PHYSIOLOGICAL AND PHYSICAL FITNESS PROFILES OF ELITE SOUTH AFRICAN SURFERS

By

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"Since the beginning of life as we know it, the sea has supported our planet. From it has come the air we breathe the food we eat and the water we drink. In short, the sea has given us life.... Perhaps it's time we returned the favour."

Bob Talbot

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ABSTRACT

The present study profiled the fitness characteristics of elite South African surfers. Sixty-one surfers volunteered to participate in the study. Each subject underwent a maximal tests in order to measure peak maximum oxygen uptake, anthropometery, co-ordination, agility, balance, Wingate test, and isokinetic strength assessments of the knee and shoulder in extension and flexion, including shoulder internal and external rotation. Lung function measurements were also measured to assess the lung capacity of the subjects.

The cardiovascular demands of surfing was high showing a peak VO_2 of 54.9 ($\pm$SD=9.73) $ml.kg^{-1}.min^{-1}$, and a peak V_E of 98.3 ($\pm$SD=17.8) $l.min^{-1}$. Actual lung function results obtained by the subjects were greater than predicted scores for age and weight. Anaerobic scores were excellent for surfers as compared to other sportpersons. Balance and agility scores were excellent. Good strength ratios and values were obtained through isokinetic testing, both for the shoulders and the knees.

The subjects showed an above level of fitness in all the measurements as compared to other water-based athletes. As a result the research showed that surfing can be best enhanced through the principle of specificity, and that the subjects engaged in this sport can be regarded as elite athletes.

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CHAPTER ONE

1.1 INTRODUCTION

Passion and the challenge of the unknown drive people to engage in high-risk sports, such as mountain climbing, canoeing rapids, free-fall parachuting, and hang-gliding culminating in a rush of adrenaline, which spurs the competitor to new heights. Surfing could well be assigned to that category of sports, with its inherent dangers and thrills **(Conway, 1988)**.

Surfing (surfboard riding), the national sport of the ancient kingdom of Hawaii, was the fastest growing outdoor aquatic sport of the seventies. Today, it attracts considerable numbers of competitors participating in annual, world-wide events, to establish world rankings and championship status in both amateur and professional ranks. The adherents range from those who relish the challenge of riding "Pipeline" to the recreational surfer.

> "Riders will be given maximum points for performing in the most difficult part of the wave. The wave is selected for it's quality and size, for the longest time, at the fastest speed, using the widest range of functional manoeuvres involving the highest degree of difficulty" **(Atkins, 1983)**.

The technique of surfing comprises several activities, which may vary from the surfboard being paddled through or around waves in the prone position to reach the take-off area.

When appropriate waves approach, powerful paddling is demanded to give the surfboard enough momentum to be gathered up by the moving swell. Having caught the wave, manoeuvres on the board are executed while standing, keeping close to the curling wave for optimum speed and enjoyment. The ride continues until the wave breaks on the beach.

Surfing is a unique sport, participants practice their skills and abilities as often as time and surfing conditions will permit without actual conscious attention to training. The amount of time spent in the water is equivalent to the training time of elite athletes in other sports. Surfers are known to practice up to seven hours a day in different sessions. However, surfers are likely to consider this time as enjoyment rather than training.

1.2 STATEMENT OF THE PROBLEM

Fitness profiles of elite South African surfers have not been examined. The identification and development of norms as performance criteria will assist the future testing, selection of the fittest individuals, and improve the level of surfing in South Africa.

1.3 HYPOTHESIS

The hypothesis is to demonstrate that the elite South African surfer has a similar level of fitness compared to that of other elite water sport performers.

1.4 SIGNIFICANCE OF THE PROBLEM

This study will enhance the sparse knowledge that is available with respect to many fitness components, including cardiovascular fitness. There are no isokinetic strength assessments of any major muscle groups regarding surfers. There are no measurements of anaerobic tests involving the arm and the leg power of these professional athletes.

There is an absence of research, an insufficiency of scientific training methods for conditioning, and no sound nutritional knowledge to enhance sport performance, on a scientific basis.

The field of surfing medicine includes fewer than thirty scientific articles. How fit are surfers?, is surfing a good form of exercise?, and to which patients can surfing be prescribed as part of an exercise program?, these are the types of questions sports medicine scientists and researchers have raised about surfing. Many of these questions remain unanswered.

1.5 PURPOSE OF THE STUDY

The purpose of this study is to determine physiological and physical fitness profiles of surfers. Additionally, norms will be developed on a multiple of fitness parameters for surfers.

Furthermore, with the establishment of a typical surfing profile, talent identification programmes may be developed, to improve the selection of potential surfers.

1.6 LIMITATIONS AND ASSUMPTIONS

In the following section, the scope and boundaries of the research will be formulated. The definitions stated are related to physical fitness, surfing, and the tests performed on the surfers in this research.

1.6.1 LIMITATIONS

The most significant constraint was the absence of scientific studies to review surfing as either a sport or a recreational activity. There are no training manuals for research studies about the fitness assessment of surfers or set norms.

Certain factors may limit the use of isokinetic devices and/or the interpretation of the collected data. Among them, the assumption that the angular velocity is truly constant, the anatomical and technical difficulty in testing certain joints, the difficulties in isolating a single muscle group and stabilising other body parts to limit the contribution of synergistic muscles. Furthermore, the lack of normative data for subject populations, the lack of reliability and validation studies for some of the numerical values included in a typical report and the cost of the equipment. Taking these factors into account, appropriate interpretation of data may be considered.

The lack of motivation does pose a problem in all testing areas. However, being elite athletes, there was a certain amount of self-motivation and competitiveness between the subjects to do well.

1.6.2 ASSUMPTIONS

It was assumed that the subjects performed their best during the testing procedures. It was also assumed that the subjects answered truthfully and honestly in filling out the questionnaire.

1.7 DEFINITION OF TERMS

For the purpose of the study, the following terms as related to the fitness batteries, equipment and physiological terms are defined.

AEROBIC CAPACITY

The capacity of the person to perform over long periods. This capacity is measured using the maximum oxygen uptake test.

AEROBIC ENDURANCE

Shows the ability to sustain exercise that is predominantly aerobic. It is often referred to as cardio-respiratory endurance.

AEROBIC POWER

Is the maximum amount of energy that can be produced, per unit of time, from (predominantly) aerobic energy.

AGILITY

The ability to move quickly over short distances with rapid changes of direction and body position. To have good agility a person must also have good mobility or range of motion in body joints.

AKRON

This is a model of isokinetic dynamometer that was used to test the subject's strength of certain joints of the body.

ANAEROBIC ENERGY

This energy is produced without using oxygen. There are two anaerobic systems: alactacid and lactacid.

ANAEROBIC POWER

Is the maximum amount of anaerobic energy that can be produced per unit of time.

ANAEROBIC WORK CAPACITY

Can be defined as the total amount of work performed during an exhausting work out, which is of sufficient duration to maximise the anaerobic ATP yield.

ANGLE OF OCCURRENCE

The specific angle at which peak torque occurred during the assessment, on an isokinetic dynamometer.

ATHLETE

As used in this study, refers to any sports person, for example; surfers, swimmers, windsurfers, and runners.

AVERAGE ANAEROBIC CAPACITY

Represents the average local muscle endurance throughout the anaerobic test.

BALANCE

Is the maintenance of equilibrium while stationary or moving.

BODY COMPOSITION

Concerns the percentages of muscle, fat, bone, and body tissues.

CONCENTRIC

This is the action whereby a muscle maintains tension and shortens, with decreasing the joint angle.

CO-ORDINATION

Is the ability to use the senses with the body parts to perform multiple motor tasks smoothly, accurately, and simultaneously.

DEFICIT

This is the difference in strength between the left and right limb under investigation. A deficit of more than fifteen percent between the agonist and antagonist muscle groups in one limb is considered significant.

EXERCISE

Is defined as any activity that involves generation of force by muscle.

EXTENSION TORQUE TO BODY WEIGHT

Peak extension torque divided by the subjects body weight expressed in Newton Meter per Kilogram (Nm.Kg).

EXTERNAL SHOULDER ROTATORS

Those muscles that are associated with the outward rotation of the shoulder joint.

FATIGUE INDEX

Specifies the drop in power from Maximum Anaerobic Power to the Minimum Aerobic Power. The lowest power usually occurs at the end of an anaerobic test. The Fatigue Index reflects the rate of glycolysis.

FLEXIBILITY

Pertains to the range of motion available in a given joint.

FLEXION TORQUE TO BODY WEIGHT

Peak flexion torque divided by the subjects body weight expressed in Newton Meters per kilogram (Nm.Kg).

FORCE (N)

The Kilopond is multiplied by ten, which is a one-kilogram resistance placed on the bicycle ergometer, which is equal to Kilopond (Kp), which is equal to ten Newtons.

INTERNAL SHOULDER ROTATORS

Those muscles that are associated with an inward rotation of the shoulder joint.

LACTACID SYSTEM

Includes glycolysis, the conversion of glucose to lactic acid, with liberation of energy in the form of adenosine triphosphate (ATP). The amount of ATP produced is small compared with that liberated in the Kreb's cycle of the aerobic energy system, but it can be provided quickly due to the high concentration of glycolytic enzymes.

LEG EXTENSOR MUSCLES

The muscle group that is responsible for extending or straightening of the lower extremities of the leg at the knee. These muscles include the Rectus Femoris, Vastus Medialis, Vastus Lateralis, and Vastus Intermedius.

LEG FLEXOR MUSCLES

The muscle group responsible for bending the lower extremity at the knee. These muscles include; Semitendinous, Semimembranosus, and Biceps Femoris.

MAXIMUM OXYGEN UPTAKE (VO_2MAX)

This is the maximum volume of oxygen consumed by the body each minute during exercise, while breathing air at sea level. Because oxygen consumption is linearly related to energy expenditure, when one measures the oxygen consumption, one is indirectly measuring an individual's maximum capacity to do work aerobically.

MOTOR FITNESS

Refers to one's ability to perform well in basic movements using the gross or major muscle groups for activities such as skipping, hopping and jumping.

MUSCULAR ENDURANCE

Is the ability of the muscles of the limbs of the body, to exert force over an extended time without undue fatigue.

MUSCULAR STRENGTH

Is the ability of muscles to exert force or to lift a heavy weight. Muscular strength presents itself in three ways; static, dynamic and explosive strength.

PEAK ANAEROBIC POWER

Is the highest mechanical power achieved at any stage of an anaerobic test. It represents the explosive characteristics of a subject's muscle power.

PEAK TORQUE

The measurement of peak angular force measured in Newton Meters (Nm)

PHYSICAL FITNESS

The ability to carry out tasks with vigour and alertness, without undue fatigue, and with ample energy to enjoy leisure time pursuits and to meet unforeseen emergencies **(Clark, 1971)**.

RATIO

Refers to the relationship of strength between the flexor and the extensor muscle groups of each leg. The ratio is achieved by dividing the peak knee flexor torque into the peak knee extensor torque. These strength ratios are measured on an isokinetic dynamometer.

SHOULDER EXTENSOR MUSCLES

Those muscles which are associated with the increase in the joint angle of the shoulder. Returns the shoulder to the anatomical position.

SHOULDER FLEXOR MUSCLES

Those muscles which are associated with the reduction of the joint angle of the shoulder.

SPEED

Is the ability to perform a movement quickly.

STATIC STRENGTH

This is the maximum effective force that can be applied once to a fixed object by an individual from a defined immobile position. The handgrip dynamometer is an example of a measuring device that tests this type of strength.

TRANSITIONAL SKILLS

These are combinations and variations of fundamental skills, such as throwing for distance and accuracy.

The following terminology, which relates directly to surfing, is defined. Surfing posses one of the most colourful vocabularies of any sport or cultural activity. While the basic words in surfing's vocabulary remain the same, subtler terms change from place to place.

BACKHAND

Surfing with one's back to the wave face.

BOTTOM TURN

The turn made at the bottom of a wave to initiate the ride. Bottom turns will most often be sweeping powerful moves that enable the surfer to establish direction for the ride.

CUTBACK

A carving or snapping motion that changes the surfboard's direction toward the part of the wave from which the surfer has come. Cutbacks are a vital element in every surfer's performance, as they reposition the surfer into the nucleus of the wave.

DUCK DIVE

This is a technique that surfers have to master, to reach the take-off area. It requires the surfer to push the surfboard forward, underneath an advancing broken wave. The wave breaks over the surfer and the surfer comes out the other side.

FOREHAND

Surfing with one's front to the wave. A natural footed surfer rides a right hand wave on his forehand.

GLASSY

Smooth, calm water surface without the presence of onshore or sideshore wind.

GOOFY FOOT

A surfer who stands on his board with his right foot forward.

GUN

A long, narrow, spear surfboard, specifically designed for riding big waves.

HOLLOW

Is a steep and concave wave-face shape.

MALIBU BOARD

A long, rounded surfboard, used by longboarders.

NATURAL FOOT

A surfer who stands on his board with his left foot forward.

OFFSHORE WIND

Winds that blow towards the ocean, creating preferred surfing conditions. Offshore winds often hold up the waves and smoothen the ocean. A light offshore with a decent swell usually means superb surfing conditions.

ONSHORE WIND

Winds that blow toward the shore, affecting the backs of breaking oceans waves. This wind tends to make paddling out difficult, spoils the shape of the waves, and causes rough seas.

OFF-THE-LIP

Rebounding the surfboard off the breaking part of the wave and into the wave face.

PEAK

The central point on the wave, from where the wave pitches forward and breaks in both directions. Most rides start from the peak.

PRONE POSITION

Lying face down on the surfboard with one's head towards the nose of the surfboard.

SURF

Is the term applied to the foaming mass of a breaking wave in the breaker or swash zone of a beach face.

SWELL

Waves caused by an ocean disturbance, usually major storms, thousands of kilometres from the location.

TAKE-OFF

When paddling for a wave, the surfer grabs the rails (sides) of the surfboard, and assumes the standing position, this is the point at which a ride begins to be scored by the judges.

1.8 ABBREVIATIONS

a-vO_2 diff.	=	Peripheral Oxygen Extraction.
Ave. Capacity.	=	Average Capacity.
Beats.min^{-1}	=	Beats per Minute.
Beats.3min^{-1}.	=	Beats per Three Minutes.
cm.	=	Centimetres.
Fat. Index.	=	Fatigue Index.
$FEV_{1.0}$	=	Forced Expiratory Volume in One Second.
FVC	=	Forced Vital Capacity.
kg.	=	Kilograms.
km.hr^{-1}.	=	Kilometres per Hour.
kp.	=	Kilopond.
L.min^{-1}.	=	Litres per Minute.
Min. Power	=	Minimum Power.
ml.	=	Millilitres.

ml.kg.beat.	=	Millilitres per Kilogram per Beat.
$ml.kg^{-1}.min^{-1}$.	=	Millilitres per Kilogram per Minute.
Nm.Kg.	=	Newton Meter per Kilogram.
no.	=	Number.
RPE	=	Rating Of Perceived Exertion.
RQ	=	Respiratory Quotient.
$\pm$ SD	=	Standard Deviation.
sec.	=	Seconds.
Total Revs (30sec.)	=	Total Revolutions in thirty seconds.
V_E	=	Minute Ventilation.
VO_2 max	=	Maximum Oxygen Uptake.
W.	=	Watts.
Max. Power.	=	Maximum Power.
W.kg.bm.	=	Weight per Kilogram per Body Mass.
W.kg.lbm.	=	Weight per Kilogram per Lean Body Mass.
^{o}/sec.	=	Degrees per Second.

CHAPTER TWO

2.1 REVIEW OF RELATED LITERATURE

In this chapter, a review of related literature on the characteristics of surfing will be highlighted, concerning the physiological, biomechanical, nutritional, physical and psychological parameters. Surfing is the most popular watersport in the warmer regions of the world **(Werner, 1993)**.

Comparisons will be made to sports related to surfing including windsurfing, skiing, swimming, lifesaving, and surf skiing, all of which need similar physical components.

2.2 HISTORY AND DEVELOPMENT OF SURFING

Surfing is the sport of riding waves with the aid of a board or other floating objects, or sometimes with the body alone. The surfer commonly stands on a tapered, hollow board and rides down the face of a breaking wave, steering the surfboard by shifting the weight of the body. Although it is possible to surf waves only 0.3 meters high, steeper waves provide a faster, more exciting ride.

The best surf is found in Hawaii, where waves may peak at nine meters. Surfing originated in Oceania and was highly developed in the Hawaiian Islands by the time the English explorer Captain James Cook reached them in 1778 **(Werner, 1993)**.

The surfboards at the time were long hardwood slabs weighing 68 kilograms or more, so only the strongest athletes could handle them. With the development of a lighter surfboard, surfing became a popular sport.

In the mid 1950's surfboards of lightweight balsa wood, fibreglass, and polyurethane were introduced, replacing the heavy wooden boards of earlier years. These boards had the advantages of low weight and high manoeuvrability, and the sport gained rapidly in popularity.

Surfing requires the participant to paddle while lying on the surfboard, until the board reaches wave speed. The rider attempts to stand up and ride on the board toward shore. Modern surfboards weigh eleven to eighteen kilograms and are 1.8 to 3.7 meters in length.

Surfboards are slightly rockered so that the middle of the surfboard is slightly lower than the nose (top) and tail (bottom) of the surfboard. The tail of the surfboard has skegs, or fins, that acts as a lateral stabiliser. Surfing demands good balance, a sense of timing, and co-ordination because boards can reach speeds of fifty-five kilometres per hour **(Werner, 1993)**.

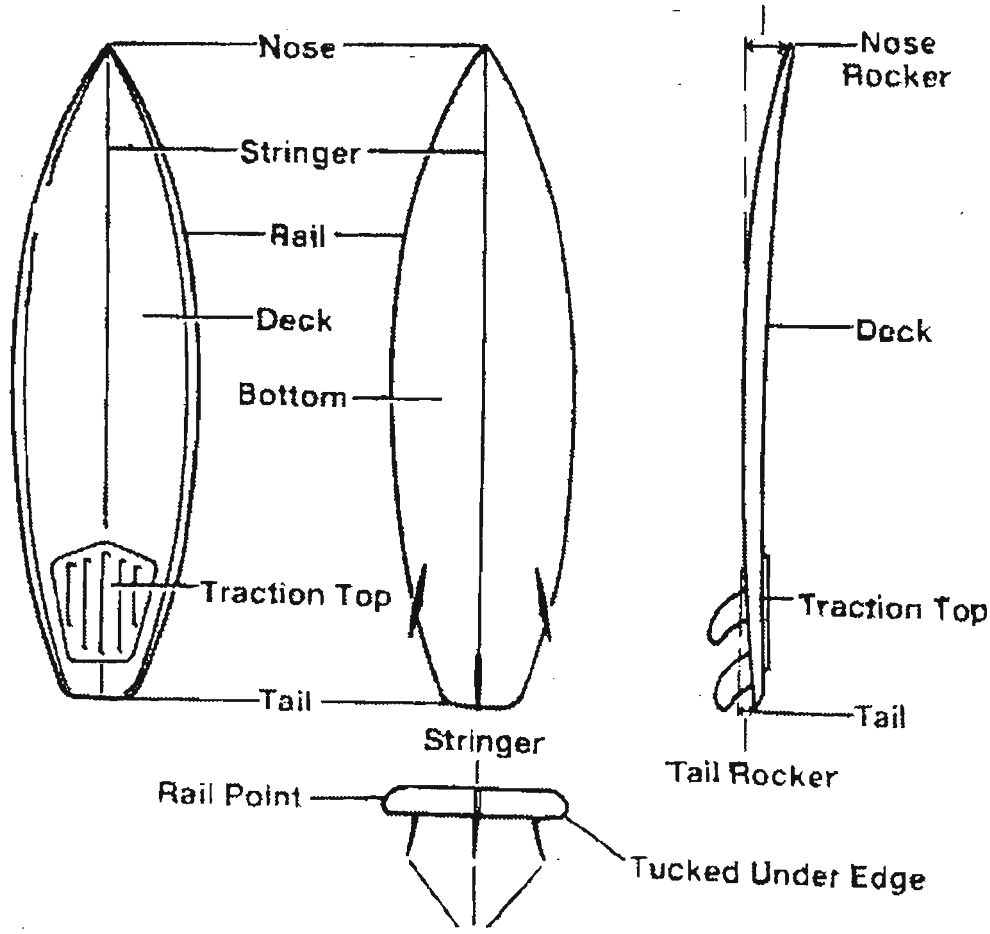


Figure 2.1 A sketch of the High Performance Surfboard

2.3 INJURIES AND SURFING

Both body surfing and surfboard riding are both excellent sports. Surfing requires suppleness, dexterity, equilibrium, co-ordination and, depending on the surf conditions, cardiovascular fitness. Sitting on a surfboard in a calm sea will not assist fitness but invigorating surf will increase the energy demands substantially.

Surfboard riders tend to be somewhat injury free, though this does not always pertain to the elite surfer who competes in the professional domain. The risk of injury in surfboarding is approximately one per 17,500 surfing days, which is below most sports **(Allen *et al.*, 1977)**. Physical problems that may be encountered are stiffness in the thoracic spine, painful or rigid shoulders, and injuries to the lower back.

The first two deterrents can be minimised by regular stretching while the latter is usually due to lower back stiffness, because of needing to lie in an arched position on the board, often for extended periods of time. Although surfing is a fun sport, being more fluid, skilled and more aerobically fit, can reduce your risk of recurrent minor muscle injuries.

Considering surfing is gaining in popularity, and many people become aware of it somewhat late in their athletic careers, surfing performance profiles, concerning fitness components and testing needs to be investigated. These investigations will enable coaches and professionals to use established criteria, to accommodate the surfer's abilities, and body components to adapt to the sport.

2.4 SURFING BIOMECHANICS AND FITNESS REQUIREMENTS

Surfing involves several different movements in upright manoeuvres while riding waves, as well as endurance and power while paddling. Based on the principles of specificity, training methods to prepare and maintain surfing fitness must be researched. Surfing comprises various motion actions. Firstly, the surfboard is paddled through or around breaking waves in the prone, or sometimes kneeling position to reach the take off area.

When suitable waves approach, powerful paddling is required to give the board enough momentum to be gathered up by the swell. Once the wave has been caught, it is necessary to stand and perform manoeuvres on the board quickly, keeping close to the curling wave. This is done for optimum speed and excitement. The ride continues until the wave breaks on the shore, the surfer falls off the board or the wave dies out **(Lowdon, 1980)**.

Surfing requires strength, mobility, speed, motor ability, perception, and reaction time. All these skills are important in the process of surfing. Such underlying factors may be more important than fitness itself in surfing. Should this be so, then the fittest surfer is not necessarily the best surfer. **Fleischman (1964)**, stated that the underlying abilities that are important to any sport may be present in any individual (for example agility, balance, multilimb co-ordination and postural discrimination).

However, this does not necessarily allow an individual to perform well in a number of different sports. Agility and mobility are requirements for a surfer to perform the variety of movements that are needed to make up the range of surfing skills.

Visual analysis of surfing manoeuvres shows that most work is done in a half to three-quarter-crouch position. It is suggested that isometric and isotonic endurance of the quadriceps is required for the sport. The section following will be a description of the components in motor fitness.

2.5 MOTOR FITNESS

Motor fitness or performance tests are concerned strictly with overall skills and abilities. Motor fitness components consist of five basic areas, viz.: ***dynamic strength, static strength, explosive strength, balance, and flexibility***.

Kirkendall et al. (1987), found a significant negative correlation between bodyweight and performance on muscular endurance and explosive power tests. Conversely, he also found a positive relationship between bodyweight and static strength.

The one-minute push-up test, found in the California Physical Fitness Test and the Indiana Motor Fitness Test, ensures the dynamic muscular endurance of the chest, triceps, and shoulders. Since the early studies, the test has been modified. Originally, a subject was required to lower his torso so that the chest touched the floor.

For greater accuracy, an assistant places a fist underneath the subject's chest to ensure each push-up is counted and incomplete push-ups are not. **Fleischman (1964)** identified push-ups to have a factor loading of 0.74. The push up test is a good field test to assess upper body strength, which is pertinent for surfing.

The one-minute sit-up test is designed to measure dynamic muscular endurance of the trunk. This test has been used extensively in the field of fitness testing, but in almost all cases, the hands are clasped behind the head. In the **Fleischman (1964)** study, sit-ups did not correlate well with pull-ups and push-ups.

It was therefore thought to measure another component of strength namely that of trunk strength and endurance which is used in the study by **(Zuidema and Baumgartner, 1974),** who established a loading factor of 0.43. The bent knee sit up test is still the most widely used test to assess dynamic strength of the abdomen.

The handgrip dynamometer test is a good measure of the static strength of each hand. It has remained unchanged in many tests over the years. **Fleischman (1964),** found the handgrip strength dynamometer test to have a factor loading of 0.72. **Phillips and Hornack (1979)** found the reliability coefficients of the grip strength test were consistently in the 0.90's and the factor loading for the right and left hands were 0.78 and 0.77 respectively.

The handgrip strength test was selected as a test of static strength as it is the most reliable and it is easily administered. Good results can be derived from such testing.

2.6 FLEXIBILITY

Flexibility is an important ingredient to successful and enjoyable boardsailing and should be worked on daily. Another motor fitness component, balance, is vital in surfing as without it a surfer would find it difficult to participate in the sport at any level.

Lowdon and Pateman (1980) determined the static and dynamic balance norms for International surfers. Results indicated that dynamic balance was better than static balance, although both had poor scores overall. Therefore, the inclusion of a balance test in the current study is essential.

The physical demands of paddling include both muscular endurance and power of the upper torso, and excellent cardiorespiratory endurance and recovery **(Anderson, 1980)**. The paddle out to the takeoff area may require up to ten minutes, and when repeated many times in a surfing session, high aerobic fitness is a necessity.

Jane and Kent (1986), confirmed that training for boardsailing should include a great deal of boardsailing in all conditions. Flexibility is a key to successful and enjoyable boardsailing, and should be worked on daily. Like surfing, boardsailing is an endurance sport, and a high level of cardiovascular fitness is best facilitated by long days in the water.

Should a surfer be required to "duck under" advancing broken waves, their aerobic needs are further taxed by these periods of breath holding. Further, the surfer requires a large amount of upper body work involving muscle power and endurance.

2.7 BIOMECHANICS OF SURFING

The movements involved would include; flexion and extension of the arm. Muscles that produce flexion are deltoid (anterior fibres), pectoralis major (clavicular fibres), caracobrachialis, and biceps brachii. Muscles that produce extension are deltoid (posterior fibres), teres major, latissimus dorsi, pectoralis major, and triceps brachii (long head).

Lateral rotation involves outward rotation of the humerus and medial rotation involves inwards rotation of the humerus, both of which assist in paddling.

The muscles that produce lateral rotation are deltoid (posterior fibres), infraspinatus, and teres minor. The muscles that produce medial rotation are pectoralis major, teres major, latissimus dorsi, deltoid (anterior fibres), and subscapularis.

While riding the wave, the surfer requires powerful leg movements to produce critical manoeuvres and turns. Surfers require strong leg muscles that are contracted isometrically while surfing on a wave. Surfing is a closed kinetic chain exercise, which trains proprioception and strength in the upper and lower limb.

The muscles of the upper leg that are utilised in surfing include the iliopsoas, rectus femoris, tensor fascia latae, sartorius, adductor longus, adductor brevis, pectineus, gluteus maximus, semimembranosus, semitendinosus, biceps femoris (long head), and the adductor magnus (ischial fibres).

Muscles in the lower leg required for balance and stabilisation include the tibialis anterior and posterior, peroneus (tertius, longus, brevis), extensor longus digitorum, extensor proprius hullucis, gastrocnemius, plantaris soleus, flexor longus digitorum and flexor longus hallucis. The above descriptions of the muscles involved in surfing, demonstrates that both upper body and lower body are involved with this sport.

2.8 TRAINING AND SURFING

Surfing is sport that is used for both fun and fitness. The physical demands of surfing include upper and lower body work, flexibility, and muscular strength and endurance in the legs, arms, and back muscles.

Surfers rarely train on land, and most training takes place under different surfing conditions. This enables the surfer to train at different intensities and durations. **Noakes (1987)** stated:

> "The only activity that may compliment one's surfing fitness is swimming."

The law of specificity states that training is specific. This suggests that surf-training sessions should ultimately be in the ocean, where different types of waves can be experienced.

Table 2.1 Training time allocated to each discipline depending on a surfer's ability Dunn (1997).

Components	Novice	Provincial	Professional
Psychological Preparation	0%	10%	40%
Tactical Preparation	0%	10%	30%
Wave Utilisation	0%	30%	10%
Technique Preparation	70%	30%	5%
Physical Preparation	30%	20%	15%

All these components interrelate at all stages of development, but more emphasis can and should be placed on dominant factors at the appropriate stage of development.

The skill of standing on a surfboard and performing manoeuvres in the fastest and steepest section of the wave, requires a combination of fast reaction time and speed of movement, good agility and mobility of all body joints.

Speed of reflexes or reaction time to a stimulus is an inborn ability. Observation suggests that elite surfers react quickly to changing wave shapes and forms without apparent time for thought process.

> "In the analysis of an extreme slowing of motion (of film) allows scrutiny of a surfer...can make impossible sections (of a wave), while he's tubed, he's constantly resetting the rails of his board...turning his head to avoid water flying at his face the speed...would have been too fast for him to see, he must have just sensed it" **(Delaney, 1979)**.

During the performance of all sports, the control system scans the short-term Sensory Store (STSS) for raw sensory information supplied by the eyes, the ears and the limbs, and selects what it believes to be the appropriate data. This system is necessary for perception, which enables surfers to analyse their movements, the sound of the waves, and how fast the surfers can move on the wave, and the time it takes them to turn.

Table 2.1, further shows deficits in the training of novice surfers, as there is no psychological, tactical preparation as well as wave utilisation. These components should be involved in the training program as soon as possible. Various fitness components will be discussed as related to surfers.

2.9 REACTION TIME

Pure reaction time responds to environmental information supplied by the eyes, ears, limbs, and is common to many sports, but a more complex type of response by the control system is demanded for surfing. Therefore a surfer must constantly employ visual dynamic astuteness **(Adams, 1984)**.

The speed of reaction to a green light stimulus has been tested on elite surfers, and compared with other age-matched groups **(Lowdon and Pateman, 1980)**. Results suggested that male and female surfers had the same average reaction times. Both surfer groups were faster than college physical education students who in turn were faster than non physical education students.

Tests of speed of movement that followed reaction time **(Lowdon and Pateman, 1980)**, revealed that highly seeded surfers in a competition had faster speed of movement than the group of surfers who were first eliminated. Sports people' time to an action coincides with the arrival of an approaching object with an accuracy of at least ten milliseconds. This is similar to the accuracy shown by elite sports persons in some sporting situations.

2.10 CO-ORDINATION AND BALANCE

Surfing involves gross and fine motor skills, fundamental skills, and transitional skills. The surfer must be able to learn and repeat these motor skills to excel in the sport at the highest level.

Once each skill is practised regularly, the sport becomes simpler and less demanding. Agility is a component of many motor skills. The surfer must acquire the capacity to change direction of movement rapidly without loss of balance. Co-ordination is a combination of speed, strength, reaction time, balance, and the neuromuscular component.

Balance (bodily stability) is also an important component of motor skills. When a body segment deviates from the desired postural position, one or more of five "righting reflexes" will cause muscle contractions to counteract the deviation. The stability of surfers while performing various manoeuvres depends on the position of the centre of mass (gravity) in relation to the base of support.

Therefore, the stature of the surfer would dictate his centre of gravity, which would influence stability. Surfers are not tall people **(Lowdon, 1982)**, and stability is one of the explanations for the deficit in height.

2.11 CARDIOVASCULAR REQUIREMENTS

An important fitness component that affects positively on all surfers' performance is cardiorespiratory endurance. Surfing can be categorised as a competitive sport that encompasses moderate dynamic and static exercise intensities.

What this indicates is that surfing involves changes in muscle length and joint movement with rhythmic contractions, which develop a relatively small intramuscular force also known as dynamic exercise. Dynamic exercise performed with a large muscle mass causes a marked increase in oxygen consumption.

There is also a considerable increase in stroke volume, cardiac output, heart rate, and systolic blood pressure. Static exercises involve the development of a relatively large intramuscular force with little or no change in muscle length or joint movement.

Static exercise on the other hand causes a slight increase in oxygen consumption, cardiac output, and heart rate **(Mitchell et al. 1994)**.

Edington and Edgerton (1976) addressing the importance of specificity of training for each sport, stated:

> "The biological end result of an exercise is directly determined by the specific exercise".

Similarly, the result of physiological testing for a particular sport would be best if directly determined by a specific test.

The cardiovascular requirements of a surfer are similar to that of a windsurfer and swimmer **(Deutsch and Kauf, 1981)**. Although the beginner may be winded at first by being knocked off the surfboard, surfing makes very energetic demands on the heart and the lungs, and could be strenuous to any healthy individual at first.

At the highest level, it is possible to sustain aerobic activity by surfing or turning continuously through a shore break, but that activity is mild compared with the aerobic activity required in cycling or cross-country skiing. This could be related to the sustained nature of the mentioned sport compared to surfing. There are definite breaks in surfing.

The demands in surfing and windsurfing are a combination of anaerobic and aerobic capacities, created by oxygen debt in strenuously and quickly exercised muscles.

The surfer's desire to catch a wave as soon as they reach the takeoff area, requires rapid cardiorespiratory recovery so that their skilled performance while riding the waves are not impeded by fatigue.

Lowdon et al., (1989), conducted a study on the specificity of aerobic fitness of surfers. To determine the most appropriate laboratory test of aerobic power for surfers, twelve male competitive college surfers completed three maximum work tests doing tethered board paddling (BP), prone hand cranking (HC), and treadmill running (TR).

The VO_2 max values suggest that this group was similar in aerobic fitness to college swimmers. The ratio of VO_2 max values for board paddling and hand cranking to treadmill running were similar to studies comparing arm ergometery to treadmill running.

Except for heart rate and VO_2 max, correlation coefficients between metabolic parameters of the board paddling and hand cranking test ranged from 0.65 to 0.80 and were significantly different from zero. As maximum physiological variables for board paddling and hand cranking were similar, it was suggested that hand cranking is a safer and easier test to conduct than board paddling or treadmill running, and hand cranking meets the principles of specificity for testing aerobic fitness of surfers.

Scores of seventy-six male and fourteen female elite international surfers tested on a bicycle ergometer, described the cardiorespiratory fitness of surfers to be high, compared with other competitive sportsmen **(Lowdon and Pateman, 1980)**.

As there is a relationship between aerobic fitness and heart rate recovery following standard exercise, rapid recovery or repayment of oxygen debt is another indicator of cardiorespiratory fitness. In the same study, recovery heart rates of surfers at five minutes after sub-maximal bicycle ergometer test was seventy-seven beats per minute for men, and seventy-six beats per minute for women respectively.

Gregg and Wainer (1994), indicated that one mile of swimming is about equivalent to four miles of running. Therefore, it would appear that surfers could improve their fitness by training, which will ultimately improve their arm capacity at the same time.

Higdon (1994), confirmed that swimming is acknowledged as an excellent builder of aerobic endurance and upper body strength, also improving flexibility and reducing stress, but is rated as only "fair" for weight control.

Davie and Newton (1998), estimated energy costs and oxygen uptake of competitive wave ski riding. The oxygen uptake and energy costs of competitive wave ski riding were estimated from the heart rates recorded during competition. Five male competitive ski paddlers volunteered to participate in the study. The mean estimated VO_2 of 3.27 litres per minute was seventy-seven percent of the mean laboratory determined peak VO_2 of 4.22 litres per minute.

The mean estimated energy expenditure during competitive ski riding was 12.8 kilojoules per minute. The study indicated that competitive wave skiing is predominantly an aerobic event and that the energy cost of competition is comparable with sports such as squash, swimming and skiing.

Bilodeau et al. (1995), investigated upper-body testing of cross-country skiers. Maximal oxygen uptake was evaluated twice during a competitive cross-country skiing season on a double-poling ski ergometer and running treadmill. The ski racers were tested during December and March.

When the ski racers were grouped according to those who peaked in December and those who peaked in April, the skiing treadmill showed significantly higher VO_2 peak measures at each peak time. A power test was also performed. Skiers who peaked in December had stable power output values across the season.

However, those who peaked at the end of the season increased in power output from December to April. It was concluded from the study that specific upper-body tests accommodated by the ski-treadmill was more related to the fitness condition of cross-country skiers than test results obtained on a running treadmill.

Holmer et al. (1974), studied maximal oxygen uptake during swimming and running by elite swimmers. They found significantly lower maximal oxygen uptake, heart rate, and ventilatory coefficients during maximal swimming than maximal running.

The study of endurance training for surfing should be swimming related, and consequently the tests should be swimming and skill specific and should be specific for surfing.

However, to date there is no valid swimming test to measure VO_2 max, a swimming flume could be used, however, this is a very expensive method. The researcher did not have access to a swimming flume, so the treadmill test was used.

Coyle et al. (1984), completed research on the time course of loss of adaptations after stopping prolonged intense endurance training. The results showed that;

> "When athletes train seasonally, fitness gains from training and participation are lost in the inactive periods. However, when athletes spend an extensive amount of time training, particularly over twelve months, a resistance to losing VO_2 max determinants, such as muscle mitochondrial and capillary density, are evident when compared to those who train less. This supports the principle that training throughout the year progressively, very little detraining takes place and the loss of training adaptations takes longer".

In a recent study **(De Vito et al., 1997)**, the researchers tried to investigate whether an Olympic Boardsailer is an endurance athlete.

Maximal cycle ergometer was used to test VO_2 peak and the cardiorespiratory demand was assessed by means of a very light telemetric device. Maximum peak oxygen uptake was 63.6 ($\pm$ 2.3) $ml.kg^{-1}.min^{-1}$ for males and 49.2 ($\pm$ 4.1) $ml.kg^{-1}.min^{-1}$ for females respectively. The data recorded during actual boardsailing show that this sporting activity can be classified as aerobic. Therefore, a boardsailer has much in common with a surfer.

