (1978) reported that more than half (56%) of the playing time activity cycles in a game lasted for less than 10 seconds, 85% lasted less than 15 seconds and only 5% exceeded 30 seconds. An activity cycle is defined as the period of time during which the ball is in play. He also reported that most (85%) recovery periods were less than 40 seconds and concluded that rugby is an *"interval type sport"* in which players must be "*capable of repeating a large number of intensive efforts, lasting 5-15 seconds each, with less than 40 seconds recovery*" (Morton 1978).

2.2.2 Computerized notation analysis

More recently, with the development of computerized notation and analysis systems, the nature and physiological demands of rugby have been described more accurately. Computerized notation analysis was first developed in an attempt to measure and describe patterns of play of successful teams (Hughes 1988). This technique has been used successfully in soccer (Association football) and field hockey to describe patterns of play. But it has been used with limited success in rugby in describing the patterns of play because of the unique problems of analyzing the set phases (scrums and lineouts) and the loose phases (rucks and mauls) (Hughes 1988). But computer notation analysis has nevertheless been used effectively in describing the physical demands of rugby.

For example, Treadwell et al (1991) conducted a computerized notation analysis of 17 rugby matches which included international matches and matches between club and international teams. During the 4 Welsh matches in the 1991 Five Nations Championships, the ball was in play for an average of 30% of the total game time and most of the playing time activity cycles (67%) never exceeded 14 seconds in duration. This is similar to the finding by Maud (1982), determined by subjective analysis, that the average playing time activity cycle lasts 12 seconds. Treadwell et al (1991) showed that 25% of all playing time activity cycles lasted less than 4 seconds, 21% lasted between 5-9 seconds and 21% lasted between 9-14 seconds. These data, however, did not measure the type and intensity of work performed within an activity cycle or the length and intensity of rest or low intensity work periods. In addition, they did not take the different positional requirements into account. But these data clearly show that the game of rugby is intermittent in nature.

2.2.3 Time-motion analysis

Time-motion analysis is a technique developed to quantify the intensity of a players activity during a game. This technique describes the work:rest ratios of the activity in a game. In a study by McLean (1992), work was categorized as running with an elongated stride, sprinting or non-running intense activity, such as rucking, mauling and scrumming. Standing, walking or jogging was classified as a low intensity activity or rest. Time motion analysis studies of the Five Nations Championship matches in 1989-90 showed that in more than half of the work:rest ratios, the duration of the rest period was greater than the preceding period of work (work < rest = 63%, work > rest = 37%) (McLean 1992). The density of activity was quantified in this study, unlike the study of Treadwell et al (1991) where only the duration of playing time activity cycles were quantified. McLean (1992) showed that all bouts of high intensity work during a game were followed by a low intensity recovery period, and that almost two thirds of the bouts of high intensity work in a game were followed by longer low intensity recovery periods.

2.2.4 Summary of the studies of the physical demands of rugby

Researchers in the late 1970's and early 1980's (Morton 1978, Maud 1982, Maud 1983, Maud and Schultz 1984) established and began to quantify, by subjective analysis, the intermittent nature of rugby union. It was not, however, until a decade later when computer notation and time motion analysis techniques were applied to rugby union (Hughes 1988, Treadwell et al 1991, McLean 1992) that the intermittent nature of rugby was accurately quantified. There is general consensus that the game of rugby consists of a series of short duration (<14 seconds), high intensity bouts of work interspersed between low intensity periods of recovery.

2.3 Anthropometric studies of rugby players

Early studies that described the intermittent nature of rugby, directed research to investigate "anaerobic" or oxygen independent capacity in rugby union (Morton 1978, Maud 1983, Maud and Schultz 1984). Bell et al (1991) showed that peak and mean power, measured during the Wingate cycle test, were related to lean body mass in rugby players. Furthermore, an increase in lean body mass and a reduction in fat mass would increase the lean body mass to body mass ratio which is desirable due to the contact nature of rugby (Bell et al 1991).

Holmyard and Hazeldine (1991) monitored the body composition of the English national squad for a year during both the competitive and non-competitive phases of the season. Surprisingly, body fat content was lowest at the end of the off-season and highest at the end of the playing season. In contrast to this, Hyland (1991) showed in a controlled 8 week in-season, circuit weight training study, a decrease in percent body fat and an increase in lean body mass in the players in the training group compared to the controls. Assuming rugby players are fittest when their body fat is low, these studies (Holmyard and Hazeldine 1991 and Hyland 1991) suggest that rugby players are not at peak fitness during the playing season and in fact lose fitness as the season progresses.

No studies have measured muscle mass in a rugby population, or monitored muscle mass changes during a season, or in response to a fitness training programme. Due to the high intensity, intermittent nature of rugby, together with the fact that rugby is a contact sport, it is clear that the development of muscle mass in rugby players should be a very important fitness training objective (Bell et al 1991).

2.4 Rugby injury studies

There is a large volume of research into rugby injuries (O'Connell 1954, Roy 1974, Walkden 1975, Durkin 1977, Scher 1977, Scher 1978, Walkden 1978, Williams and McKibben 1978, Reilly and Hardiker 1981, Scher 1982, Nathan et al 1983, Scher 1983a, Scher 1983b, Hawkins 1986, Roux et al 1987, Burry and Calcinai 1988, Scher 1988, Taylor and Coolican 1988, Akpata 1990, Clark et al 1990, Kew et al 1991 and Scher 1991). In adult rugby players, muscle (33%) and ligament (32%) injuries were most common (Clark et al 1990). However, Nathan et al (1983) found in schoolboys that concussion was the most common injury followed by injuries to muscles (22%) and ligaments (18%), whereas Roux et al (1987) found that fractures (27%) were the most common injury, followed by ligament/tendon (25%) and muscle injuries (17%).

These data have been used to motivate rule changes in an attempt to make the game safer (Burry and Calcinai 1988). For example in 1984 the New Zealand Rugby Football Union, with the permission of the International Rugby Football Union, introduced modifications to laws controlling the scrum to make the game safer for schoolboys. The duration of the scrum was reduced, scrums were prohibited from turning or wheeling through more than 90 degrees and the initial force of impact was reduced by ruling that the opposing front rows stand closer together before engaging (Burry and Calcinai 1988). Although no data are available to confirm whether this rule change has directly reduced the incidence of injury, there has been a reduction in catastrophic neck injuries since the law changes (Kew et al 1991).

There is also evidence that correct physical training may reduce the risk of injury. For example, the incidence of injury, in adult (Clark et al 1990) and schoolboy (Roux et al 1987, Nathan et al 1982) rugby players, is highest during the first 4 weeks of the competitive season and for the period immediately after the mid-winter break. Roux et al (1987) concluded that this was due to the lack of match specific fitness.

2.5 Resistance weight training studies

2.5.1 Studies on resistance weight training and rugby specific fitness

Resistance weight training is a mode of exercise training which results in muscle hypertrophy (Stone et al 1981 and Tesch 1988) and improves muscular strength and power (Stone et al 1981). Muscle strength and power are important characteristics for performing high intensity intermittent work. Therefore, there are good reasons why resistance weight training may improve rugby specific fitness. Despite this, and the fact that a number of rugby coaching manuals (Dunnill and Gray 1982, Hazeldene and Holmyard 1991, Vodanovich 1985, Hazeldine and McNab 1991 and Walsh 1990) include guidelines for weight training, there is little published evidence of the implementation of resistance weight training for rugby. McKenna (1997) surveyed English 1st, 2nd and 3rd division rugby clubs and found that 10 out of 17 clubs provided resistance training facilities and a resistance training specialist coach. Six of the 17 clubs reported that players were not required to perform resistance training. However, in clubs where players were required to perform resistance training, only 50% of the players trained regularly during the pre-season and 40% during the season.

McKenna (1997) concluded that the presence of an onsite resistance training facility and a resistance training specialist coach was associated with a higher number of reported players who regularly performed resistance training. However, the number of these players was not high and subject to individual club variability.

Guidelines for prepubescent strength training have been published (Freedom et al 1990 and Faigenbaum et al 1996 and Fleck and Kraemer 1997) and there is agreement that certain modifications need to be made to accommodate this population. Resistance training prescription should be based on 1-3 sets of 6-10 exercises performing 8-12 repetitions for the upper body and 15-20 repetitions for the lower body exercises (Freedom et al 1990 and Faigenbaum et al 1996). This population should perform strength training according to the repetition maximum (RM) method, whereby they choose a training weight that they can only lift for the prescribed number of repetitions, 8-12 for the upper body exercises (Freedom et al 1990). Progression occurs by increasing the training weight once a subject is able to lift more than 12 repetitions for a given training weight (Freedom et al 1990). Fleck and Kraemer (1997) and the guidelines in the National Strength and Conditioning Association Position Statement on Youth Resistance Training (Faigenbaum et al 1996) suggest a strength training intensity range of 6-15 RM for between 1-3 sets for a prepubescent population. There is agreement that it is acceptable for this population to perform strength training using their own body weight, resistance machines and free weights (Freedom et al 1990 and Faigenbaum et al 1996 and Fleck and Kraemer 1997). The effects and benefits of strength training for the youth population are also well documented (Freedom et al 1990, Ramsay et al 1990 and Faigenbaum et al 1996).

2.5.2 Studies on resistance weight training and injury prevention

Injuries to the muscle and connective tissue of rugby players are most common at all levels of the sport (Clark et al 1990, Roux et al 1987 and Nathan et al 1982). There is evidence to suggest that resistance weight training may reduce the injury in rugby players. For example, the correct use of resistance training has been shown to increase the strength and mass of connective tissue (Fleck and Falkel 1986 and Stone 1988). In addition, progressive heavy resistance exercise results in muscle hypertrophy (Stone et al 1981 and Tesch 1988), which also reduces the risk of injury in power and strength athletes, and in contact sports (Stone 1990). Furthermore, imbalances between agonist and antagonist muscle groups increase the risk of injury (Fleck and Falkel 1986). These imbalances can be corrected with resistance training (Fleck and Falkel 1986). Resistance training also increases bone mineral content and bone density (Fleck and Falkel 1986, Stone 1988 and Conroy et al 1993), and therefore theoretically protects against bone fracture.

Although there is much evidence to suggest that resistance training increases the strength of connective tissue, muscle and bone, and therefore may reduce the risk of injury in rugby players, this theory still needs to be tested in a scientific trial.

2.5.3 Circuit weight training studies

Circuit weight training is a form of interval training that includes selection exercise stations from calisthenic exercises, plyometric exercises and resistance exercises. Stations are usually arranged close to each other so that different muscle groups are exercised successively. Circuit weight training is a compromise between endurance training and strength training where the endurance gains are not as great as traditional aerobic training and strength training intensity ranges from 40-70% of maximum capacity (Baechle 1994).

Hyland (1991) found that peak power, vertical jump height and maximal leg strength increased in first division rugby players who incorporated an 8 week circuit weight training programme into their normal rugby training during the season. The circuit training in this study consisted of two 35 minute sessions a week comprising of calisthenics, plyometrics and resistance training. Players in the control group underwent the same rugby training but did not participate in the circuit training sessions.

2.5.4 Summary of resistance weight training

Bell et al (1991) has shown that muscle power is related to lean body mass. Muscular power is an important rugby fitness component due to the intermittent, high intensity and contact nature of rugby. This suggests that the goal of fitness training for rugby should be to increase lean body mass to the point where the muscular power is optimized. Resistance weight training is an established method of increasing muscular strength and power (Stone et al 1981) and achieving muscle hypertrophy (Stone et al 1981 and Tesch 1988). An 8 week, in-season circuit weight training study resulted in an increase in the lean body mass of the rugby players in the training group, compared to those players in the control group (Hyland 1991). Resistance weight training has also been shown to reduce the risk of injury (Stone 1990) by increasing the strength and mass of muscle and connective tissue and increasing the density of bone (Fleck and Falkel 1986, Stone 1988 and Conroy et al 1993). Therefore, there are strong arguments supporting the positive effects that resistance weight training may have on the fitness components which are important for rugby.

2.6 Descriptive physiological studies on rugby players

Morton (1978) attempted to calculate the sources of energy metabolism in a game of rugby. He estimated that tight forwards used 45% oxygen independent or "anaerobic" energy sources and 55% aerobic energy source. The players in the other positions made more use of oxygen independent energy sources which contributed between 55-85% of the energy that was metabolized during a game. He estimated that between 15-55% of the energy demand was met by oxygen dependent energy metabolism.

Fitness tests were conducted on the rugby players in the English National Squad for a year during the off-season, pre-season and the playing season (Holmyard and Hazeldine 1991). The specific fitness training prescribed to these players for this period was aimed to increase general fitness throughout the year and achieve peak fitness by the beginning of the playing season. Predicted maximal oxygen consumption increased during the off-season and deteriorated towards the end of the competitive season. Thirty meter sprint time improved for the backline players during the off-season and for the forwards during the playing season. Anaerobic capacity remained constant for all players throughout the assessment period (Holmyard and Hazeldine 1991).

This study described the different rates at which the fitness components change during the year. However, although the study did not describe the specific training content, intensity and volume during the year, it was interesting that the aerobic capacity reached a plateau and then deteriorated during the competitive season. This may be interpreted in two ways; I) either the aerobic fitness training objectives for the off-season overestimate the aerobic demands of the playing season, or, ii) that more emphasis should be placed on developing 'anaerobic' fitness through specific high intensity and intermittent training during the off-season and pre-season.

2.7 Adolescents

2.7.1 Adolescents; rugby and resistance weight training

In the Western Province, South Africa, 6060 high school pupils played rugby in 1992 which represented 8% of the total high school rugby playing population in South Africa (77 489) (South African Rugby Football Union 1992). In a survey conducted on final year high school pupils (698 males) at 13 high schools in the Western Province, 49% participated in rugby and only 11% reported doing weight-lifting training (Schwellnus et al 1992). Even though this study did not distinguish between the number of rugby players who participated in weight-lifting as a sport or those who used it as an adjunct to their traditional rugby training, it is evident that, at the most, only 20% of the rugby players did any weight training.

