

**A COMPARISON BETWEEN QUADRICEPS
MUSCLE STRENGTHENING ON LAND AND
IN WATER: A STUDY ON YOUNG
FEMALES**

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QUADRICEPS MUSCLE STRENGTHENING
ON LAND AND IN WATER:
A STUDY ON YOUNG FEMALES

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A research report submitted to the Faculty of Health Sciences,
University of the Witwatersrand, Johannesburg, in partial
fulfilment of the requirements for the degree
of
Master of Science (Physiotherapy)

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DECLARATION

I, Monika Petrick, declare that this research report is my own work. It is being submitted for the degree of Master of Science. (Physiotherapy) in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.


.....

...29th...day of.....March.., 1999

DEDICATION

I would like to dedicate this project to our Wonderful
Creator, Maker of Heaven and Earth, of Water and Land.
His loving strength, every step along the way, has made this
research possible.

ABSTRACT

A study on young, healthy females was undertaken to compare the effectiveness of a progressive resistance quadriceps muscle strengthening programme in water to one performed on land. The water ($n = 19$) and the land ($n = 18$) groups exercised five times a week for eight weeks, according to a modified DeLorme protocol, while the control ($n = 16$) group did not exercise. All three groups underwent isokinetic testing for their knee flexors and extensors at weeks 0, 4 and 8 at the speeds of $60^\circ/\text{s}$ and $270^\circ/\text{s}$. The water and land groups had their 10 Repetition Maximum (10 RM) measured before and at weekly intervals during the trial. Questionnaires were completed before, during and at the end of the trial.

There was no significant difference between the water and the land exercise groups on isokinetic or 10 RM testing. However, the land group experienced a significant reduction in comfort while exercising as the exercise weights became heavier, while the water group remained comfortable throughout. Although there was no significant difference in the number of subjects complaining of post-exercise muscle soreness, those with muscle soreness in the water group had more severe muscle soreness. Significantly more subjects in the land group complained of pain while exercising than the water group. Progressive resistance exercise for quadriceps strengthening can thus be

done as effectively in water (using home-made water weights) as on land.

Isotonic testing (10 RM) showed significant strengthening of both groups each week (except for week 1 to week 2 in the land group) whereas isokinetic testing showed no increase in strength, power or endurance of the exercised leg at 60°/s over eight weeks. Some significant increases were seen at 270°/s in the land and control groups over eight weeks, probably as a result of familiarisation to the test procedure.

There was no correlation between the 10 RM and peak extension torque or extension work of the exercised leg at 60°/s before, during or at the end of the trial. Isokinetic testing does not seem to be ideal following isotonic muscle strengthening in this population.

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GLOSSARY OF TERMS

1. Buoyancy - assisted movement

A movement in water in the direction of the force of buoyancy, i.e. upwards to the water surface, so that buoyancy assists it (1).

2. Buoyancy - neutral movement

A movement in water that occurs at 90 degrees to the force of buoyancy, i.e. parallel to the surface of the water, so that buoyancy neither assists or resists the movement, but supports the limb (1).

3. Buoyancy - resisted movement

A movement in water that occurs opposite to the direction of the force of buoyancy, i.e. downwards away from the water surface, so that buoyancy resists it (1).

4. Inertia and inertial forces

Inertia is the absence of movement. Inertial forces are forces which occur due to changes in the direction of a moving body. They are exerted to change an object's velocity. Inertial force is equal to the mass of the object times its acceleration (2).

5. Isokinetic contraction

A muscle contraction at constant speed with variable resistance (3).

6. Isokinetic dynamometer

This is an electromechanical instrument that allows movement at a constant speed and variable resistance. It can be used for testing concentric isokinetic or isometric muscle strength. Certain isokinetic dynamometers can also measure eccentric and isotonic muscle strength. Isokinetic dynamometers can also be used for strength training (4).

7. Isokinetic endurance tests

These tests are recommended for test speeds of 180 or 240°/s (5).

a) Pre-determined time bout endurance test

The subject performs as many repetitions as he/ she can in a predetermined time. The area under the torque curves is then calculated by computer analysis. It is very important that the subject be told to extend and flex the knee fully, as the total work will be less if the subject has not moved through the full range of movement (3, 5).

b) Pre-determined repetitions bout endurance test

The subject performs a certain number of repetitions and the computer records the total work. The subject again has

to extend and flex the knee fully to ensure accurate results (3, 5).

c) Endurance ratio

Work during the first 20 per cent and the last 20 per cent of test repetitions can be expressed as an endurance ratio, e.g. work over the last five repetitions divided by the first five repetitions in a 20 repetition test. This gives an indication of the fatigability of a muscle (5).

8. Isometric contraction

A muscle contraction during which the muscle length does not change and no joint movement occurs because the contractile force is equal to the resistive force (6).

9. Isotonic contraction

A muscle contraction against constant tension. Movement occurs through range and the velocity of movement is not constant. Isotonic contractions can be concentric or eccentric (4).

a) Concentric contraction

The muscle shortens while it contracts (i.e. muscle stronger than the resistance) (4).

b) Eccentric contraction

The muscle lengthens while it contracts (i.e. resistance stronger than muscle) (4).

10. Muscular endurance

Muscular endurance is an indication of how long a person can maintain a specific isometric force or a certain power level of consecutive isotonic contractions (4).

11. Muscle force/ internal force

A force generated by biochemical activity in a muscle that tends to draw the opposite ends of a muscle towards each other (6).

12. Peak torque

Torque is the magnitude of a force multiplied by the length of its moment arm (6). It is the ability of a force to produce rotation about an axis (4, 7). Torque can be measured using isokinetic dynamometers (6). Peak torque is the highest point on the torque curve, a tracing of the torque over the range of movement (3, 6) (see Figure 2.1). Peak torque gives an indication of muscle strength (3).

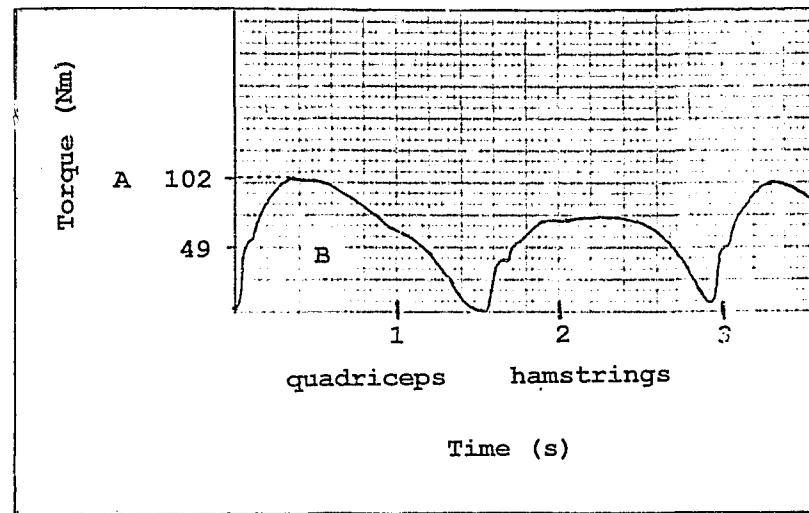


Figure 1.1 Torque curves obtained from isokinetic testing of knee flexion and extension at $60^{\circ}/s$ with paper speed of 25 mm/s (A = Peak torque, B = area under curve = rotational work)

13. Resisting force

A force resisting movement (6)

14. Rotational work

Rotational work is work done during rotation about an axis. It is equal to torque $\times$ angular displacement and is represented by the area under a torque curve obtained by isokinetic testing (3, 8) (see Figure 2.1).

15. 1 RM (1 Repetition Maximum)

The maximum weight that can be lifted correctly once only (4).

16. 10 RM (10 Repetition Maximum)

The maximum weight that can be lifted correctly 10 times only (9, 10).

ABBREVIATIONS

ptE	=	peak torque extension
EER	=	extension endurance ratio
W in E	=	work in extension
EP	=	extension power
20	=	pre-determined repetitions bout endurance test (20 repetitions)
t	=	pre-determined time bout endurance test
S.D.	=	standard deviation
NO.	=	number
$\frac{\text{wk } 4}{\text{wk } 0}$	=	$\frac{\text{week } 4}{\text{week } 0}$ = improvement over the first four weeks
$\frac{\text{wk } 8}{\text{wk } 4}$	=	$\frac{\text{week } 8}{\text{week } 4}$ = improvement over the last four weeks
$\frac{\text{wk } 8}{\text{wk } 0}$	=	$\frac{\text{week } 8}{\text{week } 0}$ = improvement over eight weeks

CHAPTER 1

INTRODUCTION

Exercise in water has been used to great benefit in the rehabilitation of patients with a wide variety of conditions (11). Golland (1) stated that "the use of water in treating patients is one of the most valuable, and ... enjoyable, techniques in the physiotherapist's repertoire."

Compared to exercise prescription on land, exercise prescription in water is often done unscientifically, without the physiotherapist being aware of the exact load a muscle is working against (12).

1.1 Significance of the study

Many patients with stiff, painful joints find exercise in water much less painful and more beneficial than conventional exercises on land (11). Water exercise is the only exercise modality well tolerated by many arthritic patients (11). The efficacy of a strengthening programme in water therefore needs to be established.

In the experience of the researcher water exercise as a means of muscle strengthening is under-utilised. The general public

has access to public and private swimming pools in many parts of South Africa, so specific home exercises in water could be used much more extensively than at present.

Many authors (1, 12, 13) have described the basic principles of exercise progression in water, i.e. the addition of longer levers, movement against buoyancy and an increase in the speed at which an exercise is performed. However, Harrison (12) suggested that there is a need to quantify the weights or resistance to exercise in water, as this would facilitate the change from water to land exercises, or the addition of land exercises while on a water exercise programme. Knowing the exact weight used in water would make it possible to progress to land exercise without wasting time on haphazard selections of the correct resistance level for land exercise. Harrison (12) maintained that water therapy should be approached more scientifically. He recommended the use of polystyrene blocks of known resistance.

A literature search showed that no clinical trials using incremental weight or speed protocols for muscle strengthening in water have been documented. Only two studies comparing muscle strengthening in water to that on land have been published (14, 15). According to Rissel (16) more research is needed to compare the "actual physical effect" of water exercise to that of land exercise.

1.2 Objectives of the study

1. To establish whether there is a difference between quadriceps muscle strengthening on land compared to in water using the DeLorme principle of muscle strengthening at a constant speed.
2. To design ankle weights of incremental resistance for use in water.

In order to achieve these objectives, healthy female volunteers were assigned to one of the water exercise, land exercise or control groups. Both exercise groups were put on an eight week progressive resistance exercise programme to strengthen the quadriceps muscles of their dominant leg. The magnitude of the resistance offered by the exercises was the same in both groups, with the land exercise group using sandbags and the water exercise group using sets of plastic bottles filled with varying amounts of water. The control group did not do any exercises. All subjects underwent isokinetic testing of their knee flexors and extensors at weeks 0, 4 and 8. In addition, the two exercise groups underwent weekly 10 Repetition Maximum (10 RM) testing. Questionnaires were completed before (Appendix A) and at the end of the trial (Appendix B), with the exercise groups completing additional weekly questionnaires (Appendix C).

CHAPTER 2

LITERATURE REVIEW

2.1 Muscle strengthening in water

2.1.1 Benefits of exercise in water

Exercise in water is gaining in popularity for the normal as well as the patient population (16). It has been used widely for rehabilitation, fitness training (17) and relaxation purposes, as exercise in this medium offers numerous advantages. The warmth of the water, the freedom of movement it offers, together with the ease of handling of very immobile patients in water, often lead to hydrotherapy being the first treatment of choice (18).

Exercise in water provides resistance throughout joint range and in various planes of movement (13). This is a definite advantage over various exercise machines which offer resistance only in one plane and often not through the full range of movement.

Even people who cannot swim can do exercise in water. The fear of water may be overcome by slow introduction into this exercise medium (19).

The patients who benefit most from hydrotherapy are those who have difficulties with weight bearing exercises on land, such as those with arthritis or low back pain (16), or those who are overweight or pregnant (20). Large muscle groups of both upper and lower extremities can be exercised through full joint range of motion in water, with a minimum of stress on joints (18, 21); this is useful if a joint is painful or where full weight bearing is contra-indicated (18). Walking re-education can be done at an early stage in water, i.e. before full weight bearing is allowed out of water (18).

For the aforementioned reasons, Rissel (16) suggested that exercise in water was the most appropriate form of exercise for the frail elderly. His group of frail elderly people reported a higher level of fitness, health and well-being after the 10 week water exercise programme than before. Rissel (16) did not, however, have a control group exercising on land and could therefore not conclusively prove the superiority of the water exercise. He based most of his findings on information gained from patient questionnaires, without the use of any objective testing.

Exercises in water, such as water running, can be used to achieve and maintain cardiorespiratory fitness (2, 17, 19, 22, 23). Hydrotherapy has also been found to increase muscle strength and musculoskeletal extensibility (2, 23). A number of studies on patients with rheumatoid arthritis have shown that water exercise improved muscle strength as well as quality of

life (14, 24), although Sanford Smith, MacKay-Lyons & Nunes-Clement (25) recently showed that land exercise may have the same, if not better results for this condition. Minor, et al. (26) found that in a group of 120 patients with osteo-arthritis or rheumatoid arthritis the aerobic walking and the aerobic water exercise groups performed better than the group that performed non-aerobic range of movement exercises.

Hydrotherapy can be very useful in the treatment of low back pain (19, 21, 27, 28). Using visual analogue pain scales and questionnaires, the effect of a group water exercise programme for chronic back pain sufferers was evaluated (27). The subjects reported a reduction in pain levels and an improvement in their quality of life. The same researchers, Langridge & Phillips (27), also mentioned that group exercise was very beneficial for patients with chronic conditions, as a "sharing of suffering" occurred. Their patients took control of their own rehabilitation programme, which could also have led to the good results. Unfortunately the researchers based all their findings on patient questionnaires and did not use objective testing or a control group.

LeFort & Hannah (19) found that their subjects with low back pain had better muscle strength and endurance after eight weeks of exercise in water. They had a lower resting heart rate and were able to lift a larger total of weights on all the weight lifting machines used for testing. The exercise programme did not reduce pain and disability ratings for all subjects. These

results would have been more meaningful if a control group had been used.

Smit & Harrison (28) found a reduction in pain levels of their patients with low back pain after their having attended hydrotherapy three times a week for four weeks. The subjects' thoraco-lumbar mobility also improved significantly. The beneficial effects of hydrotherapy were, however, not always long-lasting. They stated that patients might need ongoing sessions to maintain pain reduction and improvement in mobility. The lack of a control group was also a significant shortcoming of this research, as acknowledged by the researchers. They could therefore not rule out the possibility that their results could have been due to the natural remission of backache.

In a well-conducted, larger study, group hydrotherapy for four weeks resulted in improved function in a group of subjects with chronic low back pain (21). This was measured using a low back pain disability questionnaire. Subjects in this study were randomly assigned to the control (no exercise) (n=50) or group hydrotherapy (n=45) groups. The differences between these two groups were, however, not significant for variables such as pain, light touch, reflexes, strength or range of movement (21). There was a trend that of those subjects who improved in these measures, more were in the hydrotherapy than in the control group. It seems that four weeks of hydrotherapy make little difference to the physical signs of most subjects with

chronic low back pain. The outcome measures used were perhaps not sensitive enough for change. Four weeks of exercise could also have been too short.

In addition to the physical benefits of exercise in water, water exercise also offers numerous psychological benefits (2, 16, 18, 23, 27), such as a high level of enjoyment and the social interaction associated with water exercise in groups (16). Swimming has been found to lead to similar psychological benefits as running, and should therefore be highly recommended for injured athletes, or people who are unable to run due to some disability (2).

2.1.2 Disadvantages of water exercise

Water exercises or hydrotherapy is contra-indicated for a number of conditions, such as severe cardiac or renal failure, acute infections, febrile conditions, faecal incontinence and open wounds (29). Pool facilities are not always available and some non-swimmers have a fear of water (22). Maintenance of a heated pool is very expensive (27). In addition, skin irritation can occur due to the chlorine used in pools and consequently, the Australian Physiotherapy Association lists severe dermal sensitivity to sanitising chemicals as a possible contra-indication to hydrotherapy (29).

2.1.3 Physical principles applicable to exercise in water.

In order to safely and effectively prescribe exercises in water, an understanding of the physical properties of water as an exercise medium is essential (2).

2.1.3.1 Buoyancy

Any object in water is subject to the upward force of buoyancy, which is equal to the weight of the water displaced (2, 30). The specific gravity of an object is the mass of 1 ml of that substance divided by the mass of 1 ml of water, i.e. its density relative to the density of water (20). An object will sink in water if its specific gravity is more than 1 (i.e. if it is more dense than water) (6). Density is defined as the mass divided by the volume of the object (31).

The specific gravity of tissues in the body varies (6). Fat has a specific gravity of less than one and therefore floats, while bone has a specific gravity of more than one and sinks (4, 6). As women have a higher percentage body fat than men, they are more buoyant (2). Women therefore expend less energy to stay afloat than men (4). The specific gravity of the body

and therefore the ease of floating, also changes with age (it is 0,86 in a child, 0,37 in an adolescent/ young adult and 0,86 later in life) (20).

When a hip abduction exercise is done with the person standing in water, the centre of buoyancy moves further away from the joint as the leg abducts further. This increases the moment arm, i.e. the perpendicular distance between the line of action of the force and the pivot point (the joint). The moment of buoyancy is the force of buoyancy times the moment arm. If the knee of the abducting leg is flexed, the moment arm is reduced. The moment of buoyancy is therefore also less. The further away from the joint a buoyant float is applied, the larger the moment of buoyancy will be.

Careful attention needs to be paid to the moment of buoyancy in rehabilitation. As there is an apparent loss of body weight in water, the moment of buoyancy may cause a person to lose balance.

As a result of buoyancy, a person standing in water immersed up to his neck experiences an apparent loss of nine tenths of his body weight (2, 30). This apparent loss of weight can be used for walking re-education for patients who cannot bear full weight out of water.

Women are more buoyant than men as they have a higher percentage body fat than men (4, 32). Fat floats and bone

sinks (4, 6). Women therefore expend less energy to stay afloat than men (4).

2.1.3.2 Viscous drag force

The resistance to movement in water, the drag force (F_{drag}), is proportional to the square of the velocity of movement (2) and can be calculated using the following formula:

$F_{\text{drag}} = 0,5 \times C_d A \rho v^2$ (where C_d = coefficient of drag (a constant),
 A = projected frontal area, ρ = fluid viscosity and v = velocity of the object relative to fluid) (2)

As with land exercise, water exercises can provide muscular overload at varying speed; the faster the speed, the more the resistance. Any muscular effort made in water is met by equal and opposing force, therefore accommodating resistance is possible in water (2).

The viscous drag force is also proportional to the area of an object facing the direction of movement. Fluid flow can be made more streamlined (and viscous drag force reduced) by changing the way a resistance paddle is orientated. The paddle edge facing the direction of fluid flow is more streamlined (has a smaller surface area) than if the frontal area of the paddle were to face the fluid flow (2).

2.1.3.3 Inertial forces

Inertial forces are those required to accelerate an object. Force is equal to mass times acceleration ($F = ma$). Larger inertial forces are required to change the direction of movement of a heavy submerged object than that of a light submerged object. The weight of a float therefore needs to be considered when exercising in water (2).

2.1.3.4 Hydrostatic pressure

Hydrostatic pressure (the pressure exerted on an object submerged in a fluid) increases with the depth and density of a fluid, but is equal and opposite in all directions at any one depth. Atmospheric pressure is 10 130 Pa. Hydrostatic pressure in water increases by 9 806 Pa/m. Swelling can therefore be reduced if exercises are done well below the surface of the water (2, 20). Tovin, et al. (15) compared a water and a land exercise protocol in patients after anterior cruciate ligament surgery and found that the water group had less joint effusion than the land group at eight weeks after surgery. This finding could not, however, be attributed solely to the effect of exercise in water, as the amount of resistance to exercise was not standardised in the water group and therefore not identical in the land and water groups. Fort, et al. (33) reported a 6.3 per cent reduction in body weight after water immersion in

their patients with ascites from chronic liver disease. Research on the effects of hydrostatic pressure on oedema is, at present, very limited.

2.1.3.5 Specific heat of water

The specific heat of water, i.e. the amount of heat needed to increase the temperature by one degree, is very high. As water also conducts heat much faster than air, the rate of heat loss of an object in water is much higher than in air at the same temperature. The human body tends to store heat in warm water and loose heat in cold water. The optimal water temperature for maximal swimming performance in short distance swimming events has been found to be 28 - 30°C, as this temperature leads to just a small amount of heat being stored, thereby not hindering performance (2).

2.1.4 Exercise progression in water

Exercise in water may be progressed by adjusting the starting position, so that a buoyancy-assisted exercise changes to buoyancy-neutral or buoyancy-resisted (13). Resistance can also be increased by the addition of longer levers or by making the levers less streamlined, i.e. increasing the area of the lever that faces the direction of fluid flow. By increasing the speed

at which an exercise is performed, more resistance is created (13). The addition of buoyant materials to buoyancy-resisted exercises (1, 12) will also increase resistance.

The Bad Ragaz technique (18) in hydrotherapy involves the person floating in water. Resistance is provided by the body moving through water. The physiotherapist's hand is the fixed point about which the patient moves. Using the Bad Ragaz technique, resistance can be increased by increasing the speed of movement, by reducing the amount of flotation (34), or by the physiotherapist moving against the direction in which the patient is moving.

Resistance to stepping exercises in water can be increased by increasing the step height and by then progressively moving the step to shallower water (15).

2.1.5 Resistant devices to exercise in water

A few researchers have studied the design of devices which provide resistance to exercise in water (30, 35, 36).

Abidin, et al. (35) evaluated various hydrofitness devices for arm muscle strengthening. They described the level of comfort and the perceived amount of resistance each of the devices offered the subjects during some shoulder and elbow

movements. The subjects favoured using the nonbuoyant devices. These devices offered resistance as a result of fluid drag force, with buoyancy playing a minimal role. As the paddles were light (less than 1 kg), the inertial forces due to changing the velocity of the submerged device were thought to be nonsignificant. Provided that the frontal plane of the paddle was facing the fluid flow, reproducible forces would be encountered, regardless of water depth. The aquatoner (Figure 2.1), a device which allowed the paddle area to be changed and had a comfortable, large grip, was favoured by all of the exercisers.

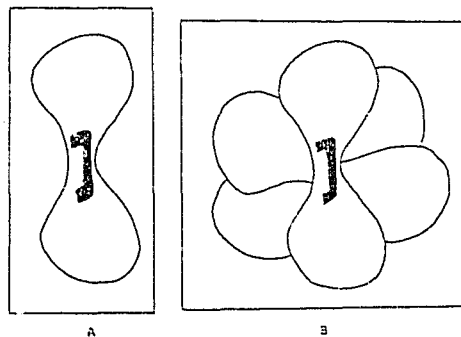


Figure 2.1 Diagrammatic representation of the "aquatoner" for the upper limb (35). A: Paddles together B: Paddles spread out

Large handles were favoured, as these did not lead to fatigue of the grasp. Abidin, et al. (35) subsequently designed an upgraded light-weight hydrofitness device with a large handle for arm strengthening (Figure 2.2). The frontal projection of this device could be changed due to the presence of fenestrations. The handle was covered in a layer of buoyant foam to enable the device to float for easy accessibility to the exerciser.

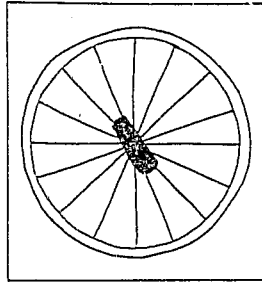


Figure 2.2 Diagrammatic representation of the upgraded hydrofitness device for arm strengthening (35)

Goitz, et al.(30) described and evaluated a hydrofitness device that could be applied to the foot. This device consisted of three separate rectangular-shaped buoyant floats made of flotation foam, which were positioned around the ankle and anchored around the foot with a strap (Figure 2.3). The device could be applied easily by the six subjects with weak legs on whom it was tested. Its potential uses included walking re-education (by reducing weight bearing on a painful leg), leg muscle strengthening and joint stretching (using buoyancy to assist stretching).

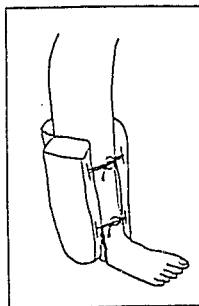


Figure 2.3 Diagrammatic representation of a flotation foam resistance device (30)

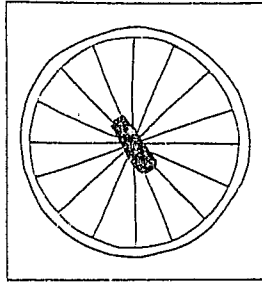


Figure 2.2 Diagrammatic representation of the upgraded hydrofitness device for arm strengthening (35)

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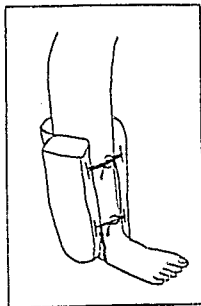


Figure 2.3 Diagrammatic representation of a flotation foam resistance device (30)

Another hydrofitness device that could be applied to the foot, which Goitz, et al. (30) evaluated, was an inflatable arm band type of device applied to the lower leg. It was found to be too close to the knee and had the potential risk of punctures (30). The third type of device investigated, had flat disc-like paddles (Figure 2.4) and could also be attached to the foot (30). The strapping was found to be inadequate for exercises performed vigorously (30). This device could also not be used for walking re-education and could only be used on one leg at a time (30).

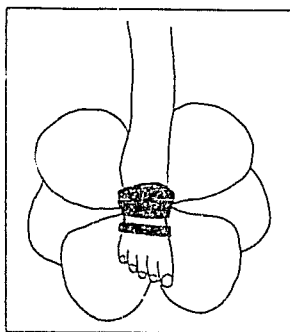


Figure 2.4 Diagrammatic representation of a paddle resistance device for legs (30)

Goitz, et al. (36) also evaluated the effectiveness of an air splint applied to the foot (Figure 2.5) as compared to the leg hydrofitness device (Figure 2.3) described before. They found the hydrofitness device to be superior, since the sole of the foot was in contact with the floor and therefore there was no risk of slipping, unlike with the air splint. The hydrofitness device also took less time to apply and was more durable.

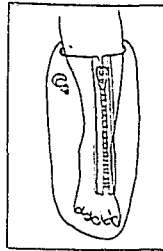


Figure 2.5 Air splint for leg exercises in water (36)

To provide resistance in water, Tovin, et al. (15) used a "hydrotone resistance boot" (Figure 2.6), which was strapped onto the foot and lower leg and provided resistance by means of three projections on each side. They encouraged their subjects to move as fast as they could, in order to increase the resistance.

The above mentioned devices were evaluated and compared subjectively only. Objective comparisons as to the effects of these devices on strengthening in a clinical trial are needed.