Tesch (1983), completed physiological characteristics of elite kayak paddlers and determined that these athletes exhibited greater upper-body muscle strength in comparison to other groups of athletes. Maximal oxygen uptake averaged 5.36 ($\pm$ 0.25) $l.min^{-1}$.

The study suggested that elite kayakers required great upper-body strength, anaerobic capacity and endurance, including high aerobic power. The results for oxygen consumption for kayaker paddlers are expressed in litres per minute. The reason for this is that a kayaker's weight is supported throughout the sport. Perhaps, similar ways of expressing VO_2 max readings in surfers should be done. The surfboard and water throughout the exercise also support surfers body weight.

Surfing is a seasonal sport, typically engaged during the hot summer months. During the winter months, even with the development of the wetsuit to help keep competitors warm, individuals train and surf less, because of the cold water and wind chill factor.

The disadvantage of this is twofold, firstly, with the lack of regular surfing, individuals will become unfit, and their aerobic condition will deteriorate and they will struggle to meet the requirements of surfing in the summer months. Furthermore, surfing is a sport that is determined by both skills (technical) and aerobic fitness.

The skill aspect will diminish, due to months of detraining. Where the elite surfer differs however, is because of international travel during the winter months. Therefore, they are constantly experiencing summer weather throughout the year permitting them to maintain their skills and fitness in peak condition.

2.12 LUNG FUNCTION

Lung function should be considered as an indicator of cardiorespiratory health or fitness. Although there is not a high correlation between VO_2 max and lung function measures, it has been demonstrated that successful athletes, particularly those requiring high endurance, have high scores of vital capacity and forced expiratory volumes.

The tests conducted on elite surfers' lung functions, **(Lowdon and Pateman, 1980)**, revealed lung function scores of surfers to be among 111 percent and 130 percent of predicted values for age and height. Vital capacity is the maximum volume of gas that can be expelled from the lungs by forceful effort following a maximal inspiration. Vital capacity is the sum of tidal volume, inspiratory reserve volume, and expiratory reserve volume.

Although values for Forced Vital Capacity (FVC) vary considerably with body size and body position during the measurement, average values are usually four to five litres in healthy young men, and three to four litres in healthy young women. FVC's of six to seven litres are not uncommon in tall individuals, and a professional football player has reported a value of 7.6 litres and 8.1 litres by an Olympic gold medallist in cross-country skiing **McArdle et al. (1994)**.

During quiet breathing at rest, the breathing rate averages twelve breaths per minute, whereas the tidal volume averages 0.5 litre of air per breath. Under these conditions, the volume of air breathed each minute or minute ventilation (V_E), is six litres.

Significant increases in minute ventilation result from an increase in either the depth or rate of breathing, or both. During strenuous exercise, the breathing rate of healthy young adults usually increases to thirty-five to forty-five breaths per minute, although elite athletes achieve rates as high as sixty to seventy breaths per minute during maximal exercise.

2.13 NUTRITIONAL PRACTICES

Felder *et al.* (1998), identified the nutritional practices of elite female surfers during training and competition. Four and five day food diaries were completed over competitive and training periods, which indicated mean energy intakes of 9,468kJ ($\pm$SD=2,007) and 8,397 kJ ($\pm$SD=1,831) per minute, respectively. The level of energy intake was less than that estimated for the requirements of surfing. It was found that female surfer's carbohydrate intakes failed to meet the recommendations of the Australian recommended daily intake (RDI).

Comparisons between competition and training, carbohydrate and confectionery intakes were significantly higher and protein intake was significantly lower during competition. Results show that body fat stores were not compromised, but self-reported energy, carbohydrate and nutrient intakes were marginal in elite female surfers.

Meir et al. (1991), tested heart rates and estimated energy expenditure during recreational surfing. In this study, the heart rates and subsequent estimated energy expenditure during approximately one hour of recreational surfing were examined. Six male surfers participated in the study. The heart rate was gathered using a modified Sports Tester (PE3000S) microcomputer telemetry system.

The mean heart rate for recreational surfing was 135 beats per minute, while mean values for paddling and stationary cycling were 143 and 127 beats per minute respectively. The estimated mean energy expenditure for the total time surfing was 2077 kilojoules. The estimated mean energy expenditure of thirty-three kilojoules per minute, suggested that recreational surfing is comparable with a variety of other recreational sporting activities in terms of energy cost. However, research in the area of surfing and nutritional practice is still scarce.

2.14 ANAEROBIC POWER

Good anaerobic power is required when using the arms to catch each wave. Sometimes two, or as many as twenty, hard powerful strokes are required to position the surfboard correctly, and gain the necessary momentum to catch the wave.

Prone paddling also involves isometric contraction of the trunk and neck hyperextensors to fixate the shoulder girdle for effective paddling and allows head rotation to read the waves at the time of take-off. Thus, a high degree of anaerobic fitness is required of the arms and upper body to position the surfboard in the take-off area successfully.

Esbjornsson et al. (1993), determined whether anaerobic performance is directly related to the quantity of fast-twitch fibres in muscles. Males and females, with similar training backgrounds, were analysed for anaerobic performance and muscle characteristics. Muscle biopsies and a thirty second all out Wingate test on a bicycle ergometer was performed.

Results showed that males had higher, peak power values (forty-four percent) and mean power values (forty-eight percent) than women. Anaerobic performance was directly related to the portion of type II fibres. This study is important in relation to surfing as the majority of the surfing action is anaerobic, therefore, surfers require fast-twitch muscle fibres **Lowdon (1982)**. This does not seem logical as the arm pulls are quite vigorous in force during the building-up phase, before the surfer rides the waves.

Anderson et al. (1990), evaluated eleven club, fourteen divisional, and nine provincial slalom skiers, on a sixty second Wingate Anaerobic test. There were significant differences found between the divisional and provincial skiers ($p<0.05$). The study was not well designed, because the sixty second test used, was of less value than the more popular thirty second Wingate Anaerobic test was.

Slalom skiing is very similar to surfing, where skiers use a board to ski on. The duration of each skiing session lasts longer than sixty seconds in any competitive event, which makes this sport primarily aerobic in nature.

A study on cycle ergometery and maximal intensity exercise completed by **Winter (1991)**, examined the use of cycle ergometery in assessments of performance during maximal intensity exercise. He concluded that cycle ergometery is a useful, simple and inexpensive model in this regard and that friction braked and isokinetic type systems has increased the sensitivity in assessing performance during maximal intensity exercise.

Bar-Or (1987) completed a study on the methodology, reliability and validity of the Wingate Anaerobic test. The author stated that there is conclusive evidence of the high reliability of the Wingate Anaerobic test in various populations in both laboratory conditions, and less standardised field conditions. High scoring in this test reflects high anaerobic capabilities but does not predict performance in high power sports events where skill and fitness are other important aspects.

An even combination of sprint and endurance muscle fibre types is ideal for overall satisfaction in surfing, allowing for quick, powerful turns. The big surf rider is best served by a higher percentage of sprint fibres, up to eighty percent in the thighs, for the spilt second turns and tactics required by this variation of the sport. These attributes are very similar to that of a sprint swimmer **(Henneman, 1984)**. Thus, the anaerobic component plays a major role in the fitness of the surfer. The anaerobic component plays an important part in surfing, thus the need to assess this fitness component of surfers is important.

2.15 BODY COMPOSITION

Body size, structure, and composition are separate but interrelated aspects of the body that contribute to what has been defined as physique. Body size refers to the volume, mass, length, and surface area of the body, whereas body structure refers to the distribution or arrangement of body parts such as the skeleton and muscle-fat distribution.

Measurements of skinfold thickness' at various sites, can be used in equations to predict percent body fat directly **(Sinning 1985; Sinning and Wilson, 1984)**. The skinfold method is based on the assumptions that the thickness of the subcutaneous adipose tissue reflects a constant proportion of the total fat mass and that the sites selected for measurement represent the average thickness of the subcutaneous adipose tissue **(Lukaski, 1987)**.

The body composition of a surfer is similar to that of a windsurfer, swimmer, and cyclist. The surfer is typically mesomorphic, with varying degrees of ectomorphy, or leanness. Like ski racers, surfers are well served by being short and light, the traits that lower the centre of gravity of the body. A body composition in which the legs are short (about trunk length) and the overall stature is small, is a physical advantage **(Carter, 1984)**.

Elite surfers are lean, well-muscled athletes. Physique or somatotype is described by three ratings, each of which is on a seven-point scale. The first rating describes fatness (or leanness); the second describes muscularity about height; and the third describes linearity.

The majority of seventy-six surfers **(Lowdon, 1980)**, had close to the body-type described by the somatotype 2.5:5.2:2.6. By comparison, the average college male student is 3.0:4.0:2.5. In other words the surfer carries less fat and is considerably more muscular than age-matched peers.

The elite surfer's mean body-type is almost identical to that of Olympic swimmer's. Although the surfer is shorter, this gives a lower centre of gravity that allows for better dynamic balance that is necessary for surfing. The average body fat of elite male surfers was found to be 10.5 percent. This is less than that of the average college male (14 percent), and more than top athletes in most individual sports, for example, swimmers (eight percent), marathon runners (seven percent), gymnasts (five percent) **(Lowdon, 1980)**.

Extreme leanness offers no real advantage from a performance perspective as the surfer's weight is supported while paddling, however excessive body fat may hamper riding agility.

It has been suggested that because the surfers are constantly in a wet and windy environment, their body adapts by furnishing some extra fat for protection **(Lowdon and Pateman, 1980)**.

Percent bodyfat in a recreational surfer is not particularly important, as long as whatever fat there is does not restrict agility and range of motion, and aerobic capacity. It may impede getting onto the surfboard quickly. However, lightness does provide a favourable opportunity in this sport. Windsurfers at the competitive level tend to have very low percentages of body fat, and regard fat as a restriction.

In endurance distance swimmers, a high percentage of body fat provides extra and helpful floatation. In ultra-long distance running, too low a body fat percentage can limit an athlete's performance by limiting the runners fuel. In summary, surfers are slightly shorter than most sport persons, and have a percentage body weight equivalent to world elite sport persons.

2.16 ISOKINETIC DYNAMOMETRY

Isokinetics is based on the concept that the angular velocity of a moving limb can be maintained constant by changing the force generated by a device to resist the intended movement. During an isokinetic movement, the device produces a force similar in magnitude to that produced by the muscle at every angle of the range of motion, but in the opposite direction **(Frontera *et al.,* 1993)**.

Isokinetic techniques are currently used for five major purposes: strength testing, rehabilitation, research, diagnosis of injury, and to some extent, as a training aid.

As isokinetic dynamometer offers the possibility of quantifiable assessment of dynamic muscle function, providing information on a range of muscle characteristics, it has become a valuable tool for research work. Provided the test protocol is strictly adhered to, objective and accurate data on a wide range of variables can be generated **(Perrin, 1993)**.

Several studies have tested the reliability and validity of isokinetic instrumentation in measuring torque, work and power **Magnusson** ***et al.*** **(1990), Montgomery** ***et al.*** **(1989),** and **Bemben** ***et al.*** **(1988)**. All these studies indicate that the technical accuracy and reliability of isokinetics are very high, as correlation coefficients between the computed mechanical work and measured work ranges between 0.93 and 0.99, respectively.

The reliability of testing different body regions differs. Certain shoulder movers, especially internal and external rotators, tend to show a greater reliability than extensors and flexors **(Greenfield** ***et al.*****, 1990)**.

Test reliability is also related to the angle of testing. Shoulder extensors and flexors tested in a neutral position appear to give more reliable results, while the reliability decreases as ninety degrees of abduction is approached.

The shoulder joint is a complex multiaxial joint capable of movement in multiple directions, accordingly valid and objective assessment of muscle function of this region is difficult. In general, the external rotator muscles generate a torque of approximately sixty percent to eighty percent of the values generated by the internal rotator cuff muscles. Corresponding values for the non dominant side are slightly lower **(Perrin, 1993)**.

Normally, shoulder flexors are able to generate torque values of approximately seventy-five percent to eighty-five percent of those recorded for the flexors **(Pawlowski and Perrin, 1989)**. In upper body sports, such as swimming, flexor muscles tend to produce only fifty percent of the force exerted by the extensors **(Perrin, 1993)**.

Research completed by **McMaster *et al.* (1991)**, pertaining to shoulder torque changes in the swimming athlete, reported that the ratio of internal and external rotation decreased, thus indicating the specificity of the repetitive action of swimming and the demands of water polo.

Participation in sporting activities, specifically those that incorporate forceful arm motions, does account for significant bilateral performance differences. Shoulder muscles of the dominant side in water polo players **McMaster *et al.* (1991)** and swimmers **Grobler (1998)** were found to be significantly stronger than their nondominant counterparts.

Findings based on normal subjects, **Ivey *et al.* (1985), Connelly-Maddux *et al.* (1989), Cahalan *et al.* (1991)** and **Shklar and Dvir, (1994)** did not indicate any effect of dominance. **Ivey *et al.* (1985)** indicated that the strongest muscle group was the adductors followed by the extensors, flexors, abductors, internal rotators and external rotators.

The same strength order was later indicated by **Shklar and Dvir, (1994)**. In a study **Freedson *et al.* (1993)**, 4541 subjects were measured in two velocities for the shoulder flexion and extension. No gravity correction was performed. The findings provided the only normative data base and are presented in terms of percentage, age and gender.

The reliability of quadriceps and hamstrings testing has been adequately established **(Kannus, 1994)**, and appears to be reliable across a variety of test speeds. One application of isokinetics has been the examination between isokinetic torque values for flexion and extension of the knee joint at different joint angle velocities.

The flexion-extension ratio has been expressed as a percentage by dividing the peak hamstrings by the peak quadriceps torque recorded **Sanderson *et al.* (1984)**. Studies investigating the hamstring to quadriceps ratio suggest that this should be fifty percent to eighty percent depending on test velocity **(Kannus and Jarvinen, 1990)**. Generally, a ratio of 60 percent measured at 60 degrees per second is accepted as normal **(Baltzopoulos *et al.*, 1989)**.

Baron *et al.* (1990) completed isokinetic measurements of the stretch strength of the femoral quadriceps muscle in twelve male surfers, and compared them to fifteen healthy male, untrained persons. The concentric peak torque of the knee extensors was measured every ten degrees in a range from ninety to 120 degrees isometrically and dynamically with a constant angle velocity of ten degrees per second.

The difference in torque between the left and right leg showed no significance, but there is a slight dominance in favour of the standing leg. The body weight related strength of the surfers was 3.2 Newton meter per kilogram (Nm.Kg) showing a higher strength characteristic compared to 2.7 Nm.Kg of the untrained subjects.

The strength values of the surfers were above the value of three Nm.Kg, which is referred to as representing a good training status. The outcome showed that long-lasting specific training like surfing will change the strength characteristics of the quadriceps muscles.

The importance of measurements regarding the extensors and flexors, including the ratio between the extensors and flexors is a major criterion for testing surfers in this research.

Freedson, (1993) tested 4541 subjects which is the most comprehensive isokinetic study completed, in terms of population size. The subjects were drawn from companies which carried out medium to heavy physical work, and the peak moments of the extensors and flexors, were recorded.

Lowe (1997) identified concentric ratios for knee extensors and flexors in elite triathletes, and these results could be compared to surfers. **Lowe (1997)** developed percentile norms for these triathletes. The only drawback of the **Lowe (1997)** study is the number of subjects that were used for the development of the norms.

Further research undertaken **Holmes *et al.* (1984), Coetzee *et al.* (1992), Fillyaw *et al.* (1986), Koutedakis *et al.* (1995)** and **Chan *et al.* (1996)** measured similar attributes in isokinetics of the upper limb and comparisons regarding results would indicate how well surfers fair compared to other sporting disciplines.

It would appear that these are few studies, currently, where the surfer's strength ratios are measured using isokinetic dynamometers. The results of this study would be pioneering in this fitness area. The current study investigates upper body and lower limb ratios for the sport population under scrutiny.

After an extensive review of related literature in comparison to surfers, the researcher investigated the weaknesses and strengths of most of the studies regarding surfers. Emanating from this, the researcher believes that the current study has taken into account some of the drawbacks of past studies in the development of the current research.

CHAPTER THREE

METHODOLOGY

The methodology section describes the selection of subjects, the qualification of the testers who aided with the study, testing procedures, the fitness protocols used, and the methods of data analysis.

3.1 METHODS AND PROCEDURES

The testing methods and procedures were all carried out with care. All testing procedures were valid, reliable, and objective. Each test used, measured one specific capacity, ability or factor. There was no technical competence required from the athlete at any time.

Each athlete understood exactly what was required for the test and at the conclusion of the testing, results were explained to the athletes. The method of conducting the tests was standardised. The same venue, equipment, machines, environment and personnel were used.

3.2 SELECTION OF THE SUBJECTS

The sample consisted of sixty-one asymptomatic male surfers from Kwa-Zulu Natal. The criterion for selection of the surfers for this study was that the subjects had to be at a provincial or national level of surfing, and had been involved in surf training for at least six months before the study.

The subjects had to be between the ages of sixteen and sixty years of age. The age difference allowed a wide scope of surfers to be tested from juniors to seniors. All subjects were in excellent health, uninjured, and participated voluntarily in the research.

All surfers who participated in the study were considered competitive and elite athletes. An informed consent was obtained from each surfer before testing, and any questions regarding the testing procedures were answered. The University of Durban-Westville ethics committee granted ethical clearance for the study. The surfers were tested over a six-month period from September to February, during the summer months in the southern hemisphere. The surfers tested could be considered as the total population of elite surfers, excepting for a few who were competing overseas at the time of testing.

3.3 QUALIFICATION OF TESTERS

The researcher and his assistants were postgraduate students in the field of Biokinetics. All testers had completed a three-year degree in Sport Science, and were qualified and competent in carrying out test procedures.

3.4 TESTING PROCEDURES

All testing procedures were carried out at the **University of Durban-Westville** at the **Sports Science Department** in the **Human Performance Research Laboratory**. Each test was standardised and all equipment was calibrated before each surfer was tested. The subjects were tested on the following test battery:

Table 3.1 Selected Components and Test Battery

Selected Components	Testing Procedures
Muscular & Strength Components	
Muscular Endurance	One Minute Push-Ups
Muscular Strength	One Minute Sit-Ups
Isometric Strength	Handgrip Strength
Muscular Strength	Isokinetic Dynamometery
Anthropometery & Fitness Components	
Bodyfat Percent	Three Site Skinfold Measurements
Flexibility	Modified Sit & Reach Test
Speed & Agility	T-Drill
Balance & Motor Co-ordination Components	
Static Balance	Blind Stork Balance
Dynamic Balance	Balance Stabilisation
Motor Skills & Co-ordination	Hexagon Obstacle
Physiological Components	
Lung Capacity	Pulmonary Lung Function Test
Cardiovascular Fitness	Maximum Oxygen Uptake (VO_2max)
Anaerobic Capacity	Wingate Anaerobic Test
Ratings of Exertion	Borg's Rating of Perceived Exertion (RPE)

The section that follows concerns the methods, purpose, apparatus, and interpretation of the tests used in this study. The tests were not conducted in the same order as indicated in **Table 3.1**, but the results will be discussed in that order.

3.5.1 BODYWEIGHT

- **Purpose**

To record the weight of each subject to the nearest kilogram.

- **Apparatus**

One medical scale.

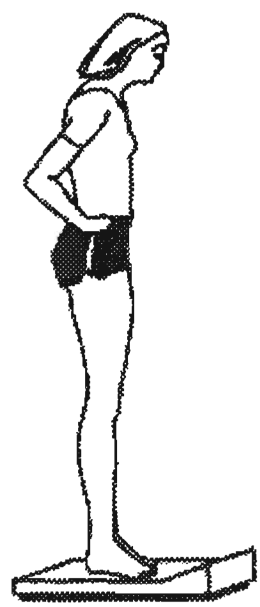


Figure 3.1 The Bodyweight Measurement

- **Performance**

The weight is registered with the male subject being in his shorts without his shoes.

- **Interpretation**

The weight is recorded in kilograms (kg), to the nearest gram (0.001kg), as read on the scale.

3.5.2 ONE MINUTE PUSH-UP (Coopoo, 1995)

- **Purpose**

To measure the dynamic muscular endurance of the arms and shoulder girdle.

- **Apparatus**

A Cardiosport Stopwatch and gymnastic mats were the equipment required.

- **Performance**

The push-ups were performed on gymnastic mats, approximately one inch thick to avoid excess pressure on the palms of the hands. The surfers assumed the conventional push-up position with feet together, palms flat on the floor, slightly wider than the shoulder and below the chest.

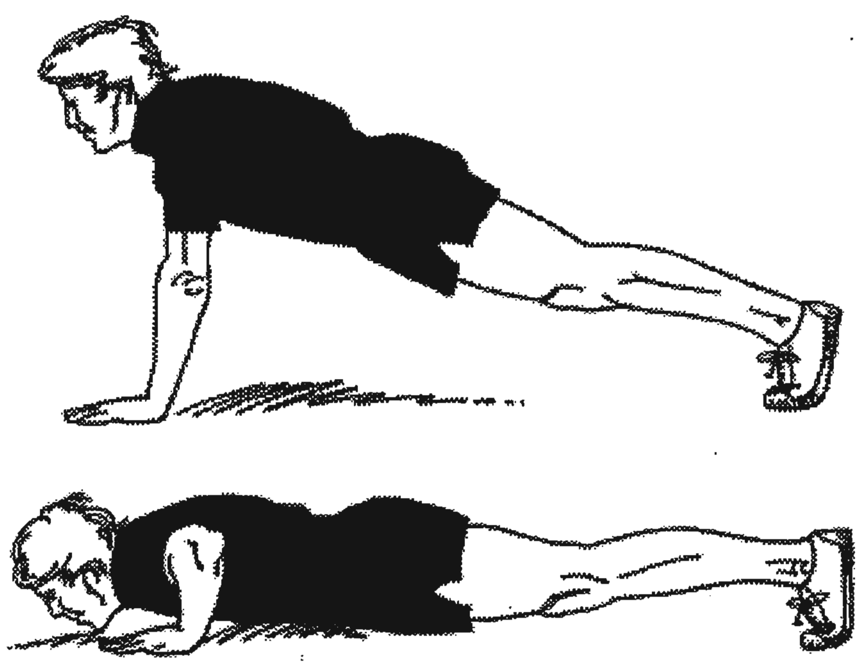


Figure 3.2 **The Push Up Sequence**

Arms had to be straight for the starting position. Assistants clenched their fists and placed them underneath the chest of the subjects torso. The chest of the subject had to touch the assistant's clenched fist in order for a push-up to be counted.

The duration of the test was one minute. The surroundings were air conditioned so that the air temperature was appropriate for the strenuous exercise. Verbal encouragement was given to each subject, and every fifteen seconds, the time was shouted out so that the subjects were aware of how much time was left.

- **Interpretation**

The movement from the starting position to the chest touching the clenched fist back up to the starting position was counted as one execution. The total score was counted as the number of complete executions performed in sixty seconds. One trial was allowed.

3.5.3 ONE MINUTE SIT-UP (Coopoo, 1995)

- **Purpose**

To measure the dynamic strength and endurance of the abdominal muscles.

- **Apparatus**

Gymnastic mats were used to avoid excessive pressure and potential bruising of the coccyx. A Cardiosport Stopwatch was used as a timer.

- **Method**

The subject assumed a supine position on the mat, palms placed over the ears, knees bent and feet held flat on the mat by the examiner or an assistant. The fingertips touched at the temples and were not interlaced behind the head, as there was an inclination to pull the head forward into a strained and potentially injurious position.

- **Performance**

The subject sits up, touched both elbows to the knees, and then returned to the starting position, (see **Figure 3.3**).

- **Scoring**

The movement "sit-up and return" was counted as one execution. The total score was the number of complete executions performed in sixty seconds. Counting began when the elbow touched the knees. One trial was allowed.

- **Controls**

The examiner or assistant kneels, straddling the subject's feet, placing his hands on the calves of the subjects' legs just below the back of the knee. This prevented the subject from sliding, and helped maintain the starting position throughout the duration of the test.

Only the subjects shoulders had to touch the mat. The sit-ups did not need to be performed continuously. The examiner or an assistant gave verbal encouragement and every fifteen seconds, the time was shouted, indicating to the subject how much time was left.

- **Interpretation**

The results were compared to available norms and ranked accordingly.

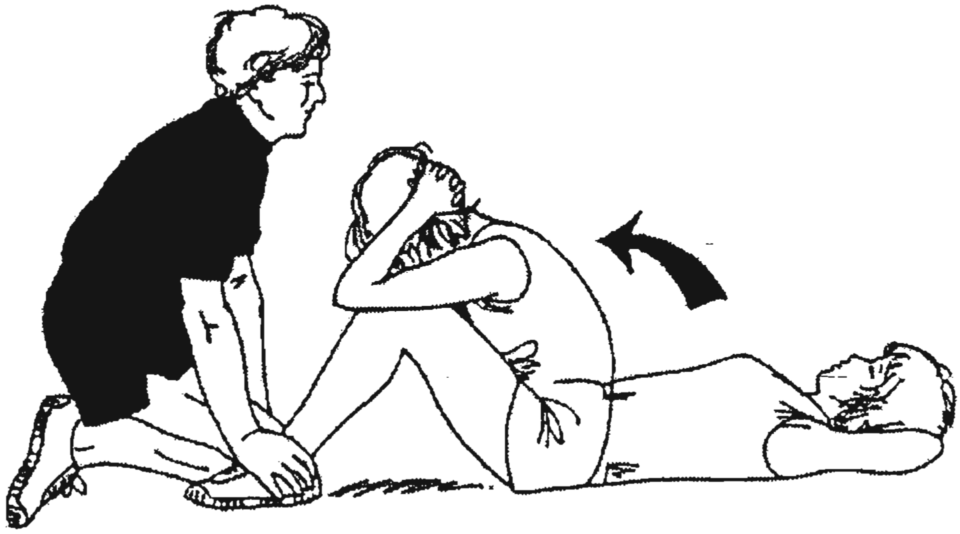


Figure 3.3 The Sit Up Sequence

3.5.4 GRIP STRENGTH (Dowell *et al.*, 1978)

- **Purpose**

To identify the isometric strength of the upper limb musculature. The hand and forearm plays a major role in the sport of surfing, making the test necessary.

- **Performance**

The subject holds the dynamometer in one hand in line with the forearm and hanging at the thigh. Maximum grip strength is then determined without swinging the arm.

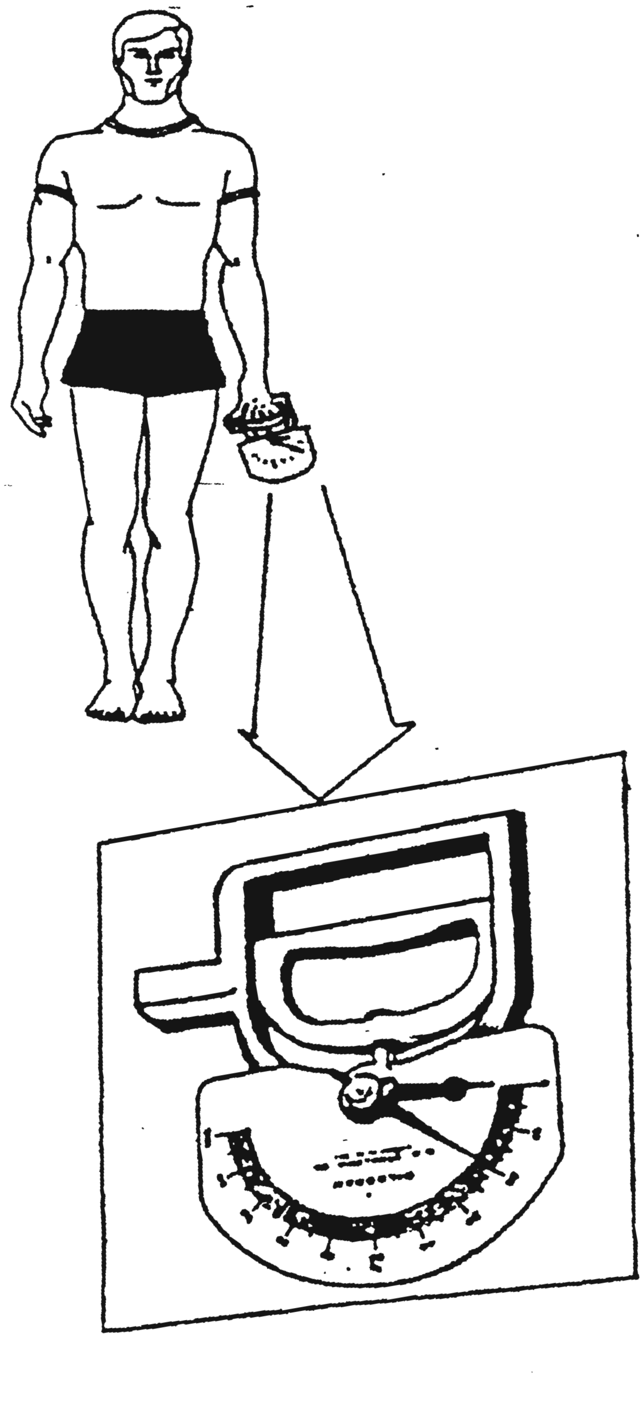


Figure 3.4 **Handgrip Strength Procedure and Dynamometer**

- **Scoring**

The best of three trials for each hand is recorded. The values are presented in Kilograms. The best score of the three attempts of each hand is recorded.

- **Equipment Required**

Takei Handgrip.

- **Validity**

The validity of this test as a measure of general strength has been questioned. However, it is an excellent test for the purpose of handgrip strength as related to surfing.

- **Advantages**

This is a simple and commonly used test of strength.

- **Interpretation**

The best result, as read on the screen of the dynamometer, is recorded in kilograms for both hands. The results of each handgrip were compared to a table of static strength norms formulated by **Coopoo *et al.* (1997)**.

3.5.5 ISOKINETIC TESTING

The reliability and validity of isokinetic measurement, like any other measurements in clinical practice and especially in research, are dependent on carefully standardised pre-test procedures. This ensures that intraindividual and interindividual test-re-test results can be compared and pooled together.

I) Pre-test Procedures:

- **Patient Information**

The examiner explained what is required from the subject and explained what isokinetic concentric, and eccentric, actions mean and how they may possibly feel during a test. The patient was advised that the dynamometer is set at a certain velocity and that the resistance will vary according to the force applied by it. The examiner also clarified the possible after-effects of isokinetic exercise, especially delayed onset muscle soreness.

- **Familiarisation**

The subject was allowed to "familiarise" with the machine, first using submaximal and then maximal force, at different speeds. Generally, before actual testing, three submaximal and three maximal repetitions have been found adequate for obtaining reliable measurements of isokinetic peak torque, work and power **(Perrin, 1986)**.

- **General Warm-up and Stretching**

The examiner included a ten to fifteen minute warm-up, so that the muscle groups being tested are flexible and warm.

- **Body Positioning and Joint Alignment**

It is important for the examiner to locate the best possible axis of rotation for each joint to allow maximum functional range of motion. This is done by palpating anatomical landmarks around the joint. Correct alignment will ensure smooth, comfortable and safe motion for the subject.

During upper body testing, the feet should be in a non weight-bearing position. Isokinetic testing procedures for the knee include the correct alignment of the biological and mechanical axes.

The knee has two major articulations, the tibiofemoral, and the patellofemoral, with only tibiofemoral alignment to be discussed. Since the femur is securely strapped, a convenient alignment axis extends through the lateral femoral epicondyle.

Further procedures include positioning and stabilisation, position of the resistance pad and test angular velocities. Stabilisation in the seated position is normally accomplished using femoral and pelvic strapping (**Magnusson *et al.*, 1992**).

- **Stabilisation**

The examiner must ensure that the muscle group to be tested is well isolated, and that the contribution from accessory muscles will be minimal. Stabilisation occurs both at the waist and chest, along with the joint being tested.

- **Gravity Correction**

Gravity correction is applied when assessing the limb through a gravity dependent position, such as knee flexion and extension. Acceleration of the limb due to gravity will artificially inflate subsequent torque output and vice versa.

- **Selection of the Test Protocol**

The examiner must consider factors such as the mode, velocity, and duration of contractions. Range of motion through which the muscle work is to be performed and the length-tension relationship of the muscle group being tested is to be determined by the tester.

- **Velocity and Duration**

Exercise at slow speeds through a given range of movement will take longer time to complete than exercises at faster speeds. As a general guideline, repetitions are determined in relation to the test speed employed. For these tests, the speed used was sixty degrees per second (60^0 / sec.), where three to five repetitions were required to be completed. The speed was chosen so that in future use, the same speed can be used as a comparison of results.

- **Number of Test Repetitions**

Peak Torque requires between two to six contractions at a given velocity. Endurance requires twenty-five contractions at the given velocity.

<u>II) Special Considerations</u>

- **Verbal Encouragement**

The examiner and assistants must ensure that verbal encouragement is given to the subject throughout the test. Verbal encouragement has shown to affect test results, and thus must be standardised both in research and in test-re-test situations.

3.5.6 ISOKINETIC TESTING OF THE KNEE

- **EXTENSION AND FLEXION**
- **Performance**

The surfers had both limbs tested in no particular order. The subjects were seated on the isokinetic dynamometer and the seat was adjusted so that an alignment axis would extend through the lateral femoral condyle. The angle of recline was set at eighty degrees, which is the optimal position for testing both the extensors and flexors. The surfers were strapped across the extended femur and just above the tibial malleolus ensuring that they were comfortable.

The resistance pads were placed at a level immediately superior to the medial malleolus. The test was explained to the subjects, including the reason for the test, which would help in motivating the surfers. The surfers were warmed up by doing ten repetitions at ninety degrees per second (90^0/sec.).

This warm-up also enabled them to become accustomed to the push-pull feel of concentric contractions. To give the surfers the opportunity to get accustomed to the test speed, they were asked to complete two repetitions at 60^0/sec.

It was explained that during the test, it was necessary that they look at the digital output meter and were encouraged to try to improve on the height of the lights every repetition.

A range block was set, with the start of the block with the leg fully extended. "Position Reset" was then activated and the ending position was set with the leg flexed at ninety degrees. The sound switch was activated.

The subjects were instructed to grasp the seat with both hands and were warned before the test was to begin, that maximum effort was required throughout the ten seconds, and that they should end each extension and flexion at the sound of a "Beep", from the range block. During the test, the instructors verbally encouraged the surfers.

- **Scoring**

Flexion and extension torque scores were expressed as Newton meters (Nm), as computed by the Akron Isokinetic Dynamometer software. The parameter of torque to body weight ration was expresses in Newton meters per kilogram (Nm/Kg). The angle of occurrence was expressed in degrees. The ratios between the quadriceps and hamstrings were expressed as a percentage.

3.5.7 ISOKINETIC TESTING OF THE SHOULDER

- **EXTENSION AND FLEXION**

Due to the risk of injury to the complex shoulder mechanisms, the safety and comfort of the patient must be the prime consideration **(Dvir, 1995)**. A warm-up is essential especially when maximal isokinetic testing is undertaken. The warm-up was set up at a low resistance where the subject had to complete ten repetitions at a speed of 120 degrees per second.

- **Performance**

The examination was carried out with the subject in the supine position. Stabilisation of the body was imperative, to minimise the assistance of other larger muscle groups. Studies indicate the most appropriate method of stabilisation in the supine position was applying two straps, at the midthoracic and pelvic levels.

The alignment and biological axes involved in extension and flexion was to position the axis of the isokinetic dynamometer against a point which is roughly two to three centimetres below the inferior lip of the acriomial arch. The elbow of the subject had to remain straight through the length of the test, which was fifteen seconds in duration.

The lever length of the hand piece was adjusted and recorded, so that the elbow was straight and that it was comfortable for the subject. It was explained that during the test, it was necessary for the surfers to look at the digital output meter lights they were verbally encouraged to try to improve on the height of the lights every repetition.

A range block was set, at the start of the block with the arm fully extended. "Position Rest" was then activated and an ending position was set with the arm fully flexed as close as comfortable to 180 degrees. The sound switch was then activated.

The subjects were instructed to grasp the sides of the plinth and were warned when the test was to begin, and that maximum effort was required throughout the fifteen seconds. The subjects were advised that each extension and flexion should end off with a "beep", which came from the activated range block.

All results were verbally explained to the surfers, indicating how well they had performed in the tests. A resistance training program was given to those surfers who requested one, including those with greater than fifteen percent reciprocal leg deficits. They were allowed to take the printout of the Isokinetic test results home. This was done so that the subject would be able to compare results after injury.

- **Scoring**

The variables of flexion and extension torque were expressed in Newton meters (Nm). The angle of occurrence was expressed in degrees. The variable of torque produced per kilogram was expressed ad Newton meter per kilogram (Nm/Kg). The extensor and flexor muscle groups ratios were expressed as a percentage.

3.5.8 ISOKINETIC TESTING OF THE SHOULDER

- **EXTERNAL AND INTERNAL ROTATION**

The same precautions were taken as stated in the flexion and extension testing procedure of the shoulder joint.

- **Performance**

The subjects had both limbs tested in no particular order, lying in the supine position. The subjects were aligned so that the upper arm was abducted to ninety degrees and the olcreoneon was placed into the cup with the forearm at ninety degrees to the olcreoneon.

This enabled the axis alignment of the isokinetic dynamometer to be in a straight line from the radio-humeral joint through to the gleno-humeral joint. The subjects were strapped in the same fashion as stated above, so that there was no assistance from larger muscles.

The lever length of the hand piece was adjusted and recorded so that the lever sat perfectly in the palm of the subject. The subjects were warmed up by completing ten repetitions at ninety degrees per second, allowing them to get accustomed to the awkward position of the testing procedure. The subjects were asked if they felt any pain, so that modifications to the testing protocol could be made.

To give the subjects the opportunity to get accustomed to the test speed, two repetitions at sixty degrees per second were allowed. It was explained that during the test, it was necessary that the subjects looked at the digital output meter lights and were encouraged to try to improve on the height of the lights with every repetition made.

A range block was set, with the arm internally rotated. "Position Reset" was activated and ending position was set with the arm being externally rotated. The arm was externally rotated as far as possible, by asking if the positioning was comfortable to the subject as excessive external rotation at low speeds can lead to serious injury. The sound switch was activated.