2.7.2 Adolescents and injuries during weight training

In a retrospective study on high school American football players, the incidence of injury caused by weight training was 7.6% (Risser et al 1990). Zemper (1990) conducted a four year prospective study sustained by college football players while undergoing weight training. The measure of risk was expressed as an athlete-exposure which is one athlete taking part in one session where there is a possibility of injury. The rate of injury was 0.13 injuries per 1000 athlete-exposures or 0.30 injuries per 100 players per season. Only two injuries resulted in the player having to stop playing football for the rest of the season. Both these studies (Risser et al 1990 and Zemper 1990) found that muscle strains were the most common types of injuries during weight training and that the lower back was the most common injury site.

In comparison, a study of 71 adolescent power-lifters reported an incidence of injury of 39.4% (28 out of 71 subjects sustained 98 injuries over a mean programme duration of 17.1 months) (Brown and Kimball 1983). Mazur et al (1993) suggests that the lower injury rates in the studies by Risser et al (1990) and Zemper (1990) compared the injury rates found for the power-lifters (Brown and Kimball 1983) was due to the coaching and supervision in the football programmes. Furthermore, the power-lifters were attempting to lift maximal weights whereas, the football players were lifting submaximal weights with the aim of improving muscular strength specific to the demands of American football (Mazur et al 1993).

Faigenbaum et al (1996), the authors of the National Strength and Conditioning Association Position Statement on Youth Resistance Training, concluded that there were no justifiable safety reasons to preclude prepubescents or adolescents from participating in a correctly taught, designed and supervised strength training programme.

2.7.3 Adolescents and injuries during rugby

The overall incidence of injury for high school rugby players was 1 injury for every 625 playing-hours of rugby (Roux et al 1987). However, the incidence increased to 1/142 playing-hours for rugby matches and decreased to 1/1825 playing-hours of rugby training. Roux et al (1987) also found that the incidence of injury was highest for the first 4 weeks at the start of the season and after the winter vacation. They concluded that this was due to a lack of match preparation in training prior to these periods during which the incidence of injury was high.

2.7.4 Summary of adolescents

Although, in a representative sample of male, final year high school students in the Western Province, half (49%) reported to be playing rugby, at the most 20% of these pupils trained with weights (Schwellnus et al 1992). Therefore, it can be concluded that a large number of schoolboy rugby players do not supplement their training with weight training.

The incidence of injury to high school rugby players is highest when they are least physically trained and the most common injuries are bone fractures and muscle, ligament and tendon strains (Roux et al 1987). Resistance weight training has been shown to protect against these types of injuries (Fleck and Falkel 1986 and Stone 1990), and in an adolescent athletic population, when correctly prescribed and supervised, this form of training is relatively safe (Risser et al 1991, Zemper 1991 and Mazur et al 1993).

2.8 Summary of the literature review and motivation for the study

Recent research has described the nature and physiological demands of the game of rugby in more accurate terms (McLean 1992, Hughes 1988, Treadwell et al 1991). The measurement of the duration and frequency of activity cycles has established that a game of rugby consists of high intensity, intermittent bouts of work (Treadwell et al 1991). Describing rugby in terms of work:rest ratios (McLean 1992) has quantified the density of this intermittent activity. Most high intensity bouts of work are followed by longer periods of rest suggestive of predominantly oxygen independent energy metabolism. Despite an understanding of the physiological demands of rugby, there are few studies which have evaluated the effects of training specifically for rugby. It is clear that traditional training methods are not optimal because Holmyard and Hazeldine (1991) showed that pre-season objectives for aerobic capacity were not maintained during the playing season. This suggests that either off-season and pre-season fitness training objectives were not based on the demands of the game or that in-season rugby in the form of training and rugby matches, were not demanding enough to maintain or improve on the pre-season objectives set for this aspect of fitness.

Weight training has been shown to improve performance in physical tasks which are dependent on strength. In addition, weight training can increase lean body mass (Stone et al 1981 and Tesch 1988). Both muscular power and an increased lean body mass are important in rugby (Bell et al 1991). Circuit weight training, performed in-season in addition to normal rugby training, improved vertical jump height, peak leg power and leg strength. These are all recognized rugby fitness components (Hyland, 1991). Finally, there is evidence that resistance weight training, if practiced correctly, is relatively safe (Risser et al 1991, Zemper 1991, Mazur et al 1993 and Faigenbaum et al 1996). Furthermore, it has been shown to increase resistance to injuries of muscle, connective tissue and bone, in power and contact sport athletes (Fleck and Falkel 1986, Stone 1988 and Conroy 1993).

Despite this evidence, which suggests that resistance training has the potential to improve performance and reduce the risk of injury, it is not known to what extent this form of training is practiced by rugby players at all levels. Of particular interest is the high percentage (49%) of senior male high school students who participate in rugby and the fact that relatively few do any weight training (Schwellnus et al 1992). Meaningful, long-term modifications to the approach to individual fitness training by rugby players should realistically begin with this population. In addition adolescent rugby players, due to their youth, are less clouded by tradition than adult players and therefore more likely to adopt new training methods.

2.9 Aims of the study

The first objective of this study is to determine the extent and type of fitness training performed by senior high school rugby players on their own, before and during the rugby season. The second objective was to measure the effect of a structured pre-season fitness programme on the recognized rugby fitness components within this population.

More specifically the aims of this study are:

i) To determine by survey, the extent and type of training performed by senior high school rugby players on their own during the pre-season and in-season.
ii) To measure the anthropometric, physiological and physical performance changes in senior high school rugby players resulting from a pre-season training programme, which will include the prescription of resistance weight training, running and flexibility exercises.
iii) To measure the effect of training supervision compared to training with no supervision on the anthropometrical, physiological and physical performance changes in senior high school rugby players.

3. Survey

3.1 Introduction

There is a high incidence of injuries sustained by senior high school rugby players at the beginning of the season and again after the mid-season break (Roux et al 1987). There is a strong theoretical basis supporting the concept of a scientific fitness training programme which will improve the components of fitness which may reduce the risk of injury. For example, resistance weight training is an accepted method of increasing muscle mass (Stone et al 1981 and Tesch 1988). Resistance training may also strengthen the connective tissue network (Stone 1988) in muscle which would reduce the risk of musculo-tendonous injury (Fleck and Falkel 1986 and Stone 1990).

Therefore, there are strong reasons why a fitness training programme for senior high school rugby players based on scientific principles may be beneficial in terms of reducing the risk of injury and improving physical performance. However, there is very little information available on the year-round training habits of high school rugby players. This information is important before an optimal training intervention study can be designed.

3.2 The aim of the survey

The aim of the survey was;

i) to quantify and describe the current fitness training habits and the attitudes towards fitness training in senior high school rugby players, and

ii) to establish a training baseline on which to base fitness training prescription for the subsequent training study.

3.3 Questionnaire

A questionnaire was compiled to collect the information under the following headings;

3.3.1 Rugby data

These questions determined the player's playing position, level of rugby representation, general sport participation and whether the player planned to play rugby after school.

3.3.2 Fitness training data

Questions in this section evaluated the extent to which rugby players trained on their own during the pre-season and the playing season. Further questions evaluated the type of training and identified the person(s) who advised them on their training. Questions also determined whether players performed four specific types of training which were defined as;

i) running training: sustained submaximal running for periods of 20 minutes or longer

ii) weight training: moderate to high intensity strength training using free weights and or resistance machines

iii) sprinting or sprint training: high intensity running with recovery periods

iv) circuit training: muscular strength endurance, plyometric and calisthenics training

The players' attitudes towards pre-season and in-season fitness training and weight training for rugby were also assessed in the questionnaire.

3.4 Subjects

Four schools in the Western Cape were selected for the survey. These schools were representative of schools that offered rugby as a winter sport and had rugby teams, in all age groups, competing at the highest schoolboy level. Clearance to include three of the schools; Rondebosch Boys High School, South African College Schools and Wynberg Boys High School in the study, was obtained from the Cape Education Department. Permission to use the school, Diocesan College, was obtained from the headmaster of the school since this was a private school. The aim of the survey was explained to the rugby coaches of the four selected high schools and their co-operation in the study was requested. Each coach was asked to identify at least 30 most promising standard nine players at his school (15 forwards and 15 backline players) for participation in the survey study. The number of names submitted by the four schools were 36 (Rondebosch Boys High School), 33 (South African College

Schools), 33 (Diosecan College) and 30 (Wynberg Boys High School) making a total of 132 players.

3.5 Methods

The questionnaire was tested in a pilot study on a representative sample of rugby players (n=12) from a school not included in the research group. Unclear questions identified in this pilot study were modified.

Thereafter, all the players identified by the coach at each school, completed the questionnaire. This was done as a group, under examination conditions. The questionnaire took about 15 minutes to complete.

An example of the questionnaire is shown in appendix A.

3.5.1 Statistics

Results are expressed either as percentages or as absolute values. Averages are presented as mean ± SD. A Chi-square analysis was used to determine differences between groups. Significance was accepted at $P < 0.05$.

3.6 Results of the survey

3.6.1 Rugby data

Of the players who completed the questionnaire (n=132), 60 were backline players, 71 were forwards and one player did not indicate his position (Table 3.1). The average age of the respondents was 17.7 ± 1.1 years.

Table 3.1.- Playing positions of the senior high school rugby players who completed the questionnaire (n=132).

Playing position	n	Percentage (%)
Fullback	12	9
Wing	15	11
Centre	17	13
Flyhalf	5	4
Scrumhalf	11	8
Eighthman	8	6
Flank	16	12
Lock	18	14
Tighthead prop	11	8
Loosehead prop	10	8
Hooker	8	6
Incomplete	1	1
Total	132	100%

Eight percent (n=11) of the respondents claimed that they were not playing in the position of their choice. Most of these players (n=8) ascribed this to pressure to represent a higher team. Almost half (n=5) of the players not playing in the position of their choice were playing for the under 16 "A" team. One player did not complete this question.

Participants in the study represented players from the 3 highest senior teams (players between the age of 17 and 19 years old) and the 2 highest under 16 teams (players who are younger than 17 years of age on the 1st January) (Table 3.2). Two players had played at a provincial representative level. Four players did not complete this question.

Table 3.2.- Teams represented by the senior high school players who completed the questionnaire (n=132).

Team	N	Percentage (%)
First	22	17
Second	28	21
Third	23	17
Under 16 'A'	42	32
Under 16 'B'	13	10
Incomplete	4	3
Total	132	100%

The majority of the sample (90%, n=115) reported that they planned to play rugby after leaving school.

The most popular other school sports reported by the subjects were track and field (n=50), cricket (n=42) and water-polo (n=42). Players could report to be playing more than one other sport in the questionnaire. Seventy seven percent (n=99) of the rugby players in this survey represented the school at first team level in another sport, the most popular being track athletics (17%, n=22), cricket (16%, n=22) and water-polo (12%, n=15).

3.6.1.1 Summary of rugby data

The questionnaire was completed by a sample comprising of players from the highest 3 senior and 2 under 16 teams (Table 3.2). All playing positions were represented in the population (Table 3.1) and most of the players (n=120) were playing in the position of their choice. A high percentage (77%, n=99) of the rugby players also represented the school in another sport at first team level and most players (90%, n=115) planned to continue playing rugby after they had left school.

3.6.2 Fitness training data

Nearly all (99%, n=130) of the rugby players believed that pre-season fitness training was important for rugby performance and the same number (99%, n=130) believed that pre-season training should include resistance weight training. However, only 80% (n=105) indicated that weight training should be practised during the playing season. More than half (57%, n=75) of the sample felt that enough time was spent on fitness training during the playing season and the majority (90%, n=119) felt that regular fitness testing was an important part of rugby fitness training. Despite this only 11% (n=15) of the players reported that they had undergone any form of supervised exercise testing. However, 84% (n=110) claimed to have performed fitness training for rugby on their own.

Almost half of the group (55%, n=60) indicated that they had designed their own training programme. Players who trained on their own were asked to indicate all sources of their training advice. Some received training advice from more than one source (Table 3.3).

Table 3.3. - Sources of advice on designing training programmes by those players who reported to be training on their own (n=110).

Source of advice	**n**
Designed own programme	60
Rugby coach	29
Gymnasium instructor	24
Parent	22
Friend(s)	20
Teacher	5
Total	160

For the season preceding the study, running was the most popular form of pre-season and in-season training, followed by weight training, sprinting and circuit training (Table 3. 4). There was a significant reduction in the number of players performing each type of training on their own during the previous season (in-season) compared to the preceding pre-season; running training 62% (n=68) vs.

86% (n=95) ($p<0.01$), weight training 48% (n=53) vs. 63% (n=69) ($p<0.05$) and sprint training 31% (n=34) vs. 57% (n=63) ($p<0.001$) (in-season vs. pre-season). However, the reduction in the number players doing circuit training during the in-season compared to the preceding pre-season was not significant 27% (n=30) vs. 35% (n=39) (in-season vs. pre-season).

Almost all of the rugby players (99%, n=130) supported the concept of weight training, in any form, during the pre-season. However, only 63% (n=69) of these players reported to have performed resistance training, either in the form of free weights or in the form of circuit training, prior to the previous season. This was also the case during the previous playing season, where 80% (n=105) of the population felt that in-season weight training was valuable but only 49% (n=65) of these players reported to have trained with either free weights or on the circuit.

Fewer players reported to be doing any form of pre-season and in-season training for each of the preceding 3 years. The pattern, however, remained similar for each type of training except for the pre-season in the year prior to the study, the same number of players did sprint training and weight training, and in the two pre-seasons prior to that, sprint training was more popular than strength training with weights.

The number of senior players compared to under 16 players participating in all types of pre-season and in-season training was the same (Table 3.4). There was a trend for the senior players to do more weight training, pre-season and during the playing season, than the under 16 players, but this was not significantly different ($p>0.05$) (Table 3.4).

Table 3.4 - The different types of training performed by subjects from the various teams during the pre-season and the playing season. Data presented as an absolute number of subjects who reported to be doing each type of training and as a percentage of the total population (n=128). Please note that the sum of the percentages will not equal 100% as each subject could report to be doing more than one type of training.