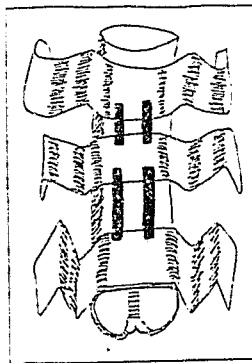


Figure 2.6 Diagrammatic representation of a water resistance boot (15)

2.1.6 Quantifying resistance to exercise in water

Resistance to exercise in water is usually not quantified, which hinders the effective change-over from water to land exercises, as the physiotherapist does not know the exact resistance the patient is working against in water (12). The researcher agrees with Tovin, et al. (15) who stated that very few studies have measured muscle strengthening following a programme of exercises in water.

Harrison (12) advocated the use of polystyrene blocks of known resistance. He specified that a 8 cm³ cube of polystyrene provided a resistance of 0,5 kg (5 N). A number of such blocks could be placed in stockinet, which would prevent the polystyrene from being chipped off. These floats could then be attached to the limb by means of velcro straps.

In an attempt to quantify the resistance against which a person has to work while performing Bad Ragaz exercises, Harrison & Allard (34) recorded the maximum resistance provided by six commonly used patterns. Ten normal adult subjects performed Bad Ragaz exercises against a spring balance. These exercises were compared to Proprioceptive Neuromuscular Facilitation (PNF) patterns out of water, as Bad Ragaz exercises utilise diagonal movement patterns following the principles of PNF (34). The

researchers demonstrated that the PNF patterns performed on land provided most resistance, followed by the Bad Ragaz patterns with floats deflated. The patterns with the floats fully inflated offered least resistance. The amount of resistance relative to the resistance on land varied considerably from pattern to pattern. Their table of values obtained for each pattern would have to be used as a guide for the physiotherapist to ascertain at which stage of rehabilitation each exercise would be suitable (34). A larger sample size and more sophisticated recording of the resistance encountered would have made the table of values more accurate.

The resistance encountered when moving table tennis bats of different diameters through water was examined in a carefully designed study by Hillman, Matthews & Pope (37). Strain gauges were attached to the aluminium rod near the handle. The electrical signal from the strain gauge was proportional to the load on the bat and was recorded on a chart recorder. Following movement trials of bats of different sizes being moved horizontally and vertically through the water at varying speeds, the researchers produced a graph that could be used to calculate resistance by knowing the time it took for a movement to be executed. This graph could be used widely, as a correction factor for arm length was included.

The hydrofitness device for leg conditioning described by Goitz, et al. (30) (Figure 2.3) had a total buoyant force of 37,6 N. These researchers also mentioned the existence of a

smaller unit, offering a total buoyant force of 22,6 N (36). The air splint to be placed over the foot described by Goitz, et al. (36) (Figure 2.5) provided a total buoyant force of 39,2 N when inflated to a volume of 4,2 litres.

2.1.7 Quadriceps rehabilitation in water

Tovin, et al. (15) published the most comprehensive research on knee rehabilitation in water. They compared rehabilitation programmes on land and in water in a group of 20 patients who had undergone intra-articular anterior cruciate ligament reconstructions. The patients all followed accelerated protocols for anterior cruciate ligament reconstruction, i.e. immediate weight bearing, no immobilisation and return to activity within six months. The researchers claimed that the exercises in both groups were matched so that each programme was identical, except for the rehabilitation environment. Unfortunately, they failed to quantify the resistance to exercise in water, so that the two programmes were, in fact, not identical. Comparative findings between the land and water groups could not therefore be conclusive.

The programme focused mainly on closed chain exercises (i.e. the distal joint is not free to move), as these put less stress on the graft and are more functional than open chain exercises. After eight weeks, the water group had higher functional outcome scores, which was determined from a questionnaire, as

well as less joint effusion when compared to the land group. There were no differences between the two groups in thigh girth, quadriceps strength or passive range of movement of the knee. The land group had a higher isokinetic knee flexion peak torque than the water group after eight weeks. Both groups had a significant, but equal, reduction in knee joint laxity eight weeks after surgery, compared to before surgery. The only disadvantage for the water group was the fact that knee flexion strength did not increase as much as in the land group (knee flexors are important in rehabilitation after anterior cruciate ligament surgery, as they reduce strain on this ligament (38)).

The researchers ascribed the finding that the hamstrings of the water group did not strengthen as much as in the land group to two differences in the programmes. The resistance in water was self-paced and depended on the person's speed of movement and motivation, whereas in the land group exercises were done against known weights that were increased regularly. More eccentric hamstring contractions also occurred in the land than in the water group.

Tovin, et al. (15) ascribed their finding of less joint effusion in the water exercise group to the exercise medium. Closed chain exercises, which they used, are more functional for rehabilitation than open chain exercises, but may lead to joint pain and effusion (15). In a water environment, the closed chain exercises pose less stress on the knee and may

therefore aid in a reduction of both pain and swelling (15). Their conclusion that the water group had less joint effusion because they exercised in water (15) is, however, questionable, as the two exercise programmes in this trial were not identical, the resistance in water having been self-paced while the land groups used incremental weights. A less vigorous exercise programme in water could also have resulted in less joint irritation and joint swelling, both of which can occur following vigorous post-operative exercise (39).

The method of testing employed by Tovin, et al. (15) was very accurate. Their patients underwent isometric and isokinetic testing at eight weeks after the anterior cruciate ligament reconstruction. Isokinetic testing consisted of three separate contractions at 90°/s of knee extension (80 - 40 degrees) and then of knee flexion (0 - 70 degrees). This increased the reliability of the testing and also reduced shearing due to position changes (40).

In addition, this study revealed smaller peak torque values on testing at eight weeks than other similar studies. This could be due to the fact that closed chain exercises were used, while muscle strength was tested using an open chain method, which would not be specific enough to the strengthening that occurred (41).

Apart from the research done by Tovin, et al. (15), only three other studies on the effects of exercise in water on quadriceps strength have been published.

Baldwin (14) found that the quadriceps strength (measured by the 1 RM and 5 RM of a straight leg raise) of her patients with juvenile rheumatoid arthritis improved more in the group that exercised in water than in the group that did individual home exercises. This was apparent after a 20 week programme. After a nine week discontinuation, strength slowly decreased in both groups, but less so in the water exercise group. Mobility also increased in both groups, but more so in the individual home exercise group, where the physiotherapist tended to concentrate more on the stiff joints and stretch them where necessary. Individual stretching was not possible in the group therapy setting of the water exercise group. These programmes differed too much for accurate comparison. The differences in quadriceps strengthening and mobility between the two groups could have been as a result of the land group having received individual therapy, while the water group engaged in group therapy. The use of a straight leg raise movement to test quadriceps is also not specific enough to the quadriceps muscles, as hip flexors play an important role in this movement.

Two months of water exercise therapy improved the knee extensor muscle strength of patients with rheumatoid arthritis (24). This improvement was still detectable two months after the

water exercise had been discontinued. The strength gain was more apparent at low isokinetic angular velocities. Danneskiold-Samsøe (24) unfortunately gave very little detail about the sample and programme design.

After a 10 week swimming and water exercise programme in which 10 patients with multiple sclerosis participated, Gehlsen, Grigsby & Winant (42) found the following results:

On isokinetic testing, the knee extension peak torque increased significantly from pre- to mid-trial only, whereas the fatigue and work values of knee extensors and flexors increased significantly from pre- to post-trial. On testing the arms on a biokinetic swim bench, all the variables obtained, except for fatigue measurements, had improved significantly by the end of the 10 weeks. Water exercise was therefore found to be very valuable for patients with multiple sclerosis.

In the same study, no strengthening was found on isometric testing. This was ascribed to the fact that there was a lack of training specificity between dynamic and static exercise. Isokinetic and isometric peak torque had been found to be poorly correlated. The lack of dynamic peak torque improvements in knee extensors and flexors was ascribed to possible extensive pyramidal pathway involvement due to multiple sclerosis. Isokinetic strength testing may also not have been specific to the strengthening that occurred in water, as water exercise is similar to, but still differs from isokinetic

exercise. The inclusion of a land exercise group as a control and a larger sample size would have made the results of this study more valid.

Scientifically based research on muscle strengthening in water is lacking, as most studies in this field lack a control group (16, 19, 27, 28, 42). In addition, some studies investigating the effects of exercise in water base most of their findings on information gained from patient questionnaires (16, 27). Two recent studies have used control groups, as well as a number of physical test procedures, which is a step in the right direction for hydrotherapy research (21, 25).

A muscle strengthening trial utilising progressive resistance exercise in water against a known resistance has not been recorded in literature.

CHAPTER 3

METHOD

The design of this project was based on research conducted by Mandelbaum & Novick (43), two final year students of the University of the Witwatersrand in 1986. They compared the strengthening of quadriceps muscles using isotonic versus isokinetic exercise.

These researchers assigned 33 female students aged 19 - 22 to the control (no exercise), the isotonic exercise or the isokinetic exercise groups. Both exercise groups exercised five times a day for four weeks, the isotonic group exercising on the Westminster pulley using the DeLorme protocol and the isokinetic group exercising a Cybex II+ dynamometer (serial number C105-0165, 1983 model). Both exercise groups performed three sets of 10 repetitions each day they came to exercise. The Cybex group exercised at 60°/s, as this was found to be the speed at which isotonic exercises are normally performed (5). Quadriceps muscle strength was measured before and after the four weeks of exercises using the Cybex dynamometer at 60°/s(43).

The above design seemed ideal for a comparative evaluation of quadriceps muscle strengthening exercises in and out of water.

After having obtained permission to proceed with this research project from the Committee for Research on Human Subjects of the University of the Witwatersrand and the Postgraduate Committee on 2.4.1991 (reference no. R14/49), the researcher completed four preliminary trials (see Appendix D). Following these trials, the final exercise trial was conducted from 14.06.93 to 22.10.93.

3.1 Sample

3.1.1 Recruitment of subjects and assigning them to the land, water or control group

Subjects for this project were recruited from the population of young female employees of the Johannesburg Hospital. Notices were put up in the nurses residences and on notice boards of the Johannesburg Hospital, asking for female volunteers. Those who were interested had the project explained to them by the researcher, using photographs and an information sheet (see Appendix E). Volunteers needed to be healthy, have no knee pathology, be 17 - 30 years old and able to attend exercise sessions five times a week, for eight consecutive weeks. They were asked to discontinue all sporting activities during the time of the project. Written

informed consent was obtained (see Appendix F) if the volunteer agreed with all the requirements of the project. Although the information handout (Appendix E), the statement of consent (Appendix F) and the questionnaires (Appendices A - C) had been approved by the Committee of Research on Human Subjects, the statement of consent (Appendix F), would have been improved if it had also stated that the subject would be free to deny answer to specific items or questions on the questionnaires. The confidentiality of questionnaires and test results should also have been stated on the statement of consent (Appendix F). Although not stated, subjects were free to leave out any questions on the questionnaires that they did not want to answer, which also occurred occasionally (see Table 3.1).

The volunteers were asked to complete an initial questionnaire (see Appendix A) and the first 21 volunteers were then randomly divided into land or water groups by spinning a coin. As this method resulted in the water group becoming very large, subsequent volunteers had to draw a piece of paper with "land" or "water" written onto it from a bag. The designations on the pieces of paper were written according to the number of volunteers still needed in each group in order to ensure groups of equal size. The division into land and water groups therefore was not done in a truly random way, but remained consistently unbiased. This was not expected to represent a large source of error. Nineteen subjects were thus placed in the water group and 18 in the land group.

Table 3.1 Reported "feeling at ease" in water: significant difference between water and land groups

	WATER		CONTROL		LAND	
"DO YOU FEEL AT EASE IN WATER?"	NO.*	%	NO.	%	NO.	%
YES	12	75,0	14	87,5	18	100
NO	4	25,0	2	12,5	0	0
TOTAL**	16	100	16	100	18	100
	p - value ***					
land vs water	0,039		s#			
land vs control	0,214		ns##			
water vs control	0,654		ns			

NO.* = number of subjects

** only 50 subjects answered this question

*** 2-Tail Fisher's Exact Test

s# = significant

ns## = not significant

The control group consisted of those who were interested in joining the project, but knew that they would not be able to attend exercises for a continuous eight weeks, as well as people specifically asked to join the control group. Sixteen volunteers thus joined the control group. They were asked not to participate in any exercise for eight weeks and just to undergo the Cybex tests at the beginning, at week 4 and at the end of week 8. Subjects were not randomly assigned to the control group, as the volunteers were keen to exercise and

would not have complied with not exercising for eight weeks, had they been randomly selected to join the control group.

It is a shortcoming of this research that the subjects were not assigned to water, land or control groups in a consistent manner. Perhaps the subjects would have been willing to be randomly assigned to the control group if the researcher had been able to promise participation in a similar strengthening programme to them after the 8 week control period, as was done by Agre, et al. (44).

3.1.2 Sampling method

Convenience sampling, using a non-probability sampling method, was used i.e. the subjects were not randomly selected. Subjects belonged to a wide variety of professions within the Johannesburg Hospital, thereby constituting a fair representation of healthy, young females working at that hospital. Convenience sampling as opposed to random selection was done as subjects had to be healthy, free of knee pathology, able to get to the hydrotherapy area of the Johannesburg Hospital five times a week during the exercise period and willing to exercise for the full eight week period.

A disadvantage of this sampling method was the unrepresentative nature of this group with respect to the general population of females 17 - 30 years of age. The results could also have been biased, as entire sections of the population were likely to have been omitted from the selection process. In addition, the sampling error could also not be quantified.

A random selection of young females aged 17 - 30 years working at the Johannesburg Hospital would have made the results of this study more representative of the population of young females working at this institution. The researcher could also have used a random selection of young females living within 5 km of the hospital would have made the results representative of a more varied and larger population. This was, however, not feasible within the constraints of this research report. In both cases, subject compliance might, however, seriously have been affected. In both cases there would still have been bias towards very motivated individuals, who would have been more likely to attend for eight weeks.

3.1.3 Characteristics of sample

Sixty nine healthy females, without knee pathology and in the age group 17 to 30 years (mean = 24,4, standard deviation =

3,9) volunteered for the project. The four subjects who had been unable to discontinue their sports activity during the eight weeks of the exercise project were excluded from the study. Forty nine of the subjects completed the full eight weeks of training. The final sample size of 53 subjects included these 49 as well as four subjects who completed more than 4 weeks, but not the full eight weeks. There was thus an experimental mortality of 23,2 per cent. The reasons for withdrawal of those not completing the full eight weeks of training can be found in Appendix G.

Subjects were classified healthy if they considered themselves healthy and not suffering from any disease and appeared healthy. Apart from one diabetic (1,9 per cent), all the subjects reported to be in good health [n = 52 (98,1 per cent)]. This subject was included as she felt well and had her condition well under control. Absence of knee pathology meant that there was nothing wrong with the knees at the beginning of the exercise trial, that the knees were not painful and that there had been no previous knee surgery. Nineteen subjects were in the water group, 18 in the land group and 16 in the control group.

From the initial questionnaire (Appendix A) which the subjects completed before the start of the trial, the characteristics of the sample were as follows:

The age, height, body mass and lower limb length of the 53 subjects can be seen in Table 3.2.

Table 3.2: Mean age, body mass, height and lower limb length of all subjects

	MEAN	STANDARD DEVIATION
AGE	24,38 years	3,87 years
HEIGHT	161,76 cm	7,01 cm
BODY MASS	63,26 kg	12,37 kg
LOWER LEG LENGTH* OF DOMINANT LEG (only water and land groups)	39,60 cm	1,69 cm

*taken as distance from lateral joint line of knee to tip of lateral malleolus of ankle.

Of these, only the ages of the subjects in the land and control groups were significantly different ($p < 0,05$) (see Table 3.3).

Table 3.3 Comparing the ages of the subjects in the water, land and control groups

WATER		LAND		CONTROL	
MEAN (years)	S.D.	MEAN	S.D.	MEAN	S.D.
24,11	3,20	22,78	3,80	26,50	3,92
<u>water vs. land:</u> $p = 0,128$ (ns*) <u>water vs. control:</u> $p = 0,027$ (ns)			<u>land vs. control:</u> $p = 0,004$ (s**)		

ns* = not significant

s** = significant (Two tailed t-test)

Most of the subjects [$n = 39$ (73,6 per cent)] reported that they had not injured their legs before, while 14 of the subjects (26,4 per cent) had sustained previous leg injuries.

There was no significant difference between the groups in whether or not they had sustained a previous leg injury ($p > 0,05$).

Most of the subjects were nurses ($n = 14$, 26,4 per cent), with radiographers and physiotherapists following closely ($n = 10$, 18,9 per cent each). The control group seemed to be somewhat different from the land and the water groups, but this could not be tested statistically. The control group had 10 physiotherapists or physiotherapy assistants, while the other two groups had no physiotherapists or physiotherapy assistants (see Table 3.4).

Table 3.4 Occupations of subjects: Comparing water, land and control groups

OCCUPATION	WATER GROUP	LAND GROUP	CONTROL GROUP
	NUMBER OF SUBJECTS		
Nurse/ Nursing Student	5	8	1
Physiotherapist/ Physiotherapy Assistant	0	0	10
Radiographer/ Radiography Student	5	4	1
Cleaner	5	3	0
Administrative Clerk	3	2	1
Clinical Technologist	1	0	1
Social Worker	0	1	0
Pharmacist	0	0	1
Microbiology Student	0	0	1
TOTAL	19	18	16

Apart from four subjects (7,7 per cent), who preferred using the left leg to kick a ball, all the others [$n = 48$ (92,3 per cent)] used the right leg to kick a ball, i.e. were right leg dominant (45). One person did not answer this question in the initial questionnaire. There was no significant difference between the groups ($p > 0,05$).

The participation in sport or other regular physical activity at the beginning of the trial was relatively low, with no significant difference ($p > 0,05$) between the three groups. Only 13 out of 53 subjects (24,5 per cent) participated in sport and eight out of 50 subjects (16 per cent) participated in other regular physical activity. Three subjects did not answer the question on current participation in other regular physical activity (see Appendix A, Pre-Trial questionnaire, question 7).

Most of the subjects [$n = 36$ (72 per cent)] were able to swim (3 subjects did not answer this question) and there was no significant difference between the groups ($p > 0,05$).

Forty four (88 per cent) of the subjects felt at ease in water, significantly more ($p < 0,05$) of which were in the land group (see Table 3.1).

There were thus no significant differences found between the three groups at the start of the study ($p > 0,05$), except for

the ages of the subjects and the reported feeling at ease in water ($p < 0,05$).

3.2 Instrumentation

3.2.1 Hydrotherapy pool: Johannesburg Hospital

A medium sized hydrotherapy pool (length = 6,68 m, width = 3,99 m, depth varying from 0,88 m to 1,24 m) with a mean water temperature of 33,8°C (standard deviation = 1,14°C) (measured over the duration of the trial) was used for this project (Figure 3.1).

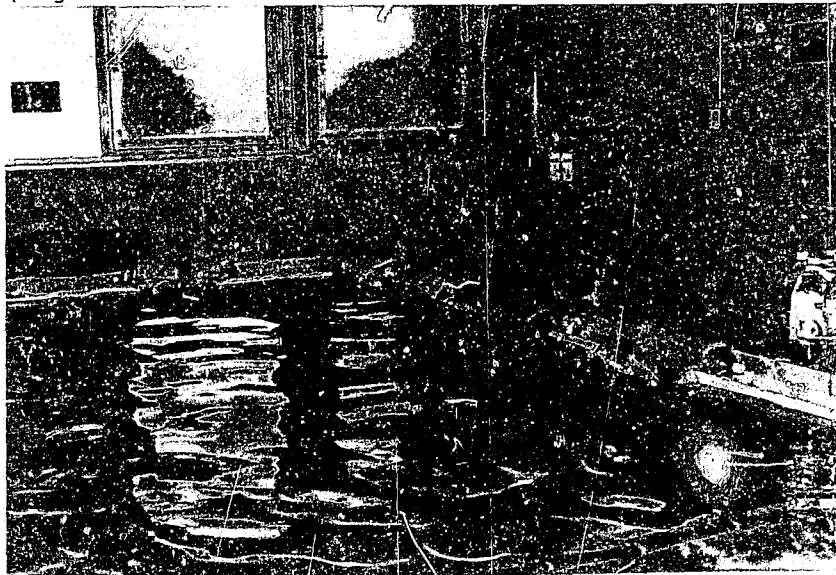


Figure 3.1 Hydrotherapy pool with "training stations" for the water exercise group

The ambient temperature of the pool area outside the water was controlled by air conditioning at 23 - 24°C.

3.2.2 Sandbags

Sandbags were manufactured by putting fine sand into plastic bags and these into canvass covers (Figure 3.2).

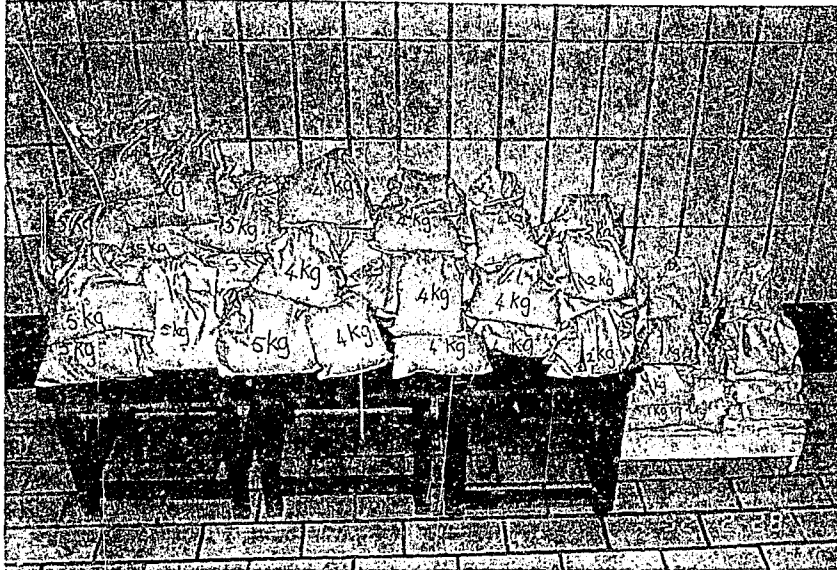


Figure 3.2 Sandbags for the land exercise group

The sandbags were weighed on a Krupps Type 844 kitchen scale while the correct amount of sand was added to make 0,5 kg, 1 kg, 2 kg, 4 kg and 5 kg sand bags, before the last seam of the sand bags was sewn closed. The sand bags were then marked at their respective levels using a permanent marking pen. The Krupps scale was found to register 10 g too little throughout when calibrated using standard G+G Ltd weights (Table H1, Appendix H), which constitutes a one percent error. The sandbags were thus one percent lighter than marked, which constitutes a small difference only. Sandbags were used for the

land exercise group and for the weekly 10 RM tests of all subjects.

3.2.3 Water weights

Ankle weights of incremental resistance using plastic bottles were designed for use in water (Figure 3.3). Eight 2 litre bottles were bound together with string, leaving an opening in the centre for the subject's leg (Figure 3.4 and Figure 3.5). A loop of material was attached to the bottles to serve as an anchor for the foot (Figure 3.5). In this way, the set of bottles could be placed on the dominant foot and lower leg. The bottles could then be filled with varying amounts of water, providing various levels of resistance. Enough water weights were manufactured to ensure that at any one time during the project, each subject in the water group could have her own set of bottles.

3.2.3.1 Resistance offered by the water weights

As the maximum weight the subjects would exercise against was not expected to be higher than 160 N (a mass of 16 kg), eight 2 litre bottles (resistance of about 160 N) were used for the purpose of this exercise trial. The figure of 160 N was obtained as follows: The upthrust of buoyancy is equal to the

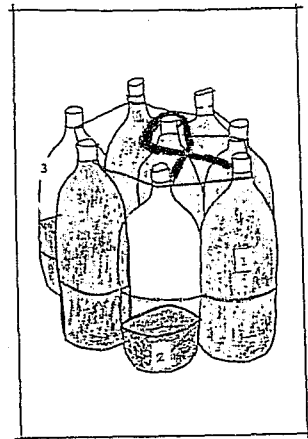


Figure 3.3 A set of bottles used as water weights: equivalent to 30 N (3 kg)

(1 = water,

2 = A 2 litre bottle with 300 ml water inside (to compensate for viscous drag force), resistance of 20 N (2 kg),

3 = bottle half-filled, resistance of 10 N (1 kg))

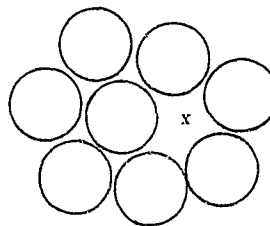
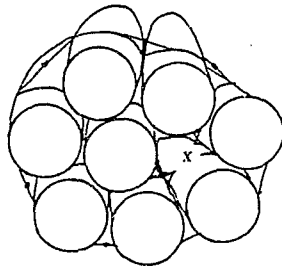


Figure 3.4 View of top end of water weights (bottle bases)
(X = opening to place foot and leg through to apply water weights)

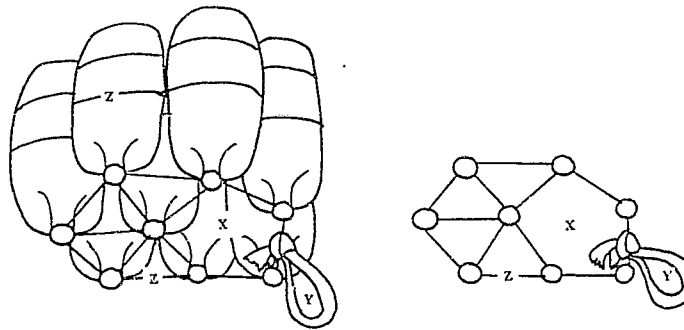


Figure 3.5 View of bottom end of water weights (bottle lids)
 (X = Opening for leg: Foot will stick out here once water weights are applied, Y = Noose to put foot through to secure water weights on leg, Z = String to hold bottles together)

weight of the water displaced by the object that is displaced under water. If eight empty 2 litre bottles (16 l) are displaced under water, the upthrust they experience is equal to the weight of the water they displaced, which is 160 N (8×20 N), as 2 litres of water weigh 20 N.

The biggest resistance to the submersion of the water weights was due to the effect of buoyancy, as mentioned above. The upthrust on the eight submerged bottles stayed constant throughout the exercise trial, but the amount of water in the bottles, i.e. the downward force due to the weight of the water inside the bottles, became less as water was let out of the bottles. The force resisting submersion of the weights (upthrust minus weight of the water in the bottles) was, therefore, in effect, equal to the weight of the water displaced by the empty bottles. A set of eight bottles

containing 3 litres of air would experience an upwards force of 30 N (upthrust - weight of water inside bottles $= 160 \text{ N} - 130 \text{ N} = 30 \text{ N}$).

Smaller factors that also affected the resistance of the water weights included the exact volume of a 2 litre cool drink bottle, the mass of the empty bottles and strings, the volume-reducing effect of hydrostatic pressure when an air-filled plastic bottles is submerged, viscous drag force and inertial forces.

The average volume of the plastic bottles was established with the aid of a 1 000 ml glass measuring cylinder (1000/1 ml at 20° C, LMS Germany). One bottle contained 2 050 ml. A volume of 2 050 ml water is therefore displaced if one empty 2 litre plastic bottle is submerged under water. This volume of water weighs 20,5 N. A force of 20,5 N is therefore needed to displace one empty 2 litre plastic bottle under water (in the absence of hydrostatic pressure and gravity).