The subjects were instructed to grasp the side of the plinth and were warned that the test was going to commence, and that maximum effort was required for the fifteen-second test duration. It was explained to the subjects that one full repetition should end off with a "Beep" from the range block.

During the test, the examiner verbally encouraged the subjects to give maximal effort. All results were explained to the subjects. A resistance-training program was given to those surfers who requested it, including those with a muscle deficit greater than fifteen percent.

- **Scoring**

Torque scores of the internal and external rotators were expressed as Newton meters (Nm). The angle of occurrence at which the torque scores were obtained was expressed in degrees. The torque produced per kilogram was expressed as Newton meter per kilogram (Nm.Kg). The ratios between the internal and external rotator cuff muscles were expressed as a percentage.

3.5.9 SKINFOLD MEASUREMENTS

- **Purpose**

Skinfold measurements were taken from three sites on the body to determine the percent fat of each surfer who participated in the examination. This enabled norms to be established for this particular population.

- **Apparatus**

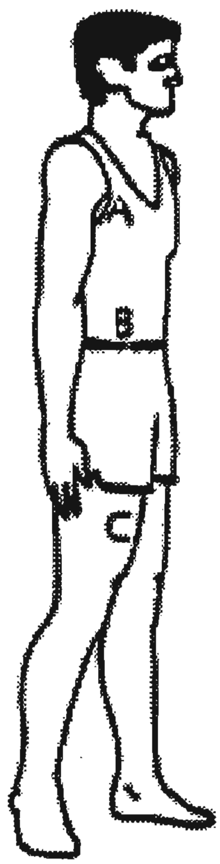
Skinfold measurements, using a **Lange Skinfold Calliper,** were taken. A **Medical Scale** was required to determine the exact weight of each surfer. Each subject was weighed on a medical balanced scale while wearing shorts only and the weight was recorded to the nearest kilogram.

The scale was calibrated after each subject had been weighed. Scores were transformed to measures of percent fat as determined by the **Jackson and Pollock (1978)** table of percent body fat.

- **Performance**

Skinfold measurements were taken from three sites on the body, in the regions of the chest, abdomen, and the thigh. The skinfolds and measurements were recorded in millimetres. All the measuring of the subjects were conducted by the same tester to allow for accuracy and validity. All measurements were made to the nearest 0.001 mm.

1



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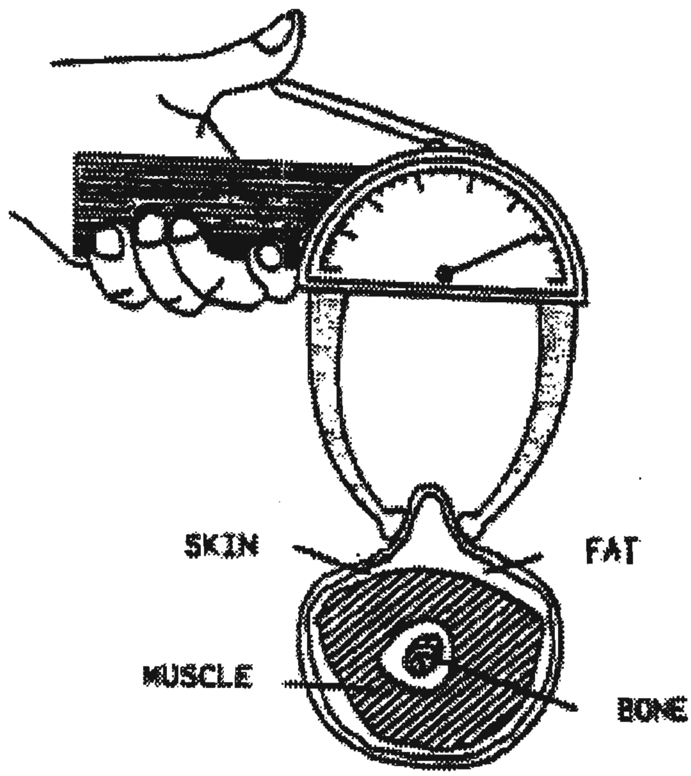


Figure 3.5.1 Skinfold Sites

Figure 3.5.2 Lifting of a Skinfold

The following sites were measured:

A) <u>Pectoral Skinfold</u>

- **Posture**

The subjects stood in an upright position, with the arms by the sides.

- **Technique**

The pectoral skinfold was picked up on the anterior axillary fold as high as possible above, and to the right of the nipple (one-half the distance from the midline side of the nipple). The measurement at this site was taken diagonally because of the natural figure of the skin.

B) <u>Abdominal Skinfold</u>

- **Posture**

The subject relaxed the abdominal wall musculature, and breathed normally. The subjects stood up straight with the body weight evenly distributed on both feet.

- **Technique**

The abdominal skinfold was pinched approximately three centimetres to the right and one centimetre inferior of the umbilicus. A vertical measurement was recorded at the site.

C) Thigh Skinfold

- **Posture**

The subject flexed the hip to assist in the location of the inguinal crease The body weight of the subject was shifted to the free foot while the measured limb is slightly flexed at an angle of five degrees. The lower half of the leg should be perpendicular to the ground.

- **Technique**

The thigh skinfold was located in midline of the anterior aspect of the thigh, midway between the inguinal crease and the proximal border of the patella. The proximal reference point was on the inguinal crease at the mid pint of the long axis of the thigh. The distal reference point (proximal border of the patella) is located while the knee of the subject is extended.

- **Interpretation**

The three site readings were summed and the sum was used along with the surfer's age to establish the body fat percentage. Percentage readings were taken from the **Pollock, Schmidt, and Jackson**, table of generalised equations. The scores will be classified as **EXCELLENT, GOOD, AVERAGE, FAIR** and **POOR**.

- **Comments**

Records must be kept whether the subject is left or right handed, as this may help in the interpretation of the results.

3.5.10 FLEXIBILITY (Hoeger and Hopkins, 1992)

- **Purpose**

Hoeger and Hopkins, (1992) modified sit-and-reach test was designed to measure hip and trunk flexion and the ability to stretch the back hamstrings of the leg.

- **Apparatus**

One modified **Hoeger and Hopkins** sit-and-reach flexibility board, which in centimetres measured the length of the subject's flexibility. The dimensions of the flexibility box were thirty centimetres in width, thirty centimetres in depth and thirty centimetres in length. Mounted on the box was a ninety centimetre ruler.

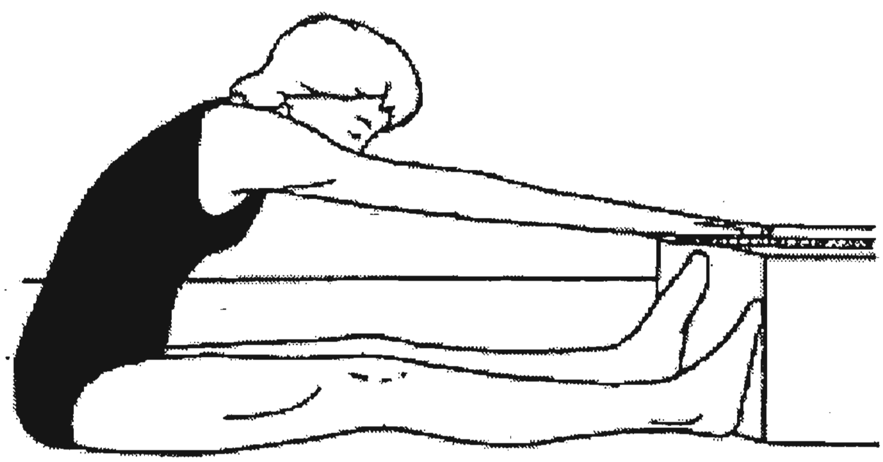


Figure 3.6 The Sit and Reach Sequence

- **Performance**

The subject assumes a sitting position on the floor, with the legs fully extended and with feet flat against the footprints outlined on the crossboard. The height of the crossboard should be adjusted so that the subject's feet do not overlap the drawn footprints.

The subject must be measured from the zero starting position on the ruler. The subject slowly reaches forward with both hands, palms facing downwards and both hands even, one on top of the other, along the ruler.

Once the subject has reached forward maximally, the position must be held momentarily. The assistants must make sure that the subject does not lead with the one hand or bend at the knees.

- **Interpretation**

The maximum distance reached is recorded as the measure of flexibility. If the hands reach unevenly, the hand reaching the shorter distance determines the score. The score is taken to the nearest centimetre. The score will be compared to the flexibility rating scale norms devised by **Poseman and Coopoo (1997)**.

3.5.11 <u>T-DRILL AGILITY TEST</u>

- **Purpose**

The T-Drill test measures the capability of a surfer to shift direction swiftly and skilfully.

- **Apparatus**

Four red beacons were required to mark each point of the letter "T". A Cardiosport Stopwatch was required for time keeping and a basketball court.

- **Setting up the Test**

The letter "T" was outlined on the gymnasium floor of the Sport Science department. The horizontal side was ten meters in length and beacons were placed at each end, one was positioned in the centre (midpoint). The vertical line was ten meters long and a beacon was placed from the start of the line to meet with the centre beacon.

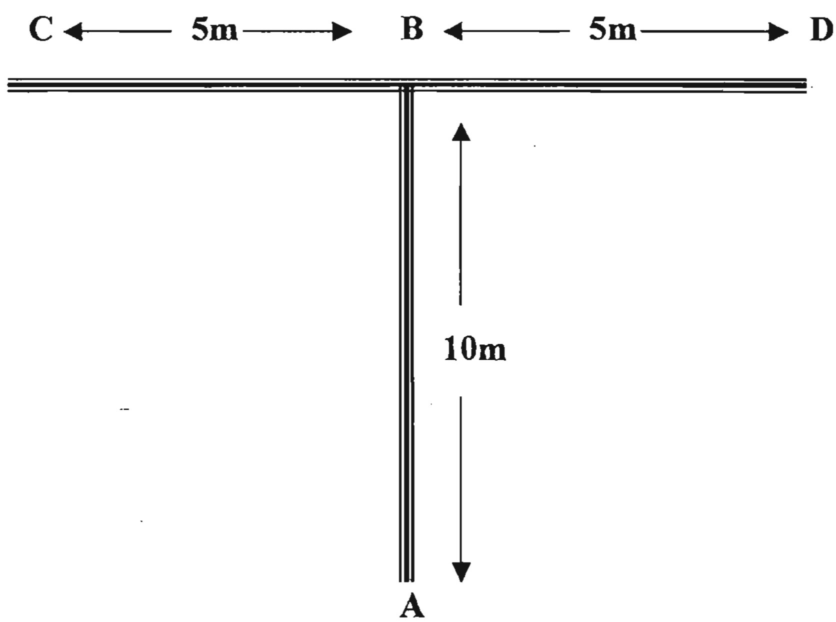


Figure 3.7 The T-Drill Agility Sequence

- **Performance**

The aim of the test was for the surfers to run as fast as possible from "A" to "B" (centre beacon), where they touched it. From here, the surfers progressed to run laterally to the right beacon, "C" and then to the left beacon "D".

Once they had touched the right beacon "C", they advanced across the centre beacon ("B") to touch the opposite beacon ("D"). From here the surfers ran back to the centre beacon ("B") and then ran backwards towards the starting position ("A"). The best time taken to complete the test was recorded.

- **Interpretation**

The time was recorded from the time when the subject left the first beacon until the exercise was completed. The times determined the level of agility, which was compared to the standard scores available.

3.5.12 BLIND STORK BALANCE (Arnot and Gaines, 1984)

- **Purpose**

To measure the static balance of the surfers. This is a "super-balance" test.

- **Apparatus**

A Cardiosport Stopwatch was needed for the test. When taking the test, the surfers were told to wear shoes, as the results would not be as accurate if the test was performed barefooted.

Figure 3.8 An Illustration of the Blind Stork Balance

- **Performance**

The surfers were instructed to stand on their dominant foot. This is the foot that is placed at the tail of the surfboard to help with manoeuvring. The free foot was fixed on the knee of the weighted leg. The hands were placed on the hips and the eyes must be closed. Once this position had been assumed, the stopwatch was activated.

The stopwatch was stopped as soon as the surfer took his hands off the hips, his foot came off the knee or if the weighted foot was moved from the primary position.

- **Interpretation**

The results were compared to a table devised by the United States Ski Federation, where the highest score represented the best skill ability. The scores were graded as; **EXCELLENT, GOOD, AVERAGE, FAIR, POOR** .

3.5.13 BALANCE STABILISATION (Arnot and Gaines, 1984)

- **Purpose**

This test, measures dynamic balance or the ability to constantly restabilise the body on a shifting platform.

- **Apparatus**

A Cardiosport Stopwatch was used in the execution of this test. The test had to take place on a smooth and slick surface. Socks had to be worn by the subjects.

- **Performance**

The same body position as in the **Blind Stork Balance** was imitated with the hands on hips, standing on the dominant leg, with the unweighted foot resting on the knee of the weighted leg.

The eyes, in this trial, had to remain open throughout the duration of the test. Once the stopwatch was activated, the position had to be maintained for at least five seconds.

Figure 3.9 An Illustration of the Balance Stabilisation

Then on the command, **"Turn"**, the subject had to turn 180 degrees to the right on the ball of the foot. After another five seconds, again on the command to turn, the surfer had to turn back to the starting position, another 180 degree turn. The surfer had to continue turning every five seconds until the weighted foot came off the knee or the hands came off the hips. The longer the time, the better the result.

- **Interpretation**

The results of the scores were compared to a table by **Arnot and Gaines (1984)**, devised by **Sportlab**, to determine how well the subjects grouped in terms of **EXCELLENT, VERY GOOD, GOOD, AVERAGE, FAIR, POOR** and **VERY POOR**.

3.5.14 HEXAGON OBSTACLE (Dillman, 1980)

- **Purpose**

Designed by the Austrians and modified by **Dillman (1980)**, this is the best single test there is for measuring agility, balance, motor learning and co-ordination required for surfing and skiing.

- **Apparatus**

What is necessary is a hard, flat surface and a minimum of twenty-five square feet of cleared area, roll of two-inch masking tape, and a Cardiosport Stopwatch.

- **Setting up the test**

A sixty-five centimetre per side hexagon was constructed on a smooth, flat surface. The edges were covered with masking tape so that the outside edge of the tape delineates the outside of the hexagon. At each side of the hexagon, the letters **"A"** through **"F"** are marked.

- **Performance**

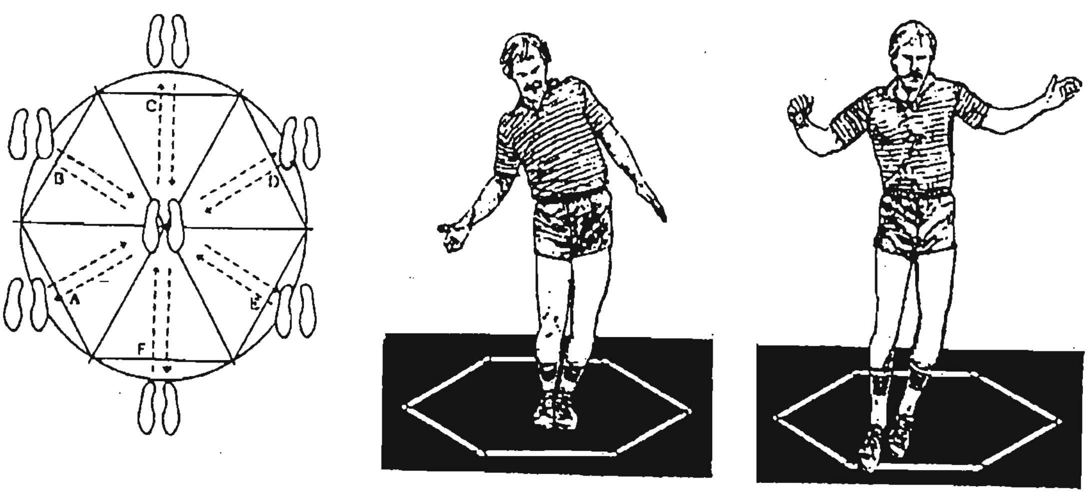
When performing the test, the surfer stands in the centre of the hexagon and faces side **"F"**, for the duration of the test. The assistant with the stopwatch, starts the test, by shouting the command **"GO"**.

The surfer begins by jumping with both feet over side **"A"** and immediately back into the centre of the hexagon. Then continuing to face side **"F"**, the surfer jumps over side **"B"** and back into the centre of the hexagon, side **"C"** and back in and so on, until one complete revolution has been made. After the surfers have completed one full revolution, the stopwatch is stopped.

The surfers are then instructed to complete three revolutions as fast as possible: these three revolutions are not timed. However, the surfers are told to complete one more revolution, a fifth revolution, and this revolution is timed in the same manner as the first test.

- **Interpretation**

The best time taken for the first performance determines the overall score for the abilities. The time recorded for the fifth trial, is the score that determines the overall motor learning ability of the surfers. The difference between the first and fifth trial is then determined and classified as; **EXCELLENT**, **GOOD**, **AVERAGE**, **FAIR** and **POOR**. Comparisons of the results were made against the Alpine Skiing test results.



<u>Figure 3.10</u> The execution of the Hexagon Obstacle Sequence

3.5.15 PULMONARY FUNCTION TESTS

- **Purpose**

The purpose of this test is to measure the lung capacity of each subject. The test measures and calculates the inspiration and expiration values of the subject.

- **Apparatus**

A **MICROSPIRO HI 298** spirometer, noseclips, disposable mouthpieces, and a role of printer paper.

- **Procedure**

It is important to make sure that the equipment has been calibrated before each subject is tested. Once calibrated, the patient data must be completed, before beginning a recording. Patient specifications included: date of birth, age, weight, height, gender and race.

The reason for such specific details is that the Caucasian race, classified as whites, have larger lungs than non-Caucasian individuals, who have smaller lungs. Once the patient information was completed, the selection and explanation of the test took place.

- **Performance**

The test was explained to the patient before the actual measurement took place. The subject was told that the flow sensor must be held very still and that no air should be breathed into the device until instructed. When the examiner was ready to take the measurement, the subject was told to inhale maximally, put the mouthpiece into the mouth, and cover the nose with the noseclips.

The subject was then urged to maximally expire all air from the lungs, as hard, fast and as long as possible, so that all air is removed from the lungs. The test must be repeated at least three times, so that the best trail can be selected.

- **Interpretation**

The results were presented on the machine as either normal, restrictive or obstructive, depending on the subject's lung capacity. The following tests were measured: **Forced Vital Capacity (FVC)**: which is an expiration volume achieved by the quickest possible exhalation after a maximal inhalation. **Forced Expiratory Volume (FEV_1)**: which is the lung volume in litres, measure after half, one or three seconds of forced expiration.

3.5.16 MAXIMAL OXYGEN CONSUMPTION TEST (VO_2 MAX)

- **Description**

Exercise is performed on a treadmill ergometer where the exercise workloads are selected to gradually progress in increments from a moderate to maximal intensity. Oxygen uptake is calculated from measures of oxygen and carbon dioxide from the expired air and minute ventilation, and the maximal level is determined at or near test completion.

- **Apparatus**

One oxygen and carbon dioxide gas analysers, a treadmill ergometer on which workloads may be modified, and in the case of this study a Woodway Motor-Driven Treadmill; a Cardiosport stopwatch, telemetry transmitter (Hewlett Packard system) and receiver, air volume analyser (spirometer). The **OXYCONSIGMA** incorporates the gas analysing unit, computer, printer, and all required options.

Integrated in the analyser compartment are the fast response differential paramagnetic Oxygen analyser, the fast infrared Carbon Dioxide analyser, and a built in fully automatic calibration system for the analysers, the built in digital volume sensor and all associated pneumatics. Breathing apparatus (bi-directional TripleV transducer), noseclips, spiral tubing, calibration gasses and surgical tape.

A mixing chamber, which, allows breath after breath or averaged data updates. The bi-directional TripleV transducer can be used instead of the mixing chamber to measure volume and gas content directly at the mouth. The digital volume sensor is insensitive to water vapour and gas composition and has an accuracy better than two percent.

- **Pattern of Testing**

Subjects were tested two to three hours after a light meal, dressed in light running shorts and running shoes. Height and weight measurements were previously recorded. A short lecture concerning the objectives and design of the experiment was given by the researcher concerned.

The subject was then set up for the test. This involved placing a Cardiosport heart rate monitor to the chest and placing a mouthpiece attached to the bi-directional TripleV transducer in the mouth. A noseclip was then positioned to divert all inspired and expired air through the mouthpiece. After the subject was accustomed to the breathing apparatus, the experiment began.

- **Performance**

Because of the high level of specialisation required for this examination, the test had to take place under the close supervision of a qualified professional exercise specialist. Before the test began, the resting heart rate was monitored for 30 seconds. Once the pre-exercise heart rate had been recorded, each subject was allowed to warm-up for five minutes to become accustomed to the workings of the treadmill.

Subjects were initially habituated on the treadmill by way of walking, jogging, and running at various speeds and inclines. The subject was familiarised with two hand signals; namely a "thumbs up" to indicate everything was going well, and a "thumbs down" to indicate withdrawal from the test. A "flat hand" indicated strain but could continue for a while longer.

The subjects were required to commence the test by walking at a speed of five $km.hr^{-1}$ for one minute at zero gradient, or longer until such time a steady rate had been achieved. After the initial minute, the speed was increase to six $km.hr^{-1}$ and this speed was maintained for a further minute.

There after the speed was increased by two $km.hr^{-1}$ every two minutes. Once a running speed of twelve $km.hr^{-1}$ had been reached, the gradient was increased to one degree and a further one degree every thirty seconds until voluntary exhaustion.

The maximum heart rate was the highest recorded from the telemetry strap throughout the duration of the test. Subjects were continually monitored and asked periodically how they felt.

The subjects responded with some simple hand signals to indicate their perception of effort. During the latter stages of the test, the subjects were verbally encouraged to do their best, to ensure a maximal or near-maximal effort.

- **Interpretation**

Results were presented as either litres per minute or millilitres per kilogram minute. The athletes were considered to have reached their peak VO_2 max if several of the following conditions occurred: a plateau or "peaking over" in oxygen uptake; maximal heart rate was reached; attainment of respiratory exchange ratio of 1.15 or greater and volitional exhaustion.

- **Advantages**

Actual measurements of body oxygen consumption and measurement of maximum heart rate by recording heart rate during the test were attained.

- **Comments**

There is often variability between the performance of different analysis systems. Stringent calibration is necessary for both the expired gas and ventilation measurement systems.

3.5.17 WINGATE ANAEROBIC TEST (Bar-Or, 1987)

- **Purpose**

The Wingate Anaerobic test was developed to estimate the potential of both the ATP-PC and the lactate systems.

- **Apparatus**

One Monarch bicycle ergometer, stopwatch, recording sheets, and assistants to monitor the tests.

- **Performance**

The subjects were first weighed as described above. The optimal resistance was determined for each individual using the following formulae and was measured in accordance with the norm chart.

Force (N) = Body Mass (Kg) x 0.75 N/Kg

Each subject was informed that the test was an "all out" examination and was required to pedal as fast as possible for a time period of thirty seconds, when instructed to **"GO"** by the examiner and only **"STOP"** when instructed to do so.

The seat height was adjusted for each subject so the leg was approximately fifteen degrees flexed when the pedal is at its lowest point.

There were four distinct phases in the test:

I) <u>Warm Up Stage</u>

The subject was instructed to cycle for four to five minutes at approximately fifty repetitions per minute (RPM) at a low resistance (10N). At the conclusion of each minute in the warm up, the subjects was instructed to sprint "all out" for five seconds in order to obtain a feel for the test.

II) Acceleration Stage

After the five minute warm up, the subject rested for a minute. The test was explained once more to the subject and any final adjustments were made. Then the subjects were given five seconds to increase to the speed to maximum.

III) The Test Stage

The test stage was of thirty seconds duration and was divided into six time intervals of five seconds each where the pedal revolutions were counted for each time period. The subject cycled "all out" for thirty seconds.

IV) The Cool Down Stage

This commenced after the completion of the thirty seconds Wingate test. The stage lasted for one minute at a low resistance.

- **Controls**

Assistants were very important in the testing procedure. They ensured that results were correctly gathered and recorded. Three assistants were required for the tests and each had a specific task to complete.

Assistant one was required to undertake the timing, firstly the one minute warm up, the five-second acceleration period, the thirty second Wingate test and finally the one minute cool down period. The timer verbally informed the subject about each stage.

The first timer was also required to count out the time every five seconds during the thirty-second Wingate test. The first command was:

"GO!", then **"5"**, **"10"**, **"15"**, **"20"**, **"25"**, **"30"**, then **"STOP!"**

The second assistant was required to count the number of pedal revolutions, every five seconds on the thirty-second Wingate test. The tester was placed at ninety degrees on to the vertical phase on the pedal cycle and counted each time the pedal passed the uppermost point of the vertical plane, which was one revolution.

The third assistant was the scribe and was required to record the number of pedal revolutions that were called out by second assistant. The pedal revolutions are recorded at 5, 10, 15, 20, 25, and 30 second time intervals during the Wingate test.

It was important to motivate the subjects during the test to get the highest possible Peak Power and Mean Power. The wording used by the examiner in introducing the task was therefore important. One could explain that it is a hard task, but a very short one.

It was also recommended that verbal encouragement be provided throughout the test, including information regarding the time left for completion. It should also be emphasised that it is important to pedal as fast as possible from the start of the test, rather than to preserve energy for the last part of the test.

- **Calculations**

Some of the measures that can be gained from the test were mean and peak anaerobic power and a fatigue index determined from the decline in power. The results were recorded in Watts.

I) Peak Anaerobic Power (Want High)

$$\textbf{Want High (W)} = \frac{\textbf{Force (N) x (Highest pedal rev. in 5 seconds) x 6}}{\textbf{5}}$$

Where: Leg Force = body mass x 0.75.

The highest pedal revolutions in any one 5 second interval

x 6 as there were six time intervals.

÷ 5 as the time intervals were of five seconds.

II) Minimum Anaerobic Power (Want Low)

$$\textbf{Want Low (W)} = \frac{\textbf{Force (N) x (Lowest pedal rev. in 5 seconds) x 6}}{\textbf{5}}$$

Where: Leg Force = body mass x 0.75.

The lowest pedal revolutions in any one 5 second interval during the test.

x 6 as there were six time intervals.

÷ 5 as the time intervals were of five seconds.

III) Average Anaerobic Capacity (AAC)

$$\text{AAC (W)} = \frac{\text{Force (N) x (Total pedal rev. in 30 seconds) x 6}}{30}$$

Where: Leg Force = body mass x 0.75.

The total pedal revolutions that were completed in the 30 second test.

x 6 as there were six time intervals.

÷ 30 as the total pedal revolutions were taken over the total 30 seconds.

IV) Fatigue Index (FI)

$$\text{FI (\%)} = \frac{\text{Want High (W) - Want Low (W)}}{\text{Want High (W)}} \times 100$$

V) Power per Kilogram Body Mass ($W.Kg.BM^{-1}$)

$$W.Kg.bm^{-1} = \frac{\text{Want High (W)}}{\text{Body Mass}}$$

VI) Power per Kilogram Lean Body Mass ($W.Kg.LBM^{-1}$)

$$W.Kg.Lbm^{-1} = \frac{\text{Want High (W)}}{\text{Lean Body Weight}}$$

3.5.18 BORG'S RATINGS OF PERCEIVED EXERTION (1985)

- **Purpose**

Borg's original intention was to construct a category scale from 6 to 20 where scale levels were roughly one tenth of the heart rate for exercise levels. A score of 6 ("no exertion at all") should exhibit a heart rate somewhere near sixty beats per minute, for a young to middle-aged mildly fit individual. This correspondence is generally reserved for middle-aged individuals exercising at moderate to high intensity levels.

It is, at best, a very rough estimation of the relationship. Large individual differences exist. Furthermore, heart rate correspondences within an individual vary between different forms of activity. RPE is best reserved for intraindividual comparisons for a specific form of exercise.

- **Instructions For Use**

During the exercise, the subject is required to appraise the perception of the exercise. The scale, where "6" means no exertion at all and "20" means a totally maximum effort, must be used. The "13" on the scale is a somewhat heavy exercise but capable of being performed at a steady state (usually indicative of anaerobic threshold).

At a level of "17", the effort level requires the individual to push even harder, although it may be possible to continue for some time. For many individuals, "19" is about as strenuous as the exercise can become, because subjects often reserve a small amount of possible extra effort.

Table 3.2 Borg's Perceived Exertion Scale

Perceived Exertion Scale (Borg, 1985)	
6	
7	Very, Very Light
8	
9	Very Light
10	
11	Fairly Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Very, Very Hard
20	

- **Controls**

The subject must try to appraise the feeling of exertion as honestly as possible. He must try not to underestimate nor overestimate the level of exertion. However, the limitation of this test is that it is totally subjective in nature.

3.6 ANALYSIS OF DATA

Descriptive and in Percentile statistical methods were employed in the analysis of data. The raw data was captured on a spreadsheet designed by Lotus 123 release 5.

Means, standard deviations, T-Test of significance and standard score tables were used to analyse and compare data. The analysis of data was completed on the Lotus statistical package. Graphs and tables were implemented to develop and interpret the data.

The answers were then substituted into the standard score equation:

$$\textbf{Standard Score} = \frac{6SD}{20}$$

where division by twenty resulted in units of five being used for percentile rankings. A standard score table was then established.

At the fiftieth percentile, the mean score was written, underlined and highlighted, and the standard scores were completed above and below the mean so that every score was written alongside its respective percentile.

CHAPTER FOUR

4.1 PRESENTATION OF RESULTS

This chapter provides comments and a description of the results gathered in this study. In this section, presentation of tables and graphs will portray the results obtained from the testing procedures, which includes the subjects' demographic characteristics, and fitness statistics. As the study is designed to identify profiles or normative data, many of the tables will consist of standard scores. The presentation of the scores within the brackets after the mean value in the test represents the standard deviations of the scores.

Table 4.1 Descriptive Demographic Statistics for 61 Elite Surfers.

Characteristics	Mean	Standard Deviation
Age (yr.)	24	± 6.60
Height (cm.)	177.1	± 6.33
Weight (Kg.)	69.9	± 7.34
Surfing Experience (yr.)	12.4	± 6.46
Surf Training (days/week)	4.9	± 1.72
Surf Training (hours/day)	3	± 1.22

The means, standard deviations, minimum, and maximum results for each of the evaluations will be presented. From these results, standard scores and norms were determined.

<u>Table 4.2</u> Means, Standard Deviations, and Ranges for Muscle Endurance and Strength Components.

	One Minute Push Up *(No.)*	One Minute Sit Up *(No.)*	Combined Grip Strength *(Kg.)*
Mean	**48**	**43**	**103**
Standard Deviation	**± 9.69**	**± 10.66**	**± 13.69**
Minimum	**25**	**28**	**72**
Maximum	**67**	**79**	**136**

Johnson and Nelson, (1979) suggested that the average number of push-ups to be completed should range from twenty-seven to forty-two per minute. The mean push-up result of forty-eight (±SD=9.69) in this study is excellent and the minimum value obtained was twenty-five and the maximum values was sixty-seven.

The number of sit-ups in one minute, achieved by the surfers in this research, amounted to forty-three per minute. The minimum obtained value recorded was twenty-eight and the maximum value recorded was seventy-nine. Other authors, **(Gillam *et al*, 1987 and Lowdon *et al*, 1980)**, went on to express that surfers' fitness levels are maintained purely from the activity of surfing, have recorded similar results.

Handgrip dynamometers used for static strength operate on the principle of compression. When an external force is applied to the dynamometer, a steel spring is compressed and moves a pointer (See **Table 4.2**).

Knowing how much force is required to move the pointer a particular distance, one can determine how much external "static" force has been applied to the dynamometer.

In this study, the mean combined grip strength score was 103 kilograms ($\pm$SD=13.69). The mean scores for the left and right hands were 50.49 ($\pm$SD=6.66) and 52.90 ($\pm$SD=8.09) respectively. There was no significant difference ($P > 0.05$) between the left and right grip strength scores. There was a high positive correlation relationship recorded between the left and right hands of 0.81.

The isokinetic testing concentrated on peak flexion and extension torque for the knees, internal and external rotation of the shoulder and peak extension and flexion of the shoulder. The results of the isokinetic testing of the knee will be discussed in relation to the left and right hamstring muscle groups, left and right quadriceps, and peak flexion to extension ratios, which were compared to the internationally accepted ratio of among fifty to eighty percent **(Kannus and Jarvinen, 1990)**.

<u>Table 4.3</u> Comparisons of Peak Flexion Torque Values between the Left and Right Legs of Elite Surfers.

	Right Leg			Left Leg		
	Peak Flexion Torque *(Nm)*	Angle of Occurrence *(Degrees)*	Flexion Torque to Body Weight *(Nm/Kg)*	Peak Flexion Torque *(Nm)*	Angle of Occurrence *(Degrees)*	Flexion Torque to Body Weight *(Nm/Kg)*
Mean	**139.76**	**40.45**	**1.99**	**138.82**	**38.41**	**1.98**
Standard Deviation	**± 29.93**	**± 23.58**	**± 0.33**	**± 32.3**	**± 24.92**	**± 0.39**
Minimum	**55.29**	**1**	**0.88**	**55.29**	**1**	**0.88**
Maximum	**225.88**	**81**	**2.69**	**235.29**	**86**	**2.8**

The isokinetic tests had mean peak flexion torque values of 139.76 Nm (±SD=29.93) for the right leg at a mean angle of occurrence at 40.45 degrees (±SD=23.58) with a mean flexion torque to body weight of 1.99 Nm/Kg (±SD=0.33).

The scores for the left leg showed a mean peak flexion torque of 138.82 Nm (±SD=32.30) at a mean angle of occurrence at 38.41 degrees (±SD=24.92) with a mean flexion torque to body weight of 1.98 Nm/Kg (±SD=0.39). There was no statistical significant difference ($P > 0.05$) between peak flexion of the left and right legs.

<u>Table 4.4</u> Comparisons of Peak Extension Torque Values between the Left and Right legs of Elite Surfers.

	Right Leg			Left Leg		
	Peak Extension Torque *(Nm)*	Angle of Occurrence *(Degrees)*	Extension Torque to Body Weight *(Nm/Kg)*	Peak Extension Torque *(Nm)*	Angle of Occurrence *(Degrees)*	Extension Torque to Body Weight *(Nm/Kg)*
Mean	**210.89**	**38.47**	**3.04**	**206.73**	**36.77**	**2.96**
Standard Deviation	**± 41.68**	**± 19.43**	**± 0.51**	**± 41.49**	**± 14.90**	**± 0.47**
Minimum	**103.53**	**3.1**	**1.64**	**96.5**	**2.5**	**1.5**
Maximum	**320**	**68**	**4.45**	**296.5**	**65**	**4**

In this study isokinetic tests had mean peak extension torque values of 210.89 Nm (±SD=41.68) for the right leg at a mean angle of occurrence at 38.47 degrees (±SD=19.43) with a mean extension torque to body weight of 3.04 Nm/Kg (±SD=0.51).

The scores for the left leg showed a mean peak extension torque of 206.73 Nm (±SD=41.49) at a mean angle of occurrence at 36.77 degrees (±SD=14.90) with a mean extension torque to body weight of 2.96 Nm/Kg (±SD=0.47). There was no significant difference ($P > 0.05$) between the left and right legs. This data seems to be well within normal limits.

Table 4.5 Comparisons of Peak Flexion and Extension Torque to Body Weight Ratio between the Right and Left Legs of Elite Surfers.

	Right Leg Flexion Torque to Body Weight *(Nm/Kg)*	Left Leg Flexion Torque to Body Weight *(Nm/Kg)*	Right Leg Extension Torque to Body Weight *(Nm/Kg)*	Left Leg Extension Torque to Body Weight *(Nm/Kg)*
Mean	1.99	1.98	3.04	2.96
Standard Deviation	$\pm$ 0.33	$\pm$ 0.39	$\pm$ 0.51	$\pm$ 0.47
Minimum	0.88	0.88	1.64	1.53
Maximum	2.69	2.80	4.45	4.00

Table 4.6 Comparisons of Peak Flexion to Extension Ratio between the Right and Left Legs of Elite Surfers.

	Right Leg Peak Flexion to Extension Ratio *(%)*	Left Leg Peak Flexion to Extension Ratio *(%)*
Mean	66.69	67.45
Standard Deviation	$\pm$ 9.48	$\pm$ 10.69
Minimum	39.36	37.50
Maximum	84.21	97.26

The mean peak flexion to extension ratio was 66.69 percent ($\pm$SD=9.48) and 67.45 percent ($\pm$SD=10.69) for the right and left legs respectively. The mean peak flexion to extension ratio was 67.07 percent. There was no significant difference between the left and right legs ($P > 0.05$).

Table 4.7 Comparisons of Peak Flexion Torque Values between the Right and Left Shoulders of Elite Surfers.

	Right Shoulder			Left Shoulder		
	Peak Flexion Torque *(Nm)*	Angle of Occurrence *(Degrees)*	Flexion Torque to Body Weight *(Nm/Kg)*	Peak Flexion Torque *(Nm)*	Angle of Occurrence *(Degrees)*	Flexion Torque to Body Weight *(Nm/Kg)*
Mean	65.14	79.62	0.93	63.94	77.48	0.92
Standard Deviation	± 16.84	± 49.25	± 0.19	± 15.98	± 46.78	± 0.19
Minimum	11.76	1	0.22	11.76	0.50	0.22
Maximum	147	182	1.75	94.12	155.5	1.33

The isokinetic tests had a mean peak flexion torque value of 65.14 Nm (±SD=16.84) for the right shoulder at a mean angle of occurrence of 79.62 degrees (±SD=49.25) with a mean flexion torque to body weight of 0.93 Nm/Kg (±SD=0.19).

The scores for the left shoulder showed a mean peak flexion torque of 63.94 Nm (±SD=15.98) at a mean angle of occurrence of 77.48 degrees (±SD=46.78) with a mean flexion torque to body weight of 0.92 Nm/Kg (±SD=0.19). There was no significant difference ($P > 0.05$) between peak flexion of the left and right shoulders. These results are within the normal ranges for this population.