Pre-season:

Team	n	Running	Weight training	Sprint training	Circuit training
1st Team	22	18 (23.0 %)	10 (12.8 %)	13 (16.6 %)	6 (7.7 %)
2nd Team	28	21 (25.2 %)	19 (24.3 %)	16 (20.5 %)	10 (12.8 %)
3rd Team	23	13 (16.6 %)	15 (19.2 %)	6 (7.7 %)	5 (6.4 %)
U16 'A'	42	33 (42.2 %)	23 (29.4 %)	23 (29.4 %)	12 (15.3 %)
U16 'B'	13	9 (11.5 %)	2 (2.6 %)	4 (5.1 %)	5 (6.4 %)

In-season

Team	n	Running	Weight training	Sprint training	Circuit training
1st Team	22	16 (20.5 %)	6 (7.7 %)	8 (10.2 %)	7 (8.9 %)
2nd Team	28	14 (17.9 %)	16 (20.5 %)	7 (8.9 %)	7 (8.9 %)
3rd Team	23	8 (10.2 %)	12 (15.3 %)	1 (1.28 %	4 (5.1 %)
U16 'A'	42	23 (29.4 %)	17 (21.8 %)	15 (19.2 %)	8 (10.2 %)
U16 'B'	13	7 (8.9 %)	2 (2.6 %)	3 (3.8 %)	5 (6.4 %)

The majority of the respondents in the sample (99%, n=130) indicated that they believed that pre-season training was important. However, only 35% (n=39) of the one hundred and eleven (n=111) players who indicated that they trained on their own, trained for a month or more before the start of the playing season. Twenty three percent (n=25) began training a month before the start of the playing season, 11% (n=12) trained for two months and 2 players trained for three months or more before the start of the playing season. More than half of the players (54% n=60) who indicated that they trained on their own, began to train during the two week period prior to the start of the season and 11% (n=12) began to supplement rugby training with additional training on their own, a month after the playing season began.

3.6.2.1 Summary of fitness training data

Most of the respondents in the sample believed that pre-season fitness training was important (99% n=130) and that this should include weight training (99% n=130). However, only 84% of the players reported to have done any fitness training on their own, prior to and during the season, and only 35% of the players trained for a month or more, on their own, before the previous season. Furthermore, only 63% of the players included resistance weight training during the pre-season. Approximately half of the players (55% n=60) designed their own training programmes (Table 3.3).

There was no significant difference in the number of senior rugby players compared to under 16 players performing any of the types of training, prior to and, during the season prior to the study (Table 3.4).

3.7 Summary of the survey

This sample of rugby players, whose average age was 17.7 ± 1.1 years old, was selected from the five highest teams from four representative high schools. Each rugby playing position was represented in the sample and a large percentage of the players (77%) had represented the school at the highest level in another school sport. Most of the group (90%) indicated that they would play rugby after school.

Despite the support for pre-season fitness training (99%) and the inclusion of resistance weight training (99%) by most of the population, relatively fewer players implemented either of these for the previous season. Sixty three percent of the players trained with weights in the pre-season, and a large percentage of the sample (65%) began any form of fitness training in the two week period up to and including the start of the season (54%) and a month after the season began (11%). Furthermore, the number of players doing their own fitness training during the previous playing season was markedly lower for, each type of training, than for the preceding pre-season; running 86% vs. 62% (pre-season vs. in-season) ($p<0.01$), weight training 63% vs. 48% ($p<0.05$), sprint training 57% vs. 31% ($p<0.001$) and circuit training 53% vs. 27% (NS).

This study revealed that the senior high school rugby players surveyed had a high level of awareness about fitness training for rugby. A fairly high percentage of the players reported to do pre-season training (60%) for the four types of training; running, weight training, sprinting and circuit training. Despite this, however, a large percentage (65%) of those players who trained during the pre-season, reported to train for less than a month prior to the playing season. Furthermore, 18% of those players who trained prior to the season did not continue with individual training during the competitive in-season. Finally, although the scope of the questionnaire did not include the determination the intensity, duration and frequency of the fitness training sessions, it did indicate that 54% of those players who trained had designed their own programmes, and only 22% sought advice from a gymnasium instructor.

4. Training study

4.1 Introduction

The survey, conducted on senior high school rugby players, showed that most of them were aware of the appropriate fitness training requirements for rugby. Furthermore, a fairly large number (63%) of these players actually performed strength training during the pre-season. However, fewer players (49%) continued with this form of training during the playing season.

The question that arises from this survey, is whether this senior high school rugby players can improve those aspects of fitness which are regarded important for rugby, through fitness training prescribed according scientific principles. In addition, few players (18%) consulted instructors about correct resistance training programme design and exercise technique. This raised the second question of whether supervision while doing resistance training improved the efficacy of a strength training programme for this population.

4.2 Aim of the training study

The aim of this study was to;

i) measure the effect of a 12 week, pre-season fitness training programme, designed according to the scientific principles that control training intensity, volume and progression, on the anthropometric, physiological and performance components of fitness in senior high school rugby players.

ii) to determine the efficacy of supervision, in contrast to no supervision during a 12 week pre-season fitness training programme for senior high school rugby players.

4.3 Subjects

Each of the four schools that participated in the survey study (Chapter 3) was randomly assigned to either a training group (n=2) or a control group (n=2). Then the players from each school were stratified according to forward or backline playing position, and 30 players (16 forwards and 14 backline players) were randomly selected from the two schools in the training group. They were then randomly assigned to a supervised training group (STG, n=15) or an unsupervised training group (UTG, n=15). The control group (CG) consisted of 8 forwards and 7 backline players randomly selected from the 2 schools assigned to the control group.

Each subject was given an information sheet explaining the aims and requirements of the study. Subjects were asked to discuss the study with their parents who were required to sign a consent form which gave permission for their son's participation in the study. The study was passed by the Ethics and Research Committee of the University of Cape Town Medical School.

4.4 Methods

4.4.1 Introduction

The STG and the UTG underwent pre- and post training fitness assessments which included anthropometric, physiological and physical performance tests. The CG underwent testing at the same time as the STG and UTG but did not participate in the 12 week training study. The results of the initial tests were reported back to the subjects in the STG and the UTG along with the same 12 week fitness training programme which included resistance weight training, running and flexibility exercises.

The STG were strongly encouraged to attend 3 supervised weight training sessions a week whereas the UTG were instructed to train on their own. Both training groups recorded their training for the 12 week period in a log book (Appendix B).

The results of the fitness assessment were not reported back to the CG, who were instructed to follow their usual preparation for the rugby season.

4.4.2 Duration of training study

The training programme lasted 12 weeks. The study was planned so that the final fitness assessments coincided with the start of the rugby season in April. Initial fitness assessments began in November and were completed by the middle of December of the same year. The training period included 3 weeks of December, January, February and the first week of March of the following year. Tests after training were completed by the end of March of the same year.

4.4.3 Fitness assessment

Testing took place at 3 venues; on a rugby field and at two separate laboratories; The MRC/UCT Bioenergetics of Exercise Research Unit and a private Biokinetic practice within a commercial gymnasium. The order of testing for each subject for the pre- and post assessments was kept the same. The first assessment began with a consultation to determine the subjects' injury history and whether there were any contra-indications to exercise testing.

4.4.3.1 Anthropometrical assessment

a) Description of measurements

Prior to the exercise tests body mass and stature were determined on an electronic digital scale (SECA Weighing and Measuring Systems, Hamburg, Germany), and the following anthropometrical measurements were recorded;

Skinfolds (Holtain/Tanner-Whitehouse Skinfold caliper, Harpenden, Dyfed, UK)

1. Biceps

   Measured from the front on the anterior surface of the arm midway between the top of the shoulder and the elbow. The upper limb hung loosely by the subjects side with the subject in a standing position.
2. Triceps

   Measured from the back on the posterior surface of the arm midway between the top of the shoulder and the elbow. The subjects stood in the same position as for the biceps measurement.
3. Abdomen

   Measured in a vertical plane 5 centimetres to the left of the umbilicus.
4. Suprailiac

   Measured 5 centimetres above the iliac crest with the fold oblique, descending medially (inwards) and downwards at an angle of about 45° to the horizontal. The subject stood erect with the upper limbs by the side and the abdominal muscles relaxed.

5. Subscapular

   Measured just below the inferior angle of the scapula with the fold in an oblique plane descending laterally (outwards) and downwards at an angle of approximately 45° to the horizontal.

6. Mid thigh

   Measured at the mid-point on the anterior surface with the fold parallel to the long axis of the thigh. The subject's weight was supported on the other leg so that the knee joint of the measured leg formed an angle of about 120°.

7. Medial calf

   Measured at the mid-point on the medial surface at the greatest circumference. The subject's weight was supported on the other leg.

Girths (Rabone Chesterman Anthropometric tape measure)

1. Relaxed upper arm

   Measured on the arm between the acromion and radial points, with the arm relaxed and hanging by the side.

2. Contracted upper arm

   The maximum girth of the arm with the biceps fully contracted. The subject's arm was horizontal with the elbow fully flexed and the fist clenched.

3. Chest

   Measured at the height of the nipples after a normal exhalation.

4. Forearm

   Measured at the maximal girth of the forearm when the arm hung relaxed by the side.

5. Sub-gluteal

   Measured 1 centimetre below the gluteal fold. Weight was distributed evenly on both legs.

6. Mid thigh

   Measured at the level at which the thigh skinfold was measured. Weight was distributed evenly on both legs.

7. Above the knee

   Measured 1 centimetre above the superior border of the patella.

8. Calf

   Measured at the greatest circumference of the calf with the subject standing erect, legs slightly apart and with the weight distributed evenly.

Heights

1. Stature (SECA Stadiometer, Hamberg, Germany)

   Measurement was taken at the greatest distance from the floor to the vertex of the head.

2. Sub-gluteal to above the knee (Rabone Chesterman Anthropometric tape measure)

   Measured as the distance between the sub-gluteal and the knee girth measurements.

b) Derived measurements

Body fat

Body fat percentage was predicted from four skinfolds; biceps, triceps, suprailiac and subscapular, according to Durnin and Womersley (1974). The sum of skinfolds was obtained by adding the following seven skinfolds; biceps, triceps, abdomen, suprailiac, subscapular, mid-thigh and calf.

Muscle mass

Muscle mass was calculated according to Martin et al (1990), from height and the following anthropometrical measurements; mid-thigh girth corrected for mid-thigh skinfold, uncorrected maximum forearm girth and calf girth corrected for calf skinfold.

Lean body mass

Lean body mass was calculated by subtracting the predicted body fat mass (Durnin and Womersley 1974) from body mass.

Lean thigh volume

Lean thigh volume was calculated assuming that the thigh was a truncated cone. The sub-gluteal, mid-thigh and above the knee girths corrected for the mid-thigh skinfold and the length between the sub-gluteal fold and line of measurement above the knee were used in the calculation. The technique was derived from a previous study (Katch and Katch 1974) and has been validated (Knapik et al 1996).

4.4.3.2 Flexibility assessment

Hip flexibility was measured using the best of three sit-reach tests (Gettman 1988) and was performed prior to the exercise tests. Subjects were instructed to stretch in preparation for the test for five minutes prior to the test.

4.4.3.3 Muscular strength tests

Muscular strength was defined as the maximum weight in kilograms that could be lifted for one repetition. The squat and the bench press exercises, using Universal barbells and weight plates, were used to determine lower and upper body muscular strength. The subjects were instructed on the correct technique for each exercise and the requirements of the test. After 2 controlled warm-up sets of 15 repetitions, at approximately half of body weight for the squat and a third of body weight for the bench press, the maximum effort was determined within three sets. Subjects were spotted, or monitored very closely, while lifting and encouraged verbally during the maximal lifts. The spotter was able to assist the subject if and when they failed during a lift

4.4.3.4. Vertical jump test

Vertical jump height was measured as the difference between the standing reach height and the maximal height attained using the counter-movement jump described by Komi and Bosco (1978). Vertical jump height is an assessment of functional leg strength. Maximum reach height was measured while the subject stood flat footed adjacent to the measurement board. From this position, they were instructed to rapidly squat to a depth of their choice and execute a maximal vertical jump using arm momentum. Subjects were instructed not to move their feet in any way prior to the vertical jump take-off. The test was demonstrated and explained to each player, and after 2 warm-up jumps, the best of three attempts was recorded.

4.4.3.5 Aerobic capacity assessment

A recovery period of 10 minutes was scheduled after the muscular strength tests. This was followed by a 5 minute cycle warm-up which included a simulated 30 second Wingate cycle test on a Monark 386 cycle ergometer (Monark Bodyguard; Varberg, Sweden). This served as a familiarisation for the Wingate test conducted at the second laboratory visit.

Then after a 10 minute period of recovery, the subjects performed a maximal cycle test on an electronically braked cycle ergometer (Ergoline, West Germany) to predict aerobic power according to the method described by Hawley and Noakes (1992). Briefly, subjects commenced exercising at an intensity equivalent to 3.3 $W \cdot kg^{-1}$ for 150 seconds. The intensity was then increased by 50 W for 150 seconds after which it was increased by 25 W every 150 seconds until subjects claimed fatigue which usually coincided with the inability to sustain the required workload (Hawley and Noakes 1992). Peak power output (W_{peak}) was defined as the highest exercise intensity completed by the subject. When an exercise intensity was not completed for 150 seconds then W_{peak} was calculated from the following equation;

$$W_{peak} = W_{final} + (t/150 \cdot 25)$$

Where, W_{peak} refers to the peak power output in Watts, W_{final} refers to the last exercise intensity completed for 150 seconds in Watts and t was the number of seconds for which the final, uncompleted exercise intensity was sustained.

Absolute maximal oxygen consumption (VO_{2max}) was calculated according to the following regression equation (Hawley and Noakes 1992);

$$VO_{2max}\,(l \cdot min^{-1}) = 0.01141 \cdot W_{peak}\,(W) + 0.435$$

Heart rate, rating of perceived exertion, total cycle time and final workload in Watts were recorded. Relative and absolute predicted maximal oxygen consumption and peak power output were calculated (Hawley and Noakes 1992).

4.4.3.6 The 30 second Wingate cycle test

Within seven days of the initial laboratory visit subjects reported to the MRC/UCT Bioenergetics of Exercise Research Unit for the 30 second Wingate cycle test to determine peak and mean leg power and power to weight ratio.