The mass of the empty bottle sets with their connecting strings and foot loops played a role in determining the resistance and was therefore measured on a Seca Paediatric scale, model QD35Ed177, no. 776624. The mass of one set of eight bottles and string was 655 g. The scale was calibrated (Table H2, Appendix H) and found to have a 0,5 per cent error at the masses of 3 and 4 kg, but to be 100 per cent accurate in the 0,5 kg - 1 kg range, in which the mass of the bottles fell.

The compression due to hydrostatic pressure of an empty bottle when displaced under water was determined empirically.

A 2 050 ml plastic bottle, such as those used for the water weights, was filled with 400 ml of water. A rubber stop, which was large enough to seal off the opening of the plastic bottle, was selected and a hole drilled through it. The hole was big enough to allow a long glass tube with an internal diameter of 5 mm to just pass through. A long glass tube was passed through the rubber stop in such a way that the tube ended just above the bottom of the bottle, but not touching it and inside the 400 ml of water once the rubber stop was secured in the opening of the bottle (Figure 3.6). To extend the length of the tube (so that the end would be higher than the water level once the bottle was submerged), a piece of plastic tubing (3 mm diameter) was attached to the end of the glass tube outside the bottle (Figure 3.6). The level of the water in the glass tube was marked before the bottle was submerged (V1). The bottle and tube were then submerged until the base of the bottle was at 64,2 cm below the water level, which is comparable to the depth of displacement during the water exercise. Hydrostatic pressure now pushed some of the water out of the bottle into the thin tube. The top of the tube was then closed with a finger while the bottle was taken up to the water surface, out of the water and onto the side of the pool. With the finger still in place, the stopper-tube combination was carefully removed and the contents of the tube emptied into a glass measuring cylinder (100/1 ml at 20° C, LMS Germany) and measured (V2). The volume

of water already in the tube (V_1) was subtracted from this volume (V_2), the resultant volume (V_3) being an indication of volume change on air-filled submerged bottles in the water weights (Figure 3.6). The bottle was refilled with 400 ml of water and the whole procedure was repeated 10 times, showing a mean volume loss of 9,65 ml when one bottle is submerged (Appendix I).

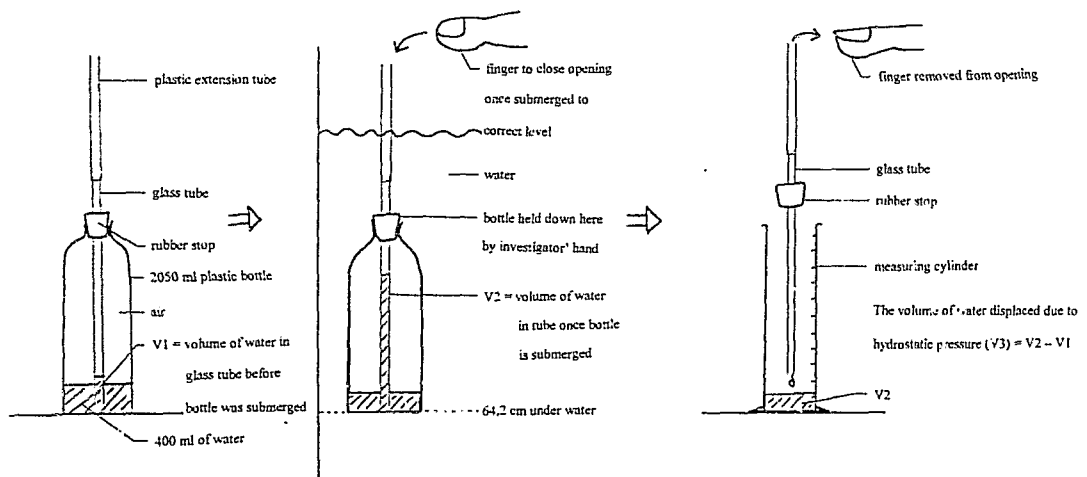


Figure 3.6 Establishing volume loss of an air-filled plastic bottle when submerged under water.

To calculate the viscous drag force on the water weights, empirical measurements were done on these in the pool. The bottle sets were hooked to a Capacity Spring Balance and then dragged through the water with the long axis of the bottles at a 90 degree angle to the direction of the movement (Figure 3.7). (During knee extension at $60^\circ/\text{s}$, the bottles would also move with their long axes at 90 degrees to the direction of movement.)

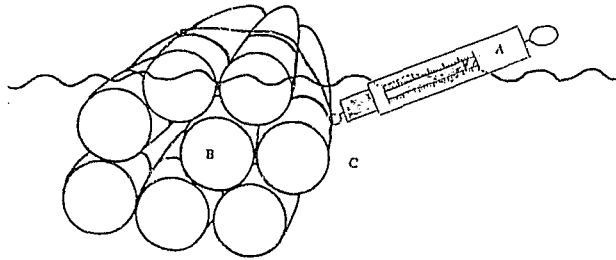


Figure 3.7 Dragging a set of bottles through water with a spring balance to establish viscous drag force (A = spring balance, B = water weights, C = water)

They were dragged at velocities of 0,09 m/s, 0,252 m/s and 0,415 m/s respectively (Figure 3.7). These velocities represent the velocities at which the top, the middle and the bottom of the water weights would move during knee extension at 60°/s (For calculations, see Appendix J). Readings on the spring balance were taken at each of these velocities (Appendix J). The velocities were obtained by dragging the bottles through a distance of 6 m in 14,5 s (to get a velocity of 0,414 m/s), in 23,8 s (to get 0,252 m/s) and in 66,7 s (to get 0,09 m/s) respectively. The time was determined with an Electronic Timer Clock (design registered number 1049496) (Appendix J). The resultant resistance at the middle of the sets of water bottles was found to be 3 N (300 g) (Appendix J) and was taken as the magnitude of the viscous drag force resisting knee extension in water for the purpose of this research.

The Capacity Spring Balances (able to measure up to 1 kg and marked in 10 g intervals) were calibrated using standard 500 g and 1 kg G+G weights (Table H3, Appendix H). These weights were

placed in a plastic bag, which was hung on the spring balances. A small two per cent error was found.

The viscous drag force was taken into account by leaving 300 ml of water in the first empty 2 litre bottle of each set of water weights. Despite the 300 ml of water in it, this bottle then represented a resistance of 20 N (or 2 kg). To mark the bottles, the researcher used a 1 000 ml glass measuring cylinder (1 000/1 ml at 20° C, LMS Germany) to pour the correct volumes of water into the first bottle (300 ml, 500 ml, 1 000 ml and 1 500 ml) and mark this bottle accordingly. All other bottles in the water weights were then marked using tape measure readings of the distances between the marks on the first bottle.

The inertial forces encountered due to changes in the direction of movement (2) ($F = ma$, F : force, m : mass, a : acceleration) did not produce a substantial amount of resistance to knee extension, as the direction changes were not abrupt and the training speed of 60°/s was relatively slow. These forces would only have had an effect for a fraction of each knee extension movement, as acceleration only occurred for a fraction of a second. Ninety degrees of knee extension took only 1,5 s at a speed of 60°/s. These inertial forces from direction changes would therefore only have occurred for a short duration at the beginning of each knee extension movement. The heavier the resistance apparatus, the larger these inertial forces would

have been. For this reason, the inertial forces would have been greatest as the water exercise subjects commenced the programme, as most of their bottles would have been filled with water at this stage, which made the resistance apparatus heavier. Techniques such as underwater time frame photography, or high speed photography (stroboscopic photographs) (6) would have been needed to accurately calculate acceleration. If one assumes that acceleration occurred during the first 0,1 s of knee extension and that the weights had to accelerate from 0 m/s to 0,252 m/s (the velocity that the middle of the water weights travelled at, Appendix J) in this time, then

$$\text{acceleration} = \text{velocity} / \text{time} = 0,252 / 0,1 = 2,52 \text{ m/s}^2.$$

If a set of water weights with 1 empty and 7 water-filled bottles is accelerated (20 N resistance), then

$$F = ma = 14 \text{ kg} \times 2,52 \text{ m/s}^2 = 35,28 \text{ N}.$$

At the end of each day of the exercise trial, the researcher filled up each set of bottles with the correct amount of water to give the lowest weight the subject would need the following day. In this way, a 20 N bottle set would have one 2 litre bottle containing only 300 ml of water while the other seven bottles were completely filled with water. A 30 N bottle set would have one bottle containing 300 ml of water and another bottle containing 1 litre of water, the other six bottles completely filled with water. More information on setting up the water weights is found in Appendix K.

A summary of the maximal resistance offered by one set of water weights moved at 60°/s follows.

For one set of water weights (eight air-filled 2 litre bottles)

1. Forces resisting knee extension

- a) buoyancy
 - = weight of water displaced
 - = weight of 8 x 2050 ml of water
 - (volume displaced by eight bottles)
 - = $2,050 \times 10 \times 8$
 - = 164 N
- b) viscous drag force = 3 N
- c) inertial forces due to changes in direction of movement
(only acted for a fraction of each knee extension, while there was acceleration)
 - = Could have varied from 35,28 N (if acceleration was $2,52 \text{ m/s}^2$ and 7 bottles were filled with water) to 7,56 N (acceleration of $2,52 \text{ m/s}^2$ and 1,5 bottles filled with water)

Largest at beginning of exercise programme. Difficult to determine the exact magnitude.

2. Forces assisting knee extension

- a) weight of bottle set, string and noose = 6,55 N (mass of 0,655 g)
- b) weight of water inside the bottles = 0 N
- c) upthrust on the air volume loss in the bottles from hydrostatic pressure = $0,00965 \times 10 \times 8$
= 0,772 N

To compensate for the viscous drag force (1.b), 300 ml of water was left in one of the bottles.

The 6,55 N weight of the bottles (2.a) was taken to balance out the resistance offered by the inertial forces due to direction changes (1.c), as these forces are of small

magnitude and occur only for a fraction of the knee extension movement.

The resultant resistance

= buoyancy - weight of water inside the bottles - upthrust on the air volume loss in the bottles from hydrostatic pressure

= 1.a - 2.b - 2.c

= 164 - 0 - 0,772

= 163,23 N

In this way, one set of air-filled water weights equalled 163,23 N of resistance. This figure was meant to be 160 N, but the compression on empty bottles displaced under water was over-estimated at the time of the trial (thought to be 50 ml instead of the measured 9,65 ml for each bottle (after the trial)). This is a two per cent error, which is small. The magnitude of the water weights was thus slightly larger than intended.

A preliminary study should have been set up to accurately assess the resistance of the water weights and the lack of this is a shortcoming of this research project.

Even though the water weights were two per cent heavier and the sandbags one per cent lighter (section 3.2.2) than planned, a three per cent difference (30 g in each 1 000 g) was still

small enough for the water and land weights to be comparable. A 10 N resistance from the sand bags was thus taken to be the same as a 10 N resistance from the water weights.

3.2.3.2 Person- specific resistance to knee extension in water

In addition to the resistance to knee extension due to the water weights, some person- specific factors also resisted knee extension in the water group: These were the viscous drag force on the lower leg moving in the water, the lower leg weight and lower leg buoyancy. These varied from person to person, as these depend on lower leg shape, volume and weight.

In an attempt to quantify the viscous drag force on the lower leg (resisting knee extension), an artificial leg with similar shape to that of a lower leg was dragged through the pool, following the same procedure as that of determining the viscous drag force on the water weights (Appendix J). At the velocity that the centre of the projecting surface of the water weights would travel, the viscous drag force on the artificial leg was 0,75 N (Appendix J). The determination of the viscous drag force on each subject's lower leg was beyond the scope of this research, but would warrant further investigation.

Lower leg weight assisted knee extension in the water exercise while lower leg buoyancy resisted knee extension. It was a

shortcoming of this research that these two variables of each subject were not measured. In order to gain an understanding of the forces likely to have been involved, the lower leg volumes and lower leg weights of 12 healthy women (age range 21 - 42) were determined subsequent to the exercise trial. The methods used and values obtained are found in Appendix L. The calibration of the Addis measuring jug and the EKS scale are found in Table H4 and Table H5, Appendix H respectively. The weights of the lower legs were higher than the upthrust of buoyancy, leaving the water group with an additional force assisting knee extension. In contrast, the land group had to perform knee extension against the weight of the lower leg as well. In order to equalise the starting resistance level of the water and the land groups, the water exercise group should have been given additional empty bottles in their water weights. This additional volume of air should have equalled each individual's lower leg weight plus the difference between this weight and the weight of the water displaced by the empty bottles (calculated from leg volume). Slightly larger water weights (consisting of 9 or 10 bottles each) would have been needed.

In this project the exercise groups did not start off with the same amount of resistance. The exercise progression (i.e. resistance provided by sandbags or water weights), however, was the same in both groups. For land exercise it is not customary to mention the lower leg weight in addition to the weight of

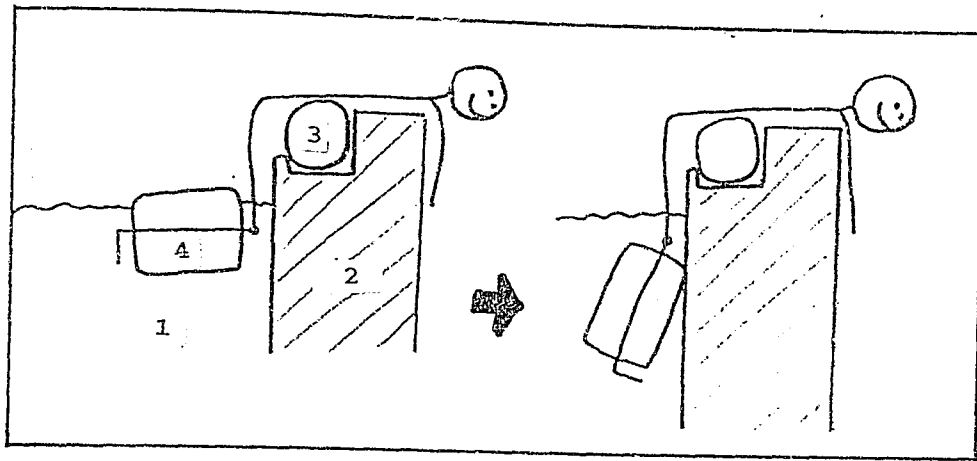
the sandbag to be lifted. When comparing water and land progressive resistance exercise, lower leg weight (for water and land groups) and the effect of buoyancy on the leg should, however, be included in determining similar resistance levels. Knowledge of the lower leg weight and volume of each subject would have helped the researcher equalise the level of the resistance for the land and water groups at the beginning of the exercise trial.

3.2.4 The "training station" for exercise in water

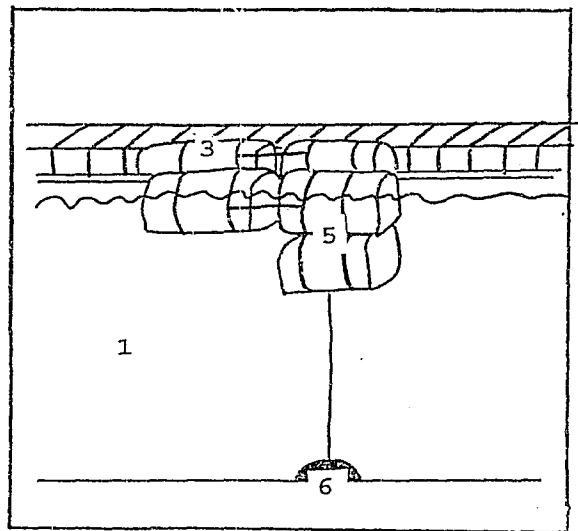
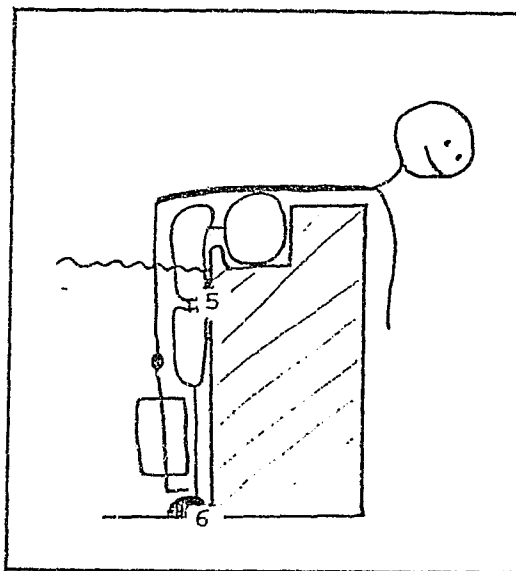
Some minor adaptations had to be made to the side of the pool to ensure that quadriceps exercises could be comfortably performed against buoyancy with the hips flexed to a right angle, in order to match the starting position used for quadriceps strengthening on land.

The edge of the pool used in this project did not form a 90 degree angle with the side wall of the pool, as an overflow trough was interposed. Consequently, two plastic bottles were placed in the trough to get the desired 90 degree angle. An additional set of bottles needed to be interposed between the side wall of the pool and the person's thigh to ensure that full knee extension would be reached when the water weights

attached to the leg were displaced maximally downwards (see Figure 3.8).



A



B

Figure 3.8 Exercise in prone lying over the side of the pool
 A: Full knee extension is hindered if "spacing" is not provided between the thigh and the side wall of the pool.
 B: Diagram of "training station" for water exercise
 (1 = water, 2 = side wall of pool, 3 = plastic bottle to fill up trough, 4 = water weight, 5 = plastic bottles used as "spacing" between thigh and side wall of pool, 6 = weight tied to bottles)

A spacing of at least one bottle's breadth between the side wall of the pool and the subject's thigh was needed. For the subsequent construction of the "training station", refer to Figures 3.1 and 3.8. A piece of adhesive foam was attached to the bottles of the training station and subjects could place a towel over the tiling of the edge of the pool to enhance comfort, when needed.

3.2.5 Metronome

In order to make sure that all exercises would occur at an angular velocity of $60^\circ/\text{s}$, a Wittner wooden metronome with a pendulum (range of 40 - 208 beats per minute) was set on 40 beats per minute and a 90 minute tape recording was made of this. Subjects would extend the knee on one beat, flex on the next, extend again on the next beat, etc. To work out how many beats per minute to set the metronome at, in order to get an angular velocity of $60^\circ/\text{s}$, the following calculation was made: The knee travelled through 90 degrees in one beat. To achieve $60^\circ/\text{s}$ the knee needed to move through 60 degrees in one second. In one second, $60/90$ th of a beat would occur. In sixty seconds, $60/90 \times 60$ beats = 40 beats would occur. The metronome was therefore set at 40 beats per minute.

All exercises and 10 RM tests were done to the beat of the metronome on this tape recording. A Blaupunkt model SZ60 portable stereo two band radio cassette recorder was used to play the tape with the metronome recording throughout the trial. The subjects just had to switch on the tape when they exercised. When the metronome was calibrated against the second hand of a wrist watch, a five per cent error was found, the metronome being slightly slower (Table H6, Appendix H).

3.2.6 Cybex isokinetic machine and dual channel recorder

A Cybex II+ Isokinetic Dynamometer (serial number C105-0165, 1983 model), a electromechanical dynamometer (Figure 3.9), was used as a means of testing muscle strength in this project.

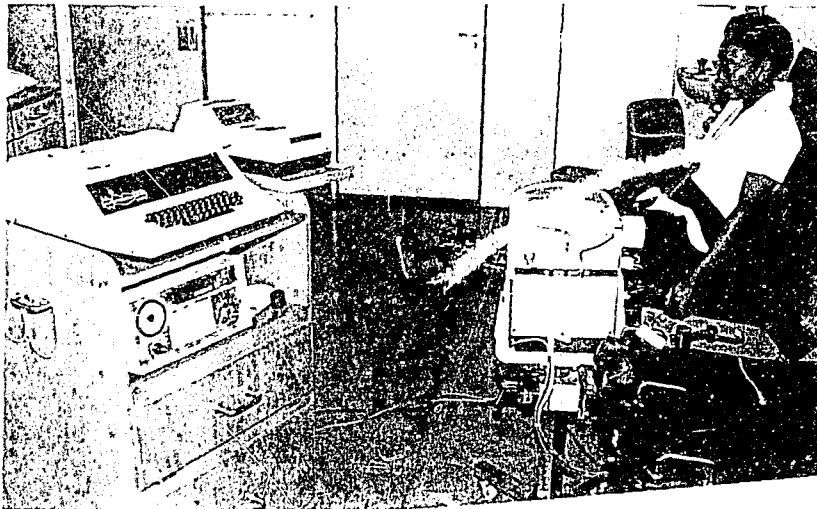


Figure 3.9 Cybex isokinetic dynamometer with data reduction computer

[illegible]

testing procedure. The fact that this was not done is a minor shortcoming of this research.

Each subject's muscle strength was measured isokinetically at weeks 0, 4 and 8. The Dual Channel Recorder, connected to the Cybex machine, recorded a tracing of the torque over time and gave a computer print-out of the values obtained. The Cybex II+ dynamometer and dual channel recorder were calibrated by technicians from the local Cybex agents before the start of the project, using the calibrated weights supplied with the machine and following the calibration procedures in the operating manual (Cybex, Division of Lumex, Inc., 2100 Smithtown Ave, PO Box 9003, Ronkonkoma, New York, USA).

3.3 Procedure

Once volunteers had been recruited and had signed the informed consent (Appendix F), they underwent a Cybex test of both legs at 60°/s and at 270°/s. Initial Cybex tests were done by either the researcher or the research assistant. On the following day they underwent a test to establish their 10 RM, the maximum weight they could lift 10 times with their quadriceps through a full range of movement. All initial 10 RM tests were done by the researcher.

Test-retest reliability of the 10 RM test was not established before the start of this project, which is a shortcoming of this research. 1 RM testing has, however, been documented to be reliable (48, 49, 50, 51, 52), while multiple RM testing has also been used (53). Determination of the 1 RM could lead to injury if done in an unsupervised way by people not used to weight lifting (4, 54, 55). DiNubile (55) recommended that a number of repetitions, such as the 10 RM, be used as this was much safer (55). The 10 RM test was used in the present research project, as it was considered safer than the 1 RM test.

The length of both lower legs was then measured with a tape measure. Measurements were taken from the lateral joint line of the knee to the tip of the lateral malleolus. The subject completed the initial questionnaire (Appendix A) and were then assigned to the land or water groups as described before.

3.3.1. Procedure of Cybex test

Cybex tests were performed by either the researcher or the research assistant, another physiotherapist. The recommended test protocol for the knee joint was followed (5). The research assistant had been trained by the researcher and performed all the tests that were carried out during lunch times and during work hours. The researcher performed all tests that were done after hours, as the assistant was not

available during those times. Both testers followed exactly the same protocol.

The subjects could choose a time of day that was convenient for them to have their tests. Testing was not always done at same time of day, as is recommended by some (57, 68), as a more recent literature review of 224 articles on factors that affect isokinetic testing (56) does not mention the time of day. Many of the tests were performed at the same time of day, however, as many subjects who did not work shifts preferred to attend their exercise and test sessions during their lunch times.

The subjects warmed up by jogging on the spot for two minutes, followed by a 20 second stretch of the hamstrings and quadriceps muscles of each leg (Figures 3.10, 3.11 and 3.12).

A warm up is done to prevent injury from the test or exercise procedure (56). Although there is probably not such a thing as an optimal warm up procedure, a warm up, if done in a standard way before a test procedure, helps to ensure that test data is accurate (56). The warm up and stretch chosen for this research aimed to increase the circulation in the muscles that would be used for exercising or testing. Stretching of hamstrings and quadriceps was done to maintain flexibility. The same warm up procedure was used throughout, to standardise exercise and testing procedures.



Figure 3.10



Figure 3.11

Figure 3.10 Warm up: Jogging on the spot for two minutes

Figure 3.11 Quadriceps stretching

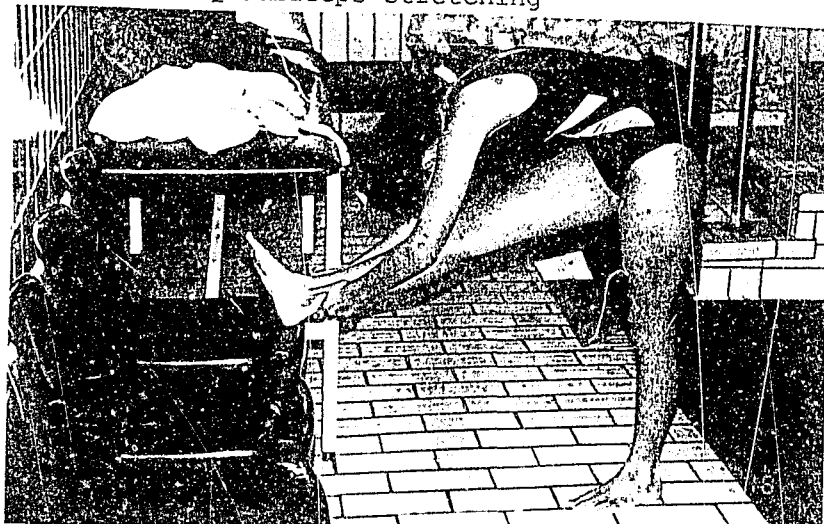


Figure 3.12 Hamstrings stretching

After the warm up, the subject was seated comfortably with her thigh, foot and hip strapped securely (57) (Figure 3.13). The hip was stabilised in order to isolate the movement to the knee joint (57). The subject was positioned in such a way that the axis shaft of the Cybex machine was aligned with the axis of the knee joint, which was taken as the centre of the lateral joint line with the knee in 90° flexion (5). The lateral joint line was found by palpation.



Figure 3.13 Cybex positioning

The number of back supporting pads needed to achieve this was recorded and this same position was used in all subsequent testing for that subject (57). In the same way, the lever length was adjusted so that the shin pad was positioned 3 - 5 cm above the tip of the medial malleolus, allowing the

subject to freely dorsiflex the foot of the leg being tested. The lever length and dynamometer position were noted and kept the same for all subsequent tests for that subject (57).

The torque scale on the dual channel recorder was set at 180 ft lbs (244 Nm) with a damp of two. In addition, the leg was weighed by means of passive knee flexion from full extension, with the lever moving at 15°/s. The subject was instructed to relax her leg completely during this procedure. Testing started with the nondominant leg (the leg that was not expected to strengthen), to enable the subject to get used to the movement required and to decrease any apprehension about the test (5). The movements required were explained to the participants. All subjects received the following identical instructions (as suggested by Davies, (5)) by either of the testers throughout all Cybex tests: "Straighten your leg as hard and as fast as you can, right to the top. Then bend it again as hard and as fast as you can and carry on doing this until I tell you to stop. We're going to do the slow/ fast speed now. Let us try it out now." Five test repetitions of knee flexion and extension were done while the subject was being encouraged ("push!, pull!") to exert maximal effort. This was done at each speed to accustom the subject to the type of muscle work required. Testing speeds of 60°/s and 270°/s were selected.

During and after the test repetitions, the tester ensured that the machine was positioned correctly and that all straps and screws were tight enough. The tester also ensured that the exercises were performed correctly through full range of movement (Figure 3.14).