Table 4.8 Comparisons of Peak Extension Torque Values between the Right and Left Shoulders of Elite Surfers.

	Right Shoulder			Left Shoulder		
	Peak Extension Torque *(Nm)*	Angle of Occurrence *(Degrees)*	Extension Torque to Body Weight *(Nm/Kg)*	Peak Extension Torque *(Nm)*	Angle of Occurrence *(Degrees)*	Extension Torque to Body Weight *(Nm/Kg)*
Mean	**95.49**	**89.82**	**1.36**	**89.49**	**87.52**	**1.28**
Standard Deviation	**± 21.65**	**± 31.26**	**± 0.24**	**± 21.47**	**± 21.47**	**± 0.21**
Minimum	**35.29**	**39**	**0.67**	**30.59**	**39**	**0.58**
Maximum	**178.82**	**173**	**2.21**	**136.47**	**156**	**1.76**

The results the isokinetic tests had a mean peak extension torque value of 95.49 Nm (±SD=21.65) for the right shoulder at a mean angle of occurrence of 89.82 degrees (±SD=31.26) with a mean extension torque to body weight ratio of 1.36 Nm/Kg (±SD=0.24).

The scores for the left shoulder showed mean peak extension torque of 89.49 Nm (±SD=21.47) at a mean angle of occurrence of 87.52 degrees (±SD=21.47) with a mean extension torque to body weight ratio of 1.28 Nm/Kg (±SD=0.21). There was no significant difference ($P > 0.05$) between the mean peak extension torque of the left and right shoulders.

The results obtained for the shoulders for peak extension torque appear to compare favourably to other studies **Freedson *et al.* (1993), Ivey *et al.* (1985)** and **Shklar and Dvir, (1994)**.

<u>Table 4.9</u> Comparison of Peak Flexion to Extension Ratio between the Right and Left Shoulders of Elite Surfers.

	Right Shoulder	Left Shoulder
	Peak Flexion to Extension Ratio (%)	Peak Flexion to Extension Ratio (%)
Mean	68.95	71.25
Standard Deviation	± 14.46	± 12.86
Minimum	33.33	38.46
Maximum	113.64	105.26

This study supports **Perrin, (1993)** findings, which indicated in the mean peak flexion to extension torque for both the left and right arms. The right arm had a mean flexion to extension torque of 68.95 percent (±SD=14.46) and the left arm had a mean peak flexion to extension torque of 71.25 percent (±SD=12.86).

An average peak flexion to extension torque for the left and right arm respectively is 70.1 percent, which is below the general population norm of between seventy-five to eighty-five percent.

Table 4.10 Comparisons of Peak External Rotation Torque Values between the Right and Left Shoulders of Elite Surfers.

	Right Shoulder			Left Shoulder		
	Peak External Torque *(Nm)*	Angle of Occurrence *(Degrees)*	External Torque to Body Weight *(Nm/Kg)*	Peak External Torque *(Nm)*	Angle of Occurrence *(Degrees)*	External Torque to Body Weight *(Nm/Kg)*
Mean	**32.53**	**58.85**	**0.47**	**31.79**	**62.62**	**0.45**
Standard Deviation	**± 8.81**	**± 44.24**	**± 0.11**	**± 8.13**	**± 39.51**	**± 0.10**
Minimum	**11.76**	**2**	**0.22**	**11.76**	**7**	**0.22**
Maximum	**61.18**	**152.5**	**0.94**	**56.47**	**146**	**0.69**

The isokinetic tests indicated a mean peak external torque value of 32.53 Nm (±SD=8.81) for the right shoulder at an angle of occurrence of 58.85 degrees (±SD=44.24) with a mean external rotation torque to body weight ration of 0.47 Nm/Kg (±SD=0.11).

The scores for the left external rotator muscles indicated a mean peak external torque of 31.79 Nm (±SD=8.13) at an angle of occurrence at 62.62 degrees (±SD=39.51) with a mean external rotation torque to body weight ratio of 0.45 Nm/Kg (±SD=0.10). There was no significant difference ($P > 0.05$) between the left and right external rotator muscle groups.

Table 4.11 Comparison of Peak Internal Rotation Torque Values between the Right and Left Shoulders of Elite Surfers.

	Right Shoulder			Left Shoulder		
	Peak Internal Torque *(Nm)*	Angle of Occurrence *(Degrees)*	Internal Torque to Body Weight *(Nm/Kg)*	Peak Internal Torque *(Nm)*	Angle of Occurrence *(Degrees)*	Internal Torque to Body Weight *(Nm/Kg)*
Mean	**59.96**	**92.68**	**0.86**	**58.69**	**95.14**	**0.84**
Standard Deviation	**± 13.22**	**± 33.83**	**± 0.16**	**± 12.06**	**± 28.66**	**± 0.15**
Minimum	**35.29**	**0.6**	**15**	**30.59**	**12**	**0.5**
Maximum	**95.29**	**1.3**	**141**	**91.76**	**161**	**1.16**

The results for sixty-one surfers isokinetic tests had a mean peak internal torque value of 59.96 Nm (±SD=13.22) for the right shoulder at angle of occurrence of 92.68 degrees (±SD=33.83) with a mean internal rotation torque to body weight of 0.86 Nm/Kg (±SD=0.16).

The values for the left internal rotator muscles indicated a mean peak internal torque of 58.69 Nm (±SD=12.06) with an angle of occurrence at 95.14 degrees (±SD=28.66) with a mean internal torque to body weight of 0.84 Nm/Kg (±SD=0.15). No significant difference ($P > 0.05$) between the left and right internal rotator muscle groups was noted.

<u>Table 4.12</u> Comparison of Peak External to Internal Rotation Ratio between the Right and Left Shoulders of Elite Surfers.

	Right Shoulder	Left Shoulder
	Peak External to Internal Ratio (%)	Peak External to Internal Ratio (%)
Mean	54.88	54.39
Standard Deviation	± 12.55	± 10.97
Minimum	33.33	37.04
Maximum	90	81.63

Peak external to internal rotation torque scores for the right shoulder showed a mean value of 54.88 percent (±SD=12.55). The result for the left shoulder peak external to internal rotation torque indicated a score of 54.39 percent (±SD=10.97).

No significant difference ($P > 0.05$) between the left and right shoulder rotator muscle groups was recorded. This may indicate the bi-lateral usage of the arms in the movement of surfing.

<u>Table 4.13</u> Mean Percent Body Fat, Flexibility and Agility results.

	Percent Body Fat (%)	Flexibility (cm.)	T-Drill (sec.)
Mean	8.20	40.80	12.62
Standard Deviation	± 4.5	± 7.59	± 1.2
Minimum	1.9	28	10.8
Maximum	22	60	15.8

Skinfold measurements were not ranked as percentiles, but rather grouped into categories. The average percent body fat in this research was 8.2 percent (±SD=4.5) and it would appear that this group was the leanest sample of surfers tested, internationally **(Lowdon et al., 1989)**.

The standard score for the T-Drill agility test in this investigation was 12.6 (±SD=1.2) seconds. The fastest and slowest time recorded by the subjects was 10.8 and 15.8 seconds respectively.

<u>Table 4.14</u> Mean Balance and Motor Co-Ordination results.

	Balance		Motor Co-Ordination		
	Static Balance (sec.)	Dynamic Balance (sec.)	Hexagon First Try (sec.)	Hexagon Fifth Try (sec.)	Hexagon Improvement (sec.)
Mean	24.40	39.80	6.29	5.27	1.02
Standard Deviation	± 12.21	± 13.08	± 0.89	± 0.67	± 0.59
Minimum	10	20	4.7	3.9	0.1
Maximum	65	68	8.5	6.8	2.7

The maximum and minimum static balance obtained in the study by the surfers was 65 and 10 seconds respectively. The mean static balance result, recorded by the surfers was twenty-four seconds (±SD=12.21).

The minimum and maximum dynamic balance scores were twenty and sixty-eight seconds respectively. The mean score for dynamic balance, in this study was thirty-nine seconds (±SD=13.08).

There was no significant difference ($P > 0.05$) between static and dynamic balance, and a low positive (0.30) correlation relationship between the two balance tests was observed. There was no significant difference between these two tests, however a positive correlation, indicates that both of the balance tests are independent tests in themselves **(Fleischman, 1964)**.

The hexagon obstacle was devised for alpine skiers by **Dillman, (1980)** to test such skills as; agility, co-ordination and speed of motor learning. The mean score for the first trial was 6.29 seconds (±SD=0.89) and the mean score for the fifth trail was 5.27 seconds (±SD=67).

The mean improvement from the first trial to the fifth trial amounted to 1.02 seconds (±SD=0.59), which was statistically significant at the five percent level ($P < 0.05$). A high positive correlation relationship of 0.74 was recorded between the first and fifth trial. The minimum improvement was 0.7 of a second, and the maximum improvement was 2.7 seconds. From this data, the researcher can conclude that the test re-test reliability is comparatively high (0.74).

Table 4.15 Mean Pulmonary Function results.

	Forced Vital Capacity (FVC)			Forced Expiratory Volume (FEV_1)		
	Actual *(ml)*	Predicted *(ml)*	Percent Predicted *(%)*	Actual *(ml)*	Predicted *(ml)*	Percent Predicted *(%)*
Mean	5591.97	5183.38	108.01	4566.9	4359.18	104.75
Standard Deviation	± 792.19	± 441.18	± 13.80	± 530.35	± 324.88	± 12.13
Minimum	3920	4340	81.30	3410	3040	75.30
Maximum	8000	6350	143.80	5550	5270	131.50

Lung Function scores and results were measured and calculated on a **MICROSPIRO HI 298** spirometer. Evaluating lung volumes must be carried out with strict adherence or results will prove invalid. Lung volumes vary with age, gender, and body size, especially stature. For this reason, these factors must be considered when comparing lung volumes among athletes.

The mean forced vital capacity value obtained was 5591.97 millilitres (±SD=792.19), with a minimum and maximum value of 3920 and 8000 millilitres respectively. Forced expiratory volume in one second values obtained by the surfers was 4566.90 millilitres (±SD=530.35), with a minimum and maximum value of 4340 and 6350 millilitres respectively.

There was no significant difference ($P > 0.05$) between forced vital capacity and forced expiratory volume values. There was a high positive (0.81) correlation relationship between FVC and FEV_1 values obtained. Scores of Forced Vital capacity (FVC) and Force Expiratory Volume in one second (FEV_1) were obtained and compared with predicted values.

Table 4.16 Mean Physiological Components scores of the Maximal Oxygen Uptake Test.

Component	Mean	Standard Deviation	Minimum	Maximum
Resting Heart Rate *(beats.min^{-1})*	67	± 9.73	50	98
VO_2 *(ml.kg^{-1}.min^{-1})*	54.93	± 6.02	39.6	70.2
VO_2 *(l.min^{-1})*	3.77	± 0.47	2.43	4.84
V_E *(l.min^{-1})*	98.31	± 17.81	28.5	138.6
Maximum Heart Rate *(beats.min^{-1})*	185	± 11.06	145	205
O_2 Pulse *(ml.kg.beat)*	30	± 3.01	23.4	36.9
RQ	1.06	± 0.08	0.87	1.17
3 minutes Recovery Heart Rate *(beats.3min^{-1})*	95	± 7.58	78	110

Cardiovascular fitness of the surfers was measured using maximal oxygen uptake (VO_2 max.) from a continuous maximal treadmill exercise test. Results obtained from the peak maximal oxygen consumption test were compared to athletes that have been assessed on similar treadmill, board paddling, and hand cranking protocols.

Of the sixty-one subjects available, only fifty-four participated in the evaluation, the balance of the surfers were not prepared to risk an injury by running on the treadmill. The surfers had mean resting heart rate, three minutes prior to the exercise test, of 76 (±SD=9.7) beats per minute (bpm).

The mean peak maximum ventilation of oxygen obtained, in this study was 54.9 $ml.kg^{-1}.min^{-1}$ (±SD=6.02) or 3.77 $l.min^{-1}$ (±SD=0.47). The lowest peak VO_2 obtained was 39.6 $ml.kg^{-1}.min^{-1}$ or 2.43 $l.min^{-1}$. The maximum peak VO_2 value obtained was 70.2 $ml.kg^{-1}.min^{-1}$ or 4.84 $l.min^{-1}$.

A mean minute ventilation (V_E) score of 98.3 $l.min^{-1}$ (±SD=17.7) and a mean respiratory quotient of 1.06 (±SD=0.08) was recorded respectively. The oxygen pulse value recorded was 30 ml.kg.beat. Three minutes post exercise test the mean resting heart rate was 95 bpm (±SD=7.5). Workloads required subjects to work at 185 (±SD=11.05) beats per minute, which was ninety-four percent of their maximum heart rate.

The following test to be discussed will be the anaerobic Wingate test.

Table 4.17 Statistics of Pedal Revolutions for the Thirty Second Wingate Anaerobic Test.

	Wingate Pedal Revolutions per 5 Second Interval						
	0 to 5	**6 to 10**	**11 to 15**	**16 to 20**	**21 to 25**	**26 to 30**	**Total**
Mean	15.61	13.43	13.38	12.10	11.93	10.95	77.39
Standard Deviation	± 2.05	± 1.74	± 1.45	± 1.31	± 1.39	± 1.31	± 6.93
Minimum	10	9	9	8	8	7	59
Maximum	20	18	16	15	15	13	92

Table 4.18 Statistics of variables measured for the Thirty Second Wingate Anaerobic Test.

	Maximum Power *(Watts)*	Minimum Power *(Watts)*	Average Capacity *(Watts)*	Power per Kilogram per Body Mass *(W/Kg/BM)*	Power per Kilogram per Lean Body Mass *(W/Kg/LBM)*	Fatigue Index *(%)*
Mean	**979.18**	**672.39**	**806.82**	**14.05**	**15.22**	**30.61**
Standard Deviation	**± 163.81**	**± 110.48**	**± 118.16**	**± 1.87**	**± 2.05**	**± 9.75**
Minimum	**600**	**336**	**496**	**8.82**	**9.13**	**10**
Maximum	**1482**	**936**	**1118**	**17.7**	**18.84**	**53.3**

Norms calculated in this study were for average capacity (W), maximum power (W), minimum power (W), power per kilogram body mass (W.Kg.BM), power per kilogram lean body mass (W.Kg.LBM) and fatigue index (FI%).

In the present study, the average anaerobic capacity of the surfers had a mean value of 806.82 watts (±SD=118.16). The ranges of scores in this research also indicate greater value than those obtained by other authors **(Miles, 1993** and **Maud and Schultz, 1989)**.

The mean minimum power value obtained in this study was 672.39 watts (±SD=110.48) and the mean maximum power value was 979.18 watts (±SD=163.80). These results showed favourable anaerobic characteristics of elite surfers as compared to sport science students **(Miles, 1993)**.

The variable of power per kilogram body mass of this study indicated a maximum value of 17.7 W.Kg.BM and a minimum value of 8.82 W.Kg.BM respectively. The mean value of power per kilogram body mass in this study is 14.05 W.Kg.BM (±SD=1.87). The scores of 61 surfers showed a mean power per kilogram lean body mass of 15.22 W.Kg.LBM (±SD=2.05) with a maximum and minimum score of 18.84 W.Kg.LBM and 9.13 W.Kg.LBM respectively.

Amongst the sixty-one surfers, the maximum fatigue index value was 53.3 percent. Minimum values among surfers indicated a score of 10 percent fatigue. The mean fatigue index score for surfers was 30.60 percent (±SD=9.75).

Table 4.19 Scores of Rating of Perceived Exertion for the Psychological Components.

	RPE for Aerobic Component	RPE for Anaerobic Component
Mean	17	17
Standard Deviation	± 2.21	± 1.7
Minimum	12	14
Maximum	20	20

In this study, ratings of perceived exertion measured two opposing fitness components. The first rating of perceived exertion was to measure the aerobic capacity of the surfer. The second rating of perceived exertion was to measure the anaerobic capacity of the surfer. The surfers found both the aerobic and anaerobic component to be very difficult.

During the testing program, the rate of perceived exertion was solicited from each participant immediately after completion of the treadmill and Wingate tests. These results do concern what the level of intensity was recorded for both tests. A correlation of this was obtained between heart rate at maximum and RPE at maximum.

The mean rating of perceived exertion for the maximal treadmill running test was 17.1 ($\pm$SD=2.2). The mean rating of perceived exertion for the Wingate anaerobic test was 17.1 ($\pm$SD=1.7) which indicated that the surfers found this testing procedure very difficult. There was a low positive correlation relationship between the ratings of perceived exertion (0.46).

The standard scores form an integral part of this research, and will be illustrated in this section. The standard scores and fitness categories are developed, to show what prerequisites are needed to excel in surfing at the highest degree. These norms are useful in the rating of the potential surfer's capacity, and how much more a surfer needs to improve for competitive performance.

Norms are classified into various components, namely, sit ups, push ups, combined grip strength, isokinetic leg flexion and extension for the left and right legs, isokinetic shoulder flexion and extension for the left and right shoulders, isokinetic internal and external rotation for the left and right shoulders, flexibility, and agility. Components such as bodyfat percent, static and dynamic balance, hexagon obstacle, lung function capacities and VO_2 max were all classified into categories, rather than assigning a standard score stable. The anaerobic tests received standard scores, all which follow.

Table 4.20 Standard Scores for the Sit-Ups, Push-Ups, and Combined Grip Strength Components.

Standard Score *(%)*	Sit-Ups *(no.)*	Push-Up *(no.)*	Combined Grip Strength *(Kg.)*
100	74	77	143
95	71	74	139
90	68	71	135
85	65	68	131
80	62	65	127
75	58	62	123
70	55	59	119
65	52	56	115
60	48	53	111
55	46	50	107
50	***43***	***48***	***103***
45	39	45	98
40	36	42	94
35	33	39	90
30	30	36	86
25	27	33	82
20	23	30	78
15	20	27	74
10	17	24	70
5	14	21	66
0	11	18	62

Table 4.21 Standard Scores for Peak Flexion and Extension Torque for the Right and Left Legs.

Standard Score (%)	Right Leg		Left Leg	
	Peak Flexion Torque *(Nm)*	Peak Extension Torque *(Nm)*	Peak Flexion Torque *(Nm)*	Peak Extension Torque *(Nm)*
100	238.63	335.93	235.72	331.21
95	229.64	323.43	226.03	318.75
90	220.65	310.92	216.34	306.31
85	211.66	298.42	206.65	293.86
80	193.69	285.91	196.96	281.41
75	184.71	273.41	187.27	268.97
70	175.71	240.91	177.58	256.52
65	166.72	248.41	167.89	244.07
60	157.74	235.89	158.21	231.62
55	148.75	223.39	148.51	219.18
50	***139.76***	***210.89***	***138.82***	***206.73***
45	130.77	198.39	129.13	194.28
40	121.78	185.88	119.44	181.84
35	112.79	173.38	109.75	169.39
30	103.81	160.87	100.06	156.94
25	94.82	148.37	90.37	144.49
20	85.83	135.87	80.68	132.05
15	76.84	123.36	70.99	119.61
10	67.86	110.86	61.31	107.15
5	58.87	98.35	51.61	94.71
0	49.88	85.85	41.92	82.26

Table 4.22 Standard Scores for Peak Flexion and Extension Torque for the Right and Left Shoulders.

Standard Score (%)	Right Shoulder		Right Shoulder	
	Peak Flexion Torque *(Nm)*	Peak Extension Torque *(Nm)*	Peak Flexion Torque *(Nm)*	Peak Extension Torque *(Nm)*
100	115.67	160.44	111.88	151.93
95	110.61	153.94	107.09	145.48
90	105.56	147.45	102.29	139.04
85	100.51	140.95	97.49	132.60
80	95.45	134.46	92.71	126.16
75	90.41	127.96	87.91	119.72
70	85.35	121.47	83.12	113.28
65	80.29	114.97	78.32	106.84
60	75.24	108.48	73.53	100.41
55	70.19	101.98	68.73	93.96
50	*65.14*	*95.49*	*63.94*	*87.52*
45	60.09	88.99	59.14	81.07
40	55.04	82.51	54.35	74.63
35	49.98	76.01	49.55	68.19
30	44.93	69.51	44.76	61.75
25	39.88	63.02	39.97	55.31
20	34.83	56.52	35.17	48.87
15	29.78	50.03	30.38	42.43
10	24.72	43.53	25.58	35.99
5	19.67	37.04	20.79	29.55
0	14.62	30.54	16.01	23.11

Table 4.23 Standard Scores for Peak External and Internal Torque for the Right and Left Shoulders.

Standard Score (%)	Right Shoulder		Left Shoulder	
	Peak External Torque *(Nm)*	Peak Internal Torque *(Nm)*	Peak External Torque *(Nm)*	Peak Internal Torque *(Nm)*
100	**58.96**	**96.62**	**56.18**	**94.87**
95	**56.31**	**92.65**	**53.74**	**91.25**
90	**53.67**	**88.68**	**51.31**	**87.63**
85	**51.03**	**84.72**	**48.86**	**84.01**
80	**48.38**	**80.75**	**46.42**	**80.39**
75	**45.74**	**76.79**	**43.98**	**76.78**
70	**43.11**	**72.82**	**41.54**	**73.16**
65	**40.45**	**68.85**	**39.11**	**69.54**
60	**37.81**	**64.89**	**36.66**	**65.92**
55	**35.17**	**60.92**	**34.22**	**62.31**
50	***32.53***	***56.96***	***31.79***	***58.69***
45	**29.88**	**52.99**	**29.35**	**55.07**
40	**27.24**	**49.02**	**26.91**	**51.45**
35	**24.61**	**45.06**	**24.47**	**47.83**
30	**21.95**	**41.09**	**22.03**	**44.21**
25	**19.31**	**37.13**	**19.59**	**40.61**
20	**16.67**	**33.16**	**17.15**	**36.98**
15	**14.02**	**29.19**	**14.71**	**33.36**
10	**11.38**	**25.23**	**12.27**	**29.74**
5	**8.74**	**21.26**	**9.83**	**26.12**
0	**6.11**	**17.31**	**7.41**	**22.51**

<u>Table 4.24</u> Standard Scores for the Flexibility and Agility Fitness Components.

Standard Score *(%)*	Modified Sit and Reach *(cm.)*	T-Drill Agility Test *(sec.)*
100	63	9.1
95	61	9.4
90	58	9.8
85	56	10.1
80	54	10.5
75	52	10.8
70	49	11.2
65	47	11.5
60	45	11.9
55	42	12.2
50	***40***	***12.6***
45	38	12.9
40	36	13.2
35	33	13.6
30	31	13.9
25	29	14.3
20	27	14.6
15	24	15.0
10	22	15.3
5	20	15.7
0	17	16.0

Table 4.25 Classification of Body Fat Percentage for Elite Surfers.

Classification	Body Fat Percent *(%)*
Excellent	< 2.4
Good	2.5 to 6.9
Average	7.0 to 9.0
Fair	9.1 to 13.6
Poor	> 13.7

Table 4.26 Classification of Blind Stork Balance (Static Balance).

Classification	Blind Stork Balance *(sec.)*
Excellent	> 48.84
Good	36.62 to 48.83
Average	24.40 to 36.61
Fair	12.18 to 24.39
Poor	< 12.17

Table 4.27 Classification of Balance Stabilisation (Dynamic Balance).

Classification	Balance Stabilisation
Excellent	> 78.96
Very Good	65.87 to 78.95
Good	52.79 to 65.86
Average	39.70 to 52.78
Fair	26.52 to 39.69
Poor	13.43 to 26.51
Very Poor	< 13.42

Table 4.28 Classification of Improvement of the Hexagon Obstacle.

Classification	Improvement (sec.)
Excellent	> 2.30
Good	1.62 to 2.29
Average	1.02 to 1.61
Fair	0.42 to 1.01
Poor	< 0.41

Table 4.29 Classification of Percent Lung Function Capacities for Surfers.

Classification	Percent of Predicted (%)	
	Forced Vital Capacity	Forced Expiratory Volume
Excellent	> 142.54	>138.44
Very Good	128.73 to 142.53	124.63 to 138.43
Good	114.73 to 128.72	110.82 to 124.62
Average	101.11 to 114.91	98.68 to 110.81
Fair	87.30 to 101.10	84.87 to 98.67
Poor	73.49 to 87.29	71.06 to 84.86
Very Poor	< 73.48	< 71.05

Table 4.30 Classification of Peak Maximum Oxygen Uptake for Elite Surfers.

Classification	Maximum Oxygen Uptake ($ml.Kg^{-1}.min^{-1}$)
Excellent	> 73.02
Very Good	66.99 to 73.00
Good	60.96 to 66.98
Average	48.91 to 60.95
Fair	42.88 to 48.90
Poor	36.85 to 42.87
Very Poor	< 36.84

Table 4.31 Standard Scores for Components of the Wingate Anaerobic Test.

Standard Score (%)	Max. Power (Watts)	Min. Power (Watts)	Ave. Capacity (Watts)	W.Kg.BM	W.Kg.LBM	Fat. Index (%)	Total Revs. (30sec.)
100	1470.61	1003.83	1161.31	19.66	21.37	1.36	98.18
95	1421.47	970.69	1125.85	19.09	20.76	4.29	96.11
90	1372.32	937.54	1090.41	18.54	20.14	7.21	94.02
85	1323.18	904.39	1054.96	17.98	19.53	10.14	91.94
80	1274.04	871.25	1019.51	17.42	18.91	13.06	89.86
75	1224.89	838.11	984.06	16.86	18.29	15.99	87.79
70	1175.75	804.97	948.61	16.29	17.68	18.91	85.71
65	1126.61	771.82	913.16	15.73	17.07	21.84	83.63
60	1077.47	738.68	877.72	15.17	16.45	24.76	81.55
55	1028.32	705.53	842.27	14.61	15.84	27.69	70.47
50	*979.18*	*672.39*	*806.82*	*14.05*	*15.22*	*30.61*	*77.39*
45	930.04	639.25	771.37	13.49	14.61	33.54	75.31
40	880.89	606.11	735.92	12.93	13.99	36.46	73.23
35	831.75	572.96	700.48	12.37	13.38	39.39	71.15
30	782.61	539.81	665.03	11.81	12.76	42.31	69.07
25	733.47	506.67	629.58	11.25	12.15	45.24	66.99
20	684.32	473.53	594.13	10.68	11.53	48.16	64.92
15	635.18	440.38	558.68	10.12	10.92	51.09	62.84
10	586.04	407.24	523.24	9.56	10.31	54.01	60.76
5	536.89	374.09	487.79	9.01	9.69	56.94	58.68
0	487.75	340.95	452.34	8.44	9.07	59.86	56.61

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 DISCUSSION

Although there has been an extensive amount of literature related to physiological profiling and physical fitness assessments, there is still a substantial need for further research in surfing and water based activities. The laboratory findings in this research are valid and reliable and can be used for comparison, in order to deduce whether or not elite surfers are as physically fit as other sport performers.

Before comparing results, **Meir *et al.* (1991)** reported on how much activity is actually performed during one hour of recreational surfing. Time in the water is spent paddling (to catch a wave and to the take off area), stationary (waiting for a wave) or riding waves.

Results showed that twenty-seven minutes were spent paddling, twenty-one minutes were spent stationary, and only three minutes was spent riding waves. The total number of waves ridden in one hour was twenty. The results presented in Chapter Four show that the surfers tested in this study surfed four times per week and for three hours a day.

These results can be extrapolated to **Meir *et al.* (1991)** study, which indicates that for a day of surfing; the subjects would paddle for eighty-one minutes, sit stationary for sixty-three minutes, and ride waves for nine minutes. This amount of training is not as great as other elite international athletes.

The following section compares the results, obtained in this study, to other sport performers in similar disciplines. The proposed norms were expected to be higher than the various general populations, but not as great as the trained elite population. This chapter will describe the results in the various fitness components. The first component to be discussed will be the muscular and strength component.

5.2 Muscular and Strength Components

5.2.1 PUSH UPS

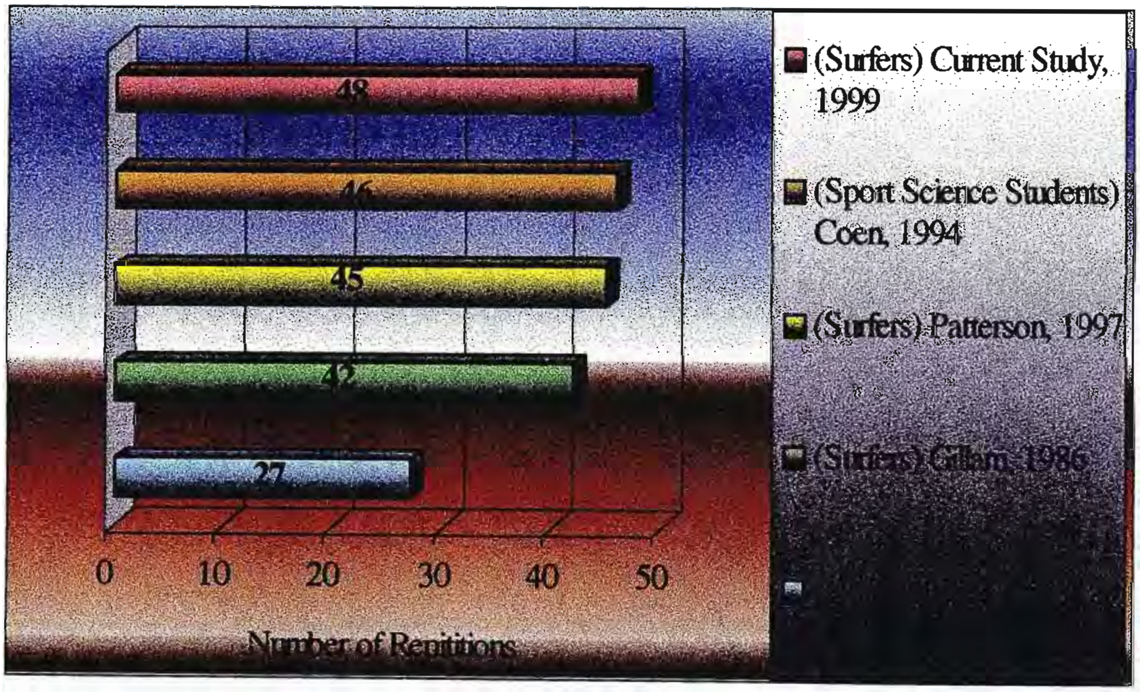


Figure 5.1 Comparisons of Push-Ups between Different Sport Populations

The average number of push-ups represented by Canadian norms **(Phillips and Hornack, 1979)** measured twenty-seven for male's aged between seventeen to nineteen years.

This score is considerably lower than those reported by **Coen, (1994)** who reported scores for sport science students of forty-six push-ups in one minute. **Gillam** ***et al.*** **(1986)** identified results for surfers to be forty-two, which was low amongst elite athletes. **Gillam** ***et al.*** **(1986)** went on to express that surfing fitness levels are maintained purely from the activity of surfing. **Patterson, (1997)** reported scores for twenty provincial surfers to have an average score of forty-five.

The mean push-up result of forty-eight (±SD=9.69) in this research is greater than those obtained by **Gillam** ***et al.*** **(1986), Coen, (1994)** and **Patterson, (1997)**. The excellent results achieved in this study could be attributed to the superior arm strength required for surfing. Surfers are required to have vast amounts of muscular endurance, in the upper body while surfing. Upper body strength is not only required for paddling, but also to push the surfboard under advancing waves, and assists in stabilising the board at take off.

Great arm strength, as seen in **Figure 5.1**, impacts positively on surfing skills and performances. External resistance and the athlete's ability to express force also maximise strength in the upper body. External resistance in surfing is in the form of water, and the surfers own body weight is the momentum as known as internal strength. The relationship between these two components in surfing is critical, as it determines different classes of muscular activity.

5.2.2 SIT UPS

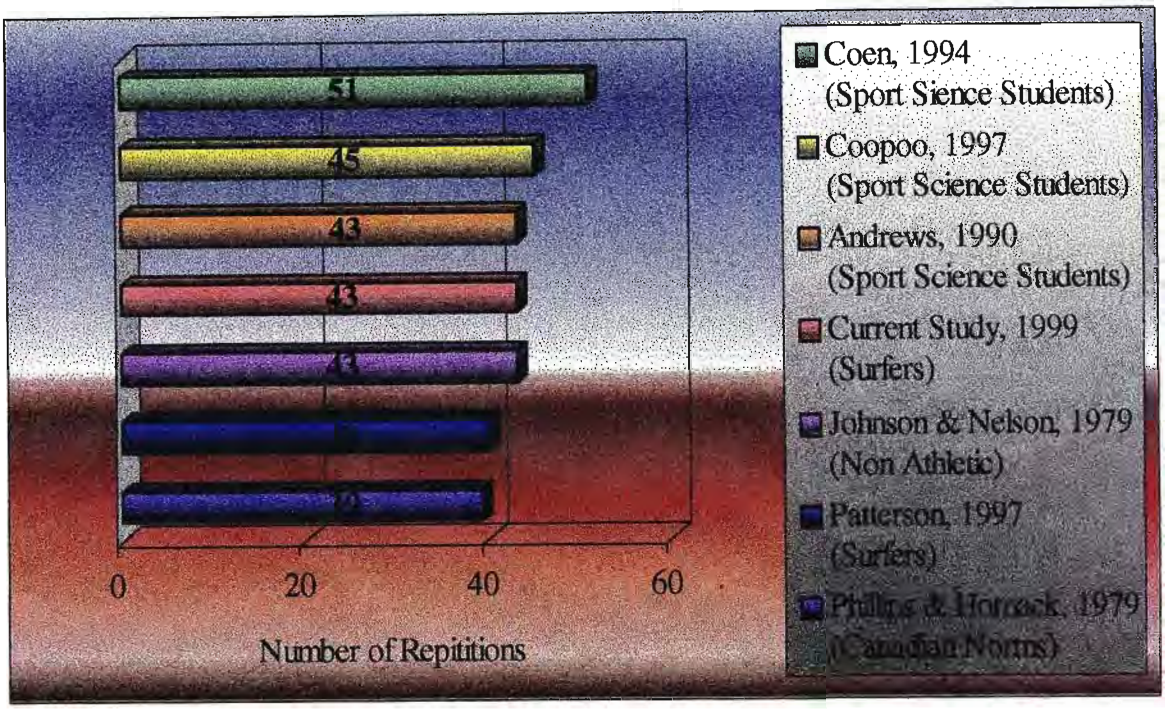


Figure 5.2 Comparisons of Sit-Ups between different Sport Populations

Andrews (1990) determined the average number of sit-ups in one minute for sport science students, to be forty-three. Canadian norms **Phillips and Hornack (1979)** for one minute sit-ups are thirty-nine for males aged among seventeen to nineteen years.

Andrews (1990) and **Phillips and Hornack, (1979)** scores are considerably lower than the fifty-one reported by **Coen (1994)** for sport science students, remembering that the population tested, should have an above average level of fitness than the general population. **Coopoo (1997)** suggested that mean norms for sport science students should be about forty-four to forty-six for males. **Patterson (1997)** recorded scores of forty sit-ups per minute for twenty provincial surfers, which was well below the standard required at that level of surfing.

The mean score in the current research was forty-three as can be seen in **Figure 5.2**. Sit-ups are an abdominal wall exercise that stresses the abdominal muscles through their full range of motion. Unfortunately, surfing is not a complete or balanced conditioning activity, which may lead to abdominal muscles being poorly developed.

Surfing does not concentrate specifically on muscular endurance activity for the abdomen. This is a disadvantage to surfers. Unlike swimming, in surfing the stomach muscle are relaxed while paddling because all of the tension is focused on the back. Trunk stability is vital for the effective transfer of momentum in surfing but this task is isokinetic in nature and will not necessarily stress the muscle group through a full range of motion.

The abdominal muscles play an important role in the lifting, sideward and backward movement of the surfers while surfing, which only amounts to four or five minutes in total per hour. The surfers should develop these abdominal muscles for better performance and reduce the risk of low-back pain. The mean score of forty-three sit-ups compare favourably with those of the studies mentioned, however, surfers should have better abdominal strength, considering the role it plays in surfing.

5.2.3 GRIP STRENGTH

Stoelting, (1972) categorised grip strength norms for the strongest hand, showed a mean score of fifty-four and forty-eight for the left and right hands respectively. **Sandler *et al.* (1991)** found a combined average of forty-eight, strength (kilogram) among women (twenty-five to thirty-four years) determining if muscle strength indicated habitual physical activity.

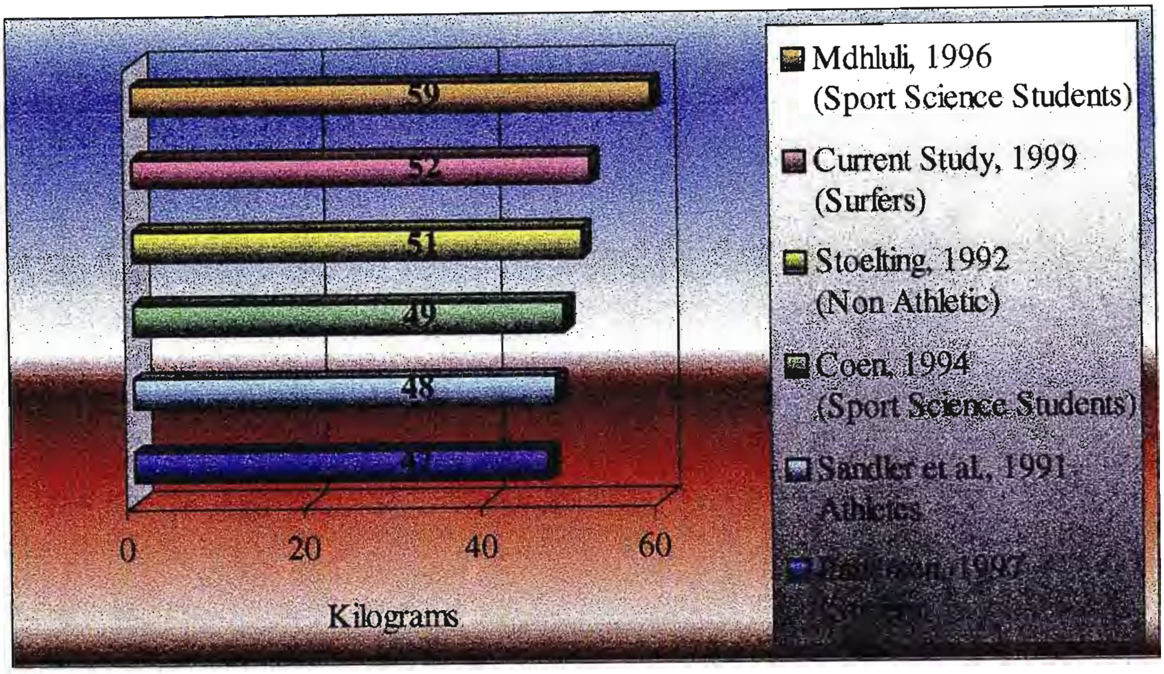


Figure 5.3 Comparison of Mean Combined Grip Strength between different Sport Performers

Coen, (1994) showed an average score of forty-nine for sport science students at the University of Durban Westville. **Mdhluli, (1996)** identified norms for sport science students of fifty-nine for combined grip strength. **Patterson, (1997)** showed that twenty elite provincial surfers achieved high scores of fifty-nine for both hands, which is ranked very high compared to other sport performers.