Cycle ergometer seat height was set and recorded and subjects warmed up at a cadence of their choice for 5 minutes with the cycle ergometer set at minimal resistance. Then, after a 3 minute recovery period, subjects performed a maximal 30 second cycle test according to the protocol described in Bouchard et al (1991). Briefly, subjects were instructed to cycle at maximal cadence. When this was reached, usually within 5-15 seconds, the resistance was increased on the fly-wheel to the pre-determined load of 75 $g.kg^{-1}$ (Bar-Or 1987). This technique has been published more recently in a strength training study using a similar population group (Hetzler et al 1997). Subjects were encouraged verbally to exert themselves maximally for 30 seconds. Fly-wheel revolutions and partial revolutions were recorded by photo-electric cells from which peak power (W), mean power (W) and power to weight ratio ($W \cdot kg^{-1}$) were calculated (Bouchard et al 1991).

4.4.3.7 Field tests

On separate occasions the subjects assembled in their assigned groups (STG, UTG and CG) between 15h00 and 17h00 for field testing. This included the paced sit-up and push-up test, according to Hazeldine and MacNab (1991), to measure abdominal and upper body muscular endurance respectively. The subjects were divided into pairs, and while one subject performed the test the other subject counted the repetitions and offered verbal encouragement. The correct techniques for the two exercises, the sit-up and the push-up, were explained to the subjects and they were required to warm-up for 30 seconds to familiarize themselves with the rhythm of the taped "bleep". The subjects then performed the exercise continuously and the test was terminated for each subject when he failed to maintain pace with the "bleep" or began to execute an incorrect technique. The number of correct repetitions in each exercise were recorded.

A short rest period of 3-5 minutes was followed by a 10 minute period of sub-maximal running and stretching. Thereafter, subjects performed the six second dash tests which measured speed and reaction time (McCloy and Young 1954). The subjects lined up in pairs at a start line, each facing down a 60 metre grass running lane which had distance markers every 5 metres from 35 metres onwards. The subjects were instructed to sprint maximally on the command of a starter who stood behind them. After 6 seconds the starter blew a whistle indicating the end of the run. Two assistants recorded the distance the subjects covered in 6 seconds. The best of 2 attempts was recorded for each subject.

4.4.4 Reporting the results of the fitness assessment

After the initial testing was completed a standard report of the results of the initial assessment was explained to the subjects in the STG and the UTG. The group test results, the standardized exercise training programme and the objectives of this programme were presented and explained. The players were instructed on how to record their training in their log books and individual appointments were made for each subject to explain the resistance weight training programme.

4.4.5 Fitness training prescription

The resistance weight training component of the training programme was designed to develop muscular strength and muscle mass. Exercises on selectorized resistance machines were chosen because the subjects were generally not experienced with resistance weight training (Freedom et al 1990 and Mazur et al 1993). Exercise selection was based on guidelines for strength training for rugby players found in the literature (Walsh 1990 and Hazeldine and McNab 1991) and modified for this population of schoolboy subjects (Freedom et al 1990, Mazur et al 1993). Two exercises for each of the major muscle groups; chest, shoulders, upper back and thighs and one exercise for each minor muscle group; biceps, triceps and calves were prescribed for each subject.

The following exercises were prescribed on selectorized resistance weight training machines in this order and according to Baechle (1994):

1. Bench press
2. Pec deck
3. Shoulder press
4. Triceps pushdown
5. Lateral pulldown
6. Seated rowing
7. Biceps curl
8. Seated leg press
9. Leg extension
10. Leg curl
11. Standing calf raise

Each training session was concluded with abdominal strengthening exercises and stretching exercises for the calves, hamstrings, quadriceps, gluteal muscles and the muscles of the chest and shoulders. Each stretch was performed twice and the position held for 30 seconds.

The subjects in the UTG were instructed on the correct technique for each exercise in two subsequent sessions. Thereafter, they were left to train on their own and instructed to keep a detailed log of their training (Appendix B). Subjects in the STG attended strength training on Monday, Wednesday and Friday between 3.30 and 5.00 p.m.. The subjects would report to the examiner on arrival, collect their log books and proceed to train under the supervision of the examiner. The examiner would monitor training technique, intensity and progression. The subjects in the STG also recorded their training in a log book (Appendix B).

The first two weeks served as a familiarisation period during which the subjects performed 2 sets of 15 repetitions for each exercise The intensity was determined subjectively by each player according to the repetition maximum

(RM) method described by Freedom et al (1990). They were told to train at a resistance that caused muscular fatigue and failure at 15 repetitions (Freedom et al 1990) in the first set. Then after a rest period of between 1 and 2 minutes, they performed the maximum number of repetitions in the second set, at the same resistance. After 2 weeks the training intensity was increased to three sets of 8-12 repetitions (Freedom et al 1990). The same RM method of determining the training intensity was used. The weight used in the first set was kept the same for the subsequent 2 sets. The training weight was increased when more than 12 repetitions could be achieved in the first set. This ensured that the intensity of training for the remaining 10 weeks was increased continuously. Subjects from both training groups were instructed on how to determine and progress training intensity in this way, however, this was supervised and monitored for the STG. This method of determining strength training intensity, volume and progression for this population has more recently been described (Faigenbaum et al 1996 and Fleck and Kraemer 1997).

The subjects were also instructed to run twice for 20 minutes each week at a comfortable pace during the first 4 weeks. They were told to adjust their pace so they could talk comfortably while running. In addition, they were instructed to record the distance covered in twenty minutes. For the final eight weeks the players were asked to run once for 20 minutes and once for 30 minutes or more each week. They were also instructed to perform the 20 minute run as a time trial and, therefore, at a higher intensity. These instructions were given to both training groups. Running sessions performed by the STG were not supervised, however, subjects were monitored and encouraged at the weekly resistance weight training sessions to adhere to the prescribed runs.

Each subject in the STG and the UTG recorded the number of training sessions attended and the following data for each prescribed exercise; the number of sets, the number repetitions, initial training weight and all changes in training weight. They also recorded the number times that they ran for 20 minutes or longer during the study. Log books were monitored every two weeks for the subjects in the STG, whereas the log books for the subjects in the UTG were collected at the final assessment.

4.4.6 Statistics

Results are expressed as the absolute value or the percentage difference between pre- and post measurements (mean ± SD or mean difference ± SD). A students t test was used to determine differences between the "compliers" and "drop-outs" from the study. A one-way analysis of variance was used to determine differences between STG, UTG and CG at initial testing. A two-way ANOVA with repeated measures was used to determine between group differences and pre- post differences. A Scheffe's post-hoc test was used to determine specific differences between groups. A Pearson product moment correlation coefficient was calculated to determine relationships between two variables. A multiple regression analysis was used to determine the relationship between more than two variables. Statistical significance was accepted when $P < 0.05$.

5. Results of the training study

5.1 Subjects

Seven of the randomly selected subjects did not make themselves available for the training study. Two of these subjects were relocating during the experimental phase of the study and the parents of 4 subjects refused consent explaining that academic and sporting commitments for that period of the year were particularly demanding. One subject, a competitive golfer, withdrew because he felt that resistance weight training would impact negatively on his golf performance. These subjects did not undergo initial testing which resulted in the groups comprising of the following numbers; supervised training group – STG: n=13, unsupervised training group – UTG: n=12 and control group - CG: n=13 (Table 5.1). Four subjects, 2 from the UTG and 2 from the CG, missed the initial Wingate cycle test and one subject from the CG missed the initial field testing session (muscular endurance tests; sit-ups, push-ups and the six second dash) (Table 5.1). There were no significant differences ($P>0.05$), between the 3 groups, for any of the test variables at the initial assessment (Table 5.1).

A further 5 players from the two training groups, withdrew from the study during the training programme. The two most important factors cited as reasons for non-compliance were the lack of time due to academic and other sporting commitments and the disruption caused by the 6 week holiday over December and January. This resulted in the STG comprising of 11 subjects, the UTG of 9 subjects and the CG of 13 subjects. Mean absolute pre- and post test results for all fitness test variables and SD are presented in Appendix C. This data is corrected for drop-outs.

Table 5.1.- Initial mean test scores for each of the 3 groups; supervised training group (STG), un-supervised training group (UTG) and the control group (CG). Test description indicates the page number where the test variable is described.

Variable	Test description	CG	STG	UTG
n		13	13	12
Age (years)		16.5	16.9	16.7
SD		0.5	0.8	0.7
Mass (kg)	p.36	72.6	73.2	71.6
SD		9.2	8.9	8.2
Stature (cm)	p.38	176.7	175.1	178.4
SD		5.3	3.9	7.2
Percent fat (%)	p.38	14.6	16.1	14.2
SD		4.6	5.0	2.9
Skinfolds (mm)	p.38	57	75	58
SD		14	31	13
Muscle mass (kg)	p.39	40.8	40.0	41.1
SD		6.5	3.9	6.0
Lean body mass (kg)	p.39	61.8	61.1	61.3
SD		6.5	4.8	7.0
Lean thigh volume (cc)	p.39	4192	4107	4196
SD		916	474	549
Chest girth (cm)	p.37	91.5	93.4	90.0
SD		6.3	5.8	3.5
Biceps girth (cm)	p.37	31.9	32.4	32.1
SD		2.6	2.2	1.8
Sit-reach (cm)	p.39	25.9	31.2	27.9
SD		10.4	7.1	9.9
Bench press 1RM (kg)	p.40	63	64	67
SD		14	9	12
Bench press 1RM/body mass	p.40	0.9	0.9	0.9
SD		0.1	0.1	0.1
Squat 1RM (kg)	p.40	119	132	122
SD		20	11	18
Squat 1RM/body mass	p.40	1.6	1.7	1.5
SD		0.5	0.5	0.7
Verical jump (cm)	p.40	49.9	49.5	50.4
SD		7.4	5.4	5.9

Variable	Test description	CG	STG	UTG
n		13	13	12
Peak power output (W)	p.41	291	282	291
SD		39	17	33
Relative VO_2 max (ml/kg/min)	p.41	51.9	50.4	52.6
SD		4.9	5.4	3.6
Absolute VO_2 max (l/min)	p.41	3.75	3.65	3.75
SD		0.43	0.18	0.38
First heart rate (b/min)	p.41	178	187	177
SD		12	8	7
Second heart rate (b/min)	p.41	190	198	192
SD		10	3	6
Final heart rate (b/min)	p.41	195	200	194
SD		9	3	9
Total cycle time (sec)	p.41	330	285	341
SD		99	90	79
Rating of perceived exertion	p.41	8.5	8.7	8.9
SD		2.0	1.3	1.7

Variable		CG	STG	UTG
n		11	13	10
Wingate - peak (W)	p.42	774	783	815
SD		99	94	128
Wingate - mean (W)	p.42	656	631	679
SD		83	74	102
Power/body mass (W/kg)	p.42	10.4	10.8	11.5
SD		0.7	1.2	1.1
Total work (W)	p.42	39364	37936	40764
SD		4954	4545	6122

Variable		CG	STG	UTG
n		12	13	12
Six second dash (m)	p.43	45.31	45.03	46.32
SD		2.29	1.95	3.15
Sit-ups (reps)	p.43	75	84	77
SD		26	36	39
Push-ups (reps)	p.43	21	27	28
SD		9	4	6

5.1.1 Characteristics of the drop-outs

The five subjects that withdrew from the study after the initial testing were identified as drop-outs. At the initial assessment there were no significant differences (P>0.05) in any of the measured variables between the average results of the 5 subjects that withdrew during the training period and the 33 subjects that completed the study (Table 5.2).

5.1.2 Summary of subjects

A total of 38 subjects out of the 45 randomly selected subjects made themselves available for the training study. During the 12 week training period 5 subjects from the 2 training groups (STG & UTG) withdrew from the study. This resulted in a CG comprising of 13 subjects, a STG of 11 subjects and UTG of 9 subjects. Mean absolute pre- and post fitness test results for all fitness test variable are presented in Appendix C. This data is corrected for drop-outs.

At the initial assessment there were no significant differences (P>0.05) in any of the measured variables between the 5 drop-outs and the rest of the subjects tested (n=33) (Table 5.2). In addition, there were no significant differences (P>0.05) between the three randomized study groups (CG, STG and UTG) at the initial assessment (Table 5.1).

Table 5.2.- Initial mean test scores for the Compliers (n=33) compared to the players who dropped out of the study (n=5). Refer to Table 5.1 for test variable descriptions.

Variable	n	Compliers	*SD*	n	Dropouts	*SD*
Age (years)	33	16.6	3.7	5	16.8	1.9
Mass (kg)	33	71.8	8.8	5	76.9	6.2
Stature (cm)	33	176.5	5.5	5	177.9	6.8
Percent fat (%)	33	14.7	4.3	5	16.8	3.9
Skinfolds (mm)	33	61	21	5	79	25
Muscle mass (kg)	33	40.4	5.6	5	41.7	4.4
Lean body mass (kg)	33	61.1	6.1	5	63.9	4.9
Lean thigh volume (cc)	33	4158	702	5	4204	318
Chest girth (cm)	33	91.3	5.6	5	94.0	4.3
Biceps girth (cm)	33	31.9	2.2	5	33.6	1.9
Sit-reach (cm)	33	28.8	9.7	5	25.2	5.5
Bench press (kg)	33	64	11	5	71	14
Squat (kg)	29	123	17	5	130	12
Vertical jump (cm)	30	50.0	5.8	5	49.0	7.3
Peak power output (W)	33	287	32	5	293	19
Relative VO_2 max (ml/kg/min)	33	52	5	5	49	5
Absolute VO_2 max (l/min)	33	3.71	0.3	5	3.78	0.2
First heart rate (b/min)	33	180	10	5	183	10
Second heart rate (b/min)	30	193	8	5	194	6
Final heart rate (b/min)	33	196	8	5	198	2
Total cycle time (sec)	33	324	89	5	282	107
Rating of perceived exertion (RPE)	33	8.5	1.7	5	9.8	0.4
Wingate - peak (W)	31	783	107	3	857	55
Wingate - mean (W)	31	652	88	3	669	63
Wingate - power/body mass (W/kg)	31	10.9	1.1	3	11.1	1.8
Wingate - total work (W)	31	39141	5307	3	40150	3,767
Six second dash (m)	32	45.76	2.49	5	44.12	2.03
Sit-ups (reps)	32	76	34	5	93	25
Push-ups (reps)	31	26	7	5	27	4

5.2 Results

5.2.1 Body composition

5.2.1.1 Body mass

The mean body mass of all subjects (CG, STG and UTG) increased significantly ($P<0.05$) over the 12 week training period (Table 5.3). There was no difference in the change in body mass between the groups ($P>0.05$) (Table 5.3). Mean body mass increased by 1.7 ± 1.5 kg in the UTG, 0.9 ± 1.7 kg in the STG and 0.1 ± 1.4 kg in the CG.