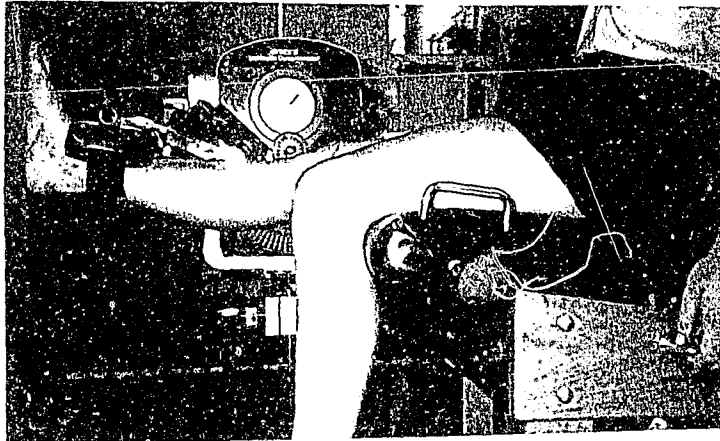


Figure 3.14 Cybex testing through full range of movement

After the five test repetitions, the graph tracing was switched on at 5 mm/s and the subject was required to perform 21 repetitions at the set speed. The subject, however, was unaware of the number of repetitions she was required to perform and was told to carry on until told to stop by the tester. This was done to prevent submaximal effort during the last few contractions. Verbal encouragement ("push!", "pull!") was given throughout the test to ensure maximal muscle contractions.

A graph tracing speed of 25 mm/s would have been better for testing at 270°/s to make sure the curves are not too small,

which makes manual analysis more difficult (5), but was not done due to the high cost of the graph paper.

The Dual Channel Recorder produced a print-out of the values obtained during the test.

Work and average power were determined by means of both a pre-determined time bout (56 s at low speed and 17 s at the high test speed testing) and a pre-determined repetitions bout (20 repetitions) endurance test (5).

All Cybex tests were performed using the same protocol, regardless of whether it was the person's first, second or third Cybex test.

3.3.2 Procedure of 10 RM test

The participant had to warm up by jogging on the spot for two minutes, followed by stretches of the hamstrings and quadriceps muscles of each leg for 20 s (Figures 3.10, 3.11 and 3.12).

The participant was seated in high sitting on a test plinth, i.e. legs hanging over the edge and hips and knees flexed to 90 degrees. A long sponge roll of 10 cm diameter was placed under both knees and the subject sat facing the wall (Figure 3.15). The nondominant knee was extended and a mark made on the wall tiles or a ruler attached to the wall to indicate the height

which makes manual analysis more difficult (5), but was not done due to the high cost of the graph paper.

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reached by the big toe of the nondominant foot, with full knee extension and dorsiflexion of the foot (Figure 3.16).

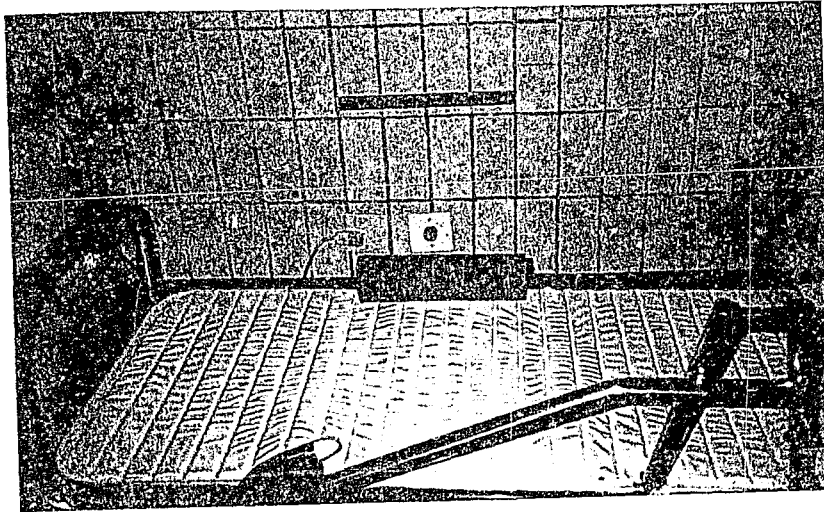


Figure 3.15 10 RM testing: Test plinth with foam roll to be placed under knees. Ruler attached to wall to ascertain correct level of knee extension.



Figure 3.16 10 RM testing: Nondominant leg is fully extended to serve as reference level for full knee extension of the dominant leg to be tested.

During the 10 RM test the participant was asked to keep the nondominant leg fully extended. All initial 10 RM tests were started using 40 N. A 4 kg sandbag was placed over the foot of the dominant leg. A tape of a metronome at 60%/s was played and the participant asked to extend her dominant leg right up to the level of the other leg 10 times to the beat of the metronome (Figure 3.17).

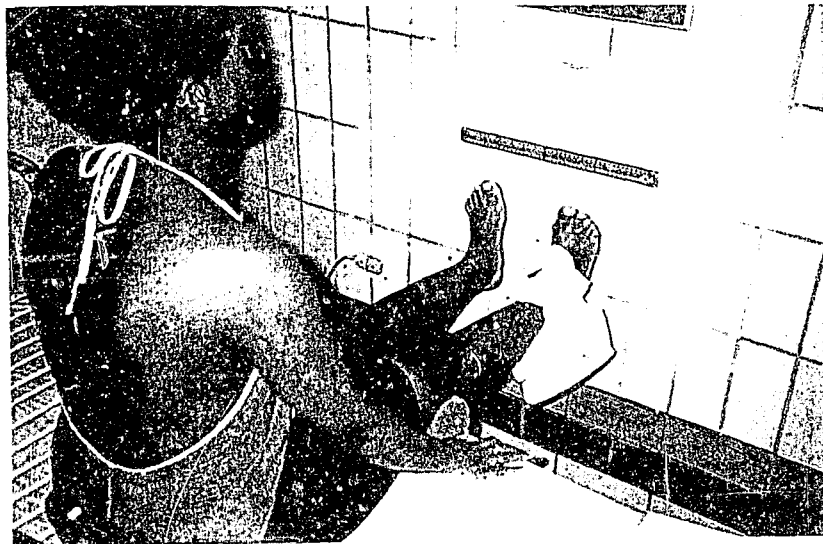


Figure 3.17 10 RM testing: The correct level of extension has been reached. The maximum weight that can be lifted in this way for 10 times, is the 10 RM.

If the participant managed to complete a full range of movement at that weight 10 times, a rest of 10 beats was allowed. The test was then repeated with 45 N and continued with increments of 5 N (0,5 kg) until the maximum weight that could be lifted through full knee extension 10 times. the 10 RM, was established. If the participant was unable to lift the initial

40 N 10 times through full extension, the test was repeated using 35 N and decreases of 5 N until that person's 10 RM was found.

Subsequent 10 RM tests followed exactly the same protocol, except that 5 N (0,5 kg) more than the highest weight lifted by that subject during that week was used as the starting point.

The initial 10 RM test was performed by the researcher and all subsequent tests by a team of six testers, which included the researcher. The researcher trained all testers to use exactly the same test procedure.

The inter-tester reliability was established as follows: All testers conducted a 10 RM test on the same person on the same day and with only a few exceptions, at the same time, to ensure that the person performing the test would not tire from the test. The same procedure was repeated on two occasions (in July and in September 1993). There was no significant difference between the 10 RM measurements performed by the six testers on subject M and J respectively ($p > 0,05$) (Table M1, Appendix M).

3.3.3 Exercise regimen

Both land and water groups exercised five times a week, for eight weeks. On occasions that subjects were not able to attend their exercise session, they had to do a double

session on the next day. The land and water exercises were not done on the days of the subjects' Cybex tests (at the end of week 4 and 8).

Exercises were done in the hydrotherapy area of the Johannesburg Hospital, either in the pool (the water group) or outside the pool, sitting on a plinth (the land group). This ensured that both groups would be exposed to the same air temperature and humidity.

The time of the day each subject came for exercising was organised on a daily basis with the researcher, who was present during all exercise sessions. Exercise times varied from 05h00 to 21h00, depending on the duty shifts and preferences of the participants.

A daily attendance register was kept and participants were telephoned by the researcher on the same day if they did not keep the exercise appointment. Alternative times were then arranged and the participant was encouraged to continue.

Both exercise groups started the exercise session with the warm up that was used for all testing and exercise sessions, i.e. jogging for two minutes (Figure 3.10), followed by stretches for 20 s each of the quadriceps (Figure 3.11) and hamstring muscles (Figure 3.12) of both legs. Only the dominant leg was exercised.

Both exercise groups then followed a modified DeLorme protocol, which the researcher had devised, i.e. using 20 repetitions at each weight, instead of 10 (see Appendix D4).

- a) Lowest weight: ($0,5 \times \text{maximum weight} (*)$)
10 repetitions, 5 counts rest, 10 repetitions
- b) Middle weight: ($0,75 \times \text{maximum weight} (*)$)
10 repetitions, 5 counts rest, 10 repetitions
- c) Highest weight: ($\text{maximum weight} (*)$)
10 repetitions, 5 counts rest, 10 repetitions

During the first exercise week, the 10 RM which was measured before the trial was taken as the maximum weight (*) and all the other weights calculated accordingly. At the end of each week, all subjects underwent a 10 RM test after their exercises. Independently of the value obtained during the weekly 10 RM test, the maximum weight for each consecutive new week was increased by 10 N for each subject. In this way, a person who had had a 10 RM of 40 N (4 kg) at the initial test would have had the following programme for week 1:

- a) 10 repetitions at 20 N (2 kg)
5 counts rest
10 repetitions at 20 N (2 kg)
put on new weight
- b) 10 repetitions at 30 N (3 kg)
5 counts rest
10 repetitions at 30 N (3 kg)
put on new weight

- c) 10 repetitions at 40 N (4 kg)
- 5 counts rest
- 10 repetitions at 40 N (4 kg)

The programme for week 2 would have had 50 N as the maximum weight, week 3 would have had 60 N, etc.

The general exercise programme as well as the individual weights with which each participant was required to exercise were displayed on the wall in the hydrotherapy area, so that all participants could refresh their memories at all times. The researcher was also present during all the sessions, counted for both groups, made sure that the exercise programme was followed strictly and actively encouraged and assisted where needed. The exercises were done to the beat of a tape of a metronome at 60 %/s.

The land group used sandbags as their weights and simply had to add another sandbag of the correct weight when changing over from the lowest to the middle and from the middle to the highest weight. While changing the weights a rest of 10 counts was kept.

The participants in the land group sat in high sitting on the plinths, with a foam roll placed under the knee and the sandbag placed over the ankle (Figures 3.18 and 3.19). The position of their arms was not specified. In contrast to the 10 RM test, where the nondominant knee was extended (Figure 3.16), the nondominant knee was relaxed in a flexed position with the

lower leg hanging over the edge of the plinth during the land exercises (Figure 3.19).



Figure 3.18



Figure 3.19

Figures 3.18 & 3.19 Quadriceps exercises on land

When performing the exercises with higher weights (e.g. those of the last two weeks), a sock was placed over the dorsum of the foot to prevent the weights causing discomfort to the skin, as they shifted slightly while the exercises were being performed.

The participants in the water group used a set of eight empty 2 litre plastic bottles filled with varying amounts of water as their weights. After the warm up, the participants of the water group were required to walk through a foot bath containing Milton (58). Then they had to wrap a towel around the dominant

leg and secure it by putting an elasticised stocking or stockinet over the towel (Figure 3.20).



Figure 3.20 Water exercise group: Towel and stockinet applied to leg.

The set of bottles was then put on the leg (Figure 3.21) and the starting position taken up, i.e. the subject positioned herself in prone lying over the edge of the pool with the hips and knees flexed at 90 degrees (Figure 3.22). The exercise involved straightening the dominant knee downwards into the water (Figures 3.23 and 3.24). The thigh was kept still by making sure that the anterior surface of the thigh touched the

set of three bottles placed vertically down against the pool wall. The exercise area was thus designed in such a way that knee extension exercises could be performed with the hip at 90 degrees and without the hip moving.



Figure 3.21 Water exercise group: Set of bottles attached to leg

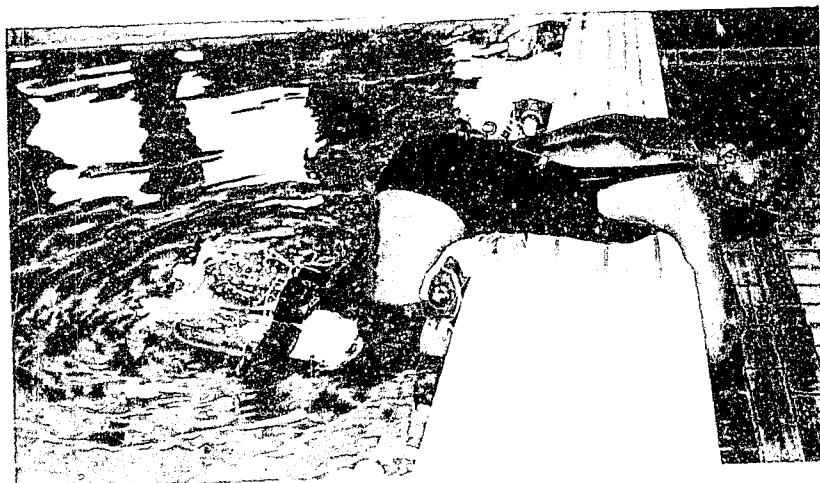


Figure 3.22



Figure 3.23

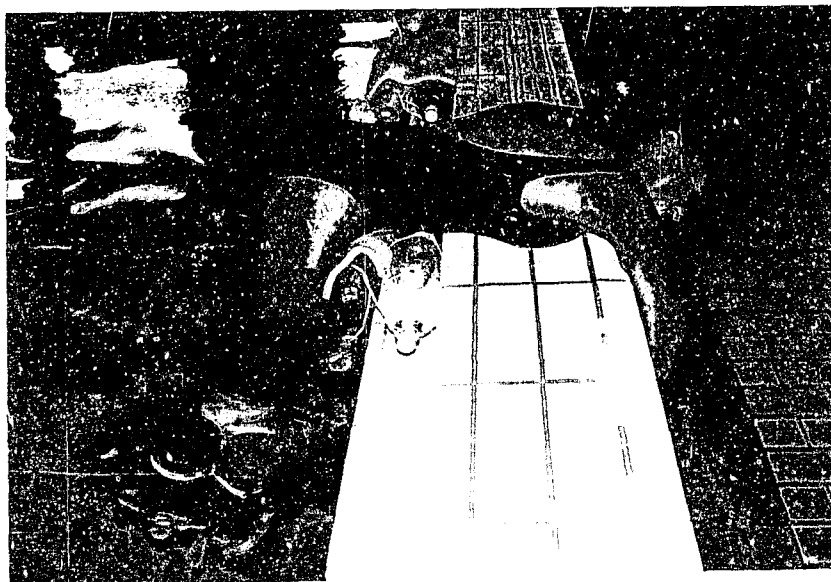


Figure 3.24

Figures 3.22, 3.23 & 3.24 Quadriceps strengthening in water

After the 20 repetitions with the lowest weight, the water exercise group removed the set of bottles from the legs. The set of bottles was placed on the edge of the pool and water was then let out of the bottles with a pipe until the required level was reached (Figure 3.25).

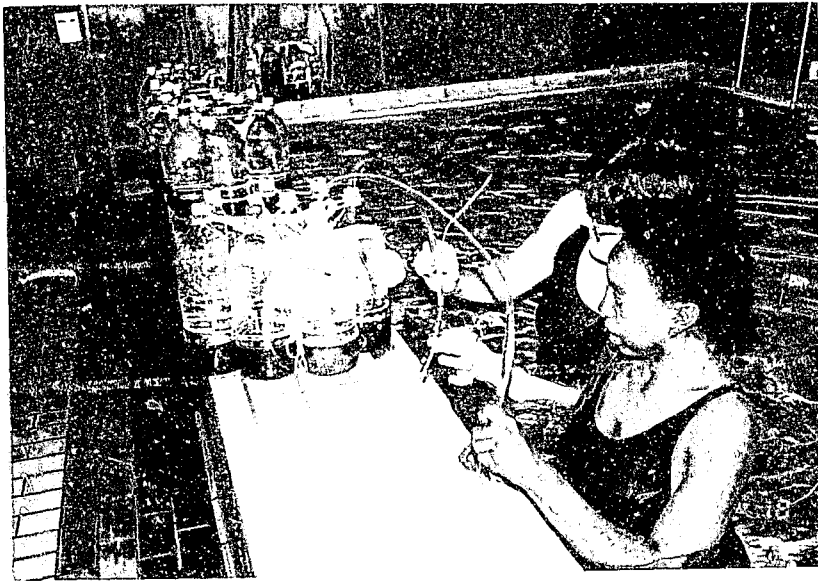


Figure 3.25 The correct amount of water is let out in-between sets to progressively increase resistance

So, for example, the person with the lowest weight of 20 N, the middle weight of 30 N and the highest weight of 40 N would have had to take out 1 litre of water to change the resistance from 20 N to 30 N. She would then have had to remove another 1 litre to change the resistance from 30 N to 40 N. After the correct amount of water had been removed, the participant put on the set of bottles again and completed her next two sets of 10 repetitions each. The bottles were then removed and placed on

the side of the pool again. The correct amount of water was removed until the required highest weight was reached and the set of bottles put on again. The participant then completed the last two sets of 10 repetitions each. The researcher closely supervised the emptying of the bottles to ensure strict adherence to the programme. At the end of the exercises, the participants in the water group were required to shower in order to cool down (58) and to wash off the chlorine.

Water, cool drinks and fruit were available in the hydrotherapy area for the participants throughout the duration of the trial.

The participants of the water and land groups had 10 RM tests done on at the end of weeks 1 - 7. Participants also had to complete a short questionnaire (see Appendix C) at this stage. The questionnaire sought answers to the questions of whether any pain or muscle soreness had been experienced during that week and how comfortable the person had been while doing the exercises. The level of comfort was indicated on a 100 mm visual analogue scale with the markings "very uncomfortable" and "very comfortable" at the ends (see question 3 on weekly questionnaire, Appendix C). The questionnaire also used visual analogue scales for establishing the severity of pain and muscle soreness. The visual analogue scale was used as this was described to be the best method available for measuring pain (59). Subjects that had experienced pain were asked to indicate the location of the pain.

At the end of weeks 4 and 8, further Cybex Tests were done on the participants of the water, land and control groups. The tests were conducted exactly as the initial Cybex Test (see procedure described previously). In addition, at the end of eight weeks, the participants were given a slightly more comprehensive questionnaire (see Appendix B). Information was sought on the perceived benefits of the exercise trial, on the perceived advantages or disadvantages of having been in the water or land group and on whether the person had been able to comply with the requirement of not participating in other sporting activity during the trial.

At the completion of the trial, each participant received a "certificate" (see Appendix N) from the researcher stating the improvement observed in that subject's weekly 10 RM tests.

3.4 Data analysis

Following the completion of the clinical trial, the data obtained from the Cybex tests was analysed. Due to the fact that the computer part of the Cybex Dual Channel Recorder had broken down half way through the trial (even though the repairs were completed in three weeks) a number of Cybex tests were done without the computer's numerical print-outs. The part of the dual channel recorder drawing the torque curves was functional throughout the test sessions.

Graph tracings were therefore obtained for all the tests. Peak torque, work, power and endurance ratios could therefore still be determined by calculating them from the torque curve tracings on the graph paper and all the Cybex graph tracings were therefore analysed manually.

An additional reason for manual calculations was the fact that the lower leg weight measurements were not always done accurately on the tests where the computer was in operation, since the subjects did not relax their legs consistently and it was difficult to repeat the test. The lower leg weight measurements would have affected the computer's numerical print-outs, as these were gravity corrected.

From the tracings of the Dual Channel Recorder, the peak torque, work, power and endurance ratios for both knee flexion and extension were calculated. Only the extension values are presented in this research report.

The manual calculations were done as follows: The flexion and extension curves were marked and analysed separately. A grid (grid D on the CYBEX II+ Chart Data Card, see Figure 3.26) was used to read off peak torque (the mean of the first five peak torques).

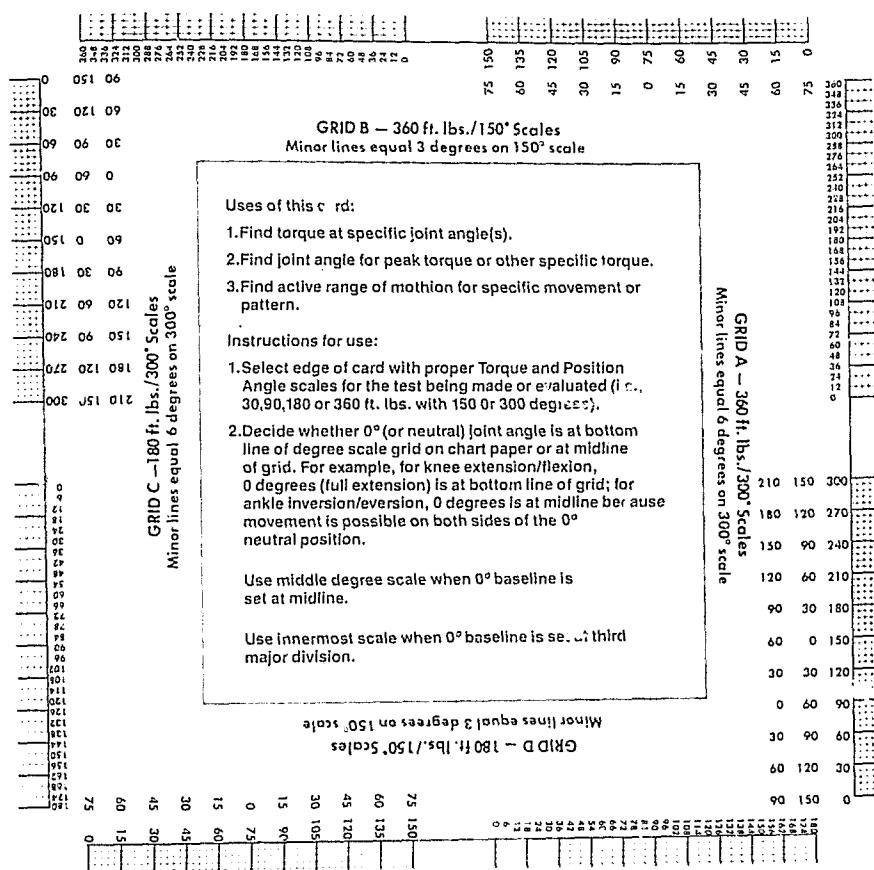


Figure 3.26 CYBEX II+ Chart Data Card (Grid D on a similar card calibrated in Nm instead of ft.lbs. was used to read off peak torque from the torque curves, 1 ft.lb. = 1,35 Nm (8))

The number of 1, 5 x 1 mm blocks under 20 curves or under the curves completed in 56 s or 17 s (for traces at 60°/s and 270°/s respectively) was counted to provide an indication of rotational work done. The work done was divided by the time taken to complete the work to get an indication of power. The endurance ratio was determined by dividing the number of blocks under the last 5 curves by the number of blocks under the first 5 curves, i.e. the work done over the last 5

contractions divided by the work done under the first 5 contractions.

The manual calculations were time-consuming, as this included the counting of the 1,5 mm x 1 mm blocks under the graphs (rotational work done) of about 132 m of graph tracings. The researcher investigated various other methods such as using a planimeter (8), using a computer scanner and weighing the cut out graph paper, but found that counting was still the most accurate. As the experiment in 1991 (the first trial) had failed due to a possible inability of the Cybex machine to register small increases in muscle strength, the researcher proceeded with the process of block counting in this trial in order to attain the highest possible level of accuracy.

The procedure of counting the blocks and using a grid to calculate peak torque was found to be reliable, as a strong correlation was found between the values obtained manually and the values of the computer print-outs that were available (Appendix O). In view of this strong correlation and the fact that more data was available using the manual calculations, the data obtained manually was used for statistical analysis.

3.4.1 Statistical analysis

Means and standard deviations were obtained for all the continuous variables in the three groups. The means and standard deviations of the groups were then compared using the student's t-test. Frequency tables were used for discrete variables. The frequency tables with two variables were compared using the 2-tailed Fisher's exact test and those with three variables using the chi-squared test. Frequency tables with more than three variables were compared using descriptive statistics only. A confidence level of $p = 0,05$ was used throughout the study.

The improvements that occurred in all Cybex test values as well as 10 RM values were analysed to establish whether they were significant ($p < 0,05$) or not, using the student's t-test.

The values obtained on two occasions by the six 10 RM testers, where all testers tested the same subject, were analysed using a one way analysis of variance test in order to establish whether there were any significant differences ($p < 0,05$) in the values obtained by the testers.

Correlation analyses were done of peak extension torque and extension work of the dominant leg at $60^\circ/\text{s}$ at weeks 0, 4 and 8, and the corresponding 10 RM, using Pearsons correlation coefficients and the coefficient of determination.

The SAS^a (Statistical Applications Systems), version 6.07, statistical computer software programme was used for statistical analysis.

^a SAS Institute, Inc., SAS Campus Drive, Cary, USA

CHAPTER 4

RESULTS

(For the abbreviations used in this chapter, refer to ABBREVIATIONS, p xxvi)

4.1 Attendance

The mean number of attendances for both exercise groups was 36,22 (standard deviation = 3,91), which means they attended 95 per cent of all sessions. There were no significant differences in the number of attendances or number of double sessions between the water and land exercise groups ($p > 0,05$) (see Table M2, Appendix M).

4.2 Isokinetic and 10 RM test values at week 0

The isokinetic extension values obtained at week 0 for all groups combined can be seen in Appendix M, Table M3. The abbreviations are given at beginning of this chapter.

The mean 10 RM of the dominant leg at week 0 for the water and the land groups combined, was 38,3 N (standard deviation = 7,8 N).

4.3 Comparisons

4.3.1 Cybex test results

When comparing the Cybex isokinetic test results, there was no significant difference between the three groups in the knee extension peak torque at 60°/s of the dominant knee in any of the tests ($p > 0,05$) (see Appendix M, Table M4).

The following significant differences ($p < 0,05$) were found between the water, land and control groups (see Appendix M, Table M4):

4.3.1.1 Values of initial Cybex tests

The water group had a significantly higher ($p < 0,05$) extension work value of the nondominant leg than the land group when tested at week 0 at 60°/s.

4.3.1.2 Changes over initial four weeks in exercised leg

The control group had a significantly larger ($p < 0,05$) improvement of the extension endurance ratio of the dominant leg at 60°/s over the first four weeks than the water group (see Table M4, Appendix M). For this test, the water group showed a decrease over the initial four weeks.

4.3.2 10 RM test results

No significant differences were found when comparing the weekly 10 RM tests of the subjects in the water to the land group ($p > 0,05$), i.e. both groups performed equally. The values can be obtained from Table 4.1.