In this research study however **Figure 5.3**, the mean grip strength score for both hands was fifty-two, which shows superior strength when compared to other sport performers. The justification for such excellent results can be attributed to the nature of surfing where hard and powerful strokes are required to catch waves and to reach the take off area. It should be noted that in one hour of recreational surfing, twenty-seven minutes is spent paddling **(Meir *et al.,* 1991)**, which is four-five percent of the time spent in the water.

This mode of training would definitely lead to superior strength in the arm muscles, leading to good grip strength, which is a rough indication of overall body strength.

5.2.4 LOWER LIMB ISOKINETIC RESULTS
5.2.4.1 ISOKINETIC LEG FLEXION STRENGTH

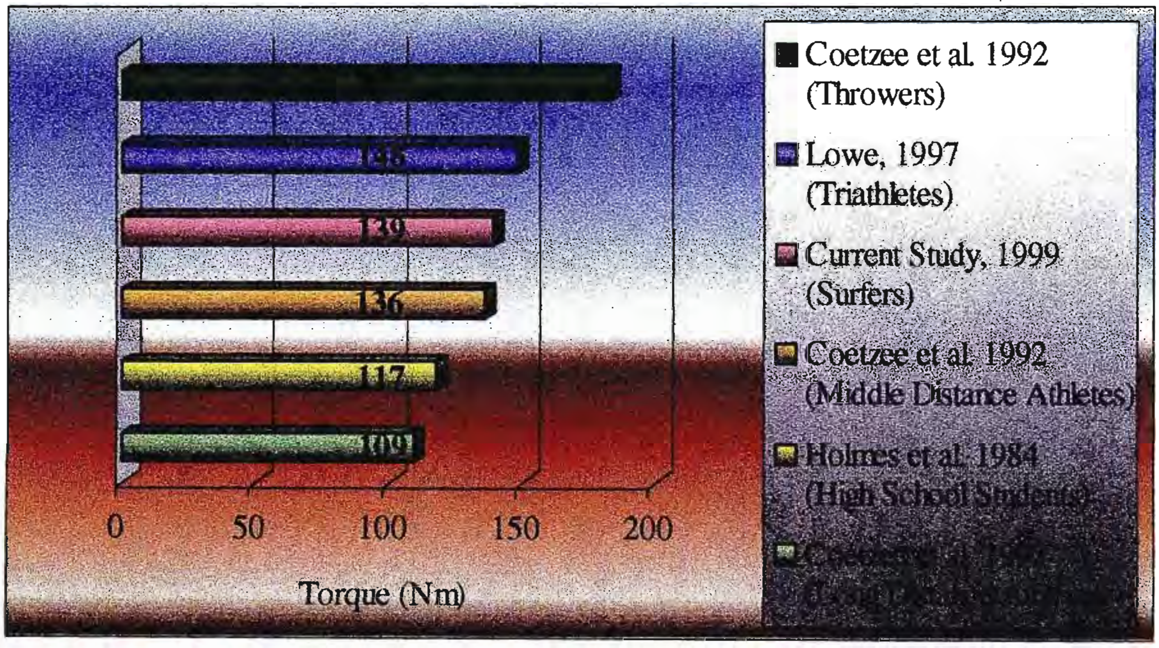


Figure 5.4 Comparisons of Mean Peak Flexion Torque among different Sport Performers

With regard to isokinetic strength, results **Freedson *et al.* (1993)** on a table of normative data indicated that mean flexion at sixty degrees per second for men between the ages of twenty-one to fifty-one years should be 133.6 Nm.

This score is very similar to the standard of both limbs for surfers, that is 139.29 Nm in the current study. **Holmes *et al.* (1984)** conducted an isokinetic study on seventeen male high school students ranging in age from fifteen to eighteen years. All students were involved in recreational or interscholastic sport. The left and right flexion values were 117.35 Nm (±SD=25.29) and 117.01 Nm (±SD=28.89) respectively.

Coetzee *et al.* (1992) conducted a study comparing elite throwers, jumpers, sprinters, middle distance athletes, and long distance athletes. Although the isokinetic assessment was performed at thirty degrees per second, reported mean peak flexion values were 136 Nm (±SD=39) and 109 Nm (±SD=29) for middle distance athletes and long distance athletes respectively, as compared to 183 Nm (±SD=37) for the throwers. In a recent study, **Lowe, (1997)** identified 21 elite triathletes to have a mean peak flexion torque of 147.56 Nm (±SD=27.55).

The leg flexion strength of an elite surfer is very important and can lead to favourable results if the correct muscles groups are well developed. Kicking in surfing plays a major role, when trying to catch a wave, or to reach the take-off area.

The kicking power of the legs is eased somewhat by the assistance of the arms while paddling in the water. Ultimately it is the hard, powerful kicking that will increase the momentum of a surfer up onto a wave. The results achieved by the surfers show great flexion strength of the leg muscles. The nature of surfing shows why explosive muscular power is needed to generate and accelerate force in a short period of time. The hamstring muscles are constantly contracted which will lead them to be superior in strength and endurance.

Riding the face of a wave is explosive in nature, and this mode of training increases the rate of force development produced by the limbs. As a result with the limbs constantly supporting the surfers body weight at all times during manoeuvres; it is not surprising that the hamstrings produce great strength.

5.2.4.2 ISOKINETIC LEG EXTENSION STRENGTH

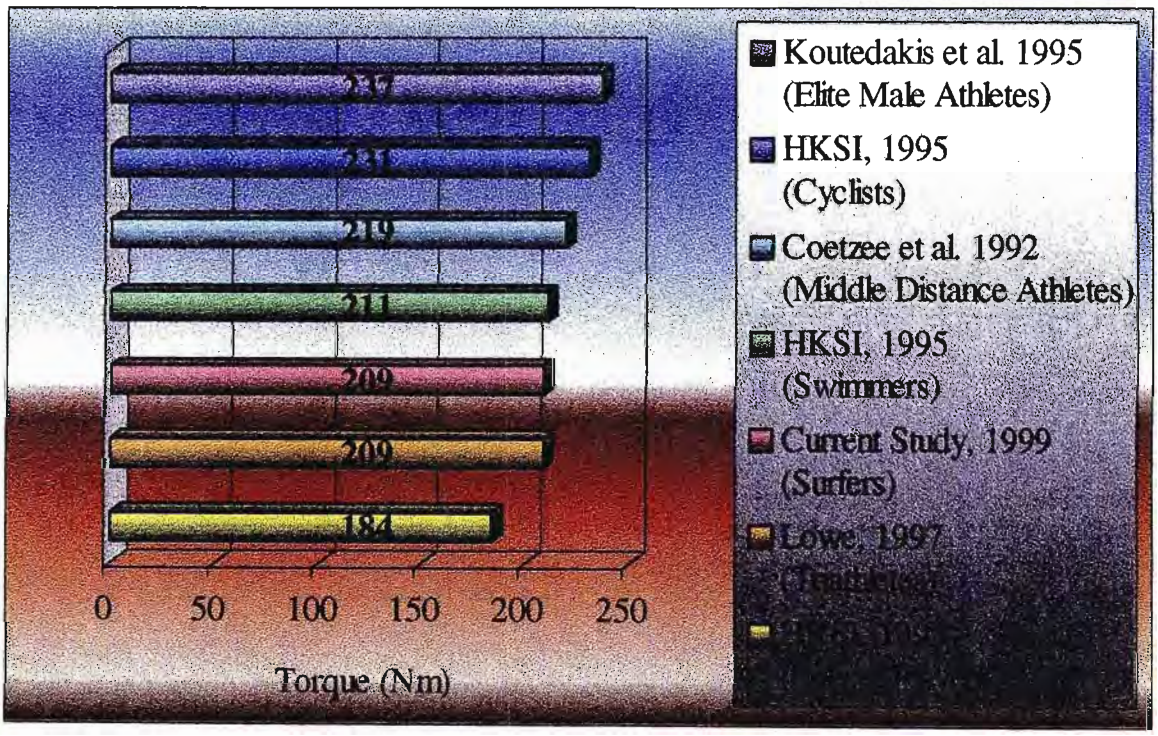


Figure 5.5 Comparisons of Mean Peak Extension Torque among different Sport Performers

The results for a limb comparison between the left and right extension values in a study by **Holmes *et al.* (1984)** was 204.71 Nm ($\pm$SD=35.22) and 198.01 Nm ($\pm$SD=34.16) respectively. **Koutedakis *et al.* (1995)** tested ten elite male athletes on an isokinetic dynamometer. The subjects were uninjured and returned mean peak extension values of 237 Nm ($\pm$SD=12).

Coetzee *et al.* (1992) reported extension values of 219 Nm (±SD=38) for middle distance athletes. **Lowe, (1997)** recorded the mean peak extension torque values of twenty-one elite triathletes, the scores measured were 207.29 Nm (±SD=26.69) and 208.26 Nm (±SD=24.11) for the right and left leg respectively.

Research conducted at the Honk Kong Sports Institute (HKSI) provided profiles among elite Hong Kong athletes. The **HKSI** identified Soccer players to have an average peak leg extension of 184 Nm. Cyclists produced scores of 231 Nm for peak extension and swimmers showed scores of 211 Nm for leg extension (**Chan *et al.*, 1996**).

According to **Freedson *et al.* (1993),** a table of normative data indicated mean extension at sixty degrees per second for men between the ages of twenty-one to thirty years to be 209.5 Nm. This score is very similar to the average of both limbs for a surfer that is 208.81 Nm recorded in study see **Figure 5.5**.

There are numerous ways the leg muscles are utilised when surfing. Surfing requires both isotonic and isometric contraction of the muscles both in a short period of time. Surfing supports a heavy load, which increases the leg strength, endurance, and should decrease the sprint performance. This is not the case for surfers, as the anaerobic results obtained were high.

The explosive muscle power required by the quadriceps muscles assist the take off of a surfer on a wave, and the impact of the surfboard when hitting the water. The isotonic contractions can be concentric or eccentric in nature, which is specific to the sport of surfing.

Leg strength is required during both slow and fast concentric actions while surfing, which will improve the rate of force development of the legs, which will produce more strength and power.

Baron *et al.* **(1990)** conducted isokinetic measurements of the stretch strength of the femoral quadriceps muscle in surfers, and discovered an average strength to body weight score of 3.2 Nm/Kg, which is an indicator of a higher strength characteristic.

The surfer population in this study has a mean strength to body weight for both the left and right legs of 3.0 Nm/Kg, which is very similar to that recorded by **Baron** *et al.* **(1990)**. Maximal force is needed for a quality manoeuvre and when supporting the body additional strength is required.

Furthermore, **Baron** *et al.* **(1990)** went on to express that any strength value above 3.0 Nm/Kg represented a good training status, and confirmed no significant differences between the left and right legs. **Sanderson** *et al.* **(1984)** reported on the values achieved by 17 males ranging in age from 18 to 25 years. All the subjects attended a local college and none had any musculo-skeletal complaints.

An isokinetic dynamometer was used to test the subjects and mean peak extension and peak flexion to body weight values of 1.67 Nm/Kg ($\pm$SD=0.33) flexion and 2.86 Nm/Kg ($\pm$SD=0.48) extension were reported respectively. **Coetzee** *et al.* **(1992)** showed a flexion to body weight ratio of 2.0 Nm/Kg ($\pm$SD=0.4) for middle distance athletes with an extension to body weight ratio of 3.3 Nm/Kg ($\pm$SD=0.5).

Lowe, (1997) reported on the mean peak flexion, and extension to body weight values of 21 elite triathletes. Scores for the left leg were 2.13 Nm/Kg (±SD=0.29) flexion and 3.05 Nm/Kg (±SD=0.32) extension. The scores for the right leg showed 2.15 Nm/Kg (±SD=0.33) flexion and 3.04 Nm/Kg (±SD=0.36) extension.

In the present study the score for the right leg regarding flexion torque to body weight is 1.99 Nm/Kg (±SD=0.33) and extension torque to body weight was 3.04 Nm/Kg (±SD=0.51). In the left leg the flexion torque to body weight was 1.98 Nm/Kg (±SD=0.39) and extension torque to body weight was 2.96 Nm/Kg (±SD=0.47). These scores are within range of the normal population, which shows that the demands placed on the legs during surfing are highly specific.

The internationally accepted norm between fifty and eighty percent concerning flexion to extension values **(Kannus and Jarvinen, 1990)**, appears to apply to this sample of surfers as in the study the peak flexion to extension ratio for the right leg was 66.69 percent (±SD=9.48) and 67.45 percent (±SD=10.69) for the left leg.

Lowe, (1997) identified the mean peak flexion to extension toque values for triathletes to be 71.11 percent (±SD=9.32) for the left leg and 70.21 percent (±SD=9.88) for the right leg. **Fillyaw *et al.* (1986)** reported mean peak flexion to extension results of 67 percent (±SD=13) in an isokinetic study on soccer players. **Sanderson *et al.* (1984)** showed a mean peak flexion to extension value of 62 percent (±SD=0.09).

Quadriceps, hamstring strength, and the quadriceps to hamstring ratio, in this research showed excellent results for surfers, and can be attributed to the lower limbs playing a major role in surfing.

It can be appreciated that the legs are bent during turns in surfing, but it is probably the static contraction in the back leg during the turn, that stabilises the centre of gravity of the body. Furthermore surfing (riding) itself is only a small component of the total time spent in the water.

Kicking for waves and reaching the take off area is a vital component in surfing and would contribute to the good flexor development of elite surfers. As stated previously, isometric and isotonic contraction will lead to favourable leg strength results and ratios.

The front leg, during surfing, assists the steering of the surfboard, but depending on the surfing style, wave height and power, the back leg has to work equally hard in creating drive, forcing through each turn and regaining balance during the land of high scoring manoeuvres.

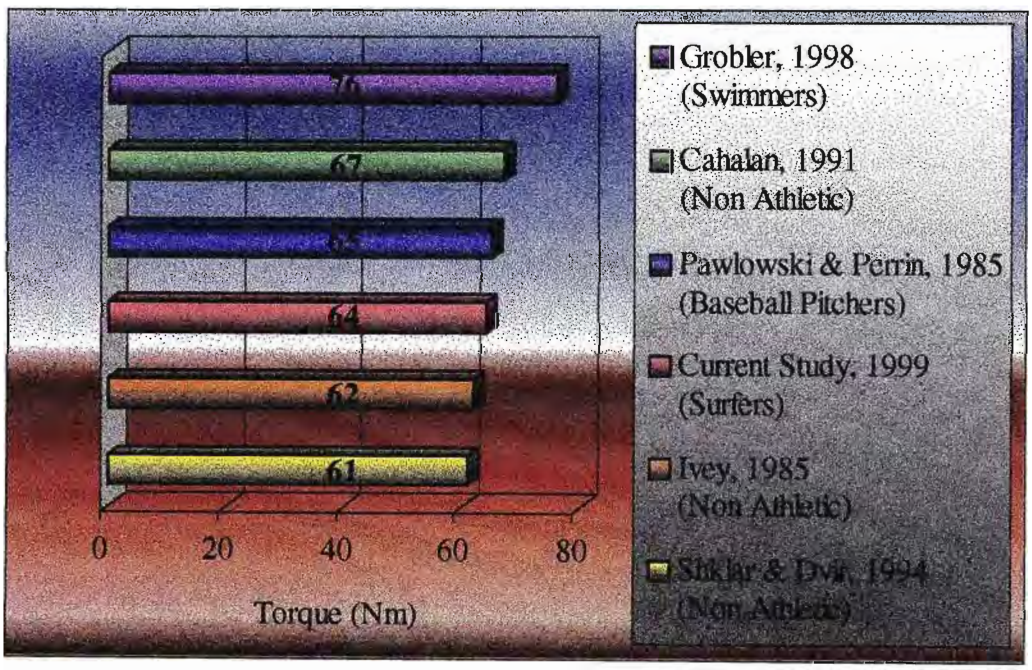
The perfect ratio between the quadriceps and hamstrings, indicates that surfing is an activity that requires perfect strength in legs in order to perform excellently.

5.2.5 UPPER LIMB ISOKINETIC RESULTS

Apart from several studies in the late 1970s, evaluation of shoulder muscle performance using isokinetic dynamometers in a clinical setting was not extensively examined before the 1980s.

The isokinetic results for the shoulder in flexion and extension focused on the comparison between the left and right peak flexors, and left and right peak extensors, as well as the peak flexion to extension torque ratios. Flexion and extension of the gleno-humeral joint occur through the sagittal plane.

5.2.5.1 ISOKINETIC SHOULDER FLEXION



<u>Figure 5.6</u> Comparisons of Mean Peak Shoulder Flexion Torque among different Sport Performers

The muscles most involved in producing flexion include the anterior portion of the deltoid muscle and the clavicular portion of the pectoralis major muscle. The biceps brachii and triceps muscles act as assistant movers during shoulder flexion and extension, respectively.

Ivey *et al.* (1985), **Cahalan *et al.* (1991)** and **Shklar and Dvir, (1994)** recorded mean peak flexion scores of the shoulder show 62.3 Nm (±SD=12.5), 67.8 Nm (±SD=16.3) and 61.2 Nm (±SD=9.8) respectively. **Pawlowski and Perrin, (1989)** identified that normative peak flexion shoulder value of college baseball pitchers was 65.03 Nm.

Grobler, (1998) identified mean peak flexion scores for male swimmers of 75.62 Nm (±SD=22.53) and 77.96 (±SD=19.78) for the left and right shoulders respectively. A study completed by **Freedson *et al.* (1993)** developed normative data for 4541 women and men for the shoulder in flexion and extension.

According to **Freedson *et al.* (1993)** the surfer population studied in this research would rank between the seventieth and ninetieth percentile, with a mean peak flexion score for the left and right shoulders of 64.54 Nm. These results may be attributed to different methods of testing protocols and the resistance of the surfboard against the water, when coming up from a duck dive, which requires the arms to pull the surfboard towards the body.

The shoulder performance results in this study show a favourable advantage over results obtained by above authors as the muscle make up of a surfer is similar to that of an elite swimmer see **Figure 5.6**.

Surfers require a high degree of muscularity in the upper limbs so that their arms can propel them to the take off area and rapidly when catching a wave. Surfers have long lever lengths of the upper limbs involved and a high proportion of fast twitch fibres in the muscles involved in the activity of surfing. There was no bilateral discrepancy, which shows that surfing is a balanced upper body activity.

5.2.5.2 ISOKINETIC SHOULDER EXTENSION

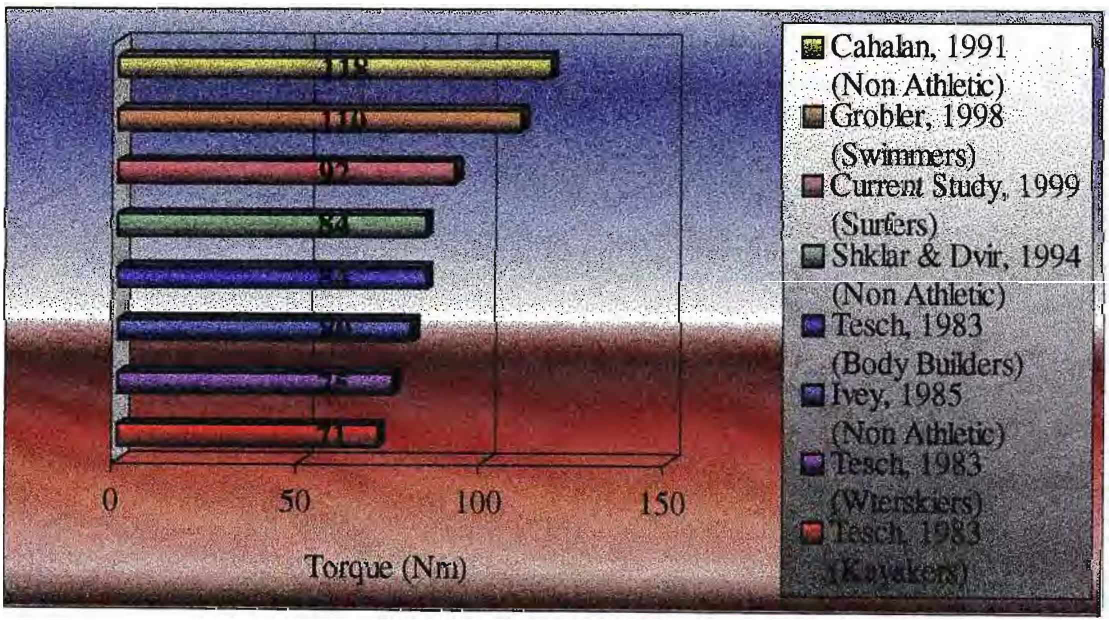


Figure 5.7 Comparisons of Mean Peak Shoulder Extension Torque among different Sport Performers

The sternal portion of the pectoralis major, the teres major, the posterior portion of the deltoid muscle and most importantly by the powerful latissimus dorsi muscle produce extension.

A study completed by **Freedson *et al.* (1993)** determining normative values of peak extension of the shoulder, indicated that a mean score of 92.49 Nm that was obtained by the surfers, in this research, would only rank in the lower fiftieth percentile. Poor results obtained by the surfers can be related to different testing protocols and the lack of resistance on the upward stroke while paddling.

The surfers peak extension scores are also similar to those obtained by **Ivey *et al.* (1985), Cahalan *et al.* (1991)** and **Shklar and Dvir, (1994)** whose scores showed 80.4 Nm (±SD=20.1), 118.0 Nm (±SD=24.4) and 84.9 Nm (±SD=20.5) respectively.

Tesch, (1983) identified the differences in peak extension torque's of elite kayakers, bodybuilders and water-skiers. The results showed an average of 71.79 Nm, 84.77 Nm and 75.71 Nm for all three sport standards respectively. Additional strength in kayaking is exposed by the nature of the sport, where competitors are required to move both forwards and backwards, against a current, and are assisted by a paddle that increases the load to move the kayak.

Grobler, (1998) identified mean peak extension scores for male swimmers to be 107.88 Nm (±SD=19.90) and 112.6 Nm (±SD=21.20) for the left and right shoulders respectively.

In nondisabled, non athletes or in athletes not requiring selected overuse of either the shoulder flexors or extensors, the shoulder flexor musculature has been shown to be in the region of seventy-five percent to eighty-five percent of the torque values generated by the extensor musculature.

In activities which require powerful extension of the shoulder muscles such as swimming, surfing, rowing and throwing, the demand on the shoulder tends to reduce the shoulder flexion to extension reciprocal muscle use to the point where flexor muscles may produce only fifty percent of the values generated by the extensor muscles **(Perrin, 1993)**.

Scores from the HKSI show that swimmers have a mean peak flexion to extension value of 54 (±SD=1) percent. Badminton players obtained peak flexion to extension values of 69 (±SD=12) percent **(Chan *et al.*, 1994)**. **Grobler, (1998)** reported peak flexion to extension torque ratios for male swimmers to be 69.84 percent (±SD=14.06) and 69.1 percent (±SD=9.52) for the left and right shoulders respectively. There as no significant difference reported by **Grobler, (1998)** between the left and right shoulders respectively.

Surfers represent scores similar to those obtained by **Grobler, (1998)**. A mean flexion to extension ratio of 69 percent indicates that the extensors are stronger than the flexors, due to the resistance of the sea water and the extensors being worked longer against resistance. High torque results of the extensor shows the ability of the surfer to generate and sustain high power outputs for booth short and long periods. There was no bilateral discrepancy recorded between the left and right extensors respectively.

5.2.6 ISOKINETIC SHOULDER ROTATION

Leroux *et al.* (1994) stated that an imbalance in the internal and external rotator muscles of the shoulder can be implicated as an etiological factor in impingement syndrome. Overuse injuries are common among surfers, especially when it comes to impingement or rotator cuff strains or sprains. For these reasons, strength profiles and norms can be developed to identify where weaknesses lie and further investigations can be implemented in the improvement of the injury.

5.2.6.1 ISOKINETIC EXTERNAL ROTATION

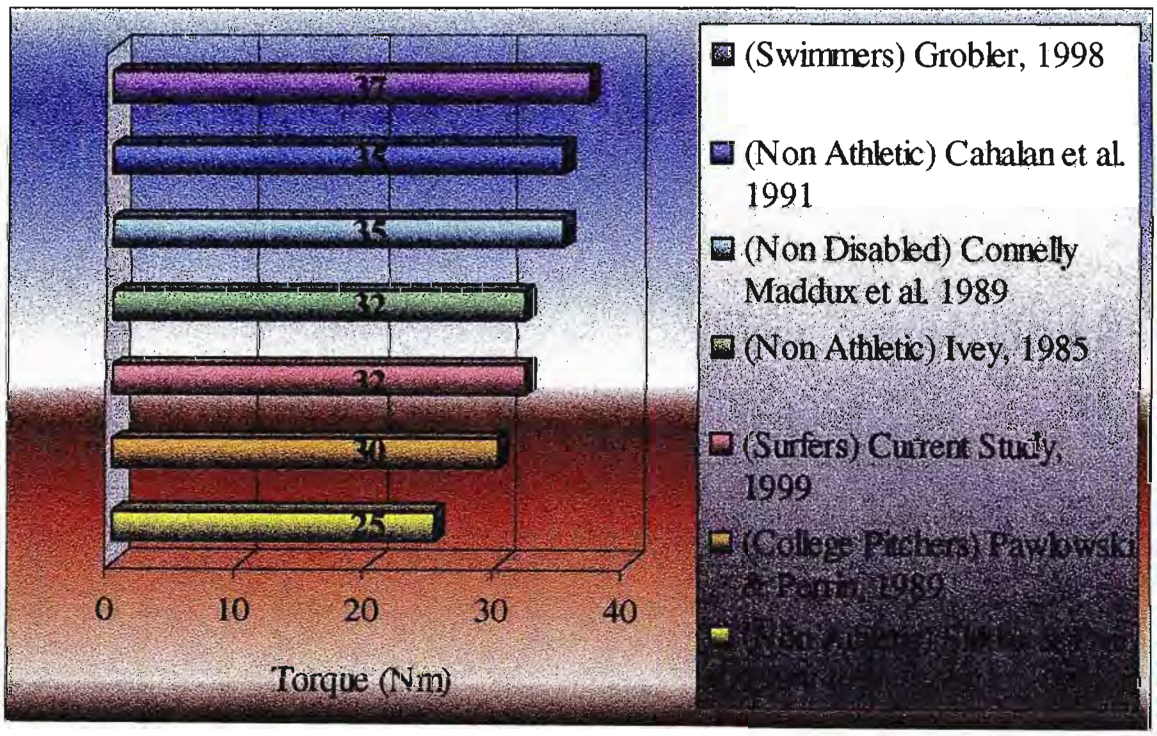


Figure 5.8 Comparison of Mean Peak External Rotation Torque among different Sport Performers

The subscapularis, teres major, pectoralis major, latissimus dorsi and anterior deltoid muscles produce internal rotation. Factors influencing internal to external ratios include sporting backgrounds. For example, **McMaster *et al.* (1991)** reported a lower ratios in water polo players.

Pawlowski and Perrin, (1989) identified mean peak external shoulder torque scores for college pitchers of 30.56 Nm. **Connelly Maddux *et al.* (1989)** identified scores for nondisabled athletes in external rotation, with a mean result of 35.15 Nm.

Data based on **Ivey *et al.* (1985), Cahalan *et al.* (1991)** and **Shklar and Dvir, (1994)** who tested 31, 50 and 30 non athletic subjects respectively. The mean peak external rotator scores showed 32.4 Nm (±SD=7.9), 35.3 Nm (±SD=6.8) and 25.6 Nm (±SD=7.9) respectively.

Grobler, (1998) reported that mean peak external torque values for male swimmers were 37.76 Nm (±SD=9.3) for the left shoulder and 37.93 Nm (±SD=11.75) for the right shoulder. There was no significant difference between the left and right internal rotator muscle groups. The mean external rotator score obtained in this research was 32.16 Nm (±SD=8.47) see **Figure 5.8**.

Scores obtained in this research again indicate that the nature of surfing neglects the external rotators due to little or no resistance of the upward paddling stroke in surfing. The external muscle groups are not under developed and no bilateral discrepancy was noted. Poor torque values may be due to the inability to strictly achieve the exact position and movement of the arms that a surfer requires while paddling for a wave.

5.2.6.2 ISOKINETIC INTERNAL ROTATION

External rotation is produced by the infraspinatus, teres minor and posterior deltoid muscles. Generally, the external rotator muscles generate torque of approximately sixty to eighty percent of the values generated by the internal rotator muscles **(Chan *et al.*, 1994)**.

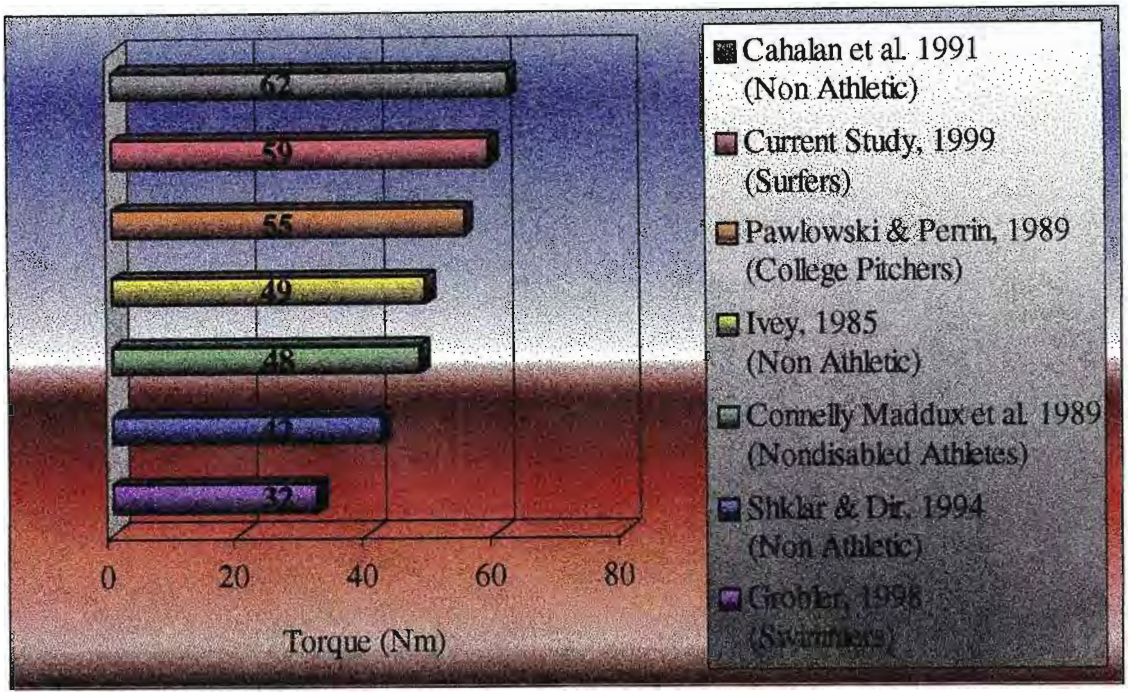


Figure 5.9 Comparison of Mean Peak Internal Torque among different Sport Performers

Pawlowski and Perrin (1989) and **Connelly-Maddux *et al.* (1989)**, noted internal torque values for college pitchers and nondisabled athletes. Mean scores showed 55.56 Nm and 48.40 Nm respectively.

Results obtained from **Ivey *et al.* (1991), Cahalan *et al.* (1991)** and **Shklar and Dvir (1994)**, who tested 31, 50 and 30 non athletes subjects respectively indicated mean peak internal rotator scores of 49.5 Nm (±SD=16.6), 62.4 Nm (±SD=19.0) and 42.7 Nm (±SD=13.4) respectively.

Grobler (1998) noted that the mean peak internal rotator torque for male swimmers produced 31.55 Nm (±SD=8.96) for the left shoulder and 32.85 Nm (±SD=5.61) for the right shoulder. In the same study, there was no significant difference noted between the left and right internal rotator muscle groups.

The surfers in this research showed a pleasing result in the external rotators muscle, with a mean score of 59.32 Nm (±SD=12.64), which was higher than other sport performers. The water resistance that surfers have to over come while paddling for a wave is great. As stated previously, as many as twenty hard powerful strokes are requires to reach the take off area, and once this has be completed, the surfer catches the first wave that appears. This again requires vigorous and fast strokes, which leads the internal rotators being super developed.

Grobler (1998) reported high scores of 65.25 percent (±SD=8.88) and 62.9 percent (±SD=9.39) for the left and right shoulders in male swimmers. The score is superior due to the predominant usage of the shoulder musculature while swimming. The scores for surfers for the same tests are not as great, as their body weight is supported throughout the paddling motion, see **Figure 5.9**.

McMaster *et al.* (1991) indicated that waterpolo player's external rotators were 59 percent of the internal rotators, whereas in control groups the external rotators were 75 percent of the internal rotators. Further research undertaken by **Bak and Magnusson (1997)** reported that the ratio between external and internal rotational strength was 75 percent in controls and 64 percent in swimmers.

The mean peak external to internal rotation torque score amongst the surfer population of 54.64 percent (±SD=11.76), cannot support the normative score indicated by **Chan *et al.* (1994)** but does however, support the **McMaster *et al.* (1991)** study.

The explanation for such a score is because the internal rotators are required for hard powerful downward stokes against the water resistance, while the external rotators are relaxed and resistance free on the upward stroke in the air.

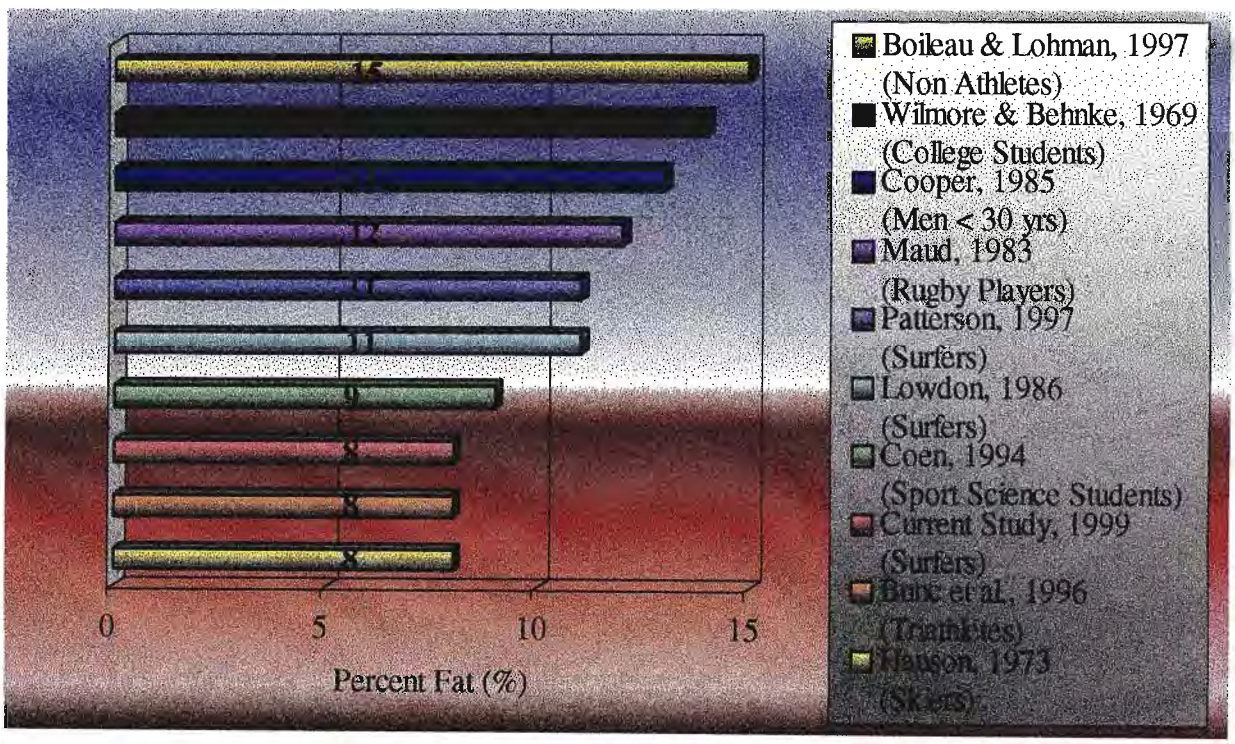
Generally, the upper body strength for surfers is great. Strong power in the triceps, biceps, deltoids and latissimus dorsi are required for surfing, as underdeveloped muscles in these regions can lead to fatigue and hinder a surfers performance. The upper body strength is not only required for paddling, but also assists in "duck unders" when oncoming waves approach.

Furthermore, the arms are used when standing up on the surfboard. Once the surfboard has gathered enough momentum on the moving wave, the arms push down the surfboard, so that the feet are quickly moved into position so that the wave can be ridden to the beach.

5.3 Anthropometery and Fitness Components

5.3.1 BODYFAT PERCENTAGE

Lowdon (1980) also theorised that because surfers are constantly in contact with a wet and windy environment, their bodies may adapt by keeping extra fat for protection. However, in a sport that requires so much agility as surfing, a large percentage of fat can be a serious disadvantage.