5.2.1.2 Stature

Mean stature increased significantly ($P<0.05$) in all subjects (CG, STG and UTG) from the initial assessment to the final assessment (Table 5.3).

5.2.1.3 Body fat

Mean sum of skinfolds (mm) and percentage body fat (%) were significantly ($P<0.05$) reduced in all the subjects (CG, STG and UTG) at the end of the 12 week training period compared to the values at the beginning of the study (Table 5.3). The reduction in the mean sum of skinfolds was significantly greater ($P<0.01$) in the STG (16.8 ± 14.3 mm) compared to the UTG (6.6 ± 5.7 mm) and the CG (6.4 ± 5.4 mm) at the final assessment. However, the reduction in mean body fat percentage was not significantly different ($P>0.05$) between the 3 groups (STG: 1.8 ± 2.0%, CG: 1.4 ± 1.8% and UTG: 0.7 ± 1.2%).

5.2.1.4 Muscle mass

Muscle mass and muscle mass expressed as a percentage of body mass increased significantly ($P<0.05$) in all subjects (STG, UTG and CG) over the 12 week training period (Table 5.3). The mean increase in absolute muscle mass in the subjects in the STG (2.7 ± 2.0 kg) and in the UTG (2.1 ± 2.7 kg) were significantly greater ($P<0.03$) than the increases found in the CG (0.3 ± 1.8 kg). There was a tendency for muscle mass, expressed as a percentage of body mass to increase by more in the training groups (STG: 3.1 ± 2.0% and UTG: 1.5 ± 3.3%) than the CG (0.3 ± 2.5%), however, these differences were not significant ($P>0.05$).

5.2.1.5 Lean body mass

Lean body mass increased significantly ($P<0.05$) in all subjects (STG, UTG and CG) from the initial assessment to the final assessment (Table 5.3). This variable increased by 2.1 ± 2.0 kg in the STG and by 2.0 ± 0.9 kg in the UTG compared to 1.2 ± 2.2 kg in the CG. The increase in lean body mass was similar in all groups.

5.2.1.6 Lean thigh volume

The mean increase in lean thigh volume found for all subjects over the training period was not significant ($P>0.05$).

5.2.1.7 Girth measurements

Chest girth and relaxed biceps girth increased significantly ($P<0.05$) in all subjects from the initial assessment to the final assessment (Table 5.3), however, the differences between the groups were not significant ($P>0.05$).

5.2.2 Laboratory tests

5.2.2.1 Flexibility

There were no significant changes in mean hip flexibility, measured with the sit-reach test, for any subjects (Table 5.3).

5.2.2.2 Upper and lower body muscular strength tests

Absolute (1RM) and relative (1RM corrected for body mass), upper (bench press) and lower body (squat) muscular strength increased significantly ($P<0.03$) for all subjects (Table 5.3). Bench press 1RM performance increased by 9.5 ± 7.0 kg in the STG and by 9.4 ± 6.0 kg in the UTG compared to 2.3 ± 5.0 kg in the CG over the training period. The changes found in the training groups were significantly greater than those found in the CG ($P<0.01$). When the 1RM bench press results were corrected for body mass (Bench press 1RM/body mass) the differences (pre vs. post) were not significant ($P>0.05$).

Squat 1RM performance increased by significantly more ($P<0.03$) in the UTG (21.4 ± 18.0 kg) than the STG (10.0 ± 12.6 kg) and the CG (0.9 ± 16.9 kg), over the training period. However, when corrected for body mass, the differences were not significant (P>0.05) (Table 5.3).

5.2.2.3 Vertical jump test

The overall time effect for vertical jump height (pre vs. post) was significantly different (P<0.03) (Table 5.3). However, there were no significant differences between the groups. The subjects in the CG and UTG increased their mean jump height by 2.2 ± 4.5 cm and 4.0 ± 3.7 cm respectively. There was a 0.3 ± 2.1 cm reduction in the mean jump height for the STG.

5.2.3 Aerobic power

There was a significant increase (P<0.03) in performance for all subjects (CG, STG and UTG) after the 12 week training period for the following aerobic power test variables; peak power output, absolute predicted maximal oxygen consumption and total cycle time (Table 5.3). All subjects had a significantly reduced heart rate response to the first workload of the final cycle test compared to the initial cycle test (P<0.03).

The peak power output (PPO) of the subjects in the STG and the UTG increased by an average of 6.7 ± 17.9 Watts and 15.5 ± 12.3 Watts respectively, compared to a 3.3 ± 24.5 Watts increase found in the CG. Changes in PPO over time (pre vs. post) for all groups were significant (P<0.03). Mean increases in total cycle time for the training groups were, STG: 56.2 ± 69.3 s and UTG: 76.3 ± 57.9 s, compared to the CG: 12.7 ± 87.3 s. The overall time effect (pre vs. post) for total cycle time was significant (P<0.002) for all groups. The differences between the groups were not significant for both peak power output and total cycle time ($P>0.05$).

5.2.4 Anaerobic power

5.2.4.1 Wingate cycle test

There were no significant changes over the training period for the variables measured during the 30 second Wingate cycle test ($P>0.05$) (Table 5.3).

5.2.5 Field tests

5.2.5.1 Six second dash

Performance of the six second dash improved significantly ($P<0.03$) in all subjects from the initial assessment to the final assessment (Table 5.3).

5.2.5.2 Muscular endurance tests

The change in the number of sit-ups performed from the initial assessment to the final assessment was not significant ($P>0.05$), however, there was a significant increase ($P<0.03$) in the average number of push-ups performed in the second assessment by all subjects compared to the first assessment (Table 5.3).

Table 5.3. - The difference in the mean scores from the initial test to the final test for all test variables for each of the groups; the supervised training group (STG), the un-supervised training group (UTG) and the control group (CG). (Diff. = difference in pre- and post measurements, SD = standard deviation)

Variable		n	**Diff.**	*SD*	**Variable**		n	**Diff**	*SD*
Mass *	*CG*	13	0.1	1.4	**Peak power output ****	*CG*	13	3.3	24.5
(kg)	*STG*	11	0.9	1.7	(Watts)	*STG*	11	6.7	17.9
	UTG	9	1.7	1.5		*UTG*	9	15.5	12.3
Stature *	*CG*	13	0.0	1.1	**Relative VO_2 max**	*CG*	13	0.4	4.7
(cm)	*STG*	11	1.1	1.7	(ml/min/kg)	*STG*	11	0.4	3.6
	UTG	9	0.6	0.6		*UTG*	9	1.4	2.4
Percent fat *	*CG*	13	-1.4	1.8	**Absolute VO_2 max ****	*CG*	13	0.0	0.4
(%)	*STG*	11	-1.8	2.0	(L/min)	*STG*	11	0.1	0.3
	UTG	9	-0.7	1.2		*UTG*	9	0.2	0.0
Skinfolds *	*CG*	13	-6.4	5.4	**First heart rate ****	*CG*	13	-6.0	6.1
(mm)	*STG*	11	-16.8[a]	14.3	(beats/min)	*STG*	11	-10.3	8.3
	UTG	9	-6.6	5.7		*UTG*	9	-8.3	8.1
Muscle mass *	*CG*	13	0.3	1.8	**Second heart rate**	*CG*	12	-3.2	5.2
(Kg)	*STG*	11	2.7[b]	2.0	(beats/min)	*STG*	10	-8.0	6.6
	UTG	9	2.1[b]	2.7		*UTG*	8	15.2	56.0
Percent muscle *	*CG*	13	0.3	2.5	**Final heart rate**	*CG*	13	-2.8	7.2
(%)	*STG*	11	3.1	2.0	(beats/min)	*STG*	11	-2.6	4.6
	UTG	9	1.5	3.3		*UTG*	9	0.7	7.5
Lean body mass *	*CG*	13	1.2	2.2	**Total cycle time ****	*CG*	13	12.7	87.3
(Kg)	*STG*	11	2.1	2.0	(seconds)	*STG*	11	56.2	69.3
	UTG	9	2.0	0.9		*UTG*	9	76.3	57.9
Lean thigh volume	*CG*	13	60.5	539.4	**RPE**	*CG*	13	0.6	2.2
(cc)	*STG*	11	73.4	339.3		*STG*	11	0.3	1.3
	UTG	9	7.6	459.6		*UTG*	9	0.2	2.4
Chest girth *	*CG*	13	0.7	1.8	**Wingate - peak**	*CG*	8	4.8	55.4
(cm)	*STG*	11	1.0	2.7	(Watts)	*STG*	8	39.8	62.5
	UTG	9	2.2	1.5		*UTG*	7	-20.7	79.4
Biceps girth *	*CG*	13	0.2	1.4	**Wingate - mean**	*CG*	8	-13.1	26.3
(cm)	*STG*	11	1.0	1.0	(Watts)	*STG*	8	33.3	67.0
	UTG	9	0.8	0.3		*UTG*	7	-5.6	43.7
Sit-reach	*CG*	13	2.3	5.0	**Power/body mass**	*CG*	8	0.1	0.8
(cm)	*STG*	11	-0.2	3.6	(Watts/kg)	*STG*	8	0.4	0.8
	UTG	9	1.4	3.6		*UTG*	7	-0.2	1.1
Bench press 1RM **	*CG*	13	2.3	5.0	**Total work**	*CG*	8	-788.0	1570.1
(Kg)	*STG*	11	9.5[a]	7.0	(Watts)	*STG*	8	1908.5	4191.2
	UTG	9	9.4[a]	6.0		*UTG*	7	-335.0	2621.1
Bench press 1RM/body mass	*CG*	13	0.0	0.0	**Six second dash ****	*CG*	10	1.9	1.6
	STG	11	0.1	0.0	(m)	*STG*	10	2.6	1.9
	UTG	9	0.1	0.0		*UTG*	7	0.8	2.1
Squat 1RM **	*CG*	11	0.9	16.9	**Sit-ups**	*CG*	10	12.3	47.1
(Kg)	*STG*	10	10.0	12.6	(reps)	*STG*	10	-3.5	31.0
	UTG	7	21.4[b]	18.0		*UTG*	7	-8.0	26.2
Squat 1RM/body mass **	*CG*	11	0.0	0.3	**Push-ups ****	*CG*	9	40.8	71.1
	STG	10	0.1	0.3	(reps)	*STG*	10	8.5	19.8
	UTG	7	0.2	0.3		*UTG*	7	14.4	34.7
Vertical jump **	*CG*	12	2.2	4.5					
(cm)	*STG*	7	-0.3	2.1					
	UTG	7	4.0	3.7					

[a] - Significant at P<0.01

[b] - Significant at P<0.03

* - Significant time effect for all groups at P<0.05

** - Significant time effect for all groups at P<0.03

5.2.5 Reported training

The subjects in the STG performed an average of 8445 ± 4982 repetitions for all the strength exercises combined for the duration of the 12 week training period, compared to 8055 ± 2613 repetitions reported by the UTG. This difference was not significant (P>0.05). Similarly, the recorded mean sum of training weight for all strength training sessions for the 12 week training period for bench press was STG: 47942 ± 30516 kg and UTG: 40059 ± 14941 kg and for leg press STG: 86803 ± 55747 kg and UTG: 84940 ± 59547 kg. These differences were not significant (P>0.05). The average increase in training weight, from the initial to the final recorded training weight, for all exercises combined was significantly greater (P<0.05) in the STG (47.9 ± 36.3 kg) than the UTG (20.3 ± 10.3 kg).

The UTG reported to have completed 16.8 ± 9.5 training runs compared to the STG (9.1 ± 7.3 training runs), however, the difference was not statistically significant (P>0.05).

5.2.6 Correlation coefficients

When the data from the STG and UTG were combined the relationship between the changes in muscle mass from the initial to final tests, were significantly correlated (r=0.45) to the average combined training weight for bench press. Furthermore, the change in lean body mass was significantly related (r=0.45) to the average combined training weight for leg press (Table 5.4). The correlation between the changes in chest girth and the average increase in combined training weight for all exercises over the training period was found to be significant (r=0.48) (Table 5.4).

The absolute bench press 1RM was significantly related to absolute squat 1RM (r=0.53) and squat 1RM expressed as a ratio of body mass (1RM : body mass) (r=0.50). Relative bench press 1RM was also significantly related to absolute squat 1RM (r=0.54) and relative squat 1RM (r=0.55) (Table 5.5).

Table 5.4.- Correlations between the change in body composition measurements (body mass, percent body fat, sum of 7 skinfolds, absolute muscle mass, lean body mass, lean thigh volume, chest and biceps girth) from the initial to the final tests and reported training data (average total number of repetitions for all exercises at all training sessions, average total training weight for bench press and leg press and average increase in training weight) for the 12 week training period.