Table 4.1 10 RM values for the water and land groups in kg

10 RM	WATER GROUP		LAND GROUP		p - values	
	MEAN	S.D.	MEAN	S.D.	water vs land	
WEEK 0	3,9	0,87	3,86	0,70	0,392	ns*
WEEK 1	4,39	0,87	4,61	1,04	0,244	ns
WEEK 2	5,5	1,15	4,97	1,17	0,087	ns
WEEK 3	6,32	1,15	6,0	1,22	0,211	ns
WEEK 4	7,19	1,16	6,89	1,15	0,217	ns
WEEK 5	7,95	1,12	7,82	0,79	0,351	ns
WEEK 6	8,58	1,48	8,5	1,04	0,423	ns
WEEK 7	9,42	1,50	9,2	1,62	0,337	ns

ns* = not significant (Two-tailed, two sample t-test)

4.3.3 Comparing the weekly questionnaires of the water and land groups

4.3.3.1 Comfort on exercising

Subjects in both the water and land exercise groups were equally fairly comfortable on exercising. The final and initial values of comfort for the water exercise group were virtually identical, whereas the land group showed a steady decline in level of comfort over the eight weeks. The land group also showed a significant difference ($p < 0,05$) between the final level and the level at week 1 (the final level being about 20 mm less than the initial level) (see Table 4.2).

Table 4.2 Comfort while exercising

WEEK	WATER		LAND	
	MEAN	S.D.	MEAN	S.D.
1	78,368*	31,129	85,056	23,643
2	78,684	31,246	83,944	24,114
3	84,158	18,109	79,778	28,663
4	80,211	26,768	81,000	24,326
5	75,368	26,487	71,556	33,344
6	75,670	20,540	74,071	27,650
7	74,400	27,230	74,640	24,780
8	79,750	17,490	65,620	30,610
CHANGE FROM WEEK 1 TO WEEK 8	Nonsignificant $p = 0,433$		Significant difference** $p = 0,020$	

* Zero is very uncomfortable and 100 is very comfortable (see visual analogue scale, Appendix C, Question Three).

** Two-tailed, two sample t-test

4.3.3.2 Thigh muscle soreness

On 42 occasions out of 149 in the water group and on 46 occasions out of 135 in the land group, thigh muscle soreness was recorded (Table M5, Appendix M). There was thus no significant difference in the number of subjects reporting thigh muscle soreness between the water and land groups over the 8 week period ($p > 0,05$) (Table M5, Appendix M). However, the water group experienced significantly more ($p < 0,05$) muscle soreness than the land group during each of the exercise weeks, except for the first week ($p > 0,05$) (Table 4.3).

Table 4.3 Differences in severity of muscle soreness between water and land groups, all significant ($p < 0,05$) except week 1

WEEK	WATER MEAN (STANDARD DEVIATION)	LAND MEAN (STANDARD DEVIATION)	p - value**
1	31,00 mm (24,58) *	26,00 mm (18,11)	0,244 ns#
2	70,50 mm (20,63)	16,20 mm (7,01)	0,000 s##
3	62,17 mm (36,36)	20,60 mm (14,05)	0,000 s
4	59,60 mm (27,02)	20,43 mm (10,91)	0,000 s
5	47,83 mm (26,35)	27,50 mm (30,56)	0,018 s
6	53,00 mm (33,79)	33,43 mm (22,62)	0,024 s
7	75,60 mm (29,99)	29,00 mm (18,32)	0,000 s
8	70,50 mm (27,61)	31,50 mm (18,84)	0,000 s

* 100 mm on the visual analogue would indicate the worst muscle soreness the subjects had ever experienced, whereas 0 mm indicates no muscle soreness.

** Two-tailed two sample t-test

ns# = no significant difference

s## = significant difference

4.3.3.3 Pain on exercising

No significant differences were found between the two exercise groups in the number of subjects who had indicated on the weekly questionnaire that they had experienced pain while exercising in any of the weeks ($p > 0,05$).

When the number of reports of pain on exercising (found on the weekly questionnaires) was taken as a total over eight weeks, a significant difference ($p < 0,05$) between the land and water groups was found (see Table 4.4). Significantly more ($p < 0,05$) reports of pain had occurred in the land than in the water group.

Table 4.4 Comparison of pain while exercising over eight weeks

	WATER GROUP	LAND GROUP	P - value #
NUMBER OF REPORTS OF <u>PAIN</u>	55	75	0,002 s*
NUMBER OF REPORTS OF <u>NO PAIN</u>	94	60	
TOTAL NUMBER OF REPORTS	149**	135***	

s* = significant

** This is less than 152 (8 questionnaires x 19 subjects) because one subject did not complete the full 8 weeks of exercise

*** This is less than 144 (8 questionnaires x 18 subjects) because 3 subjects did not complete the full 8 weeks of exercise

2-Tail Fisher's Exact Test

Due to low numbers no statistical analysis was possible to compare the areas where pain was felt during exercise between the three groups. Table M6 (Appendix M) summarises the comparison between the areas where pain was felt. In both groups, the pain occurred mostly around the knee of the exercised leg, i.e. in the quadriceps or hamstring muscles, or behind the knee cap. More subjects indicated pain in the ankle area and calf muscles in the land group than in the water group.

4.3.4 Comparing the final questionnaire of the land and water groups

All the subjects in the land and water groups indicated that the exercises had been beneficial. From Table 4.5 it can be seen that there was no significant difference in the degree of perceived benefit when comparing the two exercise groups ($p > 0,05$).

Table 4.6 lists the reasons given by the subjects as to why the exercises had been beneficial. Numbers were too small to do formal statistical testing.

Table 4.5 The perceived degree of benefit of the exercises

	WATER		LAND		
	NO.*	PERCENTAGE	NO.	PERCENTAGE	p - value #
SOMEWHAT BENEFICIAL	6	33,3	6	40,0	0,731 ns**
VERY BENEFICIAL	12	66,7	9	60,0	
TOTAL***	18	100	15	100	

NO.* = number of subjects

ns** = not significant

*** one subject in the water group and 3 subjects in the land group did not complete the full 8 weeks of exercise and therefore also not the week 8 questionnaire

2-Tail Fisher's Exact Test

Table 4.6 Reasons given for the beneficial effect of the exercises

EXPLANATIONS	WATER		LAND	
	NO.*	PERCENTAGE	NO.	PERCENTAGE
fitter	3	15	0	0
leg is stronger	8	40	5	31,3
feel able to get into an exercise programme again	2	10	2	12,5
weight loss	2	10	1	6,3
weight gain	1	5	0	0
became active	1	5	2	12,5
psychological benefits	1	5	3	18,8
legs toned/ firmer	2	10	2	12,5
gave me discipline/ routine, tested my perseverance, good stress management	0	0	1	6,3
TOTAL**	20	100	16	100

NO.* = number of subjects

** subjects could give any number of explanations

All the subjects in the water and land groups indicated that they felt that there had been an improvement in the thigh muscle strength of the leg they had exercised. The perceived amount of improvement brought about by the exercises is described in Table 4.7. No significant differences were found between the water and land groups ($p > 0,05$). The reasons for having indicated that their thigh muscles had strengthened are found in Table 4.8.

Table 4.7 Comparing the water and land groups in the perceived improvement of the thigh muscle strength of the exercised leg

	WATER		LAND		chi-squared value
DEGREE OF IMPROVEMENT	NO.*	PERCENTAGE	NO.	PERCENTAGE	3,709
slight improvement	4	22,2	0	0	p - value 0,157 ns**
moderate improvement	9	50,0	8	57,1	
tremendous improvement	5	27,8	6	42,8	
TOTAL***	18	100	14	100	

NO.* = number of subjects

ns** = not significant

*** One subject in the water group and 3 subjects in the land group did not complete the full 8 weeks of exercise and therefore also not the week 8 questionnaire. One subject in the land group did not answer this question.

One subject remarked that the trial had been too short, while another stated that she had not seen a marked improvement on her leg.

The advantages and disadvantages of having been in the water exercise group are found in Tables 4.9 and 4.10.

Table 4.8 Comparison of the explanations given when describing the degree of improvement in thigh muscle strength: water group versus land group

EXPLANATION	WATER		LAND	
	NO.*	PERCENTAGE	NO.	PERCENTAGE
stair climbing easier, jog faster, do more before running out of breath	3	20	2	18,2
no longer pain on exercise	1	6,7	1	9,1
muscles firmer, more muscle definition	7	46,7	6	54,5
feel muscle pulling when exercising	1	6,7	0	0
can easily exercise with heavier weights	2	13,3	1	9,1
weight loss	1	6,7	0	0
no more cramps at night, as I had before	0	0	1	9,1
TOTAL**	15	100	11	100

NO.* = number of subjects

** subjects could give any number of explanations

Table 4.9 Advantages of water exercises (only completed by water exercise group)

ADVANTAGE: WATER	NO.*	PERCENTAGE
you don't really feel the weight, you get used to exercising your legs/ exercises in water are much easier	5	20,8
enjoyable/ fun	3	12,5
continuous resistance through range of movement/ due to viscosity of water there is more resistance to work against water than against air	2	8,3
none	2	8,3
muscle bigger/ lost flabbiness in leg	2	8,3
motivates	1	4,2
not as boring as land	1	4,2
feel fresh and flexible when coming out of water	1	4,2
water exercises more effective	1	4,2
water exercise helps to prevent many sicknesses e.g. arthritis	1	4,2
more strenuous, work more muscles e.g. stomach and arms	1	4,2
relaxing	1	4,2
cannot cheat in water	1	4,2
improves fitness	1	4,2
more comfortable in water	1	4,2
TOTAL**	24	100

NO.* = number of subjects

** subjects could give any number of advantages

Table 4.10 Disadvantage of water exercise (only given by water exercise group)

DISADVANTAGES: WATER	NO.*	PERCENTAGE
time taken/ inconvenience of having to change clothing	5	29,4
none	3	17,6
I thought at first that I was going to get diseases from other people using the water	2	11,8
chlorine sometimes too strong	2	11,8
not being able to exercise outside in winter	1	5,9
time to get changed and put equipment on	1	5,9
if pool is a bit cold, it takes a while to get used to water	1	5,9
you get wet	1	5,9
costume is being damaged by chlorine	1	5,9
TOTAL**	17	100

NO.* = number of subjects

** subjects could give any number of disadvantages

Similarly, the advantages and disadvantages of having been in the land exercise group are listed in Tables 4.11 and 4.12.

Table 4.11 Advantages of land exercises (only listed by land group)

ADVANTAGES: LAND	NO.*	PERCENTAGE
quicker	8	30,8
don't have to change clothes	7	26,9
more practical, convenient	3	11,5
easy to perform	2	7,7
don't have to shower afterwards	2	7,7
can exercise even when menstruating	1	3,8
both water and land equally effective	1	3,8
can do exercises by yourself	1	3,8
regular physical activity which motivates me to continue an exercise programme now after completion of the trial	1	3,8
TOTAL**	26	100

NO.* = number of subjects

** subjects could give any number of advantages

Table 4.12 Disadvantages of having been in the land exercise group (only completed by those in land exercise group)

DISADVANTAGES: LAND	NO.*	PERCENTAGE
none	5	45,5
I love water and could not go in	1	9,1
too much perspiration on land; this problem does not occur in water	1	9,1
I would have liked to have been in the water exercise group to overcome my fear of water	1	9,1
my abdomen did not get as much exercise as I would have liked	1	9,1
the weights get heavy and I don't think it is good for the knees	1	9,1
not sure	1	9,1
TOTAL**	11	100

NO.* = number of subjects

** subjects could give any number of disadvantages

All the subjects in the water and land exercise groups indicated that they had been able to discontinue any other sporting activities during the eight weeks of the exercise trial.

Six subjects in the water group experienced skin irritation (33,3 per cent), while 12 subjects did not experience any skin irritation (66,7 per cent). The description of the skin irritation is found in Table 4.13.

Table 4.13 Description of skin irritation (given by 33,3 per cent of the water exercise group)

SKIN REACTION	NO.*	PERCENTAGE
Dry skin	5	55,6
Itchy skin	2	22,2
Burning sensation	1	11,1
Flaking of skin	1	11,1
TOTAL**	9	100

NO.* = number of subjects

** subjects could give any number of skin reactions

4.4 Significant improvements

4.4.1 Significant improvements over the baseline values on Cybex testing

Many of the Cybex test values in the three groups did not show significant improvements ($p > 0,05$).

The significant improvements ($p < 0,05$) that occurred

a) over the first four weeks ($\frac{\text{wk 4}}{\text{wk 0}}$),

b) over the last four weeks ($\frac{\text{wk 8}}{\text{wk 4}}$) and

c) over the total eight weeks ($\frac{\text{wk 8}}{\text{wk 0}}$) are given

in Table 4.14 for the water group,

in Table 4.15 for the land group and

in Table 4.16 for the control group.

In none of the isokinetic tests did the dominant (exercised) leg show significant improvements at 60°/s (the exercise speed) ($p > 0,05$).

4.4.1.1 Water group

The water group showed significant improvements ($p < 0,05$) of only the extension endurance ratio of the nondominant leg from week 4 to 8 (see Table 4.14).

Table 4.14 Significant improvements on isokinetic testing: water group

LEG	TEST SPEED	VARIABLE	MEAN (last test previous)	S.D.	p - value
nondominant	60°/s	EER: wk 8 wk 4	1,080*	0,132	0,008 s#

* = a value above 1 indicates an improvement over the previous test

s# = significant

4.4.1.2 Land Group

Extension work and extension power of the dominant leg showed a significant increase ($p < 0,05$) in the land group over the eight weeks when tested at 270°/s (see Table 4.15).

Table 4.15 Significant improvements on isokinetic testing: land group

LEG	TEST SPEED	VARIABLE	MEAN	S.D.	p - value (all significant)
dominant	270°/s	20:W in E: $\frac{wk\ 4}{wk\ 0}$	1,224*	0,326	0,005
dominant	270°/s	t:W in E: $\frac{wk\ 4}{wk\ 0}$	1,218	0,320	0,005
dominant	270°/s	20:EP: $\frac{wk\ 4}{wk\ 0}$	1,164	0,300	0,009
dominant	270°/s	t:EP: $\frac{wk\ 4}{wk\ 0}$	1,191	0,310	0,009
dominant	270°/s	20:W in E: $\frac{wk\ 8}{wk\ 0}$	1,261	0,400	0,007
dominant	270°/s	t:W in E: $\frac{wk\ 8}{wk\ 0}$	1,297	0,492	0,010
dominant	270°/s	20:EP: $\frac{wk\ 8}{wk\ 0}$	1,240	0,457	,,020
dominant	270°/s	t:EP: $\frac{wk\ 8}{wk\ 0}$	1,231	0,459	0,024

* a value above 1 indicates an improvement over the previous test

4.4.1.3 Control group

At the test speed of 270°/s, extension power and the extension endurance ratio of the dominant leg increased significantly ($p < 0,05$) in the control group over the eight weeks (see Table 4.16).

The control group revealed significant improvements ($p < 0,05$) in peak extension torque and extension power over the first four weeks at 270°/s only (see Table 4.16).

Table 4.16 Significant improvements on isokinetic testing:
control group

LEG	TEST SPEED	VARIABLE	MEAN	STANDARD DEVIATION	p - value: all significant
nondominant	270°/s	ptE: $\frac{wk\ 4}{wk\ 0}$	1,105*	0,200	0,027
nondominant	270°/s	20:EP: $\frac{wk\ 4}{wk\ 0}$	1,151	0,280	0,024
nondominant	270°/s	t:EP: $\frac{wk\ 4}{wk\ 0}$	1,137	0,257	0,025
dominant	270°/s	20:EP: $\frac{wk\ 8}{wk\ 0}$	1,163	0,322	0,031
dominant	270°/s	20:EP: $\frac{wk\ 8}{wk\ 4}$	1,113	0,22*	0,030
dominant	270°/s	EER: $\frac{wk\ 4}{wk\ 0}$	1,169	0,281	0,015
dominant	270°/s	EER: $\frac{wk\ 8}{wk\ 0}$	1,252	0,453	0,021

* a value above 1 indicates an improvement over the previous test

4.4.2 Significant improvements on 10 RM testing

4.4.2.1 Water group

In the water exercise group all 10 RM values showed a significant weekly improvement ($p < 0,05$) (see Table 4.17). From week 0 to week 4 the 10 RM value was nearly doubled, while the 10 RM value had increased by more than 2,5 times the initial value by week 7.

4.4.2.2 Land group

In the land group nearly all 10 RM values showed a significant weekly improvement ($p < 0,05$). Only the improvement from week 1 to week 2 was not significant ($p > 0,05$). From week 0 to week 4 the 10 RM value nearly doubled and by week 7 the 10 RM value was nearly 2,5 times the initial value (see Table 4.18).

Table 4.17 10 RM improvements in water group: all significant ($p < 0,05$)

10 RM IMPROVEMENTS*	MEAN	STANDARD DEVIATION	p - values (all significant)
$\frac{wk\ 1}{wk\ 0}$	1,194	0,145	0,000
$\frac{wk\ 2}{wk\ 1}$	1,254	0,172	0,000
$\frac{wk\ 3}{wk\ 2}$	1,163	0,148	0,000
$\frac{wk\ 4}{wk\ 3}$	1,139	0,107	0,000
$\frac{wk\ 5}{wk\ 4}$	1,149	0,142	0,000
$\frac{wk\ 6}{wk\ 5}$	1,083	0,125	0,005
$\frac{wk\ 7}{wk\ 6}$	1,109	0,147	0,002
$\frac{wk\ 4}{wk\ 0}$	1,936	0,299	0,000
$\frac{wk\ 7}{wk\ 0}$	2,560	0,435	0,000

* 10 RM improvements are indicated as the ratio of the new value over the previous value, e.g. $\frac{wk\ 1}{wk\ 0}$

will be the ratio $\frac{10\ RM\ at\ week\ 1}{10\ RM\ at\ week\ 0}$,

i.e. a value above 1 indicates an improvement over the previous test.

Table 4.18 10 RM improvements in land group ($p < 0,05$)

10 RM IMPROVEMENTS	MEAN	STANDARD DEVIATION	p - values	SIGNIFICANT IMPROVEMENT OR NOT
wk 1 wk 0	1,195*	0,162	0,000	significant
wk 2 wk 1	1,097	0,252	0,060	not significant
wk 3 wk 2	1,239	0,243	0,000	significant
wk 4 wk 3	1,193	0,172	0,000	significant
wk 5 wk 4	1,124	0,118	0,000	significant
wk 6 wk 5	1,081	0,072	0,000	significant
wk 7 wk 6	1,075	0,149	0,024	significant
wk 4 wk 0	1,833	0,244	0,000	significant
wk 7 wk 0	2,381	0,473	0,000	significant

* a value above 1 indicates an improvement over the previous test

4.5 Correlations

4.5.1 Correlation between 10 RM and isokinetic test values

No correlation was found between the 10 RM values and the isokinetic test values at 60°/s for peak extension torque and extension work of the dominant leg at weeks 0, 4 or 8 (see Tables M7, M8 and M9, Appendix M).

CHAPTER 5

DISCUSSION

5.1 Isotonic strength increases

The exercises in both exercise groups were equally effective, as both groups showed considerable isotonic (10 RM) strength increases, but no significant differences.

Although the point of maximal resistance within the range of movement differed between the two exercise regimens, the same amount of resistance in kilograms was used for both groups throughout. This resulted in similar improvements in 10 RM. Butler & Kempson (60) also found no difference between the improvements in 1 RM in their group of healthy subjects who exercised on a Westminster pulley, on a Westminster pulley with an additional pulley added or on a "constant resistance through range" apparatus. They concluded that resistance need not be at 90 degrees to the movement to lead to strengthening. Their findings could not, however, be generalised, as the subjects exercised for only three weeks.

Muscle strengthening in the present research project is most likely to have occurred as a result of neural factors (such as better muscle fibre recruitment and higher synchronisation (32,

61)) since the isotonic strengthening programme of eight weeks was relatively short for muscle strengthening (32, 61, 62, 63, 64). This research project did not establish whether or not muscle hypertrophy contributed to the muscle strengthening observed. Muscle biopsies or CT scans would have been needed to establish the cross sectional area of the quadriceps muscles (65).

5.1.1 Reliability of 10 RM testing

Despite the fact that the 10 RM test dates back to the time of DeLorme (1945) (9, 10), testing of repetition maxima, such as the 10 RM or 1 RM, is still being used as a reliable muscle strength test by many researchers today (48, 50, 51, 64).

The 10 RM test has been criticised by researchers such as DeLateur, Lehmann & Fordyce (66). They are of the opinion that the 10 RM test may itself tire subjects so that they cannot give their best and that the test procedure could itself contribute to the amount of exercise done.

Nevertheless, the researcher found that 10 RM testing can be very well controlled and is of the opinion that it should not lead to fatigue or false results if executed correctly. For this reason, careful instructions were given to the testers. The 10 RM test was done after the last exercise session of the week to the beat of a metronome and on the test bench (see

Figures 4.15, 4.16 and 4.17). Moreover a standardised test protocol was followed, in which the 10 RM test was always started at 5 N more weight (a mass of 0,5 kg) than the maximum the person had exercised with during that week, and not at any arbitrary higher level. This prevented unnecessary repetitions in establishing the new 10 RM.

Finally, there were no significant differences between all the testers in the 10 RM values assigned to a subject. This was found on two occasions and confirms that the 10 RM could be established reliably.

A disadvantage of the 10 RM testing in this trial was that the possibility of bias could not be excluded completely. Although six testers were used for the 10 RM testing, the researcher was one of the testers. As the weekly 10 RM testing took place in the exercise area, the 10 RM testers were also aware of which exercise group the subjects belonged to. Nevertheless, the researcher is of the opinion that adherence to the strict test protocol prevented bias.

5.1.2 The lack of a 10 RM tests for the control group

The control group did not have weekly 10 RM tests, as this could possibly have resulted in strengthening by itself.

It is notable that Butler, et al. (60) found that a control group that underwent weekly 1 RM testing demonstrated an increase in the 1 RM, as did the exercise groups. This increase in 1 RM in the control group, could have been due to either familiarisation or an inherent strengthening effect produced by the test. Their study was only, however, conducted for three weeks, which is much too short to come to any definite conclusions. The sample size of 26, divided into four groups, was also very small.

In the present study, if the 10 RM tests had contributed to the weekly strengthening, the control group would have been weaker on isokinetic testing than the two exercise groups, which did not occur. It would have been interesting to have compared 10 RM results of the non-exercising control group to that of the exercising groups, to establish if familiarisation could play a role over an eight week period. The lack of a 10 RM test for the control group is a shortcoming of this trial. The 10 RM strength increases of the magnitude observed for the two exercise groups could not, however, have arisen from familiarisation alone.

5.2 Isokinetic strengthening

5.2.1 Isokinetic test results

5.2.1.1 Significant improvements

Unexpectedly, no significant improvements were found in any extension test of the dominant leg at 60°/s in any of the groups. The peak extension torque values at 60°/s were expected to improve with muscle strengthening. Slow speed testing is said to be used for the determination of muscle strength (5) and all exercises were conducted at a speed of 60°/s. It is interesting to note that Rothstein, Lamb & Mayhew (40) strongly disagreed with the assumption that slow speed isokinetic testing would test muscle strength, whereas high speed testing would test power. They maintained that these statements did not have a basis in physics and that strength had to be defined according to the activity required. It therefore makes sense to test strength in the same way as the strengthening exercises were performed.

As isotonic strengthening exercises have been observed to occur at speeds approximating 60°/s, it makes sense to use isokinetic testing at this speed to measure muscle strength (5). The

researcher expected isokinetic muscle strength to have improved after an eight week strengthening programme, especially in view of the fact that the 10 RM tests showed that strengthening had occurred. This did not happen. The 10 RM testing was more specific to the strengthening that had occurred in the isotonic strengthening programme used in this trial.

The significantly improved extension endurance ratio in the nondominant leg in the water group from week 4 to week 8 cannot be explained. However, no overall improvement over the eight exercise weeks occurred. Endurance ratio (work performed over the last five repetitions divided by the work done over the first five repetitions) is a measure that is difficult to interpret and some researchers have said that it should not be used (40, 57). Absolute endurance measures, such as the total work done over 25 repetitions or the work done over the last five repetitions (40, 57) are more reliable. The endurance ratio may not change as a result of training, if work performed both over the first and the last contractions improves due to training, which will make the ratio stay the same. Knowing the absolute work done over the last five contractions would be much more meaningful (57).

Performing maximally at high testing velocities, such as 270°/s is not easy and requires some understanding and practice on the part of the subject (7). Maximal performance at 60°/s is much easier, as a combination of speed and strength is required for

high speed testing (7). Significant increases in test results at 270°/s may have been simply due to familiarisation with the test.

The significant increases in extension work and extension power over eight weeks at 270°/s of the trained, dominant leg of the land group could have been because the exercise and testing medium was the same, i.e. out of water. Subjects may have performed the test better as a result of real strengthening that had occurred. This was unlikely, as strength training at 60°/s is not known to cause strengthening at a test speed so far removed from it as 270°/s (67). A number of studies have demonstrated strengthening at the training velocity and below (61, 68, 69), while others have indicated that torque increases can be found at both higher and lower velocities than the training velocity (67, 70). The velocity of 270°/s is however, much higher than the exercise velocity of 60°/s and strengthening at 270°/s is unlikely to have occurred from training at 60°/s in this exercise trial (67). The better test performance at week 8 was probably as a result of familiarisation with the test, as high velocity testing is difficult for a subject to perform (7).

The reason for the control group's significant improvement in extension power and extension endurance ratio of the dominant leg over eight weeks at 270°/s is unclear. It could, once again

have been as a result of familiarisation with the test procedure, as high velocity testing is difficult for a subject to perform (7). The problems with interpreting endurance ratios have been mentioned before.

In those isokinetic variables that showed significant improvements, the improvement was not as large as in the weekly 10 RM tests (see lower p-values for significant improvements in 10 RM in Tables 4.17 and 4.18).

5.2.1.2 Significant differences

The absence of significant differences between the water, land or control groups in the knee extension peak torque improvement over eight weeks at 60°/s or 270°/s of the dominant knee was not anticipated. The exercise groups were expected to have got stronger while the control group would have stayed the same. This finding can be understood in the light of the absence of isokinetic strengthening at 60°/s over eight weeks in any of the groups.

The control group's significantly larger increase in extension endurance ratio of the dominant leg at 60°/s over the initial four weeks than the water group is difficult to interpret. It could have been due to the subjects not having exerted as much effort at week 4 as on initial testing, therefore tiring less

rapidly (see the problems associated with interpreting endurance ratios mentioned in 5.2.1.1 before).

While no significant differences were found on testing the exercised leg isokinetically between the land and water groups, only a few isokinetic values showed significant improvements over eight weeks in all three groups, i.e. the isokinetic tests did not show much strengthening in the exercise groups at all. Isokinetic testing was not sensitive to the strengthening that occurred. The validity of isokinetic testing for this isotonic strengthening programme was poor. For a test to be valid, a critical analysis must be made of the activity it is to measure. Isotonic strengthening was to be measured and therefore isotonic strength testing (10 RM), was more appropriate than isokinetic testing.

Significant increases of values without a concomitant significant difference

In a number of variables, a significant increase from the baseline value in the one group did not necessarily mean that a significant difference would exist between this and another group. As an example, extension work and extension power showed a significant increase in the land group over the eight weeks when tested at 270°/s. The increase was not, however, large enough to represent a significant difference between the land and water groups.

5.2.2 Reliability of isokinetic testing

The researcher decided to use isokinetic testing as this has been found to be reliable, valid and reproducible for testing of knee flexion and extension (40). In addition, it had been used successfully in an undergraduate project by Mandelbaum, et al. (43), who compared muscle strengthening in normal subjects exercising on the Westminster pulley and on the Cybex machine, using a similar exercise programme to that used in this study.