<u>Figure 5.10</u> Comparisons of Percent Bodyfat among different Sport Performers

Cooper (1985) stated that for men under the age of thirty, thirteen percent bodyfat would be acceptable, and that nine percent would be ideal. According to data from **Boileau and Lohman (1977)**, the average bodyfat for male college non athletes was approximately fifteen percent.

Coen (1994) found the average bodyfat percent of sport science students to be nine percent. **Bunc *et al.* (1996)** stated that the bodyfat percentage for the best Czech male triathletes was eight percent.

Maud (1983) recorded the bodyfat of a rugby union team, which averaged twelve percent. **Lowdon (1980)** estimated bodyfat percent from anthropometeric data, predictions of male surfers' body fat ranged from nine to thirteen percent. By comparison, **Wilmore and Behnke (1969)** identified that college students had slightly higher percent body fat at a level of fourteen percent for males.

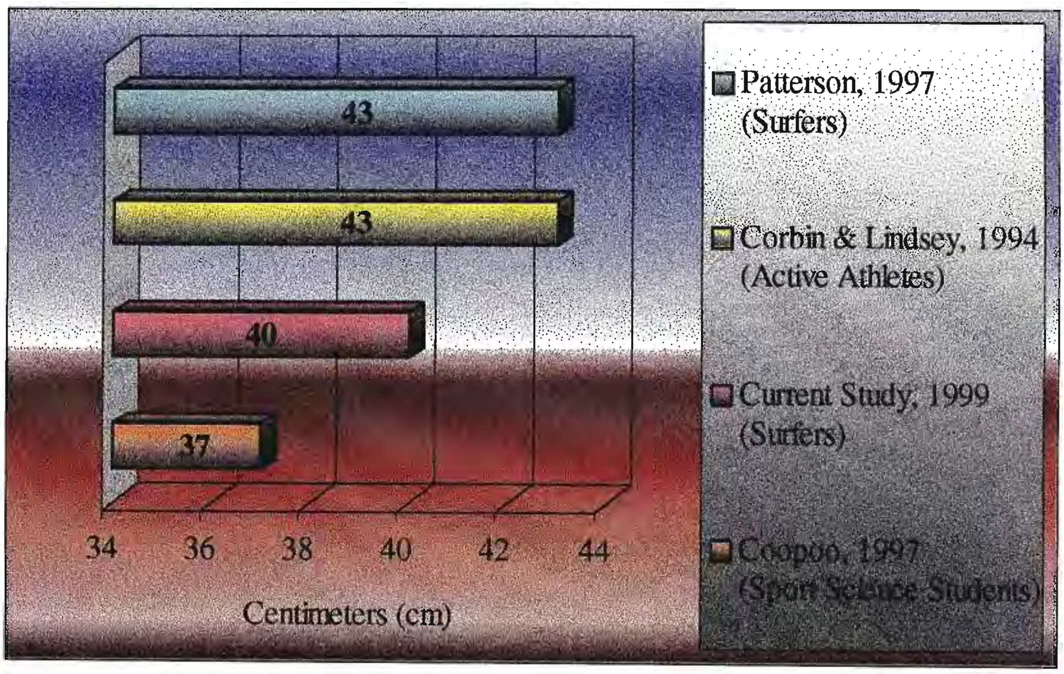
Hanson (1973) recorded scores for the U.S. Nordic ski team, through water weighing and obtained scores of eight percent for male skiers. Some sports related to surfing show average bodyfat percentages of between six to twelve percent for swimmers, seven to fifteen percent for skiers, six to twelve percent for kayakers. **Patterson (1997)** found the average percent fat for provincial surfers ranged among nine to thirteen percent.

Lower percent body fat results can be attributed to the fact that majority of the subjects tested live in the east of the country, where throughout the year, warm days and waters prevail. It was noted that surfers from the west, where colder conditions are experienced, had more percent body fat on average.

The minimum and maximum values obtained in this research were two percent and twenty-two percent respectively. Long hard training (surfing) in the summer months, often for prolong periods, leads to a more favourable reduction in bodyfat, and an increase in strength and lean muscle mass.

The advantages of a low bodyfat level include physical and mechanical gains due to an increased power to mass ratio, a reduction in "dead weight", which is very much a prerequisite in surfing. High power to mass ratios plays an important part in surfing, as it assists in the development and improvement of speed, agility and the ability to change direction quickly, all of, which are central to surfing. Low bodyfat scores also indicate the ability for the body to utilise the fats stores while surfing for prolong periods.

5.3.2 FLEXIBILITY



<u>Figure 5.11</u> Comparisons of Flexibility scores among different Sport Performers

It should be noted that few comparisons were made in the current study, as the modified **Hoeger and Hopkins** test was used, which is different to more popular protocols used by other authors not mentioned in this research. **Coopoo et al. (1997)** revealed flexibility norms for sport science students to be thirty-seven centimetres.

Corbin and Lindsey (1994) suggested that a standard flexibility of an individual should be between twenty-five and thirty-four centimetres. **Corbin and Lindsey (1994)** also demarcated in the same study that a score of approximately forty-three centimetres was considered as an excellent flexibility rating.

Patterson (1997) identified mean flexibility scores for twenty provincial surfers. Although the sample population studied was very small the surfers averaged forty-three centimetres ($\pm$SD=7.1), which is regarded as excellent. A larger sample of surfers would therefore indicate a more accurate result of flexibility among surfers. Scores in this study are better than the values obtained by **Coopoo *et al.* (1997)** and **Gillam *et al.* (1986)**, as most of the surfers could touch their toes in the sit and reach test.

A factor hindering flexibility in most surfers is genu varum. **Patterson (1997)** identified that ninety percent of the subjects studied, were bowlegged, thus leading to hypoflexibility of the muscles, joints and ligaments in the legs and the lower back and gluteal region. Minimum and maximum flexibility scores obtained were twenty-eight and sixty centimetres respectively. Mean flexibility scores obtained in this research was forty centimetres ($\pm$SD=7.59).

Satisfying results might be attributed to the specificity of the sport, where kicking is a vital component or it could be due to the flexibility evaluation being modified. Other factors that may favour good results include; young age, increased muscle size, low percentage of adipose tissue and the gender of the subjects tested.

It is necessary that every professional surfer acquires good flexibility, without this important fitness component, their ability to perform manoeuvres will be greatly restricted. Flexibility is a major component in surfing as it allows for further development of other characteristic such as speed and strength, or may enhance their effective application in the technique of surfing. It also assists surfers as it increases the range of movement through which force can be applied; therefore, total performance is enhanced.

5.3.3 AGILITY

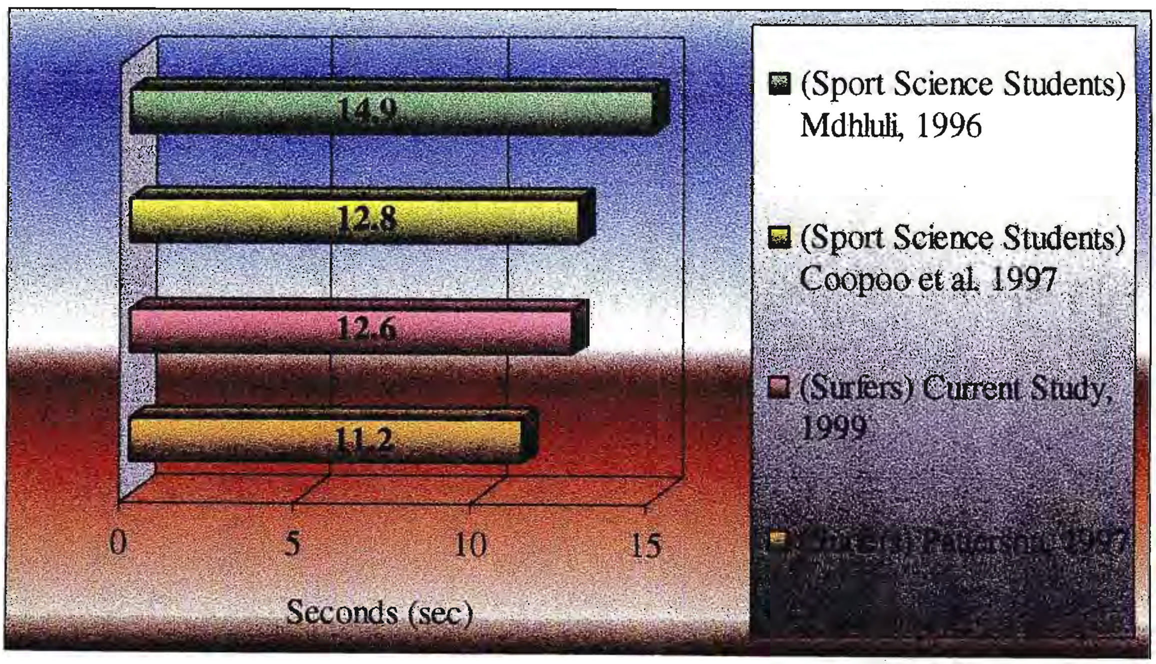


Figure 5.12 Comparisons of Agility scores among different Sport Performers

The T-Drill agility test was set up in a standard score table and was compared to the norms of male sport science students tested by **Coopoo *et al.* (1997)**.

At the fiftieth percentile, the students averaged a score of 12.86 seconds. **Patterson (1997)** recorded average scores of twenty provincial surfers for the T-Drill agility test to be 11.2 seconds ($\pm$SD=1.78).

This score is better than that recorded by **Coopoo et al. (1997)** as the agility of the sample of surfers was of a higher standard than that of sport science students. However, the score is lower than that obtained in this research, and would be due to the small sample tested, which does not accurately reflect the true agility of surfers.

The great agility score accomplished by the surfers in this research, is an indication of the fast muscle fibre types, which allows for quick powerful turns. The score also indicates better dexterity, which is very specific to surfing compared to sport science student's (12.8). One of the judging criteria in competitive surfing is for a surfer to execute the most radical controlled manoeuvre in the critical section of a wave with speed and power.

This requirement would never be accomplished if the elite surfer had a lack of agility. Improved agility also assists the surfer in the capacity to change direction of movement rapidly without loss of balance. It is a combination of speed, strength, reaction time, balance, and neuromuscular co-ordination.

5.4 Balance and Motor Fitness Components

5.4.1 STATIC BALANCE

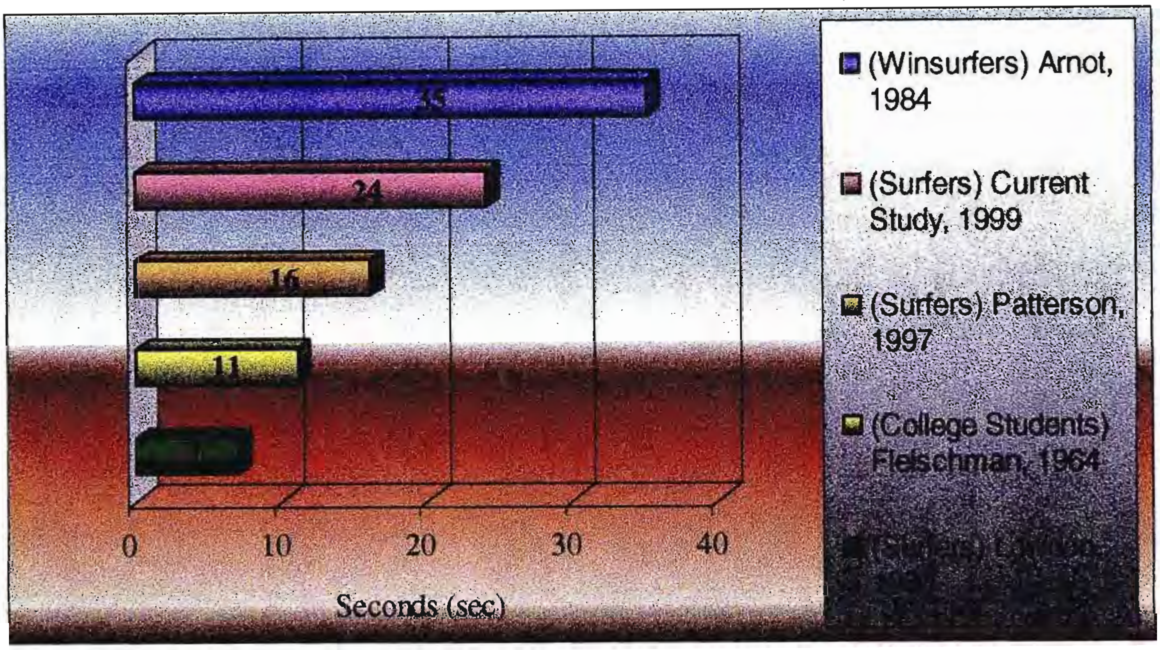


Figure 5.13 Comparisons of Mean Static Balance scores among different Sport Performers

Development of sensory perception is accompanied by knowledge of what is going on in the body. As a result, a total awareness and control of co-ordination and balance will become automated.

The two most important aspects in the sport of surfing consists of balance and balance stabilisation. Static balance starts from the moment a surfer stands on the surfboard in the water, continuing through sophisticated requirements of keeping upright on waves. All elite surfers can perfect this skill.

Lowdon (1980) examined the balance component in seventy-six international surfboard riders and showed that the mean static balance for the group of surfers tested was seven seconds (±SD=4.3). **Lowdon (1980)** recommended that the balance skills tested in the study were not those specific balance skills required for surfing. **Fleischman (1964)** obtained scores in static balance for college students, which showed a mean score of 11.93 seconds.

Arnot (1984) studied windsurfers who showed similar balance techniques to that of surfers regarding static balance. Windsurfers were able to maintain their static balance for thirty-five seconds. The mean static balance score obtained by twenty provincial surfers **Patterson (1997)**, was 16.9 seconds. In this study, the mean static balance score obtained by the surfers was better than those of the provincial surfers, (see **Figure 5.13**).

Static balance scores in this research amounted to twenty-four seconds, which is not as great as windsurfers, but is better than similar surfers and non water based activity athletes. The static balance score obtained in this research was considerably lower than other similar watersport performers, such as windsurfers and surfers.

A poor minimum value of ten seconds was recorded, and a moderate high score of sixty-five seconds was noted. However, these scores are better than provincial surfers who could only manage a mean score of sixteen seconds **Patterson (1997)**. Poor static balance scores could be attributed to the inability to accurately measure and analyse the precise static balance of a elite surfer.

5.4.2 DYNAMIC BALANCE

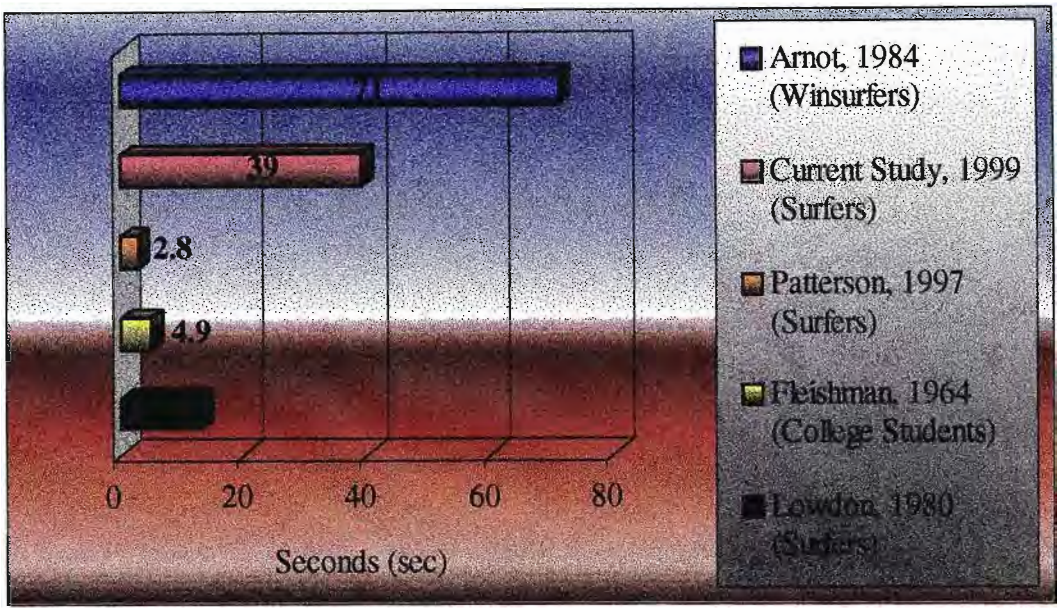


Figure 5.14 Comparisons of Dynamic Balance among different Sport Performers

Lowdon (1980) measured the dynamic balance of international surfers with the mean result of thirteen seconds (±SD=13.7). **Lowdon (1980)** found no significant difference between the two balance tests. Poor specificity of testing the components was attributed to the low score, (see **Figure 5.14**).

Fleischman (1964) reported a mean score in dynamic balance of 4.90 seconds for college students. **Arnot (1984)** showed that windsurfers have great dynamic balance, showing a mean score of seventy-one seconds. The mean dynamic score in this research is lower than that of windsurfers but better than provincial surfers with a score of twenty-eight seconds **(Patterson, 1997)**.

The agility required to keep balance on a moving board while constantly reacting with movements of the sea are central to surfing, as is the related ability to stabilise the body between movements with small, precise balance corrections.

It is unusual to observe that balance results were all of a low standard, and could be attributed to the inability to strictly assess dynamic balance. When a surfer rides a wave, there are various uncontrollable factors that cannot be avoided by the surfer, or measured in a clinical setting by a researcher. Factors such as constantly moving-water and surfboard, the size, and shapes of waves, and the spray of the water are eliminated during the testing procedures, which does not justifiably illustrate the balance ability possessed by an elite surfer. To develop sensory perception and the necessary awareness in surfing, modified activities and games can be used to create an understanding and perfecting the skills in surfing.

Surfers consciously make themselves aware of responses and reactions, thereby accumulating movement information. Thus, the aspect of self-control under a range of conditions faced by a surfer should be rehearsed, where the athlete is to maintain a performance-facilitating equilibrium.

5.4.3 MOTOR LEARNING

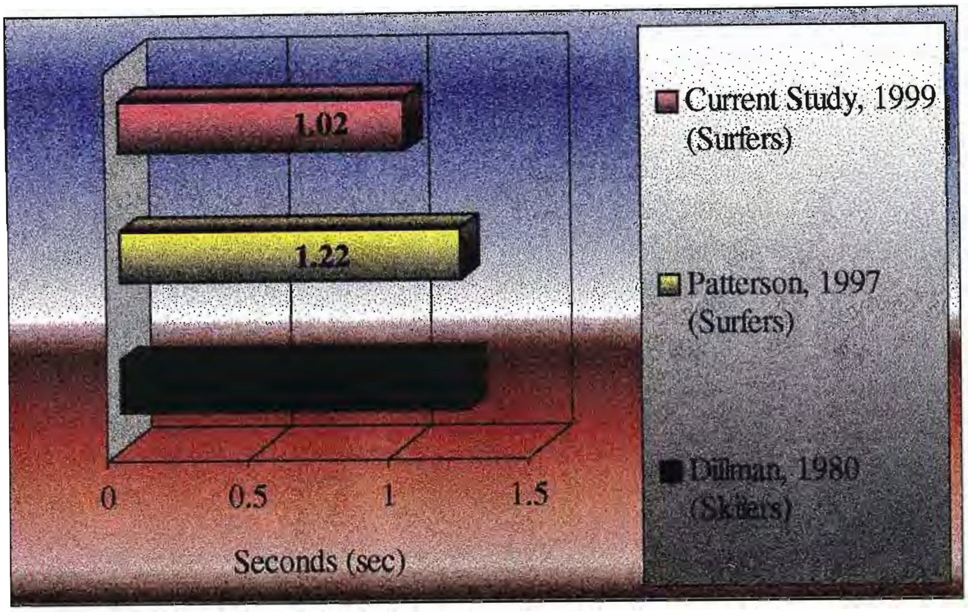


Figure 5.15 Comparisons of improvements in Motor Learning among different Sport Performers

Results of motor learning measurements among surfers, in this research, seem to show a favourable advantage of these individuals regarding agility, co-ordination and quick reaction time or reflexes.

The difference in trails, measured via the hexagon obstacle, is not as great as recorded by **Patterson (1997)** and **Dillman (1980)** who recorded mean improvements of 1.22 and 1.24 seconds respectively.

The results do suggest that the raw motor skills that underlie the skills of surfing are not very trainable but can be improved. These skills cannot be learned on land, but should rather be practised daily in different types of surfing conditions.

A well-formed image of correctness is crucial to motor learning in surfing, and such an image is best formed by practice, improving the ability to move fast in relation to body strength, power and learning. Elite surfers could move faster than other sport performers, which indicates that anticipation is an important component of surfing.

Elite surfers can surf faster and with more power than novice surfers, because they learn to perceive their movements prior to actually completing them. The part method of learning involves the breaking down information into smaller units to be learned separately, and then recombining them to perform the whole skill. Surfers master this component very quickly, as can be seen by the improvement from the first to the fifth trial.

As in any sport, the athletes who become good at that particular sport already have a certain natural ability in the necessary skills that the sport requires. The nature versus nurture argument, could be the subject for further research.

5.5 Physiological and Psychological Components

5.5.1 LUNG FUNCTION CAPACITIES

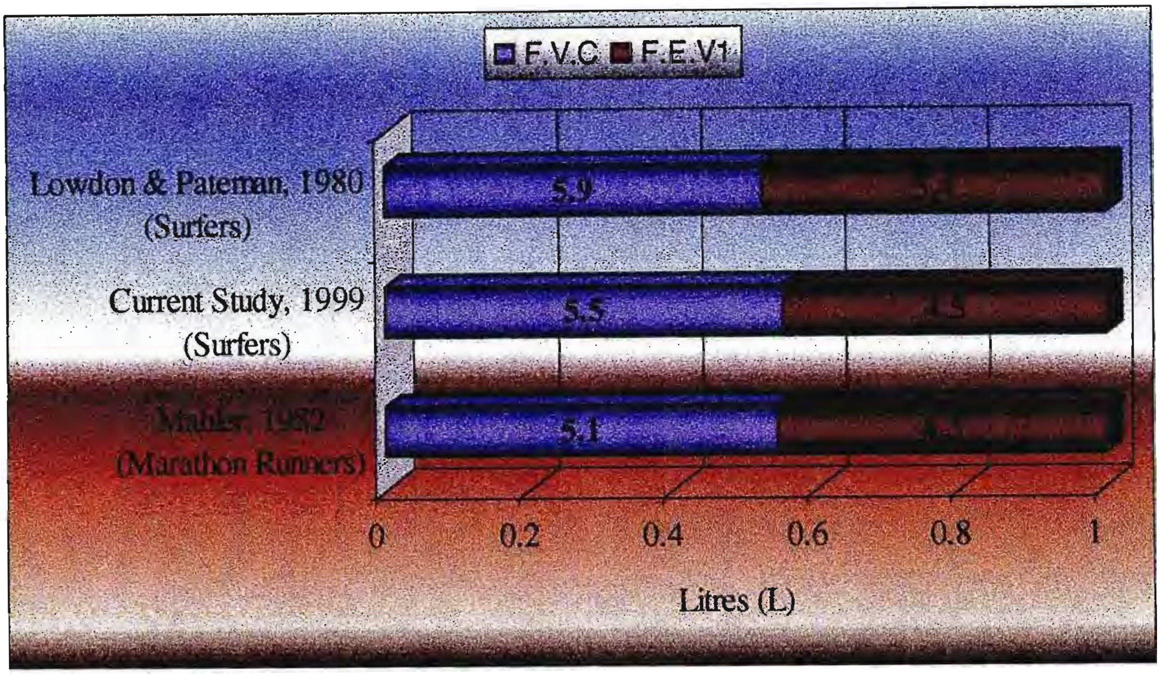


Figure 5.16 Comparisons of Lung Function Capacities among different Sport Performers

The total volume of air that can be voluntarily moved in one breath, from full inspiration to maximum expiration, or vice versa, is termed Forced Vital Capacity (FVC). FEV_1 provides an indication of expiratory power and overall resistance to air movement in the lungs.

Scores for 61 male surfers exceeded predicted values for age and height. Indicating that surfer sample tested has a more efficient lung function than that predicted for a normal age-matched population. Normally about eighty-five percent of the FVC can be expelled in one second.

The surfers tested in this study expressed a Forced Vital Capacity of 108 percent greater than what was predicted. The Forced Expiratory Volume in one second was 104.6 percent greater than the predicted values. Of the sixty-one surfers tested, twenty-six percent (n=16) of the surfers smoked cigarettes and/or marijuana and 4.9 percent (n=3) were medicated for asthma.

Although these values varied considerably regarding body position and size, the average values are usually four to five litres in healthy young men. FVC's of six to seven litres are not uncommon in tall athletes. The highest recorded FVC thus far has been 8.1 litres, which was measured from a Olympic gold medallist cross country skier **(McArdle *et al.*, 1994)**. In this research, the highest actual score achieved by any surfer was 8.0 litres with the minimum score of 3.9 litres.

Lowdon and Pateman (1980) obtained scores for seventy-six international surfers and identified similar findings. Scores that **Lowdon and Pateman (1980)** obtained for FVC and FEV_1 were 5.9 and 5.4 litres which is 111.5 percent and 118.5 percent of predicted values respectively. Marathon runners were found to have a mean FVC of 5.13 litres and a mean FEV_1 of 4.32 litres **(Mahler *et al.*, 1982)**.

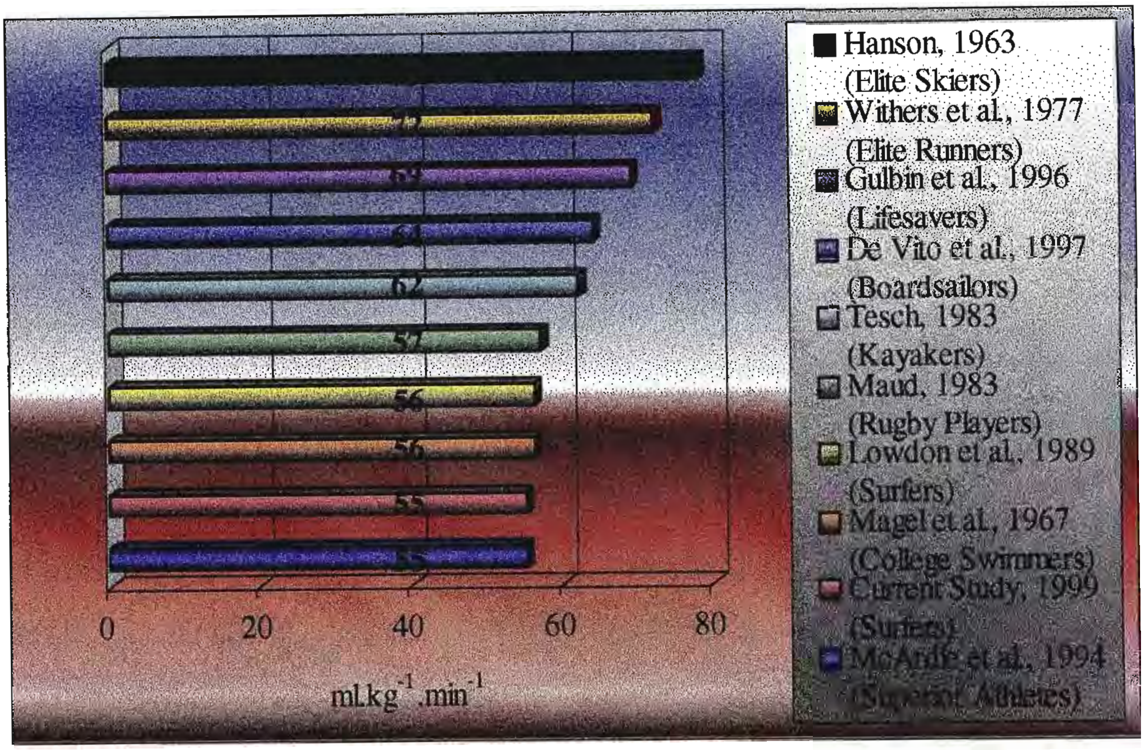
This current research confirms **Lowdon and Pateman (1980)** where surfing athletes exceed normal age-matched values. Obtained values for FVC and FEV_1 were 5.5 and 4.5 litres, which is 108 and 104 percent of age-matched population respectively. This concurs and supports **Lowdon (1985)** findings that surfing can and should be prescribed for asthmatics.

Smoking will impact negatively on the health of a surfer, later in life and should be avoided. Ventilation depends on two factors: the volume of air moved per breath and the speed at which this air can be moved. The speed of airflow depends on the resistance offered by the respiratory passages to the smooth flow of air, as well as the resistance offered by the chest and lung tissue to a change in shape during breathing.

When surfing in Hawaii, the waves are big and the water is shallow. Often there are times when an elite surfer is sucked under a wave and is submerged under water for extended periods. It is not unusual to be caught in the reef. Many novice surfers and bathers have died as a result. **(Sills, personal communications, 1999)** explained how important breathing was and how surfers improved this function for surfing.

A common custom in Hawaii, when the surfing conditions are unsuitable, is to carry a huge and heavy rock underwater in a swimming pool and walk along the bottom of the pool, holding the breath for as long as possible. This is believed to aid a surfer when held under water for long periods.

5.5.2 MAXIMUM OXYGEN UPTAKE



<u>Figure 5.17</u> Comparisons of Mean Peak Maximum Oxygen Uptake Scores among different Sport Performers

Scores of cardiovascular fitness for surfers, in the current research, appear to be very good. Results can be compared to fellow surfers, swimmers, kayakers and triathletes populations.

Lowdon and Pateman (1980) reported submaximal bicycle results of seventy-six male surfers. Pre-test average heart rates were recorded at 66 bpm (±SD=11.7) which is 10 beats slower than those obtained from this research. A reason for an elevated heart rate can be attributed to nervousness and anxiety response. Estimations of peak VO_2max and maximal oxygen uptake were shown to be 70.2 $ml.kg^{-1}.min^{-1}$ (±SD=10.7) and 4.73 $l.min^{-1}$ (±SD=0.81) respectively **(Lowdon and Pateman, 1980)**.

Lowdon *et al.* (1989) tested twelve male surfers on a maximal treadmill test. The mean values recorded for peak oxygen uptake, minute ventilation, respiratory quotient, oxygen pulse and heart rate were 56.3 $ml.kg^{-1}.min^{-1}$ ($\pm$SD=3.9), 4.02 $l.min^{-1}$ ($\pm$SD=0.44), 150.1 $l.min^{-1}$ ($\pm$SD=12.0), 1.21 ($\pm$SD=0.9), 21.1 ml.kg.beat ($\pm$SD=2.7) and 191 bpm ($\pm$SD=5.7) respectively. The scores obtained in both tests were very similar.

However better results of minute ventilation, oxygen pulse and respiratory quotient were obtained in this study. The superior scores obtained in this research are possibly due to the fact that the population tested are representative of the best surfers in South Africa.

The mean rating of perceived exertion in **Lowdon *et al.* (1989)** study was 18.5 that is higher than the 17.1 obtained in this study, which may account for the lower heart rate obtained too. A lower ratings of perceived exertion may be attributed to the inexperience of the subjects being tested on the protocols for the first time.

The current study's population was extremely fit and compared favourably to other sport performers. **McArdle *et al.* (1994)** stated that a score of 54.9 $ml.kg^{-1}.min^{-1}$ is regarded as good. The VO_2 max scores obtained in this test was average compared to other sporting disciplines.

By comparison, elite middle and distance runners average a peak VO_2max of 72 $ml.kg^{-1}.min^{-1}$ **(Withers *et al.*, 1977)**, and elite Nordic skiers average 75 $ml.kg^{-1}.min^{-1}$ **(Hanson, 1963)**. The scores are similar to those of lifesavers, kayakers, college swimmers, rugby players and boardsailors who measured scores of 68.6 $ml.kg^{-1}.min^{-1}$ **Gulbin *et al.* (1996)**, 61.5 $ml.kg^{-1}.min^{-1}$, **Tesch, (1983)**, 55.5 $ml.kg^{-1}.min^{-1}$, **Magel *et al.* (1967)**, 56.6 $ml.kg^{-1}.min^{-1}$, **Maud, (1983)** and 63.6 $ml.kg^{-1}.min^{-1}$, **(De Vito *et al.*, 1997)**.

The aerobic condition of the surfers studied, proved to be of an above average standard. Surfing incorporates both the aerobic and anaerobic energy system for the duration of the activity. Good cardiovascular fitness can be attributed to vast amounts of upper body work completed during the activity of surfing.

The heart and lungs are taxed more when lying in a supine position and it is very difficult to sustain this type of exercise for prolonged periods. **Assmussen and Hemmingsen, (1958)** demonstrated that the aerobic capacity during arm work was considerably lower than that utilising the legs.

A rectilinear relationship was demonstrated between heart rate and O_2 uptake during both arm work and leg work. The slope was steeper for arm work. A conclusion was that work with smaller muscle groups did not allow maximum heart rate to be attained. The subjects tested were at ease with the testing protocol, and perhaps a board paddling test would have produced better and more accurate results. Thus the specificity of testing surfers in the laboratory can be questioned, although it is a good starting point.

Although surfers are not involved in an endurance race, the nature of the sport and the requirements of competition develop high aerobic capacities. A surfer is required to catch and perform well on a wave immediately after a strenuous paddle.

Oxygen pulse is regarded as a marker of peripheral oxygen extraction (a-vO_2). The higher the score the better delivery of oxygen to the muscles can take place.

The score in this study is similar to those obtained by **(Reaburn, personal communications, 1999)** elite triathletes with scores of 30 to 35 ml.kg.beat. The male Czechoslovakian population has a mean oxygen pulse of 16.8 ml.kg.beat that is attained at the age of eighteen **(Macek *et al.*, 1979)**. Scores achieved by the surfers, indicate that they are more able to utilise oxygen by the demanding muscles.

Rapid recovery or repayment of oxygen debt is another excellent indicator of cardiovascular fitness, as there is a general relationship between aerobic power and heart rate recovery following standard exercise **Shepard (1971)**.

Lowdon (1980), Hagerman *et al.* (1970) and **Thomas (1975)** reported recovery heart rates through submaximal exercise tests on surfers and Olympic pentathletes respectively on a similar test protocol. Results showed scores for 5 minutes post exercise of 77 and 100 bpm respectively.

Again, this suggests that elite surfers are an extremely fit population with a recovery heart rate of 95 bpm only after 3 minutes rest. This is supported by **McArdle *et al.* (1994)** by comparing recovery heart rate results for males in the Harvard step test, although the Harvard step test is not a reliable measure of fitness.

The explanation for a good recovery heart rate achieved by the surfers, is because as soon as they have reached the take off area, they try to catch the next possible wave to the beach. Once the ride is completed, they again paddle strenuously to the take off area, where the cycle is repeated. Surfing shows that most surfers do not really have much time to recover aerobically.

The anaerobic component of surfing is fairly high as will be seen later in the chapter. The only occasion when a surfer will take longer to catch a wave, is when the muscles become tired because they are fatigued from long bouts of surfing.

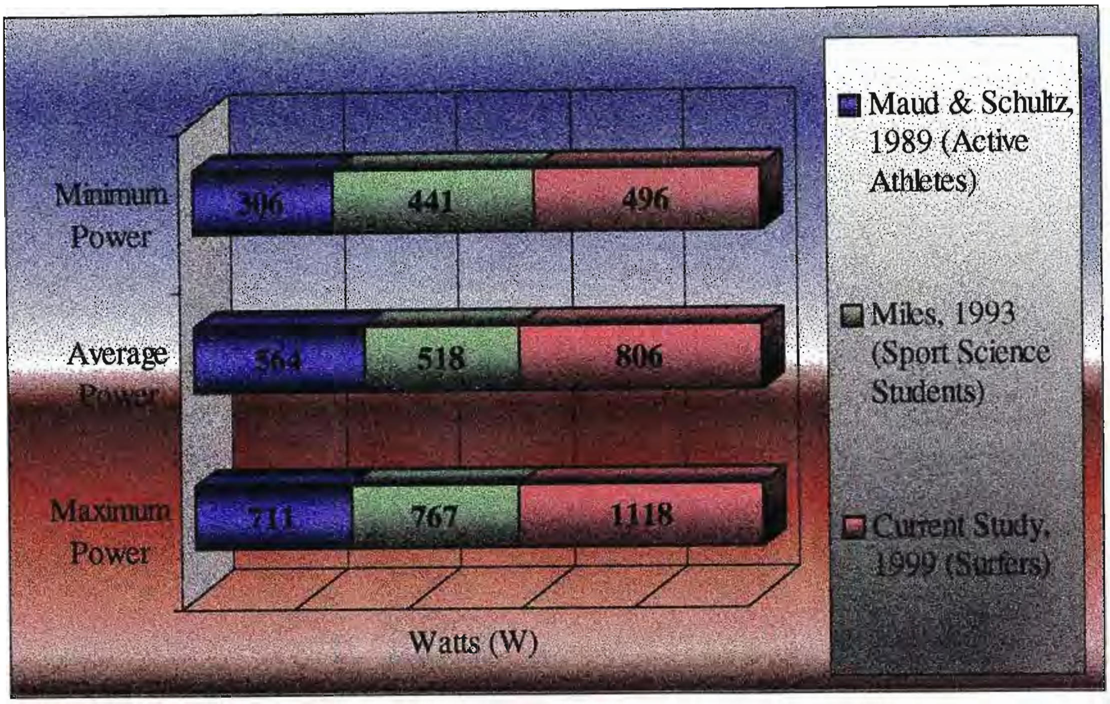
The nature of the sport, with the length of time spent in the water, involves interval paddling over distances of from 50 to 200 meters **(Lowdon and Pateman, 1980)**. The surfer must also paddle against the resistance of the water, with a surfboard being partially submerged, which increases the drag and ultimately makes it more difficult to paddle. Factors that may support good aerobic conditioning of surfers is a low level of body fat, a favourable power to weight ratio, and the ability to exercise at a high percentage of VO_2 max for sustained periods. Surfing incorporates all of these factors.