	Average total number of repetitions	Bench press (Average total mass in Kg)	Leg press (Average total mass in Kg)	Average change in training mass (kg)
Difference in body mass (kg)				
Correlation coeficient	0.18	0.27	0.19	0.3
n	20	20	20	20
Level of significance	0.46	0.25	0.41	0.19
Difference in percent body fat (%)				
Correlation coeficient	0.09	0.1	0.13	0.29
n	20	20	20	20
Level of significance	0.72	0.67	0.57	0.21
Difference in sum of skinfolds (mm)				
Correlation coeficient	0.004	0.07	0.19	0.41
n	20	20	20	20
Level of significance	0.99	0.77	0.43	0.08
Difference in muscle mass (kg)				
Correlation coeficient	0.36	0.45	0.41	0.03
n	20	20	20	20
Level of significance	0.11	0.04[a]	0.07	0.91
Difference in lean body mass (kg)				
Correlation coeficient	0.24	0.43	0.45	0.06
n	20	20	20	20
Level of significance	0.30	0.06	0.05[a]	0.81
Difference in thigh volume (cc)				
Correlation coeficient	0.17	0.1	0.03	0.07
n	20	20	20	20
Level of significance	0.49	0.67	0.89	0.77
Difference in chest girth (cm)				
Correlation coeficient	0.02	0.08	0.21	0.48
n	20	20	20	20
Level of significance	0.94	0.74	0.38	0.03[a]
Difference in biceps girth (cm)				
Correlation coeficient	0.07	0.29	0.37	0.09
n	20	20	20	20
Level of significance	0.76	0.22	0.11	0.71

[a] Significant at $P<0.05$

Table 5.5.- Relationships between the difference in pre-and post test results for relative and absolute, upper and lower body muscular strength, vertical jump height and measures of aerobic capacity determined by a maximal cycle test (peak power output, VO_2 max, total cycle time, rating of perceived exertion and peak heart rate).

	Bench press 1RM:body mass	Squat 1RM	Squat 1RM:body mass	Vertical jump	Peak power output	VO^2 max	Total cycle time	Rating of perceived exertion	Peak heart rate
	(ratio)	(kg)	(ratio)	(cm)	(Watts)	(ml/)	(seconds)		(b/min)
Bench press 1RM (kg)									
Correlation coeficient	0.98	0.53	0.50	0.06	0.00	0.06	0.19	0.19	0.26
n	33	28	28	26	33	33	20	20	15
Level of significance	0.00[a]	0.00[a]	0.01[a]	0.77	1.00	0.76	0.43	0.42	0.34
Ratio bench press 1RM:body mass									
Correlation coeficient		0.54	0.55	0.14	0.04	0.05	0.2	0.0	0.05
n		28	28	26	33	33	22	33	23
Level of significance		0.00[a]	0.00[a]	0.50	0.82	0.76	0.26	0.98	0.83
Squat 1RM (kg)									
Correlation coeficient			0.99	0.23	0.02	0.02	0.09	0.22	0.41
n			28	25	28	28	28	28	19
Level of significance			0.00[a]	0.27	0.91	0.91	0.67	0.26	0.08
Ratio of squat 1RM:body mass									
Correlation coeficient				0.29	0.05	0.1	0.1	0.18	0.38
n				25	28	28	28	0.28	19
Level of significance				0.16	0.81	0.62	0.60	0.36	0.11
Vertical jump (cm)									
Correlation coeficient					0.08	0.19	0.06	0.09	0.19
n					26	26	26	26	18
Level of significance					0.70	0.36	0.77	0.66	0.46

[a] Significant at $p<0.05$

6. Discussion

6.1 Introduction

The aims of the survey were to;

i. determine the attitudes of senior high school rugby players towards specific fitness training methods, including; strength training, circuit training, running training and sprint training,
ii. record the extent to which this population performed these modes of training during either the pre-season and the playing season.

The aims of the training study were to measure the;

i. anthropometric, physiological and performance changes in senior high school rugby players resulting from a 12 week pre-season fitness training programme which included the prescription of resistance weight training, running training and flexibility training,
ii. effect of training with supervision compared to training with no supervision on the anthropometrical, physiological and performance changes in this population.

6.2 Survey

6.2.1 Rugby data

In a population that comprised of subjects from all playing positions and that was representative of senior high school rugby players, the majority (92%) of the players reported to be playing in the position of their choice. Eight percent (n=11) of the subjects reported to be playing out of position and the majority of this group of subjects (8/11) were doing so through pressure to represent a higher team.

Playing out of position was not identified as a major predisposing risk factor for injury at schoolboy level (Roux et al 1987). The obvious risk of an inexperienced player playing out of position in the high risk positions of hooker and prop have been highlighted (Silver 1984, Burry and Calcinai 1988). This practice is also contrary to the International Rugby Board guidelines (International Rugby Board 1987). In the current survey there was only one player who reported to be playing out of position in the front row.

Most of the players who completed the survey planned to continue playing rugby after school (90%, n=115). There is a marked decrease in the number of players registered at U21 level than the number of players playing in their final year at school (South African Rugby Football Union 1992). In the Rugby World Cup in 1995 the four nations with the largest rugby playing populations reached the semi-finals. This suggests a correlation between the size of the rugby playing population of a nation and success at Rugby World Cup tournaments. Therefore, attracting and retaining rugby players at all age group levels must be viewed as a key to ongoing success at international level. It has been suggested that the youth are losing their ability to entertain themselves through sport and play (Noakes and du Plessis 1996), which has challenged schools and governing bodies is to find new ways of attracting children to sport and games. This study has shown that the majority of high school players (90%) in their penultimate year at school intend to play rugby after school. However, it is known that within 3 years of leaving school many players no longer participate in organized teams (South African Rugby Football Union 1992). Future studies need to identify the factors which cause players to stop playing the game once they leave school.

6.2.2 Fitness training data

6.2.2.1 Reported attitudes to fitness training

The survey has revealed a high level of awareness with regards to the implementation of fitness training specific to rugby performance. The majority of the population (99%) supported the concept of pre-season fitness training and the inclusion of resistance weight training (99%) during pre-season fitness training. Furthermore, most of the players (90%) believed that fitness testing was an important part of fitness training for rugby. Pre-season fitness training, rugby specific resistance weight training and regular fitness testing are all components of a scientific approach to fitness training. There is no evidence that this information is delivered to this population in a formal systematic way, which suggests that the players access this information individually and separate from their structured school rugby programme. This is reinforced by the fact that out of the 110 players who reported to have trained on their own for rugby, only 29 players (26%) had taken advice from the rugby coach on the design of their training programme, whereas 60 players (45%) designed their own programmes.

Almost the entire research population (99%) supported the concept of pre-season fitness training for rugby, and 84% of the players reported to have performed fitness training on their own for rugby. Interestingly, 99% of the players agreed that pre-season fitness training should include strength training in the form of resistance weight training, whereas 80% of the population felt that this form of training should be continued into the playing season. This suggests that 19% of the players are not aware of the principle of reversibility of the training effect (Baechle 1994 and McArdle et al 1996). The principle of reversibility is based on detraining studies and states that the adaptation to any form of exercise training will be reversed once that specific form of exercise stimulus is terminated.

McKenna (1997) found that Division 1,2 and 3 rugby union clubs in the United Kingdom required players to perform resistance weight training more frequently during the pre-season than the playing season ($P<0.05$). The average number of squad players was 34.86 ± 8.87. Fewer of these players ($P<0.01$) adhered to resistance training (performed 1 or more weight training session per week) during the playing season (39.7%:-13.85 ± 4.35 players) compared to the pre-season (56.4%: -19.65 ± 6.35 players). Furthermore, the average number of weight training session per week, prescribed by the club declined pre-season vs. in-season; Forwards: 3.00 ± 0.91 vs. 1.85 ± 0.69 and Backs: 2.85 ± 0.90 vs. 1.54 ± 0.66 sessions per week ($P<0.001$) (McKenna 1997).

A small number (11%) of the senior high school players reported to have undergone any form of fitness testing despite the fact that 90% of the players felt that regular fitness tests were an important aspect of fitness training for rugby. There are no published data on attitudes to fitness training and testing in other rugby populations or other sports with which to compare this evidence.

6.2.2.2 Reported fitness training

The most popular form of pre-season training was running, followed by resistance weight training, sprinting and circuit training. Despite the fact that 99% of the players supported the concept of strength training during the pre-season only 63% reported to have performed resistance weight training during this period. The questionnaire may have tended to overestimate individual training volume, however, any overestimation in the survey would not have effected the validity of the training load used in the training study, as this was determined from the literature. Reported in-season practice of all the measured forms of fitness training; running training, resistance weight training, sprinting and circuit training was reduced compared to the preceding pre-season. The reduction in the number of subjects performing running training, resistance weight training and sprint training from the pre-season to the playing season was significant

(P<0.001), however, the reduction in the number of subjects performing circuit training was not significant. Possible reasons for this reduction in the number of subjects practicing these forms of training, from the pre-season to the playing season are;

i. increased demands on the players time due to rugby training sessions and matches during the season
ii. a lack of understanding of the effects of detraining (Baechle 1994 and McArdle et al 1996).

In a survey of Division 1,2 and 3 rugby union clubs, McKenna (1997) found that, in clubs where strength training was required of the players, 3-4 sessions a week were expected during the pre-season and 1-2 sessions a week during the playing season. McKenna (1997) found that forwards pre-season adherence to strength training (number of players completing 1 or more session per week) was significantly higher (P<0.01) in clubs where players were required to train under the supervision of an instructor. The average number of forwards at each club was 18.64 ± 5.44. When supervised, 82.5 % (15.37 ± 4.87) of the forwards adhered to weight training compared to 51.0% (9.50 ± 0.70) in clubs where there was no supervision. Regular resistance trainers (players who trained one or more times a week) reported to be performing longer weight training sessions than required by their clubs (McKenna 1997). McKenna (1997) concluded that club support for resistance training does not match the level of adoption by players. In the current survey less than half the players (48%, n=53) had received resistance training advice from either their rugby coach or a gym instructor, on the design of their training programme. Furthermore, resistance training for rugby was not included in a formal or structured way at any of the four school teams surveyed. McKenna and Muckle (1997) found, in a population of adult first division club rugby players (age = 28.2 years) with an average playing experience of 12.9 years, that only 27% had attended a course on strength training for rugby.

Schwellnus et al (1992) reported that 49% of final year male pupils surveyed at 13 high schools in the Western Province, South Africa participated in rugby and 11% performed resistance weight training. The survey did not determine how many rugby players performed resistance weight training, either as a sport or to supplement their rugby training. However, if it was assumed that all the pupils who reported to be performing resistance weight training were also rugby players, then 23% of the pupils who play rugby also trained with weights to improve muscular strength. In comparison, the population in the current study comprised of identified elite rugby players in the year prior to their final year at high school and included high schools from a similar geographic area to the Schwellnus et al (1992) study. The current survey found a far higher percentage of player participation in resistance weight training, during both the pre-season (63%) and the playing season (48%), than that suggested by Schwellnus et al (1992). A possible explanation for this difference is that, in the current study, the population was exclusively the most promising rugby players in their penultimate year at high school, whereas Schwellnus et al (1992) surveyed a cross section of final year high school pupils. This resulted in a cross section sample of rugby players (49%) and not specifically elite rugby players. It would seem that there are differences in the players individual training methods between the levels of playing proficiency within a high school population.

6.3 Training study

6.3.1 Anthropometry

The following body composition measurements increased significantly ($P<0.05$) from the initial assessment to the final assessment for all players (STG, UTG and CG); stature (cm), body mass (kg), lean body mass (kg), relaxed biceps girth (cm), chest girth (cm), absolute muscle mass (kg), and relative muscle (muscle mass expressed as a percentage of body mass) (%). Measurements of body fat; sum of 7 skinfolds (mm) and percentage body fat (%) were significantly ($P<0.05$)

reduced at the final test after 12 weeks for all players (STG, UTG and CG). These changes associated with physical maturation are documented for adolescents (Andersen 1994 and Hetzler et al 1997) and were expected. Physical activity, sport participation and training for a sport have been shown to have no effect on rate of growth in stature, timing of peak height velocity and final attained stature in adolescents (Malina 1994).

At the initial test there was a tendency for the sum of skinfolds to be higher in subjects in the STG (75 ± 31 mm) than in subjects in both the other groups (UTG: 58 ± 13 mm and CG: 57 ± 14 mm), however this was not statistically significant. When these results were corrected for drop-outs (Appendix C) the starting differences in the sum of skinfolds between these groups became less (STG: 69.4 ± 30.8 mm, UTG: 57.2 ± 13.4 mm, 56.9 ± 14.4 mm). This may contribute to the fact that the STG recorded a significantly ($P<0.05$) greater reduction in the mean sum of skinfolds than the other groups (UTG and CG). One cannot interpret this accurately though because the initial differences were not statistically significant. There was a concern about over-interpreting this result and running the risk of incurring a type 1 error (rejecting the null hypothesis when it should be accepted).

Ozmun et al (1994) found no significant reduction in the skinfold measurements of the upper arm following an 8 week strength training programme for a prepubescent population. Hetzler et al (1997) reported a significant reduction in the sum of 7 skinfolds over 12 weeks in a prepubescent population, however, there were no significant differences between the two strength trained groups and the control group. A possible explanation for the greater reduction in the sum of 7 skinfolds in the STG compared to the UTG is the significantly greater increase in weight training intensity that was reported by the STG compared to the UTG over the 12 week training period.

The mean increase in absolute muscle mass in subjects in the two training groups was significantly greater (P<0.03) (STG: 2.7 ± 2.0 kg and UTG: 2.1 ± 2.7 kg) than that found for the CG (0.3 ± 1.8 kg). When corrected for body mass, these changes in muscle mass were not significant. It has been suggested that muscular hypertrophy, in response to strength training is blunted until after puberty (Kraemer and Fleck 1993) and that strength gains prior to puberty are due to neural adaptations (Ramsay et al 1990, Ozmun et al 1994 and Hetzler et al 1997). Hetzler et al (1997) conducted a 12 week study to determine the effects of strength training on the development of anaerobic power in prepubescent male baseball players. Flexed upper arm and calf girths increased significantly in both the training groups compared to the control group, whereas there were no significant changes to mid-thigh circumference. Hetzler et al (1997), concluded that the significant increase in leg strength (leg press 1RM) in the training groups was therefore due to increased motor unit recruitment rather than hypertrophy. Ozmun et al (1994) reported significant increases in elbow flexion isokinetic strength (27.8 %) and isotonic strength (22.6 %) after 8 weeks of training in a prepubescent population. This was associated with a significant increase in neural activity (16.8 %) compared to the control group and no significant changes to upper arm circumference or skinfolds in the training group. Ozmun et al (1994) concluded that neurological adaptations to a weight training programme in a prepubescent population play a role in the development of muscular strength.