In order to enhance the reliability of isokinetic testing in this project, the researcher ensured that a strict testing protocol was followed (5, 40, 57). The researcher and one other tester performed all the Cybex tests. The second tester was included to improve the objectivity of the testing. Although inter-tester reliability between these two testers was not established, the adherence to the testing protocol served to standardise the testing. The other tester, also a physiotherapist, had been well instructed in the testing procedure and was competent in doing the Cybex tests. She did not know which exercise group the subjects were in and followed the protocol for isokinetic testing strictly. The reliability of the isokinetic testing in this research would have been enhanced even more if two initial Cybex test had been done for each subject. The data from the second test would then have been used, following the results of the test-

retest reliability during trial 1, where the second Cybex test showed a higher knee extension peak torque value (see section 3.2.6), as well as those of other studies (46, 47). For subsequent tests this would not have been necessary, as subjects had been familiar with the test by then.

5.3 The lack of strength improvement on isokinetic testing, while strength improved isotonically

The lack of correlation between the peak extension torque or extension work at 60°/s and the 10 RM values of the exercised leg at week 0, week 4 and on final testing shows that the two tests used for determining quadriceps strength, isokinetic peak torque at 60°/s and the 10 RM test, most likely do not measure the same thing.

The lack of isokinetic strength increases in the presence of significant increases in 10 RM was very unexpected, as the undergraduate study on which this study's design was based showed significant isokinetic strength increases after isotonic strengthening on a Westminster pulley (43). However, an in depth literature review revealed other studies that also found no or only small isokinetic strength increases despite large significant isotonic strength increases after isotonic

strengthening programmes (41, 65, 71, 72, 73). These studies, which are described below, found that isokinetic testing is not always the most ideal testing modality and that a test specific to the training modality should be used (41, 65, 71, 72, 73).

Smith & Melton (71) compared isotonic and isokinetic training in a small sample of 12 adolescents, who were divided into four groups, one of which was a control group. Despite the small sample size, all exercise groups had significant strength gains when tested isometrically, isotonically or isokinetically. The strength gains of the isotonic group were, however, much larger on isotonic testing than on isokinetic testing. The researchers recommended that the ideal testing modality should most closely resemble the training modality.

Frontera, et al. (65) found that the peak extension and flexion torques of the quadriceps and hamstrings muscle groups of a group of elderly men had increased significantly after a 12 week isotonic strengthening programme. The strength gains measured by 1 RM testing were however about 10 times larger than the peak torque gains. This can be explained by the fact that the 1 RM had been done on the same machine and using the same movement pattern as that used for training. The test that was specific to the training showed the greatest strength increase.

Brown, McCartney & Sale (72), who conducted a very similar study to that of Frontera, et al. (65) on elderly men, also found that the 12 week weight lifting programme led mostly to isotonic strengthening.

Reynolds, Worrel & Perrin (41) found no increase in concentric or eccentric isokinetic strength at 60°/s in the quadriceps of their subjects who had engaged in a six week lateral step-up exercise programme. The number of repetitions and the step height were increased throughout the programme. The researchers ascribed their failure to demonstrate any strengthening to the fact that the programme may not have overloaded the quadriceps sufficiently to cause any strengthening. A lateral step-up exercise on an 8 inch step was found to produce only 22 per cent of the maximum voluntary contraction in rectus femoris and 60.3 per cent of the maximum voluntary contraction in vastus medialis. In addition, it was felt that an open chain assessment of muscle strength (as is the case with isokinetic testing) might not have been adequate to test muscle strengthening that occurred with closed chain exercise. Suggested closed chain assessments that could have been used for this study were the number of steps done in a set time, the 1 RM of the exercise at a set step height (using weighted belts) or a one-legged hop over distance or time.

Agre, et al. (73) found that their post-polio patients were able to lift significantly larger weights with their knee extensors after an eight week low-intensity isotonic

strengthening programme, but showed no increase in isometric or isokinetic extension peak torque. Although these authors attributed their findings to the fact that their strengthening programme had been of a low intensity and that a peak in strength increases had not been reached after eight weeks, they acknowledged the possible effects of the specificity of training. Their lack of isokinetic strengthening could have been because the isokinetic testing was not specific to the isotonic strengthening that occurred (73).

The muscle strengthening protocol followed in the present study was of an intensity that was high enough to provide muscular overload, which leads to muscle strengthening (74). In addition, the intensity was not so high that it would have resulted in the weakening effects of over-training (4, 55, 75). Only a relatively small number of subjects had indicated that they had experienced some pain during exercising and could possibly have had some pain inhibition (6). This is unlikely to provide an explanation for the lack of improvement in peak extension torque of the exercised knee at the exercise speed. The excellent increases in 10 RM also demonstrated that in those subjects with pain, the pain was of a very transient nature and did not influence the performance of the weekly 10 RM tests.

The main reason for the lack of correlation between the findings on 10 RM and isokinetic testing must therefore be sought in the specificity of training.

Isotonic and isokinetic strengthening differ, each of these causing a specific neural adaptation (72, 73). An important distinction between a muscle loaded isokinetically and a muscle loaded with a standard weight-lifting exercise is the position of resistance in the range of movement (6). As with all joints of the body, the muscle force exerted against an external resistance varies with the bony lever configuration as the joint moves through its normal range of motion (6). Therefore, when training with weights, the resistance is usually fixed at the greatest load that allows completion of the movement. Consequently, the resistance can be no greater than the maximum strength of the weakest joint position in the range of motion. Otherwise, the movement would not be completed (6). This is not the case in an isokinetically loaded muscle, where the resistance changes according to the muscles' ability throughout the range of movement, thereby loading the muscle maximally throughout the range of movement (76). Training isotonically, i.e. increasing the strength at the weakest joint position, may therefore not yield results that are measurable on maximal muscle strength testing through full range of motion, as in isokinetic testing.

Specific neural adaptations will occur in muscle as a result of isotonic strength training (73). The improvement in a muscle's force production is related to enhanced neural organisation, excitability and efficiency of muscle

contraction, and thus related to the type of exercise (32, 61, 62, 63, 64).

The specific strength test chosen (i.e. 1 RM, isokinetic or isometric) will show the greatest strength increase in those subjects that trained in a way that most resembles the strength test method (4, 55, 65, 73). An isotonic strengthening programme leads to specific isotonic strength increases, which should therefore be measured isotonically. The construct validity, i.e. the degree to which performance on a test corresponds to the abilities or the traits that the test purports to measure, of the Cybex isokinetic test for this research was inadequate. The researcher's findings support the literature which suggests that isokinetic testing is not as sensitive to strength gains as is isotonic testing, following isotonic training (41, 65, 71, 72, 73). Isokinetic testing therefore does not seem to be valid in the testing of isotonic exercise and should not be the test of choice in healthy young females to determine strength increases due to an eight week isotonic strengthening programme such as that used in this study. More research on this topic is needed.

This study supports the findings that for muscle strengthening in healthy, young people, it is essential that the strength test used is specific to the strengthening programme, as the strength increases in such a group are not expected to be as marked as in a group of people after surgery, or with pathology, who have marked weakness at the beginning of their

rehabilitation (6, 60). A much more sensitive test for muscle strengthening would be needed for healthy, strong people, than for those with very weak muscles, since the latter are likely to show marked increases in strength (6, 60).

In the undergraduate study by Mandelbaum, et al. (43), on which the design of this present study was based, isokinetic strength increases were found in young, healthy females following either an isotonic (Westminster pulley) or an isokinetic strengthening programme. The quadriceps muscle strength of both the isotonic and the isokinetic exercise groups had improved significantly when tested at 60°/s after four weeks of exercising (i.e. an increase in peak torque and a decrease in the time taken to reach peak torque). No improvement occurred in the control group. There were no significant differences between the isokinetic and isotonic groups and the authors came to the conclusion that at slow speeds of around 60°/s both types of exercise were equally effective in strengthening the quadriceps muscles.

When recalculating the results from their raw data, the researcher came to the same conclusion. The improvement in peak extension torque in the group who performed the isokinetic exercises, was expected, as specific isokinetic strengthening was expected in the isokinetic training group. The test involved exactly the same movements as the exercises the subjects had performed for four weeks. It remains unclear, however, why the Westminster pulley group also showed

significant strength increases, although the exercise had not been specific to the test. Perhaps the results were due to the fact that all subjects had been highly motivated. Having been one of the subjects in the Westminster pulley group herself, the researcher remembers how diligently all subjects had exercised and that a competitive element had been present amongst the subjects who were all in the same third year physiotherapy class.

Another reason for the difference in results between the above mentioned study and this present research project could be that the resistance through range using a pulley is different from resistance using sandbags or water weights (9). Although the water exercises also offered most resistance with the knee at 90 degrees of flexion (as does knee extension against a pulley), these two exercises are not identical.

5.4 Difference in resistance through range between the two exercise groups

The quadriceps muscles were stressed maximally in different parts of the range when comparing the land and the water exercise used in this project. This difference could possibly have accounted for more subjects in the land group having experienced pain on exercising. The fact that maximal resistance occurs at opposite ends of the knee extension

exercise did, however, not cause any significant differences in the 10 RM test results between the two exercise groups.

5.4.1 Land exercise group: knee extension against an ankle weight

In the land exercises, gravity resists the quadriceps most strongly when the knee is fully extended, as the pull of the muscle is at 90 degrees to the force of gravity in this position (9). The quadriceps muscles are at a mechanical disadvantage in this position, as the point in range of greatest mechanical efficiency for the quadriceps muscles is 60 degrees of knee flexion (6).

At the starting position, with the knee flexed to 90 degrees, there is virtually no resistance to quadriceps (9). As the knee is extended, the resistance is increased until maximum resistance is reached at full knee extension (9) (see Figure 5.1). In full knee extension the ankle weight does not exert a compressive force in the direction of the shaft of the femur (9). The compressive and shear forces that do occur are due to the force exerted by the patellar tendon in the direction of the shaft of the femur.

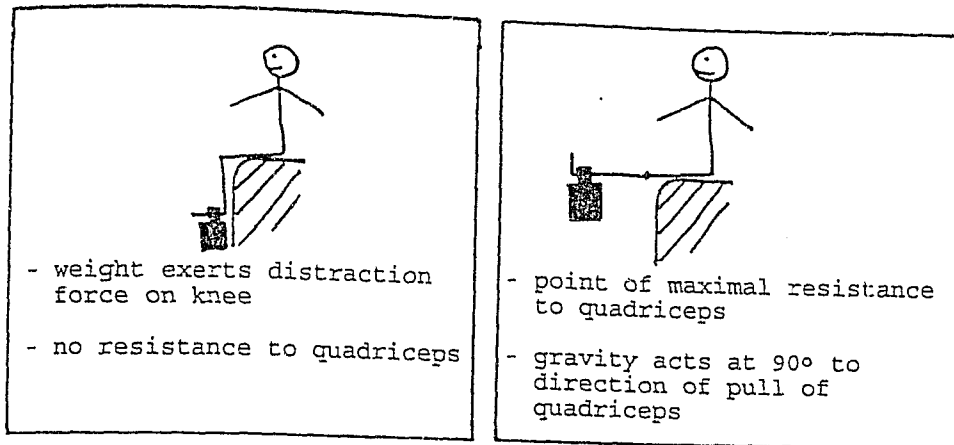


Figure 5.1 Land exercise group: knee extension against an ankle weight

5.4.2 Water group: knee extension in prone lying over the edge of the pool

In water, most resistance is experienced in the range close to 90 degrees of knee flexion, whereas least resistance is experienced by the quadriceps muscles when the knee is extended fully. This is because buoyancy now acts in the direction of the long shaft of the femur, providing a compressive force. Due to the asymmetry of the set of bottles used as water weights, some resultant force will still have to be overcome at the point of terminal extension, causing some quadriceps activity at this point of range as well. The part of range in which resistance occurs is therefore similar to that experienced when doing knee extension against a Westminster pulley (9) with terminal knee extension not being resisted maximally.

In the water exercise, buoyancy resists knee extension most strongly when the knee is flexed to 90 degrees, as it acts at 90 degrees to the pull of the muscle. Water exercise therefore maximally stressed the quadriceps close to 60 degrees of flexion, their point of maximum mechanical efficiency (6) (see Figure 5.2).

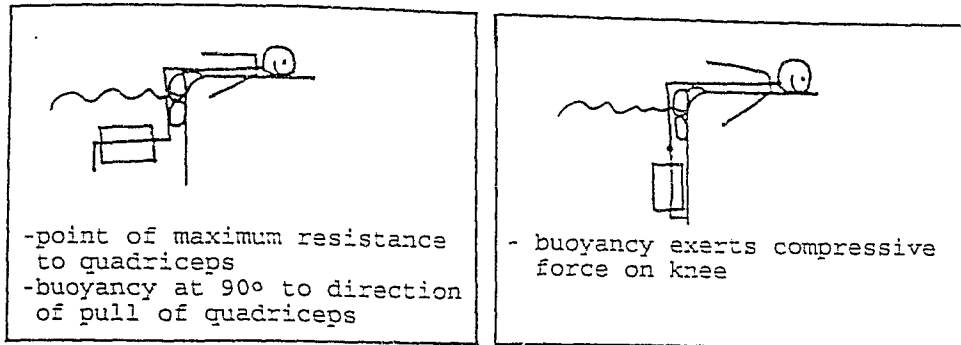


Figure 5.2 Water group: knee extension in prone lying over the edge of the pool with the hip flexed to 90 degrees and the leg in water

In the water group, the position of maximal resistance in range would have been much closer to that of the land group if the person had been completely submerged under water, head down, with the hips flexed to 90 degrees, with the thigh parallel to the water level. Gravity would however, have assisted knee extension in this position. This position is also totally impractical, as the head down position is uncomfortable, one would need oxygen cylinders to breathe under water and adequate fixation would be difficult. Water and land exercises would have had resistance in similar parts of the range if a Westminster pulley had been used by the land group, as it offers most resistance at the beginning of knee extension (9).

Another way of ensuring maximal resistance at terminal extension in both land and water-based exercise programmes, would have been to assume the same seated position in the water, as on land. Dense, nonbuoyant material could then have been used as ankle weights in water. This arrangement would have led to more resistance at terminal extension in the water group, but would still not have caused the same maximal resistance at terminal extension as on land. The upthrust of buoyancy would still have been the highest with the knee fully extended, thereby assisting knee extension, even though the force of gravity on lead ankle weights would have resisted knee extension maximally in this position. As more weight would have been added to the ankle as the exercise progressed, the volume of water displaced by the lead weights would have increased, increasing the force of buoyancy. Using the same starting positions for both exercise groups would, however, have made comparisons between "discomfort levels" more acceptable.

5.5 Findings on the weekly questionnaire

5.5.1 The degree of comfort while exercising

The finding that the water group remained fairly comfortable during the exercises over the eight week period, while there

was a significant reduction in comfort in the land group, can be explained as follows:

Some subjects in the land exercise group found the final weights very heavy. The land group had slightly more resistance than the water group throughout the exercise trial. The weight of the subject's leg in the land group added to the resistance, while the weight of the subject's leg was larger than the upthrust of buoyancy on it in the water group, which assisted knee extension. In the land group the sandbags also tended to shift slightly over the dorsum of the foot while the exercises were being performed. Despite the fact that a sock was worn to reduce the friction, this may well have contributed to some discomfort when exercising with heavier weights. This problem would not have occurred if strap-on weights had been used.

It is remarkable that the water group remained fairly comfortable in their starting position of prone lying over the edge of the pool, despite increase in weights as the programme progressed. The comfortable training station, the relaxing and sedative effect of exercising in warm water (18, 20) and the slightly smaller resistance to knee extension in the water group could have led to this finding.

The visual analogue scale used for establishing comfort on exercising in this trial (see Appendix C) presented some difficulties. As a tool for measuring pain, the visual analogue scale has been reported to be very accurate (59, 77). The

subjects in this trial understood the concept of the visual analogue scale. The scale establishing the comfort on exercising was, however, confusing, as the words "very uncomfortable" and "very comfortable", which were placed at the ends of the scale, were very similar (see Appendix C). Unlike the visual analogue scales for pain and muscle soreness, this scale also had the negative end of the scale on the left (see Appendix C). A number of subjects realised, after they had marked the scale, that they had mistakenly marked the wrong end of the scale because they had not read the wording carefully enough. This was subsequently corrected so that the data was in fact a fair reflection of the level of comfort. However, this problem could perhaps have been eliminated by underlining "un-" in the word "uncomfortable". The words "very uncomfortable" should also have been put on the right hand side of the scale to follow the pattern used for the muscle soreness and pain scales.

5.5.2 Significant differences in degree of thigh muscle soreness

Although the number of subjects with thigh muscle soreness did not differ significantly between the two groups, the water group had more severe muscle soreness over the course of the trial.

On the questionnaire, a clear distinction was made between muscle soreness and pain. It is therefore unlikely that the subjects indicated the presence of muscle soreness when they meant pain. It remains unclear why the water group should have had muscle soreness of a greater severity than the land group.

Research has shown that eccentric muscle activity causes more muscle soreness than concentric activity (78, 79). This is as a result of damage to muscle fibres and connective tissue and elevation of fluid pressure in the muscle that has done the eccentric work (78).

Both the land and water groups had to perform eccentric quadriceps work when flexing the knee after knee extension, in order to control the lowering of the weights and upward movement of the empty plastic bottles respectively. The eccentric contractions only differed in that most eccentric control was needed with the knee close to extension in the land group (where the force of gravity is at 90 degrees to the direction of the muscle pull) and with the knee close to flexion in the water group (where buoyancy is at 90 degrees to the direction of muscle pull). This could possibly have led to differences in thigh muscle soreness between the two groups, but is unlikely as the water group had slightly less resistance than the land group throughout the exercise trial. In the water group the weight of the subject's leg was larger than the upthrust of buoyancy on it, which assisted knee extension, while the weight of the subject's leg in the land group added

to the resistance. More research is needed into muscle soreness following exercise in water.

Another explanation is that although the questionnaire asked specifically for the absence or presence of thigh muscle soreness in the first part of this question, the second part of the question with the visual analogue scale did not ask specifically for the severity of "thigh" muscle soreness (see Appendix C and B, question 1). The participants may thus have indicated the severity of their general muscle soreness on the visual analogue scale. The researcher suspects that some of the subjects in the water group may have referred to abdominal muscle soreness. Some subjects in the water group complained of the effort required of their abdominal muscles to maintain the correct starting position during exercise.

Stabilisation becomes a problem when using a lot of buoyant material (1). The exercise in this project provided good stabilisation of the trunk, as the upper body was out of water. However, to stabilise the hip in 90 degrees of flexion and maintain this position throughout the exercises, the subjects had to isometrically contract their hip flexors and abdominals. Isometric contractions can, to a lesser degree than eccentric contractions, also lead to muscle soreness (4, 80). This added isometric muscular effort could possibly have led to those in the water group having experienced more severe muscle soreness.

5.5.3 Significant differences in pain on exercising

The land group had to dorsiflex their feet to keep the sandbags in place and the sandbags tended to shift slightly over the dorsum of the foot as the weight was lifted. This may have led to more subjects in the land group indicating pain in the ankle area and "calf muscles" than in the water group.

However, in both exercise groups, the pain occurred mostly around the knee of the exercised leg, i.e. in the quadriceps or hamstring muscles or behind the knee cap.

The finding that more of the land group experienced pain over eight weeks could have been because the point of maximal resistance to knee extension occurred with the knee fully extended, where the quadriceps are at a mechanical disadvantage, as explained earlier (6). It could also have been as a result of the fact that the land group had slightly more resistance than the water group throughout the exercise trial, as described in sections 5.6.1 and 5.6.2 before.

The more strenuous version of the original DeLorme programme, which was used in this trial, placed more stress on the knee and could possibly have led to the transient pain around the knee experienced by subjects in both exercise groups.

The water exercise group exercised with their knees immersed in warm water at 33,8°C, while the land group exercised with their knees exposed to the ambient temperature of 23 - 24°C. The higher temperature around the exercised leg of the water group, as well as the effects of hydrostatic pressure, could have led to less pain having been experienced on exercising. Warmth has a sedative effect (20, 81). Hydrostatic pressure has an external compressive effect, which would give external support to the knee (20), similar to that of a bandage, which those in the land group did not have.

Transient knee pain while on strengthening programmes has been reported in other studies (82, 83). Two subjects in the study by Gerberich, et al. (83) had to discontinue participation due to the onset of transient knee pain. They were both in the training group that provided concentric and eccentric resistance. The researchers ascribed this pain to the eccentric exercise. In a study on brief maximal exercise, Rose, Radzynski & Beatty (82) let their subjects perform 1 RM each day and encouraged them to try and improve their value at each session. The programme produced good strengthening results, but some transitory knee soreness was experienced during exercise. There was no post-exercise pain, stiffness or fatigue.

The pain experienced by the subjects in the present study was of a transient nature and only felt during exercise.

The pain might not have been mentioned if the subjects had not been questioned about it in the weekly questionnaire.

5.6 Subjective response to the eight week exercise programme

5.6.1 Benefits of the exercise programme

After the eight week exercise programme, it was evident that both groups found the exercises equally beneficial. They expressed the fact that they had experienced an increase in the thigh muscle strength of the exercised leg, with no significant difference in perceived degree of improvement between the two groups. Both groups explained the beneficial effects of the exercises similarly. Progressive resistance exercise in water is not normally used for muscle strengthening. As both groups found the exercises equally beneficial, water exercise could be used much more than it is being used at present for muscle strengthening.

5.6.2 Advantages and disadvantages of water exercises

Water exercise offers psychological advantages (2, 16, 18, 27), which was also found in this research. Six subjects mentioned psychological benefits of water exercise such as water exercise being enjoyable, relaxing, stimulating and motivating. The water group also described the physical effects of exercise in water as advantageous. They realised that the physical effects of exercise in water differed from exercise on land. Opinion was, however, divided on which exercise was more difficult. Some stated that the exercises in water were more difficult than the land exercises, while others said the opposite.

The disadvantage identified most frequently was the time taken to dress and undress. Two subjects felt that the chlorine had been too strong, one mentioning that it had damaged her swimming costume. A third of the subjects in the water group had experienced some skin irritation. Two people mentioned their initial fear of possibly contracting diseases from the pool water, as it was being shared with so many others. One person stated that one would not be able to exercise in an outside pool in winter.

In accordance with the literature (1, 20) water exercise in this study involved the disadvantage of being more time

consuming with the necessary changing, foot bath and showers. It took more time for the water group to change weights in between sets than for the land group. The time taken to let out water to adjust the resistance during the exercise session could have been saved by using three sets of bottles containing the correct amount of water instead of one set.

To ensure compliance with a quadriceps strengthening programme in water, good pool maintenance is needed to prevent infection while not causing skin irritation from the pool chemicals (58). Correct chlorine and acid levels need to be maintained (1, 58). The standard practice at the therapy pool of the Johannesburg Hospital of walking through a foot bath containing a sterilising solution before entering the water and regular bacteriological testing of pool water follows what the literature suggests (58). More careful monitoring and chlorine dosing is needed when a larger number of people use the pool (58). A way of safely lowering the chlorine doses without the risk of infection is the use of a deioniser. A deioniser was in fact installed after the end of the project and the researcher has found that swimming costumes last longer and that chlorine-induced skin irritations have occurred less frequently in herself and her patients since then.

The disadvantages of exercise in water may, however, be outweighed by the advantages of the strengthening effects, comfort, enjoyment and relaxation offered by exercise in warm

water (20). The water exercises were also less likely to cause transient knee pain than the land exercises.

Most South African towns have public swimming pools, many of which provide admission free of charge or at a minimal cost. (In October 1996, the fees for the Johannesburg pools that did charge were R 2 for adults and 80 c for children, while season tickets cost R 80 and R 18 respectively.) Recent years have, however, seen the closure of a number of these pools, as local authorities do not have the finances and do not consider the availability of public swimming pools to be a priority. Physiotherapists should be made aware of the findings of this study, so that they have more information to approach the responsible local authorities to lobby for the need of and uses for public swimming pools. There are many privately owned pools that are often under-utilised as water is being used for recreation only. Muscle strengthening could be done very effectively in the home pools. Most people in urban areas should therefore have access to pools during summer. As heated pools are not freely available, most South Africans would, however, not be able to use water exercise in winter.

5.6.3 Advantages and disadvantages of land exercises

The advantages of land exercise most often mentioned were the convenience, the fact that no changing was needed and that it could be performed more quickly than the water exercise. One subject in the land group mentioned the psychological benefits gained by the self-discipline of daily exercise.

A number of subjects indicated that land exercises did not offer any disadvantages. One subject mentioned that she perspired too much doing the land exercises. During exercise in a heated pool, one loses heat by sweating and evaporation of sweat in those parts of the body that are not submerged (31). Subjects in the water group were possibly less aware of sweating as they were already wet from the water. One person felt that her abdominal muscles didn't get as much exercise as she would have liked, thinking that the water group had more exercise for their abdominal muscles. Maintaining the starting position for exercise in water did require more static abdominal muscle work of the water exercise group. Another subject voiced her concern that the heavy weights used towards the end of the trial were not good for knees. The land group did in fact work against a slightly higher resistance than the water group throughout the trial (as explained in 5.6.1 and

5.6.2 before) and had more transient anterior knee pain during exercise than the water group.

Two people regretted not having been in the water group for psychological reasons. One person loved water and would have liked to be in the water group. Another subject would have liked to overcome her fear of water. The psychological effects of exercise in water should not be underestimated (2, 16, 18, 27).

Even though exercise in water is more inconvenient than out of water, it is noticeable that more psychological benefits were mentioned in conjunction with water exercise. If exercise is enjoyable, people are more likely to comply (16, 27).

5.7 The design of progressive resistance ankle weights in water

The designed ankle weights proved to be effective, as there were no significant differences between the 10 RM results of the two exercise groups. Initially, subjects required some help in applying the weights. They also needed careful instruction on adjusting the water levels to obtain the required resistance. Most subjects understood this concept within the first few exercise sessions. Adjusting the resistance levels

by letting out water using a plastic pipe took longer than adjusting the weights on land.

Constructing these home-made weights is inexpensive. Empty plastic cold drink bottles, some string, a small pipe and a three pieces of material are all that is needed. The pieces of material/ stockinet are used for the foot attachment, to wrap around the leg and to tighten around the bottles once they are applied. Appendix P compares the costs involved in making water weights, buying velcro strap-on weights and manufacturing durable home-made sandbags, of which water weights are the cheapest. Making less durable sandbags using refuse material such as plastic bags instead of canvass will make these as cheap as water weights.

As the bottles were made of smooth plastic, they were inclined to slip out of their string attachments if not tied together tightly. They occasionally needed re-adjustment. These home-made weights can, therefore, still be improved upon. A rubber encasement that would hold eight bottles may prove to be the answer, as this would prevent the bottles from slipping out.

CHAPTER 6

CONCLUSION

6.1 Comparing an isotonic strengthening programme on land to in water

Two isotonic strengthening programmes, one in water and one on land, using similar amounts of resistance, were found to be equally effective in strengthening quadriceps femoris muscles in a group of healthy, young female volunteers without knee pathology. This type of graded resistance training is not frequently done in water. Exercise in water using empty plastic bottles with varying amounts of water for resistance has not been researched before. Quadriceps strengthening using water weights in water was found to be as effective as strengthening with sandbags out of water.