5.5.3 WINGATE ANAEROBIC TEST

The Wingate anaerobic test is used world-wide and is considered one of the most valid tests of anaerobic muscle performance. The test is based on cycling at maximal speed for thirty seconds, against a high breaking force. This force remains constant throughout the test, but because it is so high, the subject cannot maintain the initial velocity for more than a few seconds, before starting to slow down.

The anaerobic findings for surfers are not surprising, and were expected to excel in this domain, as the riding of the waves is highly anaerobic in nature. Surfing is a sport that requires high amounts of power, speed and strength, all of which are central to the anaerobic system.

Comparisons against other results somewhat flatter the surfers performance in the Wingate anaerobic test. The **Maud and Schultz (1989),** research, including the **Miles (1993)** study were found to be the best related reviews regarding measurements of similar parameters practised in this research.

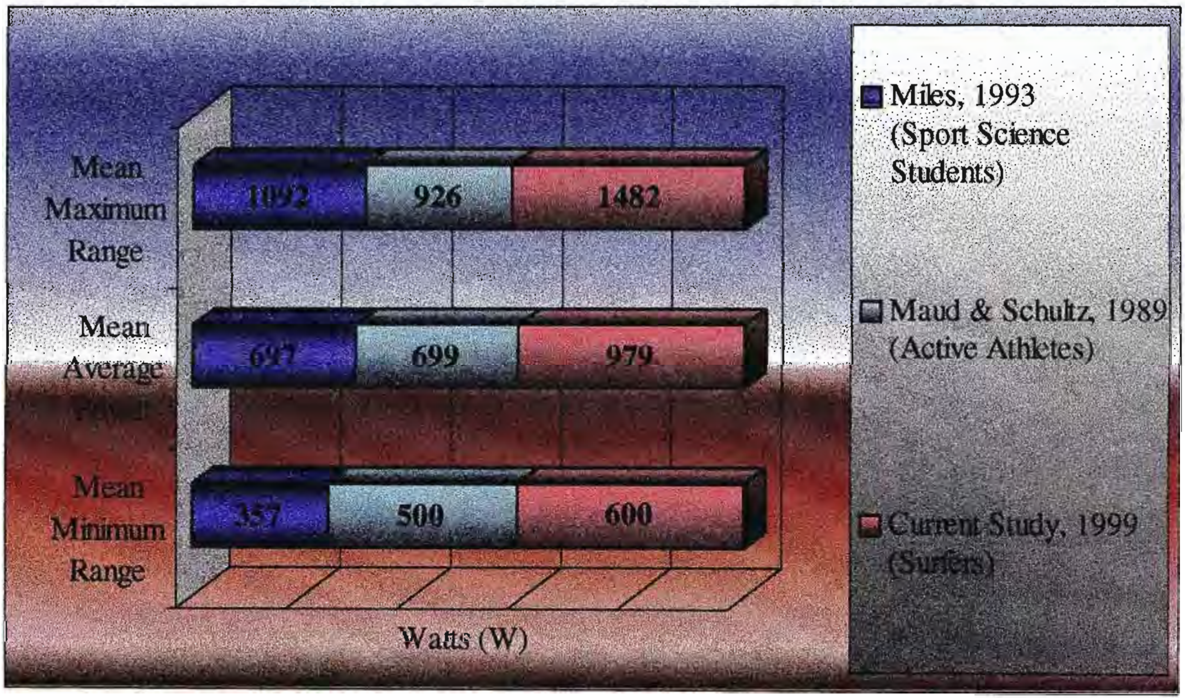


<u>Figure 5.18</u> Comparisons of Mean Maximum, Minimum and Average Anaerobic Scores among different Sport Performers

In the current study the average capacity (mean power) has a mean value of 806.82 watts compared to 564.6 watts in the study by **Maud and Schultz (1989),** and 518.9 watts by **Miles (1993)**. The maximum and minimum average capacity scores obtained in this research were 1118 watts and 496 watts respectively.

These results are favourable when compared to those of **Maud and Schultz (1989),** who obtained 711 watts and 306 watts respectively, and **Miles (1993)** who recorded 767 watts and 441.3 watts respectively. The nature of the sport of surfing is highly specific to the anaerobic component in fitness. Surfers require large amounts of high-intensity power bursts of energy, while riding on a wave, which can last for as long as twelve seconds. There will probably be a heavy reliance on the ATP-PC energy system, which is required for a part of the movement in surfing.

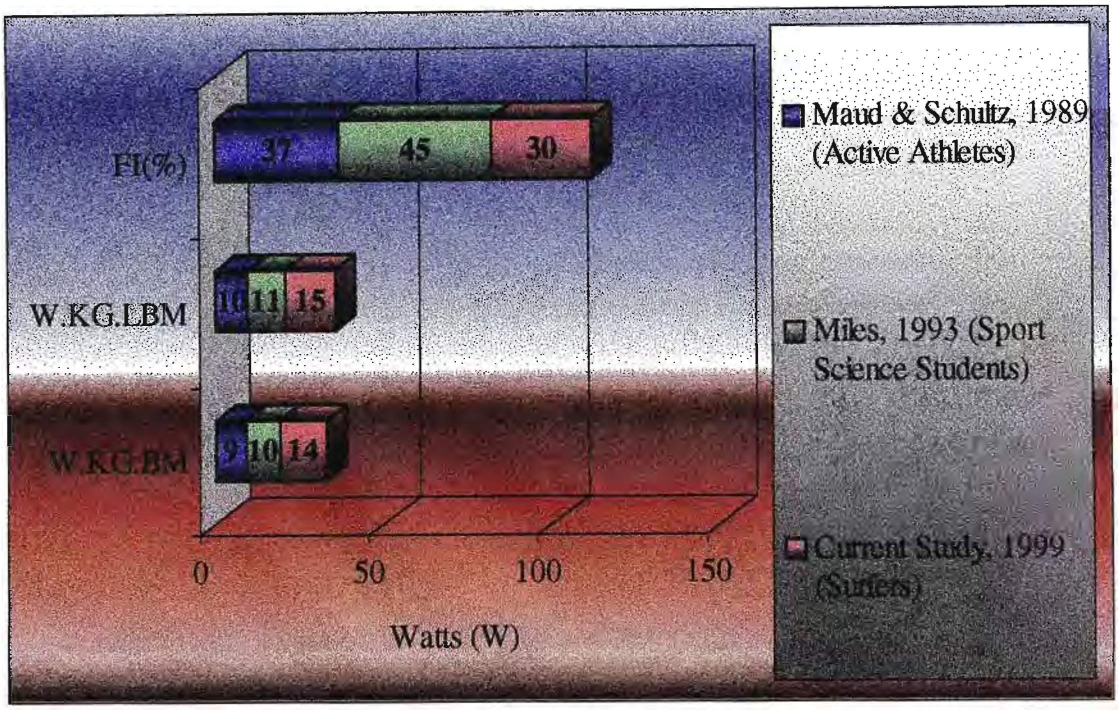
Relatively good results can also be attributed to the fast and powerful kicking demand, while paddling to the take off area and for catching a wave. Good anaerobic conditioning in surfers suggest that the lower limbs are made up of fast twitch muscle fibres for the short rides on the waves, and also slow twitch fibres, for the endurance of a competition. Fibre typing profiles has not as yet been undertaken in surfers to confirm the above statement.



<u>Figure 5.19</u> Comparison of Wingate Mean, Maximum and Minimum Scores among different Sport Performers

The maximum power in this research ranged from 1482 watts to 600 watts respectively with a mean maximum power of 979.18 watts. Again, this result scores high when compared to, **Maud and Schultz (1989),** who obtained 926.7 watts to 500.1 respectively watts with a mean of 699.5 watts.

Miles (1993) showed similar results for maximum power of 1092 watts to 357 watts respectively with a mean of 697.6 watts. Higher scores achieved by the surfers is due to the specificity of the sport, which requires high anaerobic power for prolong periods.



<u>Figure 5.20</u> Comparisons of Mean Fatigue Index, Power per Kilogram Body Mass, Power per Kilogram Lean Body Mass Scores among different Sport Performers

The variable of power per kilogram to body mass of the research had a mean maximum and minimum value of 17.7 $W.kg^{-1}.bm^{-1}$ and 8.82 $W.kg^{-1}.bM^{-1}$ with a mean of 14.05 $W.KG^{-1}.BM^{-1}$. Power per kilogram body mass indicates that the surfer population tested, produced more strength per kilogram, than those of other elite sport performers. Scores of power per kilogram lean body mass are far greater than those indicated by other authors.

Maud and Schultz (1989), obtained maximum and minimum values of 11.90 $W.kg^{-1}.bm^{-1}$ and 5.31 $W.kg^{-1}.bm^{-1}$ with a mean score of 9.18 $W.kg^{-1}.bm^{-1}$. **Miles (1993)** results were better than those obtained by **Maud and Schultz (1989),** and obtained a mean maximum and minimum values of 13.13 $W.kg^{-1}.bm^{-1}$ and 6.25 $W.kg^{-1}.bm^{-1}$, with a mean of 10 $W.kg^{-1}.bm^{-1}$.

In the current study, the power per kilogram to lean body mass generated was a mean maximum and minimum value of 18.84 $W.kg^{-1}.lbm^{-1}$ and 9.13 $W.kg^{-1}.lbm^{-1}$ respectively, with a mean of 15.22 $W.kg^{-1}.lbm^{-1}$. **Maud and Schultz (1989),** obtain maximum and minimum values of 12.96 $W.kg^{-1}.lbm^{1}$ and 6.55 $W.kg^{-1}.lbm^{-1}$ respectively and a mean of 10.18 $W.kg^{-1}.lbm^{-1}$. **Miles (1993)** showed similar results of 14.51 $W.kg^{-1}.lbm^{-1}$ and 7.03 $W.kg^{-1}.lbm^{-1}$ respectively and a mean value of 11.04 $W.kg^{-1}.lbm^{-1}$.

Surfers require the ability to sustain their anaerobic energy and power for longer durations than other sport performers, as the nature of the sport requires large amounts of fast kicking, paddling and standing. Furthermore, results do not only suggest that the subjects tested are more anaerobically trained than other sport performers, but also show that other factors improve the anaerobic component a surfer demands.

Factors such as a fast reaction time, the ability to generate and sustain high power outputs, speed of movements for up to thirty seconds, and a moderate aerobic power base are required for surfing. Great leg strength was noted during isokinetic conditions, therefore the power produced by the population tested was not surprising.

The fatigue index is an indicator of the level of anaerobic fitness of the subjects. In this study it was interesting to note that the subjects were more anaerobically trained than those used in **Maud and Schultz (1989),** and **Miles (1993)**. This study had a maximum of minimum fatigue index of 53.3 percent and 10 percent with a mean of 30.61 percent. These results of this study was expected as they were elite competitors compared to **Maud and Schultz (1989),** and **Miles (1993)**.

Maud and Schultz (1989), obtained a maximum and minimum score of 57.51 percent and 14.71 percent respectively with a mean of 37.67 percent. **Miles (1993)** results were similar which showed a maximum of 72.72 percent a minimum of 9 percent and a mean of 45.25 percent.

Explanations for such excellent anaerobic results could be attributed to the surfers being more anaerobically trained and such specific fitness properties required for the sport of surfing. The low level of fatigue among the surfers, indicates that the sport of surfing requires vast amounts of anaerobic power.

The fatigue index is a indicator of the level of anaerobic fitness of the surfers. In this research, it was interesting to note that the subjects were anaerobically well trained. The surfers also appeared to have a better score as their training is surfing specific and thus the anaerobic energy system is incorporated in their daily surfing. Fast powerful kicking, and immediate standing incorporates majority of the surfing process. Even although this time does not amount to a lot, most of the movements are anaerobic in nature, for short periods of time.

5.5.4 RATING OF PERCEIVED EXERTION (RPE)

The lowest rating obtained for the anaerobic component (RPE=14) was greater than the same rating for the aerobic component (RPE=12). Which indicated at the lowest level, that the surfers found the anaerobic component more difficult. The highest values obtained for both components were twenty, which indicated the strenuous nature of the test and the exertion carried out by the surfers. Athletes have a very well developed capacity to assess the level of exertion. Associated feelings provided essential information that was important for determining the welfare or extent of threat to an individual. How an athlete felt about exertion moderated the response to exercise and effort.

Taylor (1979) concluded that when one exercises with a "positive" attitude the efficiency of physiological function is optimal. However, when the attitude is "negative" that efficiency is reduced. The Borg Perceived Exertion Scale has been "found to be valid and reliable measure of exertion", according to **Acevedo *et al.* (1994)**.

Research on perceived exertion has shown that ratings of perceived exertion increase with intensity of exercise **(Hardy and Rajeski, 1989)**. **Acevedo et al. (1994)** supported this theory, where ratings of perceived exertion were related to heart rate and lactate levels across all running intensities. It has also been noted that;

> "Rating of Perceived Exertion at lactate threshold and/or blood lactate concentrations are not affected by gender, training state, exercise modality, specificity of training or training intensity" **(Steed *et al.*, 1994)**.

5.6 CONCLUSION

In concluding this research study, it can be stated that both of the objectives of this study have been fulfilled. The first being to develop profiles for surfers and secondly, the establishment of norms for this specific group of sportspersons.

The physiological fitness profiles that emerged from this study indicate the importance of muscular strength, anaerobic power, anaerobic endurance, aerobic endurance, co-ordination, agility, balance and flexibility. Today, successful surfers are shorter and lighter than their predecessors. Physical characteristics of elite surfers revealed an average height (1.77 cm) and body mass (69 Kg).

The nature of surfing is that the population tested surf four days a week, and for three hours per day. In each hour of surfing, approximately fourteen to nineteen waves may be caught and ridden by a surfer. The wave riding only amounts to a short time in the total hour, approximately three to five minutes. The remainder of the time is spent paddling, kicking, and waiting for more waves.

5.6.1 MUSCULAR STRENGTH & ENDURANCE

The muscular strength of surfers is particularly good, and is required for hard paddling, and will assist a surfer when catching a wave. The muscular strength is facilitated by muscular endurance, as paddling can be tiresome, when performed over a few hours.

Elite surfers have great muscular endurance to assist the aerobic component. Without great muscular endurance in the arms and legs, the paddling and kicking aspects would be hindered, and the surfer would battle in most surfing conditions and competitions. Scores of the muscular strength components showed favourable scores of forty-eight push ups and forty-three sit ups respectively.

5.6.2 AEROBIC ENDURANCE

From the moment a surfer stands on the surfboard, manoeuvres and speed are generated for maximum points and enjoyment, and all of this is done in a matter of six to fifteen seconds. Once the ride has ended, the surfer returns to the take off area to repeat the cycle again. The aerobic demands of competitive surfing may approach 90 to 95 percent of the athlete's maximal heart rate. Elite surfers have a high VO_2 max. This may reflect the demands of the sport rather than the training programs of the actual athletes.

When riding a wave, muscular activity acts to impede blood flow and oxygen delivery. Consequently, anaerobic metabolism is increased, which shows utilisation from both fast and slow twitch muscle fibres (**Anderson *et al.*, 1988**).

This cycle can be repeated ten to twenty times per hour, so great aerobic endurance is needed. The surfer must also accommodate periods of being held underwater, waves breaking on top of them and lying in a supine position for extended periods. The aerobic endurance score in this study of 54 $ml.kg^{-1}.min^{-1}$. is a good reflection of what endurance capacity is required for this sport.

5.6.3 ANAEROBIC CAPACITY

The anaerobic component of surfing is well developed and surfers will tend to excel in this component, as it is central to surfing. This sport emulates interval training. Sustained interval training follows the overload principle to increase exercise capacity.

There are numerous occasions where a surfer is required to paddle fast and furiously for a wave, which demands high amounts of anaerobic endurance and a low fatigue rate of this anaerobic capacity. Good anaerobic fitness was noted in the lower and upper limbs. The lower limbs showed little fatigue during the Wingate Anaerobic test, with a score of thirty percent. In the same test, the surfers produced 806 watts which was an excellent score.

5.6.4 ISOKINETIC EVALUATIONS

Leg strength is of particular importance. An elite surfer posses great leg strength, which can be seen in the isokinetic testing results. Great strength is produced by the nature of surfing, where bodyweight is supported while executing manoeuvres on waves for short periods. This movement which is unique to surfing, also assists the surfers favourable anaerobic performance. The most common motion while riding requires the surfer to rapidly change direction at speed, using the legs **(Williams, personal communications, 1990)**.

Elite surfers have strong legs when peak torque is measured during isokinetic conditions involving knee extension. This may be a specific adaptation, since the surfer is often in a crouched positioned for a prolonged period while surfing. A surfers leg strength correlates significantly with their performances in big and small wave riding.

There was no significant difference in leg strength between natural and goofy foot surfers. There was no significant strength or deficit differences noted between the left and right legs, and the quadriceps to hamstring ratio appeared to be normal, as compared to other sport performers **(Kannus and Jarvinen, 1990)**. The mean peak extension and flexion values were 208 Nm and 186 Nm respectively.

The shoulder muscles and actions required for surfing are important for strength and endurance. The shoulder strength of surfers is equally good when measured during isokinetic conditions involving extension, flexion, and internal and external rotation. The strength is a specific adaptation to the sport and paddling power is critical when catching waves. The lack or weakness of this component will retard a surfers improvement in the sport, as eight-five percent of the sport of surfing is paddling orientated.

Good scores of the isokinetic shoulder tests, indicate the importance of upper body for surfing. Mean peak flexion and extension results were 64 Nm and 92 Nm respectively. This score was normal when compared to other sport performers **(Freedson *et al.*, 1993)**. Internal and external rotation scores, were also similar to other sport performers. Scores obtained for mean peak internal and external rotation were 58 Nm and 31 Nm respectively.

5.6.5 MOTOR CO-ORDINATION AND AGILITY

An important perquisite in surfing, which is the underlying talent, is balance and motor learning ability. Although these abilities are very difficult to train, they can be learnt and perfected, so that surfing performance is improved. The more a surfer surfs, the better and quicker the motor learning developing will take place.

This routine and regular practice of the sport, will in turn, improve the balance ability and reaction of a surfer, which unfortunately, due to technology was unable to be exactly measured in this study. Excellent agility and improved balance, assists the surfer with better scores and levels of flexibility, which if limited, would hinder any surfers performance.

This development can be noted in the results obtained from this research study. Motor learning was quickly learnt in this research, which indicated that new and raw stimulus, can be learnt, and repeated readily. Agility also enhances the motor learning capacity of a surfer, as being able to react quickly to a stimulus is central to surfing. Good results for the T-Drill agility test were noted, with a mean score of 12.6 seconds.

5.6.6 FLEXIBILITY AND BODY COMPOSITION

A surfer's performance will be restricted if there is limited flexibility and excess body fat. As is the case for most sports, this component needs to be of the minimum hindrance to the athlete. Without adequate flexibility, a surfer will be unable to execute and perform manoeuvres in the most critical part of the wave. There are instances where a surfer performs manoeuvres, with the body in awkward positions, if these different body positions cannot be achieved, few points will be gained and could lead to an early exit in a competition.

The body composition, is also important in this regard, where any extra fat, would not only limited the flexibility of the surfer, but will also restrict the surfers agility, balance and centre of gravity. The average percent body fat achieved by the population tested in this research was approximately eight percent, which indicates a favourable body composition.

It appears from the above profiles and the surfers tested that the National surfer would have to achieve a percentile of 80% or greater, with respect to the norms developed. The Provincial surfer should achieve at least a percentage of 60% to 80% of the norm table developed. Finally the novice surfer should obtain at least 50% and above for quality training for surfing. Surfers should train specifically for surfing, however, all-round fitness training on land should not be neglected in order to achieve the best fitness results.

For the individual surfer and promising team members, comparisons against the norms developed will outline strength and weaknesses in performance and fitness. This promotes motivation and persistence to make the qualifying entry for selection by improving those parameters that are considered weak and could hinder performance. Profiles also assist in the return to peak performance following injury. Detraining due to injury could decrease reflexes, reaction times and motor learning, which was once mastered. Norms also assist coaches and fitness advisors with the classification of surfers into fitness categories.

5.7 RECOMMENDATIONS

Educating the surfing industry and athletes about the value of physical fitness and conditioning is of the utmost importance. Both water and dry land training programs should focus on the elevation of the fitness components tested in this study. The poor results of balance in surfers suggest that the protocols used in the study were not specific balance skills needed for surfing.

New balance protocols should be devised so that the test is completely surfing specific. Further research in surfing should be undertaken in the actual environment where surfing takes place.

Norms have been developed for surfers from the results attained in this study. This will be useful in the assessment of surfers in the future, as profiles of surfers were described earlier.

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Appendix A Characteristics and Training Practices of Subjects tested.

SUBJECT	AGE (yrs.)	HEIGHT (cm.)	WEIGHT (Kg.)	EXPERIENCE (yrs.)	DAYS/WEEK	HOURS/DAY	ILLNESSES	MEDICATION
1	23	182	76.2	14	7	4		
2	22	165	68	12	5	4	ASTHMA	VENTOLIN
3	28	164	68.8	16	5	2		
4	23	185	64.4	12	5	4	ASTHMA	BEROTEC
5	20	175	70	8	6	3		
6	18	181	69	2	4	3		
7	21	182	77.6	7	3	2		
8	22	177	61.6	9	5	3		
9	24	187	84	16	6	3		
10	23	196	80	12	5	4	ASTHMA	VENTOLIN
11	18	179	66	10	7	6		
12	19	178	61	10	6	2		
13	24	178	70	14	5	2	DIABETIC	HUMALIN
14	18	174	67	10	7	3		
15	16	177	66	4	3	4		
16	17	172	63	2	3	4		
17	19	177	65	12	6	4		
18	18	176	68	9	7	5		
19	16	178	65	9	5	3		
20	18	173	61	9	5	3		
21	32	167	60	20	2	2		
22	18	175	65	8	7	2		
23	18	180	69	8	7	2		
24	35	178	79.8	23	2	1.5		
25	22	176	72	12	3	2		
26	25	162	62.4	13	6	3		
27	26	182	77	15	3	2		
28	28	181	82.6	14	5	2		
29	25	176	86	15	3	3		
30	23	178	61	6	3	2		
31	34	180	68.8	16	2	2		
32	19	181	69.8	1	6	3		
33	28	184	83	7	4	3		
34	19	180	65	6	6	3		
35	33	172	72	25	5	2		
36	18	175	73	6	3	2		
37	34	180	76	20	2	2		
38	35	173	65.8	20	2	6		
39	28	167	69	20	4	3		
40	22	176	73	10	7	4		
41	27	171	66.8	12	6	3		
42	51	175	63	37	7	2		
43	32	177	78.6	18	3	2		
44	28	171	67.6	16	2	4		
45	23	178	78	15	7	3		
46	28	183	78.8	8	5	2		
47	26	178	64.8	15	3	1.5		
48	17	179	65.8	6	7	3		
49	19	190	75.6	7	7	4		
50	19	182	78.6	8	4	3		
51	29	181	71	15	5	3		
52	24	189	87.6	11	7	5		
53	34	172	61.7	20	5	1.5		
54	25	189	75.3	11	6	2		
55	27	176	65	16	5	2		
56	25	174	74.6	10	7	1.5		
57	31	171	71.6	25	2	1		
58	37	180	67	25	5	3		
59	16	171	53.2	8	7	6		
60	19	166	59.6	8	7	6		
61	17	174	60.4	6	7	5		

Appendix B: Means, Standard Deviations, Maximum and Minimum Scores for every test component

EXAMINATIONS	MEAN	STANDARD DEVIATION	MAXIMUM	MINIMUM	NUMBER OF SUBJECTS
FLEXIBILITY	40 (cm.)	7.59	60	28	61
SIT UPS	43 (reps.)	10.66	79	28	61
PUSH UPS	48 (reps.)	9.69	67	25	61
STATIC BALANCE	24.4 (sec.)	12.21	65	10	61
DYNAMIC BALANCE	39.8 (sec.)	13.08	68	20	61
T-DRILL	12.6 (sec.)	1.19	10.8	15.8	61
BODY FAT PERCENT	8.2 (%)	4.5	22	1.9	61
LEFT HAND GRIP STRENGTH	50.5 (Kg.)	6.67	65	34	61
RIGHT HAND GRIP STRENGTH	52.9 (Kg.)	8.09	71	32	61
HEXAGON OBSTACLE:					
FIRST TRY	6.29 (sec.)	0.89	8.5	4.7	61
FIFTH TRY	5.28 (sec.)	0.67	6.8	3.9	61
F.V.C.	5591.97 (mls.)	792.19	8000	3920	61
F.E.V.	4566.91 (mls.)	530.35	5550	3410	61
AEROBIC CAPACITY	54.93 ($l.Kg^{-1}.min^{-1}$.)	6.02	70.2	39.6	54
ANAEROBIC CAPACITY	806.82 (Watts.)	118.16	1118	496	61

SUBJECT	PECTORAL SKINFOLDS	ABDOMEN SKINFOLDS	THIGH SKINFOLDS	TOTAL SKINFOLDS	FLEXIBILITY	T-DRILL
1	4	15	15	10.2	45	10.80
2	3	5	7	3.3	30	11.40
3	6	11	12	8.7	29	11.20
4	4	9	9	5.5	35	12.00
5	10	19	15	12.5	33	12.80
6	3	9	6	4.2	46	11.00
7	9	19	11	10.8	43	11.90
8	4	7	8	4.2	48	11.00
9	6	8	12	7.5	60	13.30
10	4	8	9	5.5	49	14.00
11	6	8	12	6.8	57	11.80
12	6	8	11	6	52	12.40
13	6	11	15	9.3	35	13.50
14	5	10	10	5.7	45	11.10
15	8	12	20	10.5	44	13.20
16	8	10	10	6.8	40	13.70
17	4	8	12	5.8	39	14.00
18	4	8	5	3.9	38	12.60
19	3	7	7	3.9	39	13.40
20	5	8	7	4.8	37	11.90
21	4	14	9	8.5	32	14.00
22	4	6	12	4.8	40	11.00
23	6	12	17	9.5	45	12.90
24	20	21	20	18.6	28	15.80
25	12	20	15	9.9	40	11.00
26	7	20	19	12.1	39	12.90
27	10	25	8	12.4	36	13.20
28	10	14	9	9.7	30	12.30
29	27	31	12	19.7	42	15.40
30	3	7	9	4.6	36	14.00
31	7	12	12	9.4	28	13.00
32	5	7	12	5.8	37	11.60
33	20	23	32	22	43	15.00
34	4	12	8	5.8	38	12.60
35	23	29	18	20.7	35	14.30
36	4	4	10	3.9	35	11.80
37	8	12	17	11.3	30	12.40
38	9	7	-15	9.8	41	13.20
39	3	6	9	6	42	14.10
40	12	8	26	13.3	29	12.00
41	4	9	11	2.3	39	12.40
42	4	12	12	8.7	55	15.40
43	15	20	13	16.9	38	13.50
44	8	10	20	12.2	50	11.30
45	8	9	10	7.8	51	12.50
46	7	11	14	9.3	46	14.00
47	7	20	11	11.5	45	12.30
48	5	7	9	5.7	60	11.13
49	4	6	9	3.9	46	12.80
50	5	9	7	4.8	52	11.10
51	7	19	16	11.4	32	11.40
52	4	8	6	5.3	45	12.60
53	5	11	13	8.4	37	12.20
54	4	11	6	5.5	45	12.80
55	4	8	6	5.9	40	11.40
56	3	6	8	4.6	35	11.80
57	3	5	7	4.6	46	12.50
58	6	13	16	10.9	36	12.90
59	3	6	6	2.9	40	12.10
60	3	5	6	2.9	43	11.30
61	3	5	5	1.9	36	13.00

Appendix D: Raw Scores for One Minite Push Ups, Sit Ups and Left, Right, and Combined Grip Strength.

SUBJECT	PUSH UPS (no.)	SIT UPS (no.)	GRIP STRENGTH RIGHT (Kg.)	GRIP STRENGTH LEFT (Kg.)	COMBINED GRIP STRENGTH (Kg.)
1	56	40	57	50	107
2	50	35	45	45	90
3	55	40	56	50	106
4	40	30	45	50	95
5	43	40	55	45	100
6	36	45	70	54	124
7	49	40	60	55	115
8	40	41	45	55	105
9	40	50	60	60	120
10	25	37	44	40	84
11	40	37	38	37	75
12	45	40	45	40	85
13	51	41	48	48	96
14	52	50	38	45	85
15	33	35	52	48	100
16	47	39	46	45	91
17	43	34	53	45	98
18	50	48	46	39	85
19	57	50	40	40	80
20	61	55	51	50	101
21	34	30	49	51	100
22	56	76	55	53	108
23	63	29	45	53	108
24	45	34	56	60	116
25	40	41	56	50	105
26	55	79	40	45	85
27	56	46	56	54	110
28	60	50	55	54	109
29	34	29	50	46	106
30	45	35	55	48	103
31	64	56	58	51	109
32	56	54	56	54	110
33	55	47	60	52	112
34	55	48	55	47	102
35	43	36	32	34	72
36	67	55	66	64	130
37	45	37	65	55	120
38	54	29	50	48	98
39	54	50	49	46	95
40	60	52	50	46	96
41	61	56	64	58	122
42	46	45	56	60	116
43	56	45	49	54	103
44	53	64	60	59	119
45	39	60	45	45	90
46	56	45	55	50	105
47	52	38	67	64	131
48	47	47	54	57	111
49	58	39	53	48	101
50	63	58	49	50	99
51	64	53	64	61	125
52	38	28	52	49	101
53	53	45	66	55	121
54	45	47	71	65	136
55	48	48	56	55	111
56	36	38	64	59	123
57	31	29	46	46	92
58	34	30	47	44	92
59	34	36	56	54	110
60	57	49	50	49	99
61	41	35	51	46	97

Appendix E: Raw Scores for Static Balance, Dynamic Balance, Motor Skills and Co-Ordination.

SUBJECT	BLIND STORK BALANCE (sec.)	BALANCE STABLISATION (sec.)	FIRST TRIAL (sec.)	FIFTH TRIAL (sec.)	TRAIL IMPROVEMENTS (sec.)
1	45	38	6.4	5	1.4
2	25	46	5.7	4.8	0.9
3	45	52	6	4.8	
4	34	45	5.4	5	0.4
5	35	46	6.4	4.6	1.8
6	46	35	6.4	5	1.4
7	28	25	7	6	1
8	13	30	5.2	4.4	0.8
9	15	24	6.7	5.4	1.3
10	11	20	5.9	4.7	1.2
11	15	63	5.2	4.9	0.3
12	15	55	7.1	5.7	1.4
13	13	48	6.6	6	0.6
14	10	20	4.9	4.8	0.1
15	12	22	7	5.5	1.5
16	24	35	6.6	6	0.6
17	12	25	6.5	6	0.5
18	40	50	7.6	6.7	1.1
19	42	68	6.6	5.5	1.1
20	37	55	5.5	5	0.5
21	21	45	6.8	6	0.8
22	65	55	5	4.5	0.5
23	25	49	7.9	5.5	2.4
24	25	26	8.5	6.5	2
25	17	22	6	4.2	1.8
26	20	45	6.5	4.7	1.8
27	15	67	6.6	6	0.6
28	10	60	7.9	6	1.9
29	11	51	7.8	6.7	1.1
30	30	40	5.5	5	0.5
31	18	50	5.8	4.6	1.2
32	39	25	6.6	5.6	1
33	10	40	7	5.9	1.1
34	31	29	4.8	4.5	0.3
35	16	45	6.6	5.7	0.9
36	20	39	6	4.7	1.3
37	40	40	5.5	5	0.5
38	26	26	4.9	4.8	0.1
39	18	50	5.8	5.6	0.2
40	45	42	5.9	5	0.9
41	10	33	6.7	5.2	1.5
42	17	41	6.1	5	1.1
43	45	65	6	5.8	0.2
44	30	40	7.6	4.9	2.7
45	10	26	5.9	5	0.9
46	18	25	6.9	5.4	1.5
47	17	44	6.9	5.6	1.3
48	26	36	4.8	4.5	0.3
49	25	46	6.9	4.7	2.2
50	37	60	5.7	4.9	0.8
51	17	45	5	4.8	0.2
52	46	40	4.9	4.6	0.3
53	14	25	6.8	5.6	1.2
54	19	22	7.5	6.7	0.8
55	20	20	7.4	6.8	0.6
56	15	26	5.9	5	0.9
57	26	46	6.4	6	0.4
58	19	45	7.4	5.9	1.5
59	19	45	4.7	3.9	0.8
60	16	27	5.5	4.7	0.8
61	26	20	6.5	4.5	2

AppendixF: Raw Scores for Isokinetic Flexon and Extension for the Right Leg.

RIGHT	PEAK FLEXION TORQUE	ANGLE OF OCCURRENCE	FLEXION TORQUE TO BODY WEIGHT	PEAK EXTENSION TORQUE	ANGLE OF OCCURRENCE	EXTENSION TORQUE TO BODY WEIGHT	PEAK FLEXION TO EXTENSION TORQUE
1	155.29	19.5	2.43	202.35	3.16	4.45	76.74
2	148.24	30	2.12	197.65	49.5	2.82	75
3	155.29	23.5	2.25	208.24	45	3.02	74.58
4	225.88	15.5	2.69	320	55	3.81	70.59
5	170.59	28.5	2.22	251.76	53	3.27	67.76
6	129.41	22	2.12	254.12	52.5	4.17	50.93
7	136.47	16.5	1.68	254.12	57	3.14	53.7
8	143.53	20	2.17	211.76	62	3.21	67.78
9	114.12	17	1.87	170.59	67	2.8	66.9
10	143.53	1	2.14	197.65	52.5	2.95	72.62
11	136.47	26.5	1.95	214.12	52	3.06	63.74
12	127.06	38.5	1.93	225.88	60	3.42	56.25
13	115.29	14	1.86	191.76	68	3.09	60.12
14	117.65	18	1.81	202.35	57.5	3.11	58.14
15	122.35	21.5	2.01	150.59	55	2.47	81.25
16	134.12	18	1.97	171.76	48	2.53	78.08
17	91.76	21	1.41	202.35	53.5	3.11	45.35
18	160	7	2	216.47	56	2.71	73.91
19	141.18	23	1.96	197.65	53	2.75	71.43
20	141.18	16	2.28	168.24	59.5	2.71	83.92
21	145.88	30	1.89	254.12	61	3.3	57.41
22	178.82	24	2.18	272.94	53	3.32	65.51
23	183.53	61.5	2.62	265.88	15	3.8	69.03
24	87.06	72	1.43	221.18	11	3.63	39.36
25	124.71	49	1.92	221.18	25	3.4	56.38
26	145.88	58	2.11	212.94	26	3.09	68.51
27	135.29	66	1.57	208.24	18	2.42	64.97
28	141.18	78.5	2.05	185.88	25.5	2.69	75.95
29	112.94	57	1.69	148.24	16	2.21	76.19
30	178.82	50.5	2.15	240	27	2.89	74.51
31	124.71	14	1.73	218.82	51.5	3.04	56.99
32	155.29	15	2.39	247.06	64	3.8	62.86
33	148.24	30	2.14	221.18	65	3.2	67.02
34	124.71	27.5	2.08	189.41	61	3.16	65.84
35	160	16	2.19	305.88	68	4.19	52.31
36	150.59	12.5	2.32	178.82	54	2.75	84.21
37	152.94	8.5	2.01	207.06	59	2.72	73.86
38	178.82	66	2.29	230.59	22.5	2.96	77.55
39	141.18	76	1.86	214.12	27	2.82	65.93
40	55.29	66.5	0.88	103.53	8.5	1.64	53.41
41	107.06	81	1.6	175.29	27.5	2.62	61.07
42	165.88	56.5	2.27	211.76	22	2.9	78.33
43	124.71	46	1.86	205.88	15.5	3.07	60.57
44	115.29	69.5	1.48	211.76	28.5	2.71	54.44
45	169.41	57	2.23	216.47	18	2.85	78.26
46	156.47	69	2.37	243.53	8	3.69	64.25
47	128.24	68	1.81	228.24	18.5	3.21	56.19
48	128.24	60	1.97	170.59	20.5	2.62	75.17
49	155.29	63	2.19	197.65	9	2.78	78.57
50	156.47	69.5	2.09	247.06	26.5	3.29	63.33
51	211.76	66	2.41	300	25.5	3.41	70.59
52	112.95	9	1.74	172.94	55	2.66	65.31
53	123.53	66	1.99	174.12	26	2.81	70.95
54	181.18	77	2.42	263.53	20.5	3.51	68.75
55	129.41	56	1.8	216.47	25.5	3.01	59.78
56	71.76	64	1.35	108.24	27.5	2.04	66.3
57	96.47	32.5	1.61	141.18	16	2.35	68.33
58	136.47	60.5	2.27	190.59	24	3.18	71.6

Appendix G: Raw Scores for Isokinetic Flexion and Extension for the Left Leg.