In the current study the increases in absolute muscle mass in the training groups (STG and UTG) compared to the CG suggest that strength training during adolescence does result in hypertrophy which is significantly (P<0.03) greater than that resulting from normal growth patterns. However, the fact that these changes in muscle mass do not translate to relative muscle mass support the evidence that hypertrophy is reduced until after puberty (Kraemer and Fleck 1993).

An equation to predict muscle mass in men, from limb girths and skinfold thickness, was validated by Martin et al (1990). Spenst et al (1993) used this equation to compare the muscle mass of competitive male athletes and found that absolute and relative muscle mass rankings supported the functional demands of the various sports. Track (61.7%) and field athletes (62.7%), basketball players (60.9%) and body-builders (65.1%) had relative muscle masses of greater than 60% of body mass. Whereas gymnasts (59.5%), long distance runners (58.6%) and non-athletes (56.5%) had an average relative muscle mass of less than 60%. In the current study the average final relative muscle mass for each group was less than 60% despite a non-significant increase over the 12 week training period (STG: 58.5 ± 3.07 %, UTG: 59.1 ± 3.75 % and CG: 57.3 ± 2.57 %).

In comparison to elite adult rugby players the current population had a lower relative and absolute muscle mass for the same phase of the season. The combined (STG, UTG and CG) post-training mean relative muscle mass for the adolescent population was 58.2 ± 3.08 % compared to 60.2 ± 4.3 % for national level adult rugby players (n=19) (Clark 1997) and 59.0 ± 3.47 % for adult provincial players (n=23) (Clark 1992). The difference was greater when comparing the mean absolute muscle mass for these three population groups; Adolescents: 42.3 ± 5.5 kg vs. National players: 59.0 ± 9.6 kg vs. Provincial players: 58.1 ± 8.79 kg (Clark 1992). Body mass and muscle mass increases during late puberty and early adulthood are well documented and may explain the difference in absolute muscle mass, however, the elite adult population were exposed to strength training for rugby (Clark 1997), which would also have contributed to the development of muscle mass.

Correlation's were found between the change in selected anthropometrical measurements and reported training volume and intensity. The change in muscle mass over the training period explained 20% (r = 0.45) of variance in the average combined training weight for bench press in the training groups. Change in LBM explained 20% (r = 0.45) of the variance in average combined leg press training weight for the duration of the training period. Mean change in chest girth explained 23% (r= 0.48) of the variance in the average increase in combined training weight for all exercises. These correlation's between the measures of body composition and the reported training data were significant ($P < 0.05$). Gains in muscular strength during puberty have been ascribed to neural adaptations (Ramsay et al 1990) and technical proficiency.

6.3.2 Physiological and physical performance tests

Vertical jump, push-ups and the measurements of aerobic power (peak power output, absolute predicted maximal oxygen consumption, total cycle time and first heart rate) changed significantly ($P<0.03$) for all groups across the training period (12 weeks). This can either be attributed to maturation or seasonal changes as all groups changed similarly. There were no changes in flexibility and sit-ups for any of the groups and therefore it must be concluded that neither of these variables were effected by the training stimulus or motivation.

The change in vertical jump height was not significantly different between the groups, however a possible explanation for the lack of improvement in this variable is that continuous running may have blunted the power development. Hetzler (1997) in a strength training study on a similar population found that vertical jump increased significantly in both training groups compared to the control group. The duration (12 weeks) of the strength training programmes of the two studies were the same, however in the current study continuous running was included which may have blunted the power development. This is an important finding as it may have implications for performance in high intensity, intermittent sport requiring muscular power. Further research into the effect of continuous running and muscular power development in a dynamic team sports such as rugby is required.

Absolute and relative, upper and lower body muscular strength increased significantly ($P<0.03$) for all subjects over the training period. Mean initial 1RM results for bench press for the three groups (STG: 64 ± 9 kg, UTG: 67 ± 12 kg and CG: 63 ± 14 kg) were much lower than that reported for 30 collegiate forwards (106 ± 13 kg) (Tong and Wood 1997). The average age and body mass of the collegiate players was 20.5 years and 94.4 kg respectively, compared to 16.7 years and 72.5 kg for the subjects in this study. The collegiate players lifted an average of 11.6 kg more than average body mass, compared to the current study where the average bench press 1RM was 7.8 kg lower than average body mass at the initial test. At the final test the average body mass was 1.7 kg higher than the average 1RM for bench press. This suggests that over the 12 week training period the ratio of upper body muscular strength to body mass improved. The possible mechanisms for this improvement are;

i. a training effect resulting in increased absolute muscular strength
ii. physical maturation
iii. improved weight lifting technique

Bench press 1RM increased by significantly ($P<0.01$) more in the two training groups (STG and UTG) compared to the CG. Bench press 1RM improved by 15.8 % and 16.2 % in the STG and the UTG respectively compared to 9 % in the ETG (experienced training group) and 15 % in the NTG (novice training group (Hetzler et al 1997). The population in the current study was not experienced in strength training which possibly explains similarity in improvements in upper body strength between the NTG (Hetzler et al 1997) and the STG and UTG of the current study.

Squat 1RM increased in both training groups, however the increase was only significant ($P<0.03$) in the UTG suggesting that training supervision does not enhance the adaptation to training. There is concern, however, about the large variance in the delta measurement for the squat 1RM. This large variance is possibly brought about by the fact that one subject in the UTG increased his squat 1RM by 55%. As a result of this large variance there has been a concern about over-interpreting these results. The UTG increased squat 1RM by 19.1 % and the STG by 8.2 % compared to 41 % and 40 % for the ETG and the NTG respectively for the leg press 1RM (Hetzler et al 1997). In the current study the subjects were tested using the squat 1RM, however they trained for 12 weeks using the leg press, whereas Hetzler et al (1997) tested and trained using the leg press. This may be a limitation in the current study and an explanation for the smaller increases in leg strength.

In a 12 week study measuring the effect of strength training on anaerobic power in prepubescent male baseball players, Hetzler et al (1997) reported significant increases in upper and lower body muscular strength performance. The population (mean age 13.6 ± 0.9 years) comprised three groups; the novice strength training group with no strength training experience (n=10), the experienced strength training group with approximately 8 months strength training experience (n=10) and the control group that performed only baseball training (n=10). The training groups performed 3 sets of the following exercises 3 times a week; supine bench press, wide grip cable pulldowns, leg extension, leg curl, leg press, biceps curl, triceps extension, wrist curls, reverse wrist curls and a shoulder dumbbell routine to develop shoulder stability specific to baseball. Leg press and bench press 1RM improved by significantly more in the two training groups than the control group after the12 week training period (Hetzler et al 1997). The two training groups also increased vertical jump height by significantly more than the control groups (Hetzler et al 1997), however in the current study vertical jump increased significantly in all groups across the training period and there were no significant differences between the groups.

Short duration sprint performance improved significantly for all groups in both the current study (6 second dash) and in the study conducted by Hetzler et al (1997) (40 yard sprint). The respective strength training programmes prescribed in these two studies were therefore not specific enough in their design to result in improvements in sprint times. Hetzler et al (1997) also found that performance (peak and mean power output in Watts) in the Wingate test did not change as a result of the 12 weeks of strength training. In the current study peak (W) and mean (W) power output in the Wingate test did not change significantly for any of the groups across the training period. A possible reason for this is the fact that the Wingate test is not appropriate for a pubescent population (Hetzler et al 1997).

Absolute bench press 1RM and absolute squat 1RM were found to have a 28% ($r = 0.53$) common variance. Absolute bench press 1RM also contributed 25% ($r = 0.50$) to the explained variance in the relative squat score (squat 1RM corrected for body mass). Bench press 1RM,corrected for body mass, explained 29% ($r = 0.54$) of the variance in absolute squat 1RM and 30% ($r = 0.55$) of the variance in relative squat 1RM (Table 5.5). These correlation's were significant ($P < 0.05$) which suggest that there are certain factors that determine muscular strength performance across all muscle groups. It was beyond the scope of this study to identify these factors.

The STG increased their mean combined training weight for all exercises by significantly more ($P<0.05$) than the UTG (STG: 47.9 ± 36.3 kg vs. UTG: 20.3 ± 10.3 kg). McKenna (1997) found in Division 1,2 and 3 rugby clubs, that the presence of a resistance-training specialist was associated with a higher number of players who regularly performed resistance training. He also suggests that the presence of a resistance training specialist was associated with greater control of resistance training volume over the course of the training year. In the current study the combined average number of repetitions for all strength exercises, was not significantly ($P>0.05$) effected by supervision. Nor was the average training volume in kilograms for bench press and leg press, significantly different for the STG than the UTG ($P>0.05$). Training volume is defined the total weight lifted for any given period and is calculated by multiplying the number of sets by the number of repetitions and then by the training weight in kg for the 12 weeks

(Baechle 1994). It would appear that in the current study the effect of supervision was on the quality of the progression of intensity of strength training rather than on execution of training per se. There are advantages to supervised training, however, if players are well taught and technically proficient, un-supervised training is almost as effective.

6.4 Summary of the discussion

The majority (90%) of the players surveyed intended to continue playing rugby after leaving high school, however, there is a high level of drop-out of players after school (South African Rugby Football Union 1992). A possible reason for this departure from rugby may be the fact that adolescent players find the physical demands of playing against adult players challenging. This may be overcome by developing muscular strength through a systematic, progressive, resistance weight training programme.

The high level of awareness towards the need for strength training in rugby found in the senior high school population did not follow through to implementation of this form of training during the season. The training study showed that a structured strength training programme will result in adaptations to body composition and muscular strength for this population group that are associated with improved rugby performance according to an analysis of the physical demands of the game of rugby.

Training supervision did not impact consistently on adaptations; the STG had a significantly greater reduction in the sum of skinfolds than the UTG and CG and the UTG had a significantly greater improvement in the squat 1RM than the STG and CG. The increase in absolute muscle mass and improvement in bench press 1RM was significantly greater in both the STG and the UTG compared to the CG. However, supervision did effect the quality of the progression of the training volume and intensity. It is possible that over a longer training period the progressive increase in training volume and intensity, associated with supervision, would impact on physical adaptations including body composition and muscular strength. The significant increases in upper body strength (STG and UTG), lower body strength (UTG) and absolute muscle mass (STG and UTG) found in the current study support the use of resistance weight training in the physical preparation of senior high school male rugby players.

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APPENDIX A.

THE FOLLOWING QUESTIONNAIRE IS FOR RESEARCH PURPOSES.

SECTION A: PERSONAL DATA:

School: ____________________

Surname: ______________________________ Date of birth: ___/___/___

First names: ____

Address: ____

____ Code: __________

Standard: __________ Class: ___________ Tel: ___________________(h)

INSTRUCTIONS:

1. PLEASE READ THE FOLLOWING QUESTIONS CAREFULLY AND ANSWER TO THE BEST OF YOUR ABILITY.

2. PLEASE ANSWER BY MARKING YOUR CHOICE WITH A CROSS (X).

SECTION B: RUGBY DATA:

1. Indicate the position you played most often this season and in the "Other" column indicate any other positions that you played.

	Yes	Other
Fullback	(1)	(2)
Wing	(1)	(2)
Centre	(1)	(2)
Flyhalf	(1)	(2)
Scrumhalf	(1)	(2)
Eighthman	(1)	(2)
Flank	(1)	(2)
Lock	(1)	(2)
Tight head prop	(1)	(2)
Loose head prop	(1)	(2)
Hooker	(1)	(2)

2. Is the position you played most often the position you choose to play:

Yes	No
(1)	(2)

If you answered YES the proceed to question 5.

3. What position would you choose to play:

	Yes
Fullback	(1)
Wing	(1)
Centre	(1)
Flyhalf	(1)
Scrumhalf	(1)
Eighthman	(1)
Flank	(1)
Lock	(1)
Tight head prop	(1)
Loose head prop	(1)
Hooker	(1)

4. Were you pressurized to play a position that you would prefer not to play:

	Yes
by parents/guardian	(1)
by other family members	(1)
by coach	(1)
by teacher (other than coach)	(1)
by school friends	(1)
by the school	(1)
so that you could play for a higher team	(1)

5. Which is the highest team that you played for in 1992 and for which team did you play the most number of games?

	Highest	Most
WP schools "A"	(1)	
WP schools "B"	(1)	
1st team	(1)	(2)
2nd team	(1)	(2)
U16 A tea	(1)	(2)
U16 B team	(1)	(2)
U15 A team	(1)	(2)
U15 B team	(1)	(2)

7. Do you plan to play rugby after school?

Yes	No
(1)	(2)

8.. On the following table please indicate;

a. other school sport in which you participate

b. your highest level of school participation.

c. other sports you play outside school

	School sport			Outside sport
	1st	Other	Social	
Athletics track	1	2	3	1
Athletics field	1	2	3	1
Cross country	1	2	3	1
Tennis	1	2	3	1
Cricket	1	2	3	1
Hockey	1	2	3	1
Swimming	1	2	3	1
Cycling	1	2	3	1
Rowing	1	2	3	1
Weight lifting	1	2	3	1
Waterpolo	1	2	3	1
Squash	1	2	3	1
Basketball	1	2	3	1
Soccer	1	2	3	1
Volleyball	1	2	3	1
Surfing	1	2	3	1
Gymnastics	1	2	3	1
Judo	1	2	3	1

Other:______________________________

____________________ Level:____________________

SECTION C: TRAINING HISTORY:

1. Have you ever undergone any form of scientific exercise testing for rugby training?

Yes	No
(1)	(2)

2. Have ever performed any rugby fitness training on you own?

Yes	No
(1)	(2)

If you answered NO please proceed to question 6.