In this research project water offered the additional benefit of less knee pain and a higher degree of comfort compared to muscle strengthening out of water with sandbags, but more intense muscle soreness.

Although there was no significant difference in the number of subjects with muscle soreness, the subjects complaining of

muscle soreness in the water group had more severe muscle soreness than those in the land group.

More subjects in the land group experienced pain, mainly around the exercised knee, on exercising. Progressive resistance training for quadriceps in water caused less transient knee pain on exercising than the corresponding exercise out of water.

Water exercise also provided psychological benefits such as enjoyment and relaxation, which were not mentioned by the land exercise group.

Progressive resistance training for quadriceps with water weights in water could prove to be very useful for rehabilitation. Patients with knee pathology, who need strengthening without undue stress on the knee joint (15, 39), may benefit from the isotonic strengthening programme used in this project.

6.2 The design of the water weights

The designed ankle weights for water exercise proved to be effective, as there were no significant differences between the 10 RM results of the two exercise groups. The weights were made of inexpensive materials and were easy to assemble. After

initial instruction, subjects were able to independently apply and adjust the weights. A method of attaching the bottles to each other more tightly is still needed to prevent the bottles from slipping out of the string that tied them together.

The water exercise in this study was done against a known resistance. More research is still needed into establishing the exact resistance due to the viscous drag force on asymmetrical objects, such as the lower leg with the set of water weights in this study. Knowing the resistance a patient is working against aids rehabilitation, as water and land exercises can then be interchanged more effectively (12). If a patient starts exercising in water at a known resistance, exercise progression and the addition of exercises out of water at the correct level of resistance can then be done more effectively (12). On the other hand, if an isotonic strengthening programme is followed on land, water exercise at the correct level of resistance can then be added to give variety to the exercise programme (12). The water weights in this study have a known resistance and can be used in this way.

Provided that access to a pool is possible, home-made equipment for water exercise is cheap. The fitness industry is using water mostly for aerobic type exercise. Strength training in water could easily be introduced. This research concentrated on the quadriceps femoris muscles. It is possible that progressive

resistance training in water for other muscle groups would also yield good strengthening results.

CHAPTER 7

SUGGESTIONS FOR FURTHER STUDY

1. A comparison between quadriceps muscle strengthening on land and in water, using the same study design as described in this research report, but including weekly 10 RM tests on subjects in the control group.
2. A comparison between quadriceps strengthening in an isokinetic exercise group, a water exercise group, a land exercise group and a control group. Weekly 10 RM should be done on all participants, including those in the control group. Cybex tests should also be done at weeks 0, 4 and 8.
3. A study to establish which muscle strength test is most suitable to slow speed strengthening. Four exercise groups with a large sample size are suggested.
 - a. Cybex group
 - b. Control group
 - c. Land group
 - d. Westminster pulley group

Each of the subjects should have Cybex tests at weeks 0, 4 and 8 in addition to a weekly 10 RM test using sandbags as well as a weekly 10 RM test on the Westminster pulley. This would help to establish which muscle strength test

was most effective in determining muscle strengthening in the different groups.

4. A quadriceps muscle strengthening trial on subjects with knee pathology, using the original DeLorme programme and weekly 10 RM testing comparing subjects on land and in water.
5. Research into suitable water weights and starting positions for progressive resistance exercise in water for other muscle groups.
6. Research on the resistance provided by water for specific exercises at specific speeds, in order to establish normative data for use in rehabilitation. Strain gauges or pressure sensors would have to be attached to resistance devices or the body part to be moved. The gauges/ pressure sensors would have to be connected to a chart recorder/ computer for continuous recording of the values obtained. The research by Hallman, et al. (37) could serve as a guideline. Research could include:
 - A. An accurate assessment of the resistance of water resistance devices such as the water weights used in this project, including the effects of viscous drag force, and inertial forces due to acceleration.
 - B. The determination of the viscous drag force on body parts moving through water during exercise.

7. Comparison of the effectiveness in muscle strengthening of various resistive devices for water exercise.
8. An investigation into muscle soreness following exercise in water.

APPENDIX A

APPENDICES

APPENDIX A

PRE-TRIAL QUESTIONNAIRE

1. NAME:Field of study/ occupation:Tel no.2a) AGE: b) HEIGHT:m c) WEIGHT: ...kg

3a) Are you in good health?

YES	
NO	

b) If NO, please specify

.....

.....

.....

.....

4a) Have you ever injured your legs?

YES	
NO	

b) If YES, please specify which leg was involved and the type and date of injury.

right or left leg	injury	date
e.g. right	torn meniscus of knee	July '89

5. Which leg do you prefer to use when you are kicking a ball?

left	
right	

APPENDIX A

6. Do you participate in any sport?

YES	
NO	

7. Do you participate in any regular physical activity that is not covered by question 6. above?

YES	
NO	

8. If your answer to question 6. or 7. was YES, name the activity or sport and indicate how much time you spend on it a week.

physical activity/ sport	less than once a week	1-2 h a week	2-3 h a week	3-4 h a week	more than 4 h a week
e.g. jogging			x		

9a) Will you be able to discontinue your sport for the eight week duration of the trial?

YES	
NO	

b) If NO, please specify

.....

.....

.....

10a) Are you able to swim?

YES	
NO	

[illegible]

YES	
NO	

```
[Official use only: 10 RM (dominant leg) ..... (date:.....)
                    peak torque (0 weeks) L.... R.....
                                   (date:.....)
                    lever distance.....]
```

APPENDIX B

APPENDIX B

FINAL QUESTIONNAIRE

Thank you for having completed the EIGHTH AND LAST week of exercise for quadriceps strengthening!

Would you please complete this last questionnaire and answer the following questions:

NAME:.....

1. Did you have any thigh muscle soreness this week?

YES	
NO	

If your answer is YES, please make a mark on the line, indicating the severity of your muscle soreness:

no muscle
soreness

the sores my
muscles have ever been
after exercise

2. Did you have any pain while performing the exercises?

YES	
NO	

If your answer is YES: a) Where did you feel the pain?

.....

b) Make a mark on the line to indicate the severity of the pain.

no pain

the worst pain
I have ever had

APPENDIX B

3. Mark on the line how comfortable you were while doing the exercises.

very
uncomfortable _____ very
comfortable

4. Do you feel that the exercises were beneficial?
(Please mark a block and explain.)

not beneficial at all	☐
somewhat beneficial	☐
very beneficial	☐

Explanation:.....
.....
.....

5. Do you feel that the thigh muscle strength of the leg that you have exercised has improved?
(Please mark a block and explain.)

no improvement	☐
slight improvement	☐
moderate improvement	☐
tremendous improvement	☐

Explanation:.....
.....
.....
.....

6. What do you see as the advantages of having been in the group? [The researcher filled in "water" or "land", depending on the exercise group the subject had been assigned to]

.....
.....

7. What do you see as the disadvantages of having been in thegroup? [The researcher filled in "water" or "land", depending on the exercise group the subject had been assigned to]

APPENDIX B

-
8. Please describe any changes in your sport participation or participation in other physical activities during the eight weeks that you joined this project.
-
-

9. (Only for the water exercise group:) Did you experience any skin irritation during the eight weeks of exercise in water?

YES	
NO	

If YES, please explain:

.....

.....

10. Any comments/ suggestions:
-
-

11. If you'd like to be notified of the results of this project, please write down your postal address and tel. no. below:
-
-
-

THANK YOU !

Monika Petrick

APPENDIX C

APPENDIX C

WEEKLY QUESTIONNAIRE

Thank you for having completed the week of exercise for quadriceps strengthening!

I would just like you to give me some feedback on this week. Would you please answer the following questions:

NAME:.....

1. Did you have any thigh muscle soreness this week?

YES	
NO	

If your answer is YES, please make a mark on the line, indicating the severity of your muscle soreness:

no muscle
soreness

the sorest
my muscles have
ever been after exercise

2. Did you have any pain while performing the exercises?

YES	
NO	

If your answer is YES: a) Where did you feel the pain?

.....

APPENDIX C

b) Make a mark on the line to indicate the severity of the pain.

no pain _____ the worst pain
I have ever had

3. Mark on the line how comfortable you were while doing the exercises.

very _____ very
uncomfortable comfortable

APPENDIX D

APPENDIX D

PRELIMINARY RESEARCH DONE

D.1 Trial 1 (1991): A comparison between
quadriceps muscle strengthening on
land and in water

D.1.1 Method

Young females (aged 19 - 30) with no knee pathology were asked to volunteer for this project. They were assigned to land or water exercise groups. The first subject's group placement was determined by spinning a coin. The next subject was placed into the other group and from there on subjects were alternatively placed into the water or land exercise groups as they volunteered. Eleven subjects were assigned to the water group and eleven to the land group. Four subjects formed a control group, i.e. they had two Cybex tests done eight to nine days apart. The control group helped to establish the test-retest reliability of the Cybex testing. Informed consent was obtained and subjects were asked not to change their present level of sport participation at all for the eight weeks of the trial.

The method followed was that of the final trial, except for using the original DeLorme protocol in Trial 1, i.e. the subjects completed the following at each exercise session:

APPENDIX D

10 x 0,5 10 RM,
10 x 0,75 10 RM and
10 x 10 RM.

Another difference to the final trail is that no weekly 10 RM tests were performed. The maximal weight to be lifted each week was increased by 5 N each week (this value was based on the increment used in an undergraduate study (43)). Cybex tests were done at weeks 0, 4, 8 and 8,5. Tests involved six reciprocal repetitions of knee extension and flexion at 60°/s.

D.1.2 Results

Although all the participants indicated in their final questionnaire that their thigh muscles had increased in strength and although an increase in strength could be demonstrated by the fact that heavier weights could be lifted each week, the Cybex test did not indicate any strengthening. There was no significant increase in peak extension torque of the dominant or nondominant legs of either exercise group over eight or 8,5 weeks ($p > 0,05$) (see Tables D1 and D3). Significant improvements ($p < 0,05$) in peak extension torque from week 4 to week 8 were seen in both the water and land exercise groups (see Table D1), but these were of no importance, as there was no significant improvement overall over the eight weeks ($p > 0,05$).

The control group showed a significant improvement ($p < 0,05$) of peak extension torque of the dominant leg from day 0 to day 8 or 9 (see Table D2). As the control group only had two tests done eight to nine days apart, the results of the control group could not be compared to those of the land or the water exercise groups.

APPENDIX D

No significant improvements in peak extension torque were seen from week 8 to week 8,5 ($p > 0,05$) (see Table D3). No significant differences were found between the peak extension torque values on the Cybex tests of the land and water exercise groups ($p > 0,05$) (see Table D1).

Table D1 Trial 1: Peak extension torque improvements over four and eight weeks in the water and land groups at 60°/s

PEAK EXTENSION TORQUE	WATER		LAND		p- values**
	MEAN OF IMPROVEMENT*	S.D.	MEAN OF IMPROVEMENT*	S.D.	water vs land (all ns***)
Nondominant leg, ptE: week 4 week 0	0,968 (worse)	0,099	1,024 (better, ns, $p=0,383$)	0,264	0,259
Dominant leg, ptE: week 4 week 0	1,014 (better, ns, $p=0,405$)	0,184	0,992 (worse)	0,072	0,359
Nondominant leg, ptE: week 8 week 0	0,999 (worse)	0,071	1,074 (better, ns, $p=0,193$)	0,260	0,164
Dominant leg, ptE: week 8 week 0	1,043 (better, ns, $p=0,230$)	0,186	1,033 (better, ns, $p=0,151$)	0,100	0,438
Nondominant leg, ptE: week 8 week 4	1,037 (better, ns, $p=0,073$)	0,079	1,025 (better, ns, $p=0,072$)	0,051	0,338
Dominant leg, ptE: week 8 week 4	<u>1,030</u> (better, s****, $p=0,032$)	0,048	<u>1,044</u> (better, s, $p=0,014$)	0,057	0,270

* values above 1 indicate an improvement over the previous value. Significant improvements are underlined.

** The two-tailed two sample t-test was used to establish significant differences between the groups

ns*** = not significant

s**** = significant

Table D2 Trial 1: Peak extension torque improvements in control group at 60°/s (subjects tested twice, eight or nine days apart)

PEAK EXTENSION TORQUE	CONTROL GROUP	
	MEAN OF IMPROVEMENT*	S.D.
Nondominant leg, ptE: D 9 D 0 **	0,965 (worse)	0,044
Dominant leg, ptE: D 9 D 0	<u>1,037</u> (better, s***, $p=0,011$)	0,017

* values above 1 indicate an improvement over the previous value. Significant improvements are underlined.

** change from day 0 to day 8 or 9

s*** = significant

APPENDIX D

Table D3 Trial 1: Peak extension torque improvements over 8,5 weeks in water and land groups at 60°/s

PEAK EXTENSION TORQUE	WATER		LAND		p - values (all ns)*
	MEAN OF IMPROVEMENT* *	S.D.	MEAN OF IMPROVEMENT*	S.D.	
Nondominant leg, ptE: <u>week 8,5</u> week 0	0,999 (worse)	0,071	1,051 (better, ns, p=0,275)	0,274	0,275
Dominant leg, ptE: <u>week 8,5</u> week 0	1,035 (better, ns, p=0,219)	0,144	1,014 (better, ns, p=0,296)	0,084	0,340
Nondominant leg, ptE: <u>week 8,5</u> week 8	1,002 (better, ns, p=0,289)	0,052	0,977 (worse)	0,042	0,115
Dominant leg, ptE: <u>week 8,5</u> week 8	0,997 (worse)	0,041	0,964 (worse)	0,047	0,249

* The two-tailed two sample t-test was used to establish significant differences between the two groups, ns = not significant

** values above 1 indicate an improvement over the previous value. No significant improvements ($p < 0,05$).

D.1.3 Discussion

The fact that the peak extension torque of the dominant leg of the control group was significantly more on the second test than on the first test may be due to the small sample size of four, or alternatively, due to the fact that the subjects were more familiar with the test the second time round (46, 47). It is a shortcoming of this research that test-retest reliability was not established using a larger sample. In the light of a number of other studies having established test-retest reliability of Cybex testing of knee flexion and extension torque, work and power using specific protocols (7, 40, 84), test-retest reliability was not pursued further in this study.

The significant improvements of peak extension torque of the exercised, dominant leg from week 4 to week 8, but not overall from week 0 to week 8, indicates that no real overall

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improvement had occurred. The subjects did not perform well in the test at week 4. When this trend was seen after the week 4 test, an additional Cybex test at 8,5 weeks was introduced, giving the subjects a few days rest before this final test to ensure that there was no element of fatigue, which could prevent maximal performance of the subjects on testing. There were, however, no improvements of the peak extension torque values seen at 8,5 weeks compared to those seen at eight weeks.

The finding that extension muscle strength, as measured in terms of peak extension torque, did not improve over eight or 8,5 weeks, was totally unexpected. No extension work measurements were taken, therefore it was impossible to determine whether the extension work or power would have increased. An improvement in extension work or power was not expected, as the exercise trial focused on improving muscle strength by exercising at a low speed. Cybex testing revealed that the eight week exercise trial had caused no isokinetic muscle strengthening when measured at 60°/s. As no strengthening had been shown up in either the water or land groups, exercise in these mediums could not be compared. The research question could not be answered.

D.1.4 Possible faults identified in TRIAL 1

- a) By mistake, the metronome determining the exercise speed, had been set at 45°/s instead of at 60°/s.

According to Davies (5) there is physiological overflow from faster to slower speeds when people train isokinetically, i.e. if a person trains at 300°/s, there is a strengthening effect on all the other exercise speeds below it. The biggest training

APPENDIX D

effect occurs at the frequencies closest to the exercise speed. Davies (5) added that no strengthening would occur at a speed higher than the exercise speed. From the above, the researcher concluded that the exercise speed of 45°/s could possibly have resulted in a failure of any strengthening to show up at the test speed of 60°/s.

- b) Isokinetic testing might not have been specific enough to the strengthening that occurred

The researcher realised that she had not used an isotonic muscle strength test to establish whether any muscle strengthening had occurred in this isotonic muscle strengthening programme. Although the exercises were done to the beat of a metronome, the movements were not necessarily executed at a constant speed and were consequently not isokinetic. Isokinetic testing might not have been specific enough.

- c) There was a possibility that the Cybex machine at the Johannesburg Hospital had not been sensitive enough (despite the fact that it had been calibrated before commencement of the project) to measure strength increases.

- d) The research assistant who conducted the Cybex tests might not have encouraged the subjects enough during the test. This was not very likely, as both the researcher and the tester had been meticulously instructed by the same physiotherapist on the exact procedure of performing a Cybex test.

In order to find the fault of the first trial, three more pilot studies were embarked upon.

APPENDIX D

D.2. Trial 2 (1992): Does quadriceps muscle strengthening according to the DeLorme principle and done to the rhythm of a gong at 60°/s lead to an increase in peak extension torque?
-A case study

D.2.1 Method

The researcher put herself on the land exercise programme, after having corrected the exercise speed to 60°/s. Apart from the speed, exactly the same exercise protocol and progression was used as in the first trial. The researcher did not do any other regular physical activities during the time of the trial. The 10 RM was tested at the end of each week. Cybex tests were done at 60°/s and at 300°/s at week 0, 4 and 8.

D.2.2 Results

D.2.2.1 10 RM test results

The 10 RM was found to be increased by 5 N each week (see Table D4).

Table D4 Trial 2: Weekly 10 RM values (in kg)

	wk 0	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8
10 RM	4,5	5	5,5	6	6,5	7	7,5	8	8,5

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D.2.2.2 Isokinetic test results

As only one person took part, statistical testing could not be done and data had to be described. This was done as follows:

If the initial peak torque had been 100 Nm, the researcher would have considered 110 Nm to have indicated an improvement. Conversely, if the initial value had been 110 Nm, a value at the next test of 100 Nm would have been taken as a significant weakening.

$110/100 = 1,100$. Therefore any improvement more than or equal to 1,100 (110 per cent) was taken to be significant.

$100/110 = 0,909$. Therefore any worsening less than or equal to 0,909 (91 per cent) was taken to indicate significant worsening.

Table D5 Trial 2: Isokinetic test results

	60°/s			300°/s		
	wk 4 wk 0	wk 8 wk 0	wk 8 wk 4	wk 4 D 9 *	wk 8 D 9	wk 8 wk 4
DOMINANT LEG: ptE	0,880 ***	1,004	1,142 **	0,862 ***	0,941	1,092
NONDOMINANT LEG: ptE	0,935	1,025	1,097	0,807 ***	1,037	1,286 **

* the initial isokinetic test at 300°/s had only been done at day 9

** values > 1,100

*** values < 0,909

From Table D5 the following can be seen:

- a) dominant leg, 60°/s: ptE worsened over first four weeks
 ptE improved from wk 4 to 8
 Other values stayed the same.

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- c) dominant leg, 300°/s: ptE worsened over first four weeks
Other values stayed the same
- d) nondominant leg, 60°/s: Values stayed the same
- e) nondominant leg, 300°/s: ptE worsened from day 9 to week 4
ptE improved from wk 4 to 8.
Other values stayed the same.

D.2.3 Discussion

The only increase in extension torque of the exercised dominant leg was that from week 4 to week 8 at 60°/s. There was therefore no overall improvement over the eight weeks.

These results were found despite the fact that the exercise speed had been corrected and the fact that the subject (the researcher) had done all the Cybex tests on herself and had been highly motivated to perform maximally during all the tests.

It was therefore taken as unlikely that the results of the first trial had been due to the tester not having encouraged the subjects enough. The incorrect exercise speed of the first trial did not seem to have been the only problem. Extension work measurements, which might have offered some additional information, had not been done.

From the findings of this second trial, the researcher concluded that the incorrect exercise speed of the first trial was probably not the reason for the Cybex test failing to reveal any improvement in peak extension torque in Trial 1. The fact that the 10 RM had improved each week, indicated to

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the researcher that some strengthening had occurred, despite the fact that no real improvement of peak extension torque had occurred.

The next trial would have to focus on whether the Cybex machine at the Johannesburg Hospital was sensitive enough (despite the fact that it had been calibrated before commencement of the project).

APPENDIX D

D.3 Trial 3 (1992): The adequacy of the Cybex Isokinetic Dynamometer at the Johannesburg Hospital for muscle strength testing after an eight week isotonic strengthening programme: A comparison between test results on two isokinetic machines

D.3.1 Method

In September 1992, a small trial with four participants doing only land exercises was done. Subjects were asked not to participate in any sporting activity during the eight weeks of the trial. One of the participants had to withdraw in the second half of the trial due to a work-related acute herniating disc problem.

The exercise programme was exactly the same as the one used during the second trial. The exercise speed was at 60°/s and the isokinetic tests were done both on the Cybex machine of the Johannesburg Hospital and on an Akron isokinetic machine at a private physiotherapy practice. These tests were done one day apart, the Cybex test always being done first. Cybex tests were done at 60°/s as well as at 270°/s. The speed of 270°/s was taken in preference to 300°/s, which was at the top of the scale, as 270°/s could be more accurately selected on the Cybex II machine. Weekly 10 RM tests were also done.

A private physiotherapist conducted the isokinetic tests at his private practise. These were done on an Akron Isokinetic

The researcher conducted the Cybex tests at the Johannesburg Hospital and also gave encouragement. Both nondominant and dominant legs were tested, starting with the nondominant leg. Testing speeds were 60°/s and 270°/s. Tests at both speeds were done for 25 repetitions. Data was analysed for 30 s at 60°/s (pre-determined time bout endurance test) and for 20 repetitions at 270°/s (pre-determined repetition bout endurance test).

D.3.2 Results

D.3.2.1 10 RM test results

Table D6 Trial 3: Weekly 10 RM values (in kg)

[illegible]

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D.3.2.2 Isokinetic test results

Tests done on Cybex Isokinetic Dynamometer

Significant improvements ($p < 0,05$) in the Cybex isokinetic tests can be found in Table D7.

Table D7 Trial 3: Significant improvements ($p < 0,05$) in extension isokinetic test results on Cybex

CYBEX ISOKINETIC TEST	MEAN OF IMPROVEMENT*	S.D.	p - values
dominant leg, 60°/s, 30s PE: <u>week 8</u> week 0	1,110	0,059	0,043 s**
nondominant leg, 60°/s, 30s WZ: <u>week 8</u> week 4	1,106	0,057	0,043 s
nondominant leg, 270°/s, ptE: <u>week 8</u> week 4	1,154	0,039	0,010 s
nondominant leg, 270°/s, 20 WZ: <u>week 8</u> week 4	1,238	0,076	0,016 s
nondominant leg, 270°/s, 20 PE: <u>week 8</u> week 4	1,250	0,058	0,003 s
nondominant leg, 270°/s, EER: <u>week 8</u> week 4	1,165	0,064	0,024 s
dominant leg, 60°/s, ptE: <u>week 8</u> week 4	1,122	0,062	0,038 s
dominant leg, 60°/s, 30s WZ: <u>week 8</u> week 4	1,100	0,027	0,011 s
dominant leg, 60°/s, 30s PE: <u>week 8</u> week 4	1,101	0,051	0,038 s
dominant leg, 270°/s, ptE: <u>week 8</u> week 4	1,191	0,094	0,036 s
dominant leg, 270°/s, 20 WZ: <u>week 8</u> week 4	1,388	0,156	0,025 s
dominant leg, 270°/s, 20 PE: <u>week 8</u> week 4	1,294	0,150	0,038 s
dominant leg, 270°/s, EER: <u>week 8</u> week 4	1,312	0,087	0,012 s

* values above 1 indicate an improvement over the previous value.

s** = significant

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Isokinetic test results on Akron Isokinetic Dynamometer

Significant improvements ($p < 0,05$) on Akron testing can be found in Table D8.

Table D8 Trial 3: Significant improvements ($p < 0,05$) in extension isokinetic test results on Akron

AKRON ISOKINETIC TEST	MEAN OF IMPROVEMENT*	S.D.	p - values
dominant leg, 270°/s, ptE: <u>week 8</u> <u>week 0</u>	1,194	0,099	0,038 s**

* values above 1 indicate an improvement over the previous value.

s** = significant

D.3.3 Discussion

The weekly improvement of the values obtained during the 10 RM tests indicated that strengthening did occur.

D.3.3.1 Differences between the Akron and Cybex tests

The Cybex test at the Johannesburg Hospital showed a significant improvement ($p < 0,05$) in 8 extension test variables on the dominant leg, whereas the Akron only showed one significant improvement on the dominant leg. This variable did not correspond with a Cybex test variable.

On Cybex testing, the only significant improvement over eight weeks of an extension value of the dominant exercised leg occurred for extension power at 60°/s.

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On Akron testing, the only significant improvement over eight weeks of extension values of the dominant exercised leg was for peak extension torque at 270°/s.

A number of extension variables showed improvement on both machines, but these were not significant, probably as the sample size was so small.

No significant improvement in peak extension torque of the exercised leg over eight weeks was revealed by either of the two isokinetic machines when testing at the exercise speed of 60°/s. However, the weekly 10 RM increased significantly ($p < 0,05$) each week and over the eight week period. This could indicate that isokinetic testing probably is not sensitive enough to pick up the strengthening that occurs due to an isotonic programme as used in this trial on healthy females. As the sample size was so small, this could not be proven conclusively.

As neither the Akron nor the Cybex machines showed strengthening of the trained leg at the exercise speed, it was evident that the failure of isokinetic testing to show strengthening of the quadriceps at the exercise speed was not due to a faulty Cybex machine. It was consequently decided to continue using the Cybex machine at the Johannesburg Hospital for subsequent trials, but to include the weekly 10 RM as an additional test, as this seemed to be highly specific to the strengthening that occurred.

The Akron and Cybex machines produce their resistance differently, the Akron with a hydraulic component (personal

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communication with Mr D. Roworth, Huntleigh Akron) and the Cybex with the use of an electric motor (4, 7). Ideally, this trial should therefore have compared the results on two Cybex machines and not a Cybex and an Akron machine. At the time of the research, very few of these expensive Cybex machines were available and the researcher consequently only had access to one Cybex machine in the Johannesburg area.

At the end of this trial it was concluded that the fault with the initial trial did not lie with the exercise speed, nor with the Cybex Machine at the Johannesburg Hospital. The Cybex test probably was not sensitive enough to measure the strengthening that occurred. The researcher decided that a more strenuous exercise programme might be needed, so that strengthening would show up on isokinetic testing.

APPENDIX D

D.4 Trial 4 (1993): Does a strenuous isotonic strengthening programme lead to significant isokinetic test results ?

D.4.1 Method

During the fourth trial, the researcher put herself on a more strenuous modified 10 RM programme and did the exercises on land. The researcher did not participate in any form of sporting activity for the duration of the trial. The exercise programme was as follows:

- a) Each day: 10 times 50 per cent 10 RM (maximum weight),
 5 counts rest
 10 times 50 per cent 10 RM (maximum weight),
 10 counts rest

 10 times 75 per cent 10 RM,
 5 counts rest
 10 times 75 per cent 10 RM,
 10 counts rest

 10 times 10 RM,
 5 counts rest
 10 times 10 RM.
- b) At beginning of each week: Maximum weight was taken as 10 N more than the previous week and weights worked out accordingly.
- c) At the end of each week: 10 RM tests were done at the end of each week.
- d) Cybex tests: These tests were done at week 0, 4 and 8 at 60°/s and at 270°/s. Cybex tests were analysed over 28 s at

APPENDIX D

60°/s for both left and right legs. At 270°/s the analysis was done over 27s.