LEFT	PEAK FLEXION TORQUE	ANGLE OF OCCURRENCE	FLEXION TORQUE TO BODY WEIGHT	PEAK EXTENSION TORQUE	ANGLE OF OCCURRENCE	EXTENSION TORQUE TO BODY WEIGHT	PEAK FLEXION TO EXTENSION TORQUE
1	162.35	18	2.54	222.35	45.5	3.47	73.02
2	151.76	31	2.17	188.24	50.5	2.69	80.62
3	117.65	30	1.71	175.29	48	2.54	67.11
4	235.29	14.5	2.8	296.47	49	3.53	79.37
5	164.71	18.5	2.14	272.94	55.5	3.54	60.34
6	103.53	30.5	1.7	208.24	37.5	3.41	49.72
7	112.94	36.5	1.39	185.88	47.5	2.29	60.76
8	112.94	4	1.71	221.18	58	3.35	51.06
9	112.94	24.5	1.85	161.18	65	2.64	70.07
10	147.06	1	2.19	200	54	2.99	73.53
11	145.88	15	2.08	192.94	39	2.76	75.61
12	141.18	12	2.14	212.94	49.5	3.23	66.3
13	124.71	1	2.01	197.65	53	3.19	63.1
14	127.06	18	1.95	197.65	56	3.02	64.28
15	109.41	20.5	1.79	188.24	49	3.09	58.12
16	108.24	22	1.59	170.59	46	2.51	63.45
17	77.65	32	1.19	207.06	47	3.19	37.5
18	157.65	9.5	1.97	223.53	49	2.79	70.53
19	108.24	36	1.5	218.82	58	3.04	49.46
20	130.59	12	2.11	192.94	46	3.11	67.68
21	160	5.5	2.08	265.88	48.5	3.45	60.18
22	185.88	23	2.26	288.24	35	3.51	64.48
23	178.82	53	2.55	250.59	17	3.58	71.36
24	132.94	75	2.18	183.53	20	3.01	72.44
25	160	67	2.46	242.35	29	3.73	66.02
26	141.18	47.5	2.05	208.24	22.5	3.02	67.8
27	145.88	66.5	1.7	188.24	13	2.19	77.5
28	132.94	7	1.93	189.41	46	2.75	70.19
29	103.53	65	1.55	136.47	29	2.04	75.86
30	168.24	58.5	2.03	264.71	32	3.19	63.56
31	108.24	14	1.5	192.94	47.5	2.68	56.1
32	168.24	13	2.59	244.71	64	3.76	68.75
33	162.35	28	2.35	242.35	52	3.51	66.99
34	117.65	17.5	1.96	171.76	50	2.86	68.49
35	143.53	10	1.97	291.76	45	4	49.1
36	160	8.5	2.46	169.41	36	2.61	94.44
37	134.12	3	1.76	175.29	42	2.31	76.51
38	178.82	51.5	2.29	247.06	26	3.17	72.38
39	142.35	81	1.87	216.47	22	2.85	65.76
40	55.29	64	0.88	96.47	16	1.53	57.32
41	122.35	86	1.83	168.24	36.5	2.51	72.73
42	149.41	58	2.05	243.43	24	3.34	61.35
43	134.12	62	2	197.65	27.5	2.95	67.86
44	108.24	67	1.39	202.35	26	2.59	53.49
45	150.59	52.5	1.98	221.18	19	2.91	68.09
46	165.88	70.5	2.51	178.82	2.5	2.71	92.76
47	167.06	74	2.35	171.76	13.5	2.42	97.26
48	123.53	60.5	1.9	181.18	26	2.79	68.18
49	183.53	69.5	2.58	221.18	19	3.12	82.98
50	192.94	56	2.57	243.53	23	3.25	79.23
51	183.53	70	2.09	280	31	3.18	65.55
52	122.35	13.5	1.88	183.53	48.5	2.82	66.67
53	131.76	59.5	2.13	178.82	27	2.88	73.68
54	174.12	58.5	2.32	256.47	24	3.42	67.89
55	122.35	66	1.7	211.76	27.5	2.94	57.78
56	75.29	63	1.42	117.65	30	2.22	64
57	76.47	41	1.27	132.94	8	2.22	57.52
58	136.47	55	2.27	200	24	3.33	68.24

Appendix H: Raw Scores for Isokinetic Flexion and Extension for the Right Shoulder.

RIGHT	PEAK FLEXION TORQUE	ANGLE OF OCCURRENCE	FLEXION TORQUE TO BODY WEIGHT	PEAK EXTENSION TORQUE	ANGLE OF OCCURRENCE	EXTENSION TORQUE TO BODY WEIGHT	PEAK FLEXION TO EXTENSION TORQUE
1	68.24	82.5	0.9	92.94	80	1.22	73.42
2	56.47	150	0.88	87.06	57	1.36	64.86
3	51.76	31	0.76	92.94	56.5	1.37	55.7
4	75.29	32	1.11	112.94	39	1.66	66.67
5	84.71	155	1.21	77.65	52.5	1.11	109.09
6	61.18	40	0.89	98.82	72	1.43	61.9
7	147.06	5	1.75	129.41	103	1.54	113.64
8	72.94	61.5	0.95	84.71	89	1.1	86.11
9	54.12	100.5	0.89	84.71	123.5	1.39	63.89
10	75.29	3	0.93	178.82	88.5	2.21	42.11
11	55.29	123	0.84	115.29	146	1.75	47.96
12	56.47	70	0.93	80	77.5	1.31	70.59
13	65.88	134.5	0.98	76.47	54	1.14	86.15
14	65.88	73.5	0.94	87.06	58	1.24	75.68
15	57.65	105	0.87	90.59	96	1.37	63.64
16	49.41	95	0.8	72.94	81	1.18	67.74
17	65.88	182	1.01	77.65	84	1.19	84.85
18	65.88	11	1.08	89.41	88	1.47	73.68
19	61.18	141	0.9	91.76	55	1.35	66.67
20	38.82	93.5	0.6	77.65	93	1.19	50
21	65.88	67.5	0.82	98.82	103	1.24	66.67
22	56.47	113	0.78	84.71	70	1.18	66.67
23	65.88	102	1.06	80	73	1.29	82.35
24	84.71	104	1.1	98.82	48	1.28	85.71
25	87.88	92	1.07	99.21	57	1.21	88.58
26	57.65	115	0.82	103.53	159	1.48	55.68
27	55.29	134	0.91	92.94	162.5	1.52	59.49
28	48.24	121	0.74	75.29	74.5	1.16	64.06
29	57.65	136.5	0.84	98.82	88	1.43	58.33
30	55.29	119.5	0.64	89.41	89.41	1.04	61.84
31	68.24	81	0.99	100	106	1.45	68.24
32	58.82	5.5	0.88	80	108	1.19	73.53
33	80	137	0.96	122.35	88.5	1.47	65.38
34	62.35	96	0.87	65.88	147	0.92	94.64
35	55.29	107.5	0.85	91.76	133	1.41	60.26
36	61.18	3	0.94	84.71	86	1.3	72.22
37	70.59	1.5	1.18	65.88	140.5	1.1	107.14
38	81.18	8.5	1.11	124.71	173	1.71	65.09
39	57.65	89	0.89	100	88	1.54	57.65
40	65.88	107.5	0.87	103.53	58.5	1.36	63.64
41	72.94	75	0.94	129.41	79	1.66	56.36
42	75.29	118	0.99	109.41	96.5	1.44	68.82
43	47.06	116.4	0.75	76.47	61	1.21	61.54
44	54.12	103	0.81	80	63.5	1.19	67.65
45	68.24	118.5	0.93	103.53	84.5	1.42	65.91
46	63.53	22	0.95	84.71	79	1.26	75
47	65.88	107	0.84	103.53	127	1.33	63.64
48	65.88	4	0.87	122.35	86	1.61	53.85
49	67.06	25.5	1.02	98.82	77.5	1.5	67.86
50	65.88	95	0.93	118.82	99	1.67	55.45
51	55.29	126	0.85	104.71	86	1.61	52.81
52	80	5.5	1.13	141.18	141	1.99	56.67
53	85.88	76	1.15	117.65	46.5	1.57	73
54	103.53	100	1.18	129.41	80	1.47	80
55	63.53	117.5	0.98	84.71	94.5	1.3	75
56	58.82	1.5	0.95	77.65	75	1.25	75.76
57	72.94	1	0.97	112.94	65	1.51	64.58
58	54.12	102	0.75	75.29	55.5	1.05	71.88
59	11.76	108	0.22	35.29	100	0.67	33.33
60	55.29	3	0.92	77.65	81	1.29	71.21
61	61.18	2	1.02	82.35	155	1.37	74.29

Appendix I: Raw Scores for Isokinetic Flexion and Extension for the Left Shoulder.

LEFT	PEAK FLEXION TORQUE	ANGLE OF OCCURRENCE	FLEXION TORQUE TO BODY WEIGHT	PEAK EXTENSION TORQUE	ANGLE OF OCCURRENCE	EXTENSION TORQUE TO BODY WEIGHT	PEAK FLEXION TO EXTENSION TORQUE
1	51.76	54	0.68	85.88	81.5	1.13	60.27
2	80	155.5	1.25	87.06	64	1.36	91.89
3	52.94	77	0.78	95.29	64	1.4	55.56
4	75.29	142.5	1.11	120	66.5	1.76	62.75
5	68.24	90.5	0.97	82.35	69.5	1.18	82.86
6	61.18	31	0.89	95.29	108	1.38	64.2
7	94.12	3.5	1.12	117.65	99	1.4	80
8	80	49	1.04	85.88	69.5	1.12	93.15
9	51.76	126	0.85	65.88	96.5	1.08	78.57
10	72.94	2	0.9	122.35	84.5	1.51	59.62
11	51.76	115.5	0.78	85.88	81	1.3	60.27
12	54.12	84	0.89	70.59	103	1.16	76.67
13	76.47	150	1.14	80	66.5	1.19	95.59
14	72.94	152.5	1.04	103.53	72	1.48	70.45
15	58.82	76	0.89	84.71	71.5	1.28	69.44
16	54.12	86	0.87	71.76	78	1.16	75.41
17	55.29	78	0.85	81.18	64	1.25	68.12
18	63.53	115	1.04	104.71	101.5	1.72	60.67
19	65.88	105.5	0.97	89.41	39	1.31	73.68
20	37.65	112.5	0.58	84.71	95.5	1.3	44.44
21	23.53	53.5	0.29	58.82	114	0.74	40
22	51.76	115.5	0.72	84.71	68	1.18	61.11
23	71.76	0.5	1.16	95.29	70.5	1.54	75.31
24	94.12	3	1.22	89.41	81.5	1.16	105.26
25	87.45	36	1.06	100.21	78.5	1.22	87.27
26	70.59	1	1.01	91.76	87	1.31	76.92
27	51.76	133	0.85	81.18	91.5	1.33	63.77
28	56.47	133.5	0.87	75.29	122.5	1.16	75
29	55.29	106	0.8	103.53	85	1.5	53.41
30	51.76	117	0.6	76.47	69.5	0.89	67.69
31	80	2.5	1.16	104.71	96	1.52	76.4
32	63.53	115	0.95	80	156	1.19	79.41
33	92.94	13	1.12	136.47	68.5	1.64	68.1
34	50.59	108	0.7	80	66	1.11	63.24
35	56.47	112.5	0.87	90.59	108	1.39	62.34
36	52.94	1.5	0.81	84.71	89.5	1.3	62.5
37	58.82	100	0.98	84.71	94	1.41	69.44
38	65.88	94.5	0.9	98.82	90	1.35	66.67
39	61.18	80.5	0.94	95.29	95	1.47	64.2
40	65.88	102	0.87	70.59	92	0.93	93.33
41	89.41	95.5	1.15	114.12	58.5	1.46	78.35
42	68.24	84	0.9	105.88	88	1.39	64.44
43	48.24	119	0.77	75.29	61.5	1.2	64.06
44	62.35	4.5	0.93	85.88	85	1.28	72.6
45	65.88	94	0.9	84.71	90.5	1.16	77.78
46	61.18	101	0.91	82.35	82	1.23	74.29
47	70.59	90	0.9	81.18	127.5	1.04	86.96
48	55.29	109.5	0.73	96.47	94	1.27	57.32
49	65.88	108.5	1	89.41	106	1.35	73.68
50	65.88	2.5	0.93	117.65	82	1.66	56
51	65.88	110.5	1.01	90.59	76.5	1.39	72.73
52	94.12	4	1.33	103.53	147	1.46	90.91
53	89.41	11.5	1.19	100	73	1.33	89.41
54	90.59	83.5	1.03	118.82	60.5	1.35	76.24
55	61.18	86	0.94	75.29	80.5	1.16	81.25
56	47.06	95	0.76	71.76	86	1.16	65.57
57	80	1	1.07	112.94	132.5	1.51	70.83
58	57.65	103	0.8	80	96.5	1.11	72.06
59	11.76	90	0.22	30.59	113	0.58	38.46
60	51.76	96	0.86	70.59	88	1.18	73.33
61	56.47	2.5	0.94	75.29	112	1.25	75

Appendix J: Raw Scores for Isokinetic External and Internal Rotation for the Right Shoulder.

RIGHT	PEAK EXTERNAL TORQUE	ANGLE OF OCCURRENCE	FLEXION TORQUE TO BODY WEIGHT	PEAK INTERNAL TORQUE	ANGLE OF OCCURRENCE	EXTENSION TORQUE TO BODY WEIGHT	PEAK FLEXION TO EXTENSION TORQUE
1	32.94	148	0.43	47.06	23	0.62	70
2	38.82	142.5	0.61	51.76	33	0.81	75
3	29.41	98	0.43	47.06	34	0.69	62.5
4	34.12	132.5	0.5	62.35	28.5	0.92	54.72
5	42.35	114	0.61	47.06	35.5	0.67	90
6	37.65	148	0.55	48.24	52	0.7	78.05
7	42.35	81.5	0.5	84.51	109	1.01	50
8	47.06	149	0.61	54.12	40	0.7	86.96
9	35.29	30	0.58	70.59	141	1.16	50
10	30.59	29	0.38	84.71	42.5	1.05	36.11
11	25.88	15.5	0.39	70.59	84	1.07	36.67
12	28.24	4	0.46	48.24	102	0.79	58.24
13	28.24	120.5	0.42	61.18	15	0.91	46.15
14	42.35	79	0.61	75.29	34	1.08	56.25
15	28.24	47.5	0.43	49.41	81.5	0.75	57.14
16	16.47	88	0.27	42.35	81	0.68	38.89
17	32.94	13	0.51	63.53	79	0.98	51.85
18	34.12	133.5	0.56	72.94	116	1.2	46.77
19	28.24	25	0.42	71.76	104	1.06	39.34
20	21.18	49	0.33	49.41	88	0.76	42.86
21	30.59	110	0.38	56.47	114.5	0.71	54.17
22	23.53	27	0.33	56.47	119	0.78	41.67
23	30.59	34	0.49	49.41	111	0.8	61.9
24	25.69	49	0.33	57.95	105	0.75	44.33
25	30.59	2	0.4	65.88	136	0.86	46.43
26	37.65	35	0.54	65.88	136	0.94	57.14
27	30.59	55.5	0.5	40	136.5	0.66	76.47
28	28.24	38	0.43	57.65	124.5	0.89	48.98
29	30.59	39.5	0.44	54.12	85	0.78	56.52
30	37.65	90	0.44	65.88	124	0.77	57.14
31	37.65	20.5	0.55	56.47	124	0.82	66.67
32	21.18	27.5	0.32	41.18	58	0.61	51.43
33	43.53	111	0.52	95.29	117	1.15	45.68
34	23.53	95.5	0.33	47.06	133.5	0.65	50
35	35.29	21.5	0.54	61.18	117	0.94	57.69
36	61.18	3	0.94	84.71	86	1.3	72.22
37	18.82	16.5	0.31	47.06	66	0.78	40
38	30.59	33	0.42	72.94	133	1	41.94
39	23.53	30	0.36	58.82	90	0.9	40
40	28.24	63.5	0.37	61.18	87	0.8	46.15
41	47.06	44.5	0.6	75.29	114.5	0.97	62.5
42	37.65	20	0.5	71.76	105.5	0.94	52.46
43	21.18	152.5	0.34	42.35	119.5	0.67	50
44	23.53	68	0.35	51.76	71.5	0.77	45.45
45	32.94	98	0.45	70.59	110.5	0.97	46.67
46	29.41	20.5	0.44	80	77.5	1.19	36.76
47	37.65	8	0.48	47.06	27.5	0.6	80
48	49.41	76	0.65	75.29	118	0.99	65.63
49	28.24	75	0.43	54.12	132.5	0.82	52.17
50	28.24	62	0.4	49.41	112	0.7	57.14
51	34.12	9	0.52	56.47	89	0.87	60.42
52	30.59	3	0.43	75.29	97.5	1.06	40.63
53	37.65	24	0.5	61.18	83	0.82	61.54
54	52.94	19	0.6	84.71	120	0.96	62.5
55	29.41	69.5	0.45	57.65	112	0.89	51.02
56	28.24	16	0.46	49.41	91	0.8	57.14
57	47.06	14	0.63	70.59	116	0.94	66.67
58	30.59	75	0.42	48.24	116	0.67	63.41
59	11.76	108	0.22	35.29	100	0.67	33.33
60	28.24	52	0.47	47.06	133.5	0.78	60
61	32.94	26.5	0.55	56.47	80.5	0.94	58.33

Appendix K: Raw Scores for Isokinetic External and Internal Rotation for the Left Shoulder.

LEFT	PEAK EXTERNAL TORQUE	ANGLE OF OCCURRENCE	FLEXION TORQUE TO BODY WEIGHT	PEAK INTERNAL TORQUE	ANGLE OF OCCURRENCE	EXTENSION TORQUE TO BODY WEIGHT	PEAK FLEXION TO EXTENSION TORQUE
1	28.24	141	0.37	37.65	63	0.5	75
2	32.94	74	0.51	44.71	38	0.7	73.68
3	40	62	0.59	51.76	53	0.76	77.27
4	35.29	128	0.52	67.06	57	0.99	52.63
5	37.65	126.5	0.54	48.24	70	0.69	78.05
6	32.94	124.5	0.48	49.41	52	0.72	66.67
7	47.06	89.5	0.56	84.71	119	1.01	55.56
8	47.06	146	0.61	57.65	39.5	0.75	81.63
9	37.65	35	0.62	58.82	135	0.96	64
10	32.94	19.5	0.41	80	66.5	0.99	41.18
11	28.24	27.5	0.43	62.35	12	0.94	45.28
12	30.59	144.5	0.5	51.76	33.5	0.85	59.09
13	24.71	54	0.37	56.47	54	0.84	43.75
14	47.06	81	0.67	70.59	34.5	1.01	66.67
15	23.53	75.5	0.36	47.06	95.5	0.71	50
16	28.24	18	0.46	40	116	0.65	70.59
17	28.24	39	0.43	65.88	103	1.01	42.86
18	42.35	23.5	0.69	70.59	70.5	1.16	60
19	28.24	39.5	0.42	51.76	96	0.76	54.55
20	28.24	23	0.43	47.06	71	0.72	60
21	23.53	53.5	0.29	58.82	114	0.74	40
22	30.59	86	0.42	51.76	109.5	0.72	59.09
23	34.12	91	0.55	65.88	116	1.06	51.79
24	24.71	102	0.32	55.29	96	0.72	44.68
25	34.12	75	0.42	65.88	105	0.8	51.79
26	28.24	30	0.4	61.18	118.5	0.87	46.15
27	35.29	115.5	0.58	52.94	92.5	0.87	66.67
28	23.53	128	0.36	56.47	161	0.87	41.67
29	35.29	81	0.51	56.47	98.5	0.82	62.5
30	28.24	75	0.33	47.06	117	0.55	60
31	32.94	14	0.48	65.88	119.5	0.95	50
32	24.71	102	0.37	52.94	124.5	0.79	46.67
33	34.12	11	0.41	65.88	114.5	0.79	51.79
34	28.24	12.5	0.39	55.29	100	0.77	51.06
35	30.59	31	0.47	65.88	106	1.01	46.43
36	32.94	103.5	0.51	70.59	76	1.09	46.67
37	18.82	10.5	0.31	47.06	115.5	0.78	40
38	35.29	24	0.48	80	122	1.1	44.12
39	23.53	7	0.36	55.29	117.5	0.85	42.55
40	23.53	63	0.31	51.76	119	0.68	45.45
41	47.06	57	0.6	89.41	88.5	1.15	52.63
42	32.94	48	0.43	61.18	132	0.8	53.85
43	23.53	95.5	0.37	47.06	97	0.75	50
44	23.53	116.5	0.35	56.47	91.5	0.84	41.67
45	43.53	52.5	0.45	54.12	110	0.69	65.22
46	29.41	19	0.44	62.35	78	0.93	47.17
47	35.29	52.5	0.45	54.12	110	0.69	65.22
48	34.12	105.5	0.45	70.59	127.5	0.93	48.33
49	29.41	30	0.45	61.18	91.5	0.93	48.08
50	32.94	95	0.46	65.88	102	0.93	50
51	28.24	17	0.43	49.41	106	0.76	57.14
52	34.12	19.5	0.48	75.29	109.5	1.06	45.31
53	47.06	17	0.63	67.06	119	0.89	70.18
54	56.47	28.5	0.64	91.76	106	1.04	61.54
55	24.71	49.5	0.38	52.94	89	0.81	46.67
56	21.18	33	0.34	44.71	105	0.72	47.37
57	43.53	34	0.58	67.06	88	0.89	64.91
58	24.71	38	0.34	47.06	108	0.65	52.5
59	11.76	90	0.22	30.59	113	0.58	38.46
60	28.24	77.5	0.47	42.35	112	0.71	66.67
61	23.53	57.5	0.39	63.53	98.5	1.06	37.04

Appendix L: Raw Scores for Actual and Predicted Lung Function Capacities.

SUBJECT	FVC ACTUAL	PREDICTED	%PRED	FEV1 ACTUAL	PREDICTED	%PRED
1	5100	5710	89.30	4190	4970	87.40
2	6040	4590	131.50	4190	3960	105.50
3	4540	4440	102.20	3920	3760	104.20
4	5020	5710	87.90	4110	4790	85.80
5	5350	5220	102.40	4810	4450	108.00
6	4940	5610	88.00	4070	4770	85.30
7	4960	5590	88.70	4350	4720	92.10
8	4850	5280	91.80	4150	4480	92.60
9	6200	5800	106.80	4970	4850	102.40
10	7440	6350	117.10	5010	5270	95.00
11	5300	5500	96.30	4560	4680	97.40
12	4980	5410	92.00	3860	4610	83.70
13	6160	5280	116.60	4810	4460	107.80
14	5060	5210	97.10	4230	4470	94.60
15	5800	4780	121.30	4720	4040	116.80
16	5150	4760	108.10	4560	3990	114.20
17	5270	5360	98.30	4480	4570	98.00
18	5750	5320	108.00	4850	4550	106.50
19	6790	4850	140.00	5380	4090	131.50
20	5380	5150	104.40	5101	4420	113.30
21	4390	4440	98.80	3820	3760	101.50
22	4700	5270	89.10	4270	4510	94.60
23	8000	5560	143.80	4850	4720	102.70
24	5770	5000	114.60	4400	4140	106.20
25	5230	5220	100.10	4270	4440	96.10
26	4540	4340	104.60	4150	3750	110.60
27	6500	5460	119.00	5140	4580	112.20
28	6150	5350	114.90	4720	4480	105.30
29	5720	5140	111.20	4560	4350	104.80
30	5460	5310	102.00	4350	4490	96.80
31	5610	5140	109.10	4890	4260	114.70
32	4840	5590	86.50	4400	4740	92.80
33	6510	5530	117.70	4720	4610	102.30
34	6290	5530	113.70	5420	4690	115.50
35	4580	4700	97.40	3900	3040	98.90
36	5740	5500	104.30	4970	4680	106.10
37	5950	5140	115.70	5550	4260	130.20
38	4820	4710	102.30	4480	3930	113.90
39	6670	5060	131.80	5460	4170	130.90
40	5830	4550	128.10	4600	3870	118.80
41	4920	5220	94.60	3740	4440	84.20
42	5470	4800	113.90	4720	4080	115.60
43	3920	4410	88.80	3410	3550	96.00
44	5130	5020	102.10	3980	4190	94.90
45	6140	4780	128.40	5140	4050	126.90
46	6560	5310	123.50	5300	4490	118.00
47	6710	5470	122.60	4810	4560	105.40
48	5770	5230	110.30	4680	4410	106.10
49	5310	5090	104.30	4600	4270	107.70
50	4970	6110	81.30	3860	5120	75.30
51	6090	5640	107.90	5380	4780	112.50
52	5910	5330	110.80	4640	4450	104.20
53	6720	5030	133.50	5510	4260	129.30
54	6200	5920	104.70	5260	4940	106.40
55	6560	5210	125.90	5380	4380	122.80
56	6470	5890	109.80	5050	4910	102.80
57	5070	4680	108.30	3900	3920	99.40
58	5080	4700	108.00	3900	3960	98.40
59	4170	4400	94.70	3740	3700	101.00
60	5290	4720	112.00	4560	4090	111.40
61	5270	4760	110.70	3780	3990	94.70

SUBJECTS	Resting Heart Rate (bpm)	Peak VO_2 ($l.kg^{-1}.min^{-1}$)	VO_2 (l.min)	V_E (l.min)	RQ	Maximum Heart Rate (bpm)	O_2 Pulse (ml.kg.beat)	Recovery Heart Rate (bpm)	RPE
1	84	61.6	3424	100.7	1.08	186	0.328	109	20
2	64	70.2	4844	117.4	0.91	190	0.369	82	20
3	51	56.9	3980	111.4	1.13	198	0.285	110	19
4	60	52.9	3587	98.3	1.14	186	0.278	98	20
5	54	60.8	4684	138.6	1.17	190	0.321	90	18
6	60	59.1	3590	116.7	1.08	190	0.317	100	20
7	75	52.9	3901	104.1	1.09	189	0.274	100	18
8	69	44.9	3511	104	1.11	180	0.243	89	18
9	90	56.2	3711	92.6	1.07	185	0.304	90	17
10	70	59.1	3958	93.2	1.04	190	0.311	100	20
11	69	45.8	3149	90	1.07	189	0.238	87	20
12	62	53.5	3584	90.6	1.07	179	0.299	89	20
13	69	58.2	3844	107	1.09	204	0.285	93	20
14	69	53.2	3297	106.7	1.14	190	0.286	89	20
15	79	62.6	4066	111.5	1.07	190	0.329	90	19
16	70	56.5	3839	108.5	1.16	183	0.309	89	18
17	69	57.1	3707	103.8	1.17	178	0.329	88	18
18	70	53.4	3258	89.2	1.03	194	0.275	109	19
19	75	52.4	3045	88.7	1.17	170	0.362	90	17
20	70	61.7	3981	109.9	1.08	180	0.339	90	19
21	78	53.3	3655	92.4	1.17	198	0.268	110	19
22	57	41.9	3150	66	1.07	171	0.234	87	18
23	64	47.1	3577	65.7	1.03	175	0.269	100	18
24	69	50.7	3759	104.8	1.16	189	0.265	100	19
25	59	49.9	3886	116.9	1.12	188	0.265	98	17
26	59	56.8	4657	118.1	1.07	190	0.299	96	18
27	70	45.8	3439	98.7	1.03	187	0.245	96	15
28	86	62.4	3808	97.9	1.08	180	0.346	100	17
29	69	57.5	3931	94.5	1.12	190	0.314	97	16
30	98	62.4	4305	121.8	1.07	205	0.304	99	18
31	84	49.5	4105	124.9	1.08	193	0.256	90	17
32	60	61.9	3964	109.4	1.09	202	0.302	110	17
33	69	48.3	2886	88.5	1.14	185	0.256	100	16
34	52	59.9	4281	104.1	1.14	177	0.338	86	16
35	62	52.9	3797	87.9	1.03	178	0.297	100	15
36	64	53.4	3608	85	1.02	178	0.305	91	14
37	62	39.6	2426	55.6	1.12	150	0.257	78	14
38	58	55.6	4333	28.5	1.08	172	0.323	92	12
39	62	51.2	3361	88.4	1.11	190	0.264	100	15
40	69	45.7	3449	85.4	1.05	181	0.252	91	13
41	60	49.3	3848	104.6	1.11	189	0.261	105	14
42	72	59.7	3778	106.1	1.09	202	0.292	100	14
43	60	56.9	3758	104.9	1.06	178	0.329	97	17
44	80	58.6	4396	123.3	1.04	188	0.312	100	15
45	70	51.4	4011	105.8	1.08	194	0.265	110	16
46	64	51.1	3627	108.5	1.13	181	0.282	86	14
47	65	60.8	4499	91	0.95	179	0.349	95	17
48	73	51.9	4514	97.8	0.87	145	0.366	89	14
49	69	54.3	3603	99.6	0.97	180	0.392	98	14
50	61	59.1	4050	80.6	0.87	175	0.344	95	15
51	53	54.3	3855	106.2	1.04	183	0.297	102	14
52	77	57.9	3022	76.4	0.88	199	0.286	100	20
53	50	61.2	3251	93.8	0.93	195	0.314	85	18
54	72	64.7	3879	92.8	0.97	186	0.348	88	19

Appendix N: Raw Scores obtained for the 30 second Wingate Anaerobic Test.

SUBJECTS	BODY WEIGHT (Kg)	LEAN BODY WEIGHT (Kg)	KP	0 - 5 (sec.)	6 - 10 (sec.)	11 - 15 (sec.)	16 - 20 (sec.)	21 - 25 (sec.)	26 - 30 (sec.)
1	76.2	68.40	5.5	14	13	13	12	12	11
2	68.0	65.75	5.0	11	10	9	9	10	10
3	68.8	62.81	5.0	14	12	13	13	11	12
4	64.4	61.56	5.0	16	13	11	13	13	11
5	70.0	61.25	5.0	15	12	15	12	11	12
6	69.0	66.10	5.0	15	12	13	12	11	11
7	77.6	69.21	6.0	16	11	12	13	11	9
8	61.6	59.00	4.5	12	14	13	12	11	12
9	84.0	77.70	6.5	16	14	15	10	10	12
10	80.0	75.60	6.0	11	9	10	8	11	10
11	66.0	61.50	6.0	15	16	14	13	12	11
12	61.0	57.34	4.5	20	15	15	12	13	11
13	70.0	63.49	5.0	14	12	12	11	12	11
14	67.0	63.18	5.0	17	13	13	12	11	11
15	66.0	59.07	5.0	16	14	11	13	13	13
16	63.0	58.71	5.0	14	12	12	11	14	12
17	65.0	61.23	5.0	16	15	14	11	15	13
18	68.0	65.34	5.0	15	12	13	11	11	10
19	65.0	62.46	5.0	16	13	14	12	13	12
20	61.0	58.07	4.5	18	14	13	12	13	12
21	60.0	54.90	4.5	17	15	14	13	12	12
22	65.0	61.88	5.0	17	13	14	14	13	12
23	69.0	62.44	5.0	15	14	13	12	11	11
24	69.0	56.16	5.0	16	13	12	11	10	8
25	72.0	64.87	5.5	15	15	13	12	12	12
26	62.4	54.84	4.5	15	14	13	13	12	11
27	77.0	67.45	5.5	14	12	14	15	14	12
28	82.6	74.58	6.0	17	13	15	13	13	12
29	86.0	69.05	6.5	13	12	12	11	12	11
30	61.0	58.19	4.5	20	18	16	13	12	11
31	68.8	62.33	5.0	12	12	13	13	12	10
32	69.8	65.75	5.0	16	17	16	13	10	11
33	83.0	64.74	6.0	16	13	13	12	10	9
34	65.0	61.23	5.0	16	14	15	14	13	11
35	72.0	57.09	5.5	13	12	12	11	10	8
36	73.0	70.15	5.5	17	15	16	15	15	12
37	76.0	67.41	5.5	13	10	12	11	10	9
38	65.8	59.35	5.0	10	12	12	12	12	10
39	67.0	62.98	5.0	18	12	13	12	11	11
40	69.0	59.82	5.0	15	14	13	11	10	10
41	73.0	71.32	5.5	18	15	15	13	13	12
42	66.8	60.98	5.0	15	15	15	13	12	10
43	63.0	52.35	5.0	14	11	12	12	12	10
44	78.6	69.00	6.0	18	16	15	14	13	12
45	67.6	62.32	5.0	17	14	15	12	13	12
46	78.0	70.74	6.0	16	14	13	12	12	13
47	78.8	69.73	6.0	15	13	13	13	13	12
48	64.8	61.10	5.0	16	15	13	11	10	9
49	65.8	63.23	5.0	15	13	12	12	12	12
50	75.6	71.90	5.5	16	14	12	12	12	12
51	78.6	69.63	6.0	18	16	15	15	15	13
52	71.0	67.23	5.5	18	14	15	13	13	9
53	74.6	68.33	5.5	17	14	15	12	13	12
54	87.6	82.78	6.5	19	16	15	13	12	11
55	65.0	61.16	5.0	17	13	13	11	11	9
56	75.3	71.80	5.5	18	16	14	12	12	11
57	61.7	58.86	4.5	16	14	15	11	11	10
58	71.6	63.79	5.5	16	13	14	12	14	10
59	53.2	51.65	4.0	15	10	13	9	8	7
60	59.6	57.87	4.5	18	14	14	11	12	12
61	60.4	59.25	4.5	14	13	12	12	13	11

Appendix O: Raw Scores for different Components measured during the 30 second Wingate Anaerobic Test.

SUBJECTS	TOTAL	RPE	MAX (Watts)	MIN (Watts)	W.Kg BM	W.Kg LBM	FATIGUE INDEX (%)	AVERAGE CAPACITY (Watts)
1	75	19	858	726	11.26	12.54	15.38	814
2	59	20	600	540	8.82	9.13	10.00	580
3	75	19	780	660	11.33	12.67	15.38	740
4	77	20	960	660	14.90	10.48	31.25	790
5	77	19	900	660	12.85	14.69	26.60	770
6	74	20	900	660	13.04	13.61	26.60	740
7	72	19	1152	648	14.84	16.64	43.75	864
8	74	18	756	594	12.27	12.81	21.43	666
9	77	18	1248	780	14.86	16.06	37.50	1014
10	59	19	792	576	9.90	10.48	27.27	672
11	81	18	960	660	14.55	15.61	31.25	810
12	86	17	1080	594	17.70	18.84	45.00	774
13	72	18	780	660	11.14	12.28	15.38	710
14	77	18	1020	660	15.22	16.14	35.29	770
15	80	17	960	780	14.55	16.25	18.75	820
16	75	18	840	660	13.55	14.31	21.42	750
17	84	18	960	660	14.77	15.68	31.25	840
18	72	19	900	600	13.23	13.77	33.30	720
19	80	19	960	720	14.77	15.37	25.00	800
20	82	19	972	648	15.93	16.74	33.30	738
21	83	15	918	648	15.30	16.72	29.41	747
22	83	16	1020	720	15.69	16.48	29.41	830
23	76	17	900	660	13.04	14.41	26.60	760
24	70	18	960	480	13.91	17.09	50.00	700
25	79	18	990	792	13.75	15.26	19.49	869
26	78	19	810	594	12.98	14.77	26.60	702
27	81	19	990	792	12.85	14.68	20.00	880
28	83	18	1224	864	14.82	16.41	29.41	996
29	71	17	1014	858	11.79	14.69	15.38	923
30	90	18	1080	594	17.70	18.56	45.00	810
31	72	17	780	600	11.33	12.51	23.07	720
32	83	18	1020	660	14.61	15.51	35.29	830
33	73	18	1152	648	13.88	17.79	43.75	876
34	83	18	960	660	14.77	15.68	31.25	830
35	66	18	858	528	11.91	15.03	38.46	726
36	90	17	1122	792	15.37	15.99	29.41	990
37	65	17	858	594	11.28	12.23	30.76	715
38	68	17	720	600	10.94	12.13	16.60	680
39	77	17	1080	660	16.12	17.15	38.80	770
40	73	16	900	600	13.04	15.05	33.30	730
41	86	15	1188	792	16.27	16.66	33.30	946
42	80	14	900	600	13.47	14.76	33.30	800
43	71	14	780	600	12.38	14.90	23.07	700
44	88	14	1296	864	16.49	18.78	33.30	1056
45	83	16	1020	720	15.08	16.37	29.41	830
46	80	14	1152	864	14.77	16.28	25.00	960
47	79	14	1080	864	13.70	15.49	20.00	948
48	74	15	960	540	14.81	15.71	43.75	740
49	76	17	900	720	13.67	14.23	20.00	760
50	78	14	1056	792	13.96	14.69	25.00	858
51	92	17	1296	936	16.49	18.61	27.77	1104
52	82	15	1188	594	16.73	17.67	50.00	902
53	83	16	1122	792	15.04	16.42	29.41	913
54	86	15	1482	858	16.92	17.90	42.10	1118
55	74	15	1020	540	15.69	16.68	47.05	740
56	83	17	1188	726	15.77	16.55	38.80	913
57	77	17	864	540	14.00	14.68	37.50	693
58	79	15	1056	660	14.74	16.55	37.50	869
59	62	15	720	336	13.53	13.94	53.30	496
60	81	17	972	594	16.30	16.80	38.80	729
61	75	15	756	594	12.52	12.76	21.43	675

APPENDIX O:

INFORMED CONSENT FOR CLINICAL EVALUATION AND EXERCISE TESTING

1. Explanation of the Tests

You will perform exercise tests on a treadmill, cycle, arm ergometers, isokinetic machinery and fitness skills. Blood samples will be taken by trained personnel to determine various biochemical parameters, which are also required. The exercise intensities will begin at a low level and will be advanced in stages depending on your fitness level and heart rate. We may stop the test at any time because of signs of fatigue or abnormal changes in your heart rate, electrocardiogram (ECG), or blood pressure. It is important for you to realise that you may stop when you wish because of feelings of fatigue or any other discomfort.

2. Attendant Risks and Discomforts

There exists the possibility of certain changes occurring during the test. They include abnormal blood pressure, fainting, irregular, fast or slow heart rhythm or slow heart rhythm. Every effort will be made to minimise these risks by evaluation of preliminary information relating to your health and fitness and by observations during testing. You may expect muscle soreness and stiffness to occur after the fitness testing. Emergency equipment and trained personnel are available to deal with unusual situations that may arise.

3. Responsibilities of the Participant

Information you possess about your health status or previous experiences of unusual feelings with physical effort may affect the safety and value of your exercise test. Your prompt reporting of feelings with effort during exercise test itself is also of great importance. You are responsible for fully disclosing such information when requested by the testing staff.

4. Benefits to be Expected

The results obtained from the exercise test may assist in the diagnosis in the evaluation of your own personal fitness. It will assist in the diagnosis of illness of in evaluation what type of physical activities you might do with low risk.

5. Inquiries

Any questions about the procedures used in the exercise test or the results of your tests are encouraged. If you have any concerns or questions, please ask us for further explanations.

6. Freedom of Consent

Your permission to perform in these exercises is voluntary. You are free to stop the tests at any point, if you so desire.

I have read this form and I understand the test procedures that I will perform and the attendant risk and discomforts. Knowing these risks and discomforts, and having had the opportunity to ask question that have been answered to my satisfaction, I consent to participate in these tests.

____________________ ______________________________

DATE **SIGNATURE OF PARTICIPANT**

____________________ ______________________________

DATE **SIGNATURE OF WITNESS**