3. If you have trained on you own during the pre-season, for the period up to April, then indicate on the following table the year and the type of training:

Year	Running	Gym (Weights)	Sprints	Circuit	Aerobics	Swimming
1992	(1)	(2)	(3)	(4)	(5)	(6)
1991	(1)	(2)	(3)	(4)	(5)	(6)
1990	(1)	(2)	(3)	(4)	(5)	(6)
1989	(1)	(2)	(3)	(4)	(5)	(6)

4. If you trained on your own during the competitive season between April and September then indicate on the following table the year and type of training:

Year	Running	Gym (Weights)	Sprints	Circuit	Aerobics	Swimming
1992	(1)	(2)	(3)	(4)	(5)	(6)
1991	(1)	(2)	(3)	(4)	(5)	(6)
1990	(1)	(2)	(3)	(4)	(5)	(6)
1989	(1)	(2)	(3)	(4)	(5)	(6)

5. Who advised you on what type of training to do?

	Yes
Parents	(1)
Coach	(1)
Teacher (other than coach)	(1)
Gym instructor	(1)
School friends	(1)
Designed your own programme	(1)

6. Indicate roughly when you began school rugby practice for the 1992 season:

	Early	Mid	Late
October 1991	(1)	(2)	(3)
November 1991	(1)	(2)	(3)
December 1991	(1)	(2)	(3)
January 1992	(1)	(2)	(3)
February 1992	(1)	(2)	(3)
March 1992	(1)	(2)	(3)
April 1992	(1)	(2)	(3)
May 1992	(1)	(2)	(3)

7. Do you think that pre-season training is important in rugby?

Yes	No
(1)	(2)

8. Do you think that enough time is spent on fitness training during the season?

Yes	No
(1)	(2)

9. Do you think that you would benefit from doing weight training for rugby during the pre-season?

Yes (1) No (2)

10. Do you think that weight training, during the season, is important for rugby players?

Yes (1) No (2)

11. Do you think that regular fitness tests should be a part of rugby training?

Yes (1) No (2)

12. Would you be available to take part in a pre-season fitness testing and training programme for the 1993 rugby season?

Yes (1) No (2)

SECTION D: INJURY HISTORY:

1. On the following table please indicate all rugby injuries that kept you from playing for 7 days or more and in which year the injury occurred. Please answer by writing in the abbreviation month in the correct column corresponding to the year and the type of injury.

	1992	1991	1990	1989	1988
Concussion					
Muscle tear/strain					
Ligament tear/strain					
Fracture					
Internal					
Bone bruising					
Laceration					
Dislocation					

SECTION E: GENERAL TRAINING KNOWLEDGE QUIZ:

PLEASE INDICATE WHETHER YOU THINK THE FOLLOWING ARE TRUE OR FALSE:

1. Aerobic fitness means the ability to sprint fast.

   True (1) False (2)

2. Weight training can change fat to muscle.

   True (1) False (2)

3. Regular long runs improve your aerobic fitness.

   True (1) False (2)

4. Weight training should form part of a programme aimed at increasing running speed.

   True (1) False (2)

5. Rugby forwards should carry more fat than backline players because they have to push in the scrum.

   True (1) False (2)

6. Hip flexibility, or stretching exercises will allow you reach your toes if you cannot touch them now.

   True (1) False (2)

7. You cannot increase your running speed through training.

True (1)   False (2)

8. Long slow runs during the rugby season are more important for rugby fitness than sprints.

True (1)   False (2)

9. If you have flu or a cold you should dress up warmly and go for a run.

True (1)   False (2)

10. Improving leg strength with weight training is important for forwards and not for backline players.

True (1)   False (2)

11. Any form of weight training will cause you to lose running speed.

True (1)   False (2)

12. Muscles developed through weight training will turn to fat once you stop training with weights.

True (1)   False (2)

13. Sprint training is not important in a fitness programme for forwards.

True (1) False (2)

14. You can change your body composition with correct training.

True (1) False (2)

15. To reduce your body fat you have to eat correctly and do regular aerobic exercise.

True (1) False (2)

16. Sprint training performed before the season does not benefit you during the season.

True (1) False (2)

17. The different parts of the year; the off-season, the pre-season and the playing season, require specially adjusted fitness training programmes.

True (1) False (2)

18. Muscle stiffness after training means that you did not stretch enough at the end of the training session.

True (1) False (2)

19. If you feel pain while you are training then you are training very well.

True (1) False (2)

20. If you are exercising regularly then you can eat anything you want, including junk food, because you burn it up.

True (1) False (2)

Appendix B.

*Name:*________________________ *Training group:*_______

Strength training	Week 1									Week 2								
	Session 1			Session 2			Session 3			Session 4			Session 5			Session 6		
Date																		
	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps
Bench press																		
Pec deck																		
Shoulder press																		
Tricep pushdown																		
Lateral pulldown																		
Seated row																		
Biceps curl																		
Seated leg press																		
Leg extension																		
Leg curl																		
Standing calf raise																		

Running	Run 1		Run 2		Run 3		Run 4	
	Date: / /		Date: / /		Date: / /		Date: / /	
	Distance	Time	Distance	Time	Distance	Time	Distance	Time

*Name:*________________________ *Training group:*_______

Strength training	Week 3									Week 4								
	Session 7			Session 8			Session 9			Session 10			Session 11			Session 12		
Date																		
	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps
Bench press																		
Pec deck																		
Shoulder press																		
Tricep pushdown																		
Lateral pulldown																		
Seated row																		
Biceps curl																		
Seated leg press																		
Leg extension																		
Leg curl																		
Standing calf raise																		

Running	Run 5		Run 6		Run 7		Run 8	
	Date: / /		Date: / /		Date: / /		Date: / /	
	Distance	Time	Distance	Time	Distance	Time	Distance	Time

Name:________________________ Training group:_______

Strength training	Week 5									Week 6								
	Session 13			Session 14			Session 15			Session 16			Session 17			Session 18		
Date																		
	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps
Bench press																		
Pec deck																		
Shoulder press																		
Tricep pushdown																		
Lateral pulldown																		
Seated row																		
Biceps curl																		
Seated leg press																		
Leg extension																		
Leg curl																		
Standing calf raise																		

Running	Run 9		Run 10		Run 11		Run 12	
	Date: / /		Date: / /		Date: / /		Date: / /	
	Distance	Time	Distance	Time	Distance	Time	Distance	Time

*Name:*______________________ *Training group:*______

Strength training	Week 7									Week 8								
	Session 19			Session 20			Session 21			Session 22			Session 23			Session 24		
Date																		
	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps
Bench press																		
Pec deck																		
Shoulder press																		
Tricep pushdown																		
Lateral pulldown																		
Seated row																		
Biceps curl																		
Seated leg press																		
Leg extension																		
Leg curl																		
Standing calf raise																		

Running	Run 13		Run 14		Run 15		Run 16	
	Date: / /		Date: / /		Date: / /		Date: / /	
	Distance	Time	Distance	Time	Distance	Time	Distance	Time

Name:________________________ **Training group:**_______

Strength training	Week 9									Week 10								
	Session 25			Session 26			Session 27			Session 28			Session 29			Session 30		
Date																		
	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps
Bench press																		
Pec deck																		
Shoulder press																		
Tricep pushdown																		
Lateral pulldown																		
Seated row																		
Biceps curl																		
Seated leg press																		
Leg extension																		
Leg curl																		
Standing calf raise																		

Running	Run 17		Run 18		Run 19		Run 20	
	Date: / /		Date: / /		Date: / /		Date: / /	
	Distance	Time	Distance	Time	Distance	Time	Distance	Time

Name: ______________________ *Training group:* ______

Strength training	Week 11									Week 12								
	Session 31			Session 32			Session 33			Session 34			Session 35			Session 36		
Date																		
	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps	Training weight	Sets	Reps
Bench press																		
Pec deck																		
Shoulder press																		
Tricep pushdown																		
Lateral pulldown																		
Seated row																		
Biceps curl																		
Seated leg press																		
Leg extension																		
Leg curl																		
Standing calf raise																		

Running	Run 21		Run 22		Run 23		Run 24	
	Date: / /		Date: / /		Date: / /		Date: / /	
	Distance	Time	Distance	Time	Distance	Time	Distance	Time

Appendix C.

The mean pre- (initial test) and post (final test) test results and SD for all fitness test variables. The data presented is for all the subjects in all the groups (STG, UTG and CG) and is corrected for drop-outs.

Variable	Group	n	Initial test	SD	Final test	SD
Mass	*CG*	13	72.6	9.2	72.7	9.2
(kg)	*STG*	11	71.6	8.6	72.5	8.9
	UTG	9	71.0	9.3	72.7	9.0
Stature	*CG*	13	176.7	5.3	176.7	4.8
(cm)	*STG*	11	174.8	3.2	175.8	3.0
	UTG	9	178.5	7.6	179.0	6.2
Percent fat	*CG*	13	14.6	4.6	13.1	3.9
(%)	*STG*	11	15.3	5.0	13.5	4.4
	UTG	9	14.2	3.1	13.5	3.2
Skinfolds	*CG*	13	56.9	14.4	50.4	10.7
(mm)	*STG*	11	69.4	30.8	52.6	16.7
	UTG	9	57.2	13.4	50.6	10.6
Muscle mass	*CG*	13	40.8	6.5	41.1	6.4
(Kg)	*STG*	11	39.6	4.1	42.3	5.2
	UTG	9	41.0	6.3	43.0	6.6
Percent muscle	*CG*	13	56.0	3.4	56.3	4.1
(%)	*STG*	11	55.4	1.8	58.5	3.1
	UTG	9	57.6	2.4	59.1	3.8
Lean body mass	*CG*	13	61.8	6.5	63.0	7.2
(Kg)	*STG*	11	60.3	4.8	62.4	5.5
	UTG	9	60.8	7.4	62.8	7.3
Lean thigh volume	*CG*	13	4192.5	916.4	4252.9	641.5
(cc)	*STG*	11	4084.8	512.7	4158.2	625.0
	UTG	9	4198.8	607.6	4206.3	558.6
Chest girth	*CG*	13	91.5	6.3	92.2	5.8
(cm)	*STG*	11	92.5	5.9	93.5	5.6
	UTG	9	89.6	4.0	91.8	3.1
Biceps girth	*CG*	13	31.9	2.6	32.0	3.4
(cm)	*STG*	11	32.0	2.1	32.9	2.1
	UTG	9	31.8	1.7	32.7	1.8
Sit-reach	*CG*	13	25.9	10.4	28.2	9.4
(cm)	*STG*	11	32.6	6.7	32.5	7.0
	UTG	9	28.3	11.0	29.8	9.3
Bench press 1RM	*CG*	13	63.5	13.6	65.8	15.8
(Kg)	*STG*	11	64.6	9.6	74.1	8.3
	UTG	9	63.3	9.7	72.8	6.7
Bench press 1RM/body mass	*CG*	13	0.9	0.1	0.9	0.2
	STG	11	0.9	0.1	1.0	0.1
	UTG	9	0.9	0.1	1.0	0.1
Squat 1RM	*CG*	11	120.9	19.2	121.8	31.6
(Kg)	*STG*	10	131.0	11.0	141.0	9.9
	UTG	7	120.0	18.3	141.4	19.5
Squat 1RM/body mass	*CG*	11	1.7	0.3	1.7	0.4
	STG	10	1.8	0.2	2.0	0.2
	UTG	7	1.8	0.3	2.0	0.2

Variable	Group	n	Initial test	SD	Final test	SD
Vertical jump	*CG*	12	50.4	7.4	52.6	5.4
(cm)	*STG*	7	51.4	4.0	51.1	2.8
	UTG	7	49.0	5.5	53.0	8.6
Peak power output	*CG*	13	290.9	39.1	294.2	38.0
(Watts)	*STG*	11	282.4	17.8	289.1	25.6
	UTG	9	286.5	37.0	302.0	26.4
Relative VO_2 max	*CG*	13	51.9	4.9	52.4	3.9
(ml/min/kg)	*STG*	11	51.6	5.0	52.0	5.6
	UTG	9	52.4	4.1	53.8	5.1
Absolute VO_2 max	*CG*	13	3.8	0.4	3.8	0.4
(L/min)	*STG*	11	3.7	0.2	3.7	0.3
	UTG	9	3.7	0.4	3.9	0.3
First heart rate	*CG*	13	177.9	12.2	171.9	12.4
(beats/min)	*STG*	11	185.9	8.2	175.6	9.0
	UTG	9	177.1	7.3	168.8	9.8
Second heart rate	*CG*	12	189.8	9.9	186.6	10.6
(beats/min)	*STG*	10	197.7	2.9	189.7	7.0
	UTG	8	192.3	6.4	186.1	6.7
Final heart rate	*CG*	13	194.9	8.7	192.1	11.4
(beats/min)	*STG*	11	200.2	3.8	197.6	5.1
	UTG	9	192.8	10.1	193.4	7.6
Total cycle time	*CG*	13	330.2	99.4	342.9	99.5
(seconds)	*STG*	11	306.4	81.4	362.6	108.2
	UTG	9	335.7	90.3	412.0	107.0
RPE	*CG*	13	8.5	2.0	9.1	1.2
	STG	11	8.5	1.3	8.7	1.4
	UTG	9	8.7	1.9	8.9	1.6
Wingate - peak	*CG*	8	793.6	110.2	798.4	111.4
(Watts)	*STG*	8	770.4	98.8	810.1	70.5
	UTG	7	805.0	151.0	783.9	84.3
Wingate - mean	*CG*	8	677.5	88.2	664.4	87.1
(Watts)	*STG*	8	622.7	87.4	656.0	44.7
	UTG	7	676.1	122.2	670.5	88.1
Power/body mass	*CG*	8	10.3	0.7	10.4	0.8
(Watts/kg)	*STG*	8	10.7	1.2	11.0	1.4
	UTG	7	11.2	1.1	11.0	0.7
Total work	*CG*	8	40651.8	5294.1	39863.8	5228.1
(Watts)	*STG*	8	37448.8	5416.6	39357.3	2679.1
	UTG	7	40566.6	7331.0	40231.6	5287.8
Six second dash	*CG*	10	45.1	2.3	47.0	2.4
(m)	*STG*	10	45.4	1.8	48.0	2.5
	UTG	7	47.1	3.0	47.9	3.5
Sit-ups	*CG*	10	76.0	28.1	88.3	51.7
(reps)	*STG*	10	81.0	37.0	77.5	56.1
	UTG	7	69.3	45.6	59.0	28.8
Push-ups	*CG*	9	21.6	6.6	27.7	9.5
(reps)	*STG*	10	29.0	3.6	31.0	5.9
	UTG	7	27.1	8.0	30.3	11.7