D.4.2 Results

D.4.2.1 10 RM results

The weekly 10 RM test showed improvements of about 10 N every week. After the first week, the 10 RM was only 5 N more than the pre-exercise 10 RM. The 10 RM was 15 N more again after the second week and from there on increased by 10 N each week. A 260 per cent increase occurred over eight weeks. The results of the weekly 10 RM tests are shown in Table D9.

Table D9 Trial 4: Weekly 10 RM test results (in kg)

	wk 0	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8
10 RM	5	5,5	7	8	9	10	11	12	13

D.4.2.2 Isokinetic test results

As only one person took part, no statistical testing could be done. Data was described in the same way as in the second trial. The isokinetic Cybex test results are shown in Table D10.

From Table D10 it can be seen that many of the isokinetic tests showed an improvement in muscle strength. Some values stayed the same. All the values for the dominant leg at 270°/s improved significantly from week 0 to week 8.

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Table D10 Trial 4: Isokinetic test results: significant improvement or worsening

ISOKINETIC TEST	VALUES*
dominant leg, 60°/s, ptE: <u>week 4</u> week 0	1,153
dominant leg, 60°/s, 28s WE: <u>week 4</u> week 0	1,228
dominant leg, 60°/s, 28s PE: <u>week 4</u> week 0	1,210
dominant leg, 270°/s, 27s WE: <u>week 4</u> week 0	1,164
nondominant leg, 270°/s, 27s WE: <u>week 8</u> week 0	1,158
nondominant leg, 270°/s, 27s PE: <u>week 8</u> week 0	1,196
dominant leg, 60°/s, ptE: <u>week 8</u> week 0	1,154
dominant leg, 60°/s, 28s WE: <u>week 8</u> week 0	1,301
dominant leg, 60°/s, 28s PE: <u>week 8</u> week 0	1,279
dominant leg, 270°/s, ptE: <u>week 8</u> week 0	1,158
dominant leg, 270°/s, 27s WE: <u>week 8</u> week 0	1,273
dominant leg, 270°/s, 27s PE: <u>week 8</u> week 0	1,283
nondominant leg, 270°/s, 27s WE: <u>week 8</u> week 4	1,100
nondominant leg, 270°/s, 27s PE: <u>week 8</u> week 4	1,166
dominant leg, 270°/s, 27s PE: <u>week 8</u> week 4	1,191

* values above 1 indicate an improvement over the previous value. Only significant improvements/ worsening are listed.

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D.4.3 Discussion

The results obtained from this trial showed more improvements in extension variables of the exercised leg than when the

original DeLorme protocol for muscle strengthening had been used. Peak extension torque, extension work and extension power of the dominant leg at 60°/s increased over four and over eight weeks, whereas no increases occurred in the nondominant leg at this speed. All values (i.e. peak torque, work and power) increased over eight weeks at the test speed of 270°/s on the dominant leg.

For this reason, the more strenuous modified DeLorme programme used in this trial was thought to be better suited to showing up improvements in muscle strength of the exercised muscle on isokinetic testing. It was therefore decided to go ahead with the more strenuous programme and that the Cybex test would probably be sensitive enough to show up improvement in muscle strength using this programme.

The 10 RM test again consistently showed up weekly improvements in muscle strength and it was therefore decided to use the 10 RM test as a backup to the Cybex test for the final trial.

Following Trial 4, the final project was done from 14.06.93 until 22.10.93, using the more strenuous modified DeLorme principle.

APPENDIX E

APPENDIX E

INFORMATION HANDOUT

INTERESTED IN JOINING A MUSCLE STRENGTHENING EXPERIMENTAL TRIAL?

I am a physiotherapist doing research on muscle strengthening in water and on land. I'm interested in establishing a more scientific way of approaching exercise in water. This research will be of value to a very wide variety of patients that require rehabilitation in water.

Volunteers are needed and I am approaching nursing, medical and allied medical students and staff for help. Your help would be greatly appreciated!

What joining this project will entail

1. An exercise test to establish the strength of your thigh muscles on the Cybex isokinetic machine ($\pm$ 20 min)

2. A test of the maximal load you can lift with your dominant leg for 10 times ($\pm$ 10 min)

3. The attendance of exercise sessions five times a week (each for $\pm$ 20 min) for a total of eight weeks, from to

(You will be assigned either to land or to water exercises, with the aim of strengthening your thigh muscles. The water exercises will be done in the heated pool in the hydrotherapy area of the Johannesburg Hospital and the land exercises in the same area on treatment couches.)

4. A test of the maximal load you can lift with your dominant leg for 10 times, performed at the end of each week of exercises

5. An exercise test on the Cybex machine at the end of four weeks and eight weeks to establish the strengthening that has occurred in your thigh muscles

6. Completing short questionnaires before, after and during the exercise trial

APPENDIX E

I would also like to ask you, in the interest of helping to ensure valid findings, not to participate in other regular physical activity/ sport at all during the eight weeks of the exercise trial.

Participation is voluntary and if at any time you find it necessary to withdraw from the study, you are free to do so.

Ethical clearance for this project has been obtained from the Committee for Research on Human Subjects.

Should you be prepared to participate in the projec' please sign the Statement of Consent.

Monika Petrick (Physiotherapist)

P.S: Times for the daily exercises will be arranged so that they suit you. Please come and speak to me (area 259) or phone me (488-3258/9) if you have any queries.

APPENDIX F

APPENDIX F
CONSENT FORMSTATEMENT OF CONSENT

I,(name), hereby
agree to participate in the research project of Monika Petrick.

I understand that participation is voluntary and that it will
involve the following:

- exercise tests before, during and after the trial
- the attendance of exercise sessions five times a week for
eight weeks
- the completion of weekly short questionnaires

I understand that for results to be valid, I need to complete
the eight week exercise trial, but should I need to withdraw
from the study, I shall be free to do so.

..... (signed)

APPENDIX G

APPENDIX G

CERTIFICATE

THIS IS TO

CERTIFY

that (name)

has successfully completed

8 weeks of exercise in water/ on land

5 times a week,

thereby

strengthening her quadriceps muscles

from (10 RM at week 0) to (10 RM at week 7)

and

furthering the cause of

physiotherapy research.

.....
(signature of researcher).....
(date)

APPENDIX H

APPENDIX H

CALIBRATION OF EQUIPMENT

Table H1 Calibration of Krupps Type 844 kitchen scale
(range: 0 - 2,2 kg)

STANDARD WEIGHTS	SCALE READING	PERCENTAGE ERROR
1 000 g	990 g	1%
500 g	490 g	1%

Table H2 Calibration of Seca paediatric scale (model QD35 ED
177, NR. 776624) (range: 0 - 4 kg)

STANDARD WEIGHTS	SCALE READING	PERCENTAGE ERROR
500 g	500 g	0 %
1 000 g	1 000 g	0 %
2 000 g	2 000 g	0 %
3 000 g	3 005 g	0,5 %
4 000 g	4 005 g	0,5 %

Table H3 Calibration of Capacity spring balance

STANDARD G+G Ltd WEIGHTS	READING: SPRING BALANCE 1 *	READING: SPRING BALANCE 2 *
1 000 g	1 010 g	1 015 g
1 000 g	1 010 g	1 015 g
1 000 g	1 010 g	1 015 g
1 000 g	1 010 g	1 015 g
500 g	500 g	515 g
500 g	510 g	510 g
0 g	-	10 g
	%ERROR = $10/500 \times 100$ = 2%	%ERROR = $10/500 \times 100$ = 2%

* Readings exclude the weight of the plastic bag, which hung from the spring balance and into which the weights were placed.

APPENDIX H

Table H4 Calibration of Addis 1,5 l measuring jug

VOLUME USING Labotec 500 ml MEASURING CYLINDER (ml)	VOLUME USING ADDIS MEASURING JUG (ml)
450	470
500	520
1000	1020
1380	1400
730	750
	20 ml error in 1400 ml = 1,3% error

Table H5 Calibration of EKS Doctor's scale (max 150 kg, 1 kg intervals) (range of 12,5 kg - 36,5 kg was chosen, as this was used during leg weighing)

Kenricks + Sons and G+G LTD standard weights (kg)	Reading on EKS scale (kg)
12,5	12,5
17,5	17,5
22,5	22,5
28	28
29	29
31	31
32	32
33	33
33,5	33,5
34	34
34,5	34,5
35	35
35,5	35,5
36	36
36,5	36,5
	No error, 100% accurate

Table H6 Calibration of Wittner wooden metronome with pendulum

METRONOME SETTING	NUMBER OF BEATS COUNTED IN A MINUTE (WRIST WATCH WITH A SECOND HAND)
40	38
40	37
40	38
40	38
40	38
40	38
40	38
	% ERROR = $2/40 \times 100 = 5\%$

APPENDIX I

APPENDIX I

HYDROSTATIC PRESSURE MEASUREMENTS

Table II Volume loss in a 2050 ml air-filled bottle submerged under water (as a result of hydrostatic pressure)

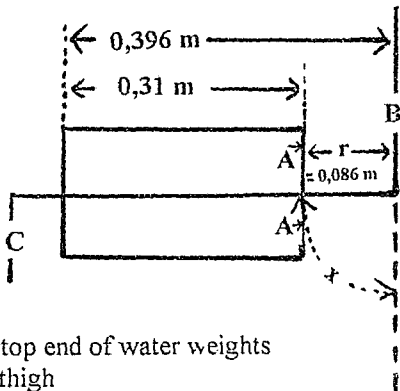
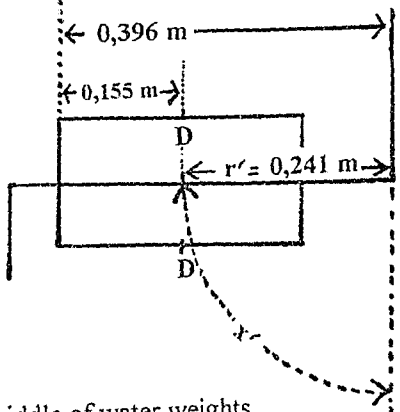
TRIAL	VOLUME (ml)	MEAN VOLUME (ml)
1	10,5	9,65
2	9	
3	10	
4	9	
5	10	
6	10,5	
7	10	
8	9	
9	9	
10	9,5	

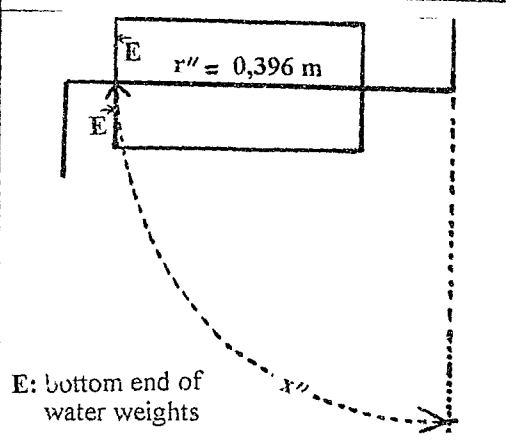
APPENDIX J

APPENDIX J

VISCOUS DRAG FORCE

Table J1 Calculations and measurements to establish the magnitude of viscous drag force on one set of water bottles moving at an angular velocity of $60^\circ/\text{s}$

VELOCITY CALCULATIONS	
Velocity at the TOP of the water weights (closest to the knee) (v)	
Drawing of lower leg with water weights	Calculations
 A: top end of water weights B: thigh C: foot	r = lever length at the top of the water weights = mean of the lower leg lengths* - length of bottle = $0,396 \text{ m} - 0,31 \text{ m}$ = $0,086 \text{ m}$ time (t) to complete 90° at a velocity of $60^\circ/\text{s} = 1,5 \text{ s}$ $x = \pi r/2 = 3,142 \times 0,086/2$ = $0,135 \text{ m}$ velocity (v) = $x/t = 0,135/1,5$ = $0,09 \text{ m/s}$
Velocity at the MIDDLE of the water weights (v')	
Drawing of lower leg with water weights	Calculations
 D: middle of water weights	r' = lever length at the middle of the water weights = mean of the lower leg lengths* - $0,5 \times$ length of bottle = $0,396 \text{ m} - (0,5 \times 0,31) \text{ m}$ = $0,241 \text{ m}$ time (t) to complete 90° at a velocity of $60^\circ/\text{s} = 1,5 \text{ s}$ $x' = \pi r'/2 = 3,142 \times 0,241/2$ = $0,379 \text{ m}$ velocity (v') = $x'/t = 0,379/1,5$ = $0,252 \text{ m/s}$

Velocity at the BOTTOM of the water weights (closest to the ankle) (v'')					
Drawing of lower leg with water weights			Calculations		
 E: bottom end of water weights			r'' = lever length at the bottom of the water weights = mean of the lower leg lengths* = 0,396 m time (t) to complete 90° at a velocity of $60^\circ/\text{s} = 1,5 \text{ s}$ $x'' = \pi r/2 = 3,142 \times 0,396/2$ = 0,622 m velocity (v'') = x/t = $0,622/1,5$ = 0,415 m/s		
VISCOUS DRAG FORCE MEASUREMENTS AND CALCULATIONS					
Velocity		Time needed to drag water weights for 6 m through the pool to achieve this velocity	Viscous drag force: Values obtained dragging sets of water weights (in g)		Viscous drag force: Values obtained dragging artificial limb (in g) (similar shape to a lower leg)
0,09 m/s	velocity of the top end of the water weights during knee E in water at $60^\circ/\text{s}$ (v , see above)	66,7 s	first set 10 10 10	second set 10 10 10	unable to measure, artificial leg too buoyant and floating too fast
0,252 m/s	velocity of the middle of the water weights during knee E in water at $60^\circ/\text{s}$ (v' , see above)	23,8 s	first set 300 200 300 300	second set 300 350 350 300	100 50 75 75
			mean viscous drag force = 300 g		

0,415 m/s	velocity of the bottom end of the water weights during knee E in water at 60°/s (v'' , see above)	14,5 s	first	second	450
			set	set	350
			500	600	400
			450	600	
			400	600	

* See Table 5.2 for mean of the lower leg lengths

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APPENDIX K

PREPARING WATER WEIGHTS

Table K1 Preparing water weights

WEIGHTS in N (kg)	HOW TO PREPARE A SET OF WATER WEIGHTS
10 (1)	1 bottle filled with 1,3 litre of water All other bottles filled completely
20 (2)	1 bottle filled with 300 ml of water All other bottles filled completely
30 (3)	1 bottle filled with 300 ml of water 1 bottle filled with 1 litre of water All other bottles filled completely
40 (4)	1 bottle filled with 300 ml of water 1 bottle empty All other bottles filled completely
50 (5)	1 bottle filled with 300 ml of water 1 bottle empty 1 bottle filled with 1 litre of water All other bottles filled completely
60 (6)	1 bottle filled with 300 ml of water 2 bottles empty All other bottles filled completely
70 (7)	1 bottle filled with 300 ml of water 2 bottles empty 1 bottle filled with 1 litre of water All other bottles filled completely
80 (8)	1 bottle filled with 300 ml of water 3 bottles empty All other bottles filled completely
90 (9)	1 bottle filled with 300 ml of water 3 bottles empty 1 bottle with 1 litre of water All other bottles filled completely
100 (10)	1 bottle filled with 300 ml of water 4 bottles empty All other bottles filled completely
110 (11) - 160 (16)	Follow the same pattern as above

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APPENDIX L

LOWER LEG VOLUMES AND LOWER LEG WEIGHT

1. Determining lower leg volumes

The lower leg volumes of 12 healthy young females were determined as follows: A piece of plastic tubing (internal diameter of 8 mm) was inserted into a small hole drilled 0,49 m along the height of a rectangular container (height = 0,57 m, length = 0,25 m, width = 0,25 m). The container was filled with water up to the level of the pipe, i.e. until no more water flowed out of the pipe. The right lateral

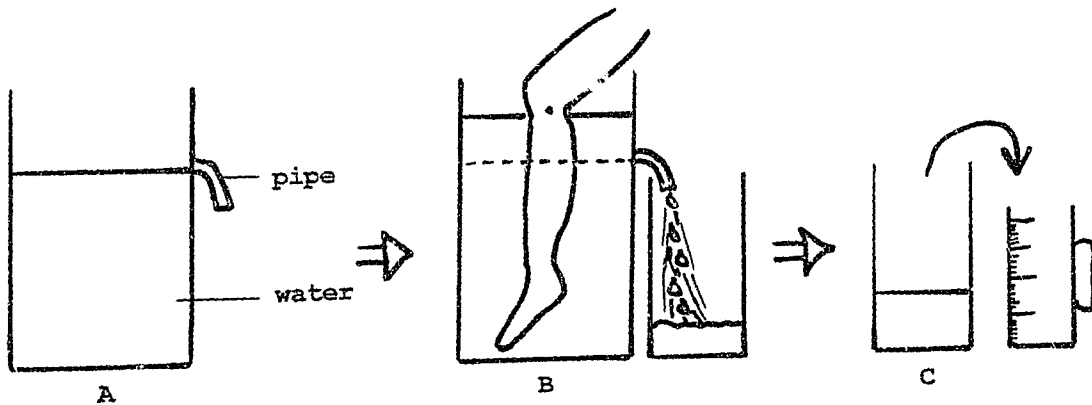


Figure L1 Measuring lower leg volume: A: Water just not overflowing through pipe, B: Right lower leg inserted up to level of the lateral epicondyle. Water overflows via the pipe into the bucket, C: The volume of water that overflowed into the bucket (lower leg volume) is measured using a measuring jug.

epicondyle of the volunteers was marked. An empty bucket was placed under the pipe. The volunteers then submerged their

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right lower legs into the water in the big container up to the level of the lateral epicondyle. The leg was then held still until no more water overflowed through the pipe (Figure L1). The volume of the water that had flown out of the pipe, which is the volume of the lower leg, was then measured with an Addis 1,5 l measuring jug (for calibration of the jug, see Table H4, Appendix H).

2. Weighing the lower leg

The weight of the lower leg was established in the same 12 volunteers as above, using the method described by Williams & Lissner (85). The subject lay prone on a board, one end of which rested on a support and the other end on a scale. The reading of the scale was taken with the right knee extended and then flexed to 90 degrees. The centre of gravity of the lower leg was found to be 43 per cent down the length of the lower leg. The horizontal distance this centre of gravity travelled from knee extension to 90 degrees knee flexion was measured. Using levers and moments, the lower leg weight was then determined as follows:

$$\text{lower leg weight} = \frac{L (S1-S2)}{d}$$

where L = distance between the supports for the board,
 S1 - S2 = the difference in scale readings with knee
 flexed and extended, and

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d = horizontal distance the centre of gravity of the lower leg and foot moved from knee flexion to knee extension

(See Figure L2)

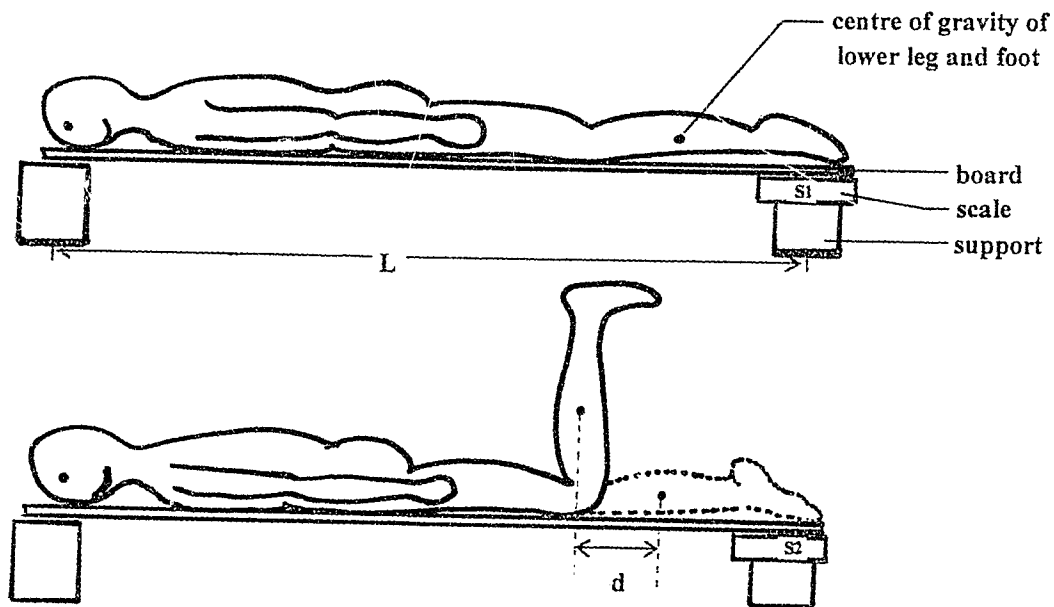


Figure L2 Measuring lower leg weight: $S1$ = scale reading with knee extended, $S2$ = scale reading with knee flexed to 90 degrees, L = distance between the supports for the board, d = horizontal distance the centre of gravity of the lower leg and foot moves from knee flexion to knee extension

As the difference of scale reading with the right knee extended and flexed was 0,5 - 1 kg in most subjects, the accuracy of these readings would have been enhanced if an electronic scale with 10 g intervals had been used. Possibly as a result of this, the researcher's findings of lower leg weight were high

APPENDIX L

(11,4 per cent of body weight) when compared to the figures for lower leg weight of 6,4 per cent and 6 per cent body weight found when lower legs of cadavers were detached and weighed (85). Even with the figure of 6,4 per cent body weight, the downward force of gravity (46,85 N) on the lower leg is larger than the upthrust of buoyancy (37,78 N), with a resultant downward force (Table L1).

Table L1 Lower leg volumes and lower leg weight in 12 healthy young females.

AGE	BODY WEIGHT	6,4% BODY WEIGHT	MEASURED LOWER LEG WEIGHT	LOWER LEG VOLUME AND UPTHRUST
MEAN (S.D.)	MEAN (S.D.)	MEAN (S.D.)	MEAN (S.D.)	MEAN (S.D.)
29,8 (5,80) years	732,1 (137,9) N	46,85 (8,83) N	83,28 (14,43) N (11,4% body weight)	3778 (466) ml 37,78 (4,66) N

Lower leg weight could also have been determined using the leg weighing procedure on an isokinetic dynamometer (5).

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TABLES OF RESULTS

Table M1 Test results of the 10 RM when all the testers tested two people

TESTER	SUBJECT M JULY 1993: 10 RM	SUBJECT J 9.9.93: 10 RM
M	45 N	40 N
B	50 N	40 N
MA	45 N	50 N
J	45 N	45 N
A	45 N	45 N
C	45 N	45 N
F = 0,4 and p = 0,83		

Table M2 Comparing the number of attendances and double sessions between the water and land groups

	WATER		LAND		p - VALUE	
	MEAN	S.D.	MEAN	S.D.		
NO. OF ATTENDANCES*	36,47	3,12	35,94	4,68	0,343	ns**
NO. OF DOUBLE SESSIONS	3,63	3,24	2,22	2,10	0,064	ns

the maximum number of exercise sessions possible = 38

** = not significant (Two-tailed two sample t-test)

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APPENDIX M

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ns** = not significant (Two-tailed two sample t-test)

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Table M3 Isokinetic extension test results at week 0

ISOKINETIC TEST RESULTS AT WEEK 0			
Leg and speed	Isokinetic Test	Mean	Standard Deviation
Nondominant leg, 60°/s	ptE	101,166 Nm	14,749 Nm
Nondominant leg, 60°/s	20: W in E	951,7028 b*	135,1437 b
Nondominant leg, 60°/s	20: EP	6,14696 b/mm**	0,85317 b/mm
Nondominant leg, 60°/s	EER	67,632 %	13,036 %
Nondominant leg, 270°/s	t: W in E	887,9528 b	121,1285 b
Nondominant leg, 270°/s	t: EP	6,27951 b/mm	0,84429 b/mm
Nondominant leg, 270°/s	ptE	40,726 Nm	9,325 Nm
Nondominant leg, 270°/s	20: W in E	106,9104 b	134,2998 b
Nondominant leg, 270°/s	20: EP	1,93430 b/mm	0,65205 b/mm
Nondominant leg, 270°/s	EER	47,874 %	13,570 %
Nondominant leg, 270°/s	t: W in E	84,9906 b	29,5955 b
Nondominant leg, 270°/s	t: EP	2,00355 b/mm	0,6428 b/mm
Dominant leg, 60°/s	ptE	101,747 Nm	14,248 Nm
Dominant leg, 60°/s	20: W in E	936,6132 b	187,197 b
Dominant leg, 60°/s	20: EP	6,12572 b/mm	1,18138 b/mm
Dominant leg, 60°/s	EER	65,513 %	11,528 %
Dominant leg, 60°/s	t: W in E	890,1085 b	173,8991 b
Dominant leg, 60°/s	t: EP	6,24987 b/mm	1,20686 b/mm
Dominant leg, 270°/s	ptE	40,423 Nm	9,733 Nm
Dominant leg, 270°/s	20: W in E	91,3726 b	29,5782 b
Dominant leg, 270°/s	20: EP	1,97515 b/mm	0,63171 b/mm
Dominant leg, 270°/s	EER	48,479 %	14,501 %
Dominant leg, 270°/s	t: W in E	99,0566 b	99,1109 b
Dominant leg, 270°/s	t: EP	2,04174 b/mm	0,6415 b/mm

b* = "blocks", i.e. the number of 1 x 1,5 mm blocks of area under the curve, used as the measure of work. (Following the method used by Moffroid, et al. (86), one block represents about 2 J at 60°/s and 8 J at 270°/s. These values were found to be too inaccurate to use, as the graph paper had run at a speed of 5 mm/s and not at 25 mm/s, which would have provided more accuracy.)

b/mm** = "blocks per millimetre", i.e. the number of blocks of area under the curve divided by the distance the graph paper moved, used as a measure of power.

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Table M4 A sample of isokinetic extension test results for the water, land and control groups (all values that are significantly different, as well as some values that are not significantly different, are tabulated)

TEST	WATER GROUP (W)		LAND GROUP (L)		CONTROL GROUP (C)		p-values	
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	W vs L	W vs C
NONDOMINANT LEG, 60°/s, value at 0 weeks								
W in E (in bl*)	1006	107,5	910,9	119,1	933,06	165,08	0,008 0,063 0,327	s** ns# ns
DOMINANT LEG, 60°/s, value at wk 4 ## value at wk 0								
EER	0,968	0,116	1,006	0,139	1,095	0,205	0,179 0,013 0,072	ns s ns
DOMINANT LEG, 60°/s, value at wk 8 value at wk 0								
PtE	0,944	0,134	0,957	0,129	0,952	0,141	0,393 0,432 0,457	ns ns ns
20: W in E	1,000	0,123	1,023	0,117	1,062	0,379	0,282 0,253 0,340	ns ns ns
20: EP	0,986	0,132	1,022	0,139	1,091	0,391	0,212 0,139 0,244	ns ns ns
EER	0,997	0,131	1,064	0,236	1,079	0,218	0,145 0,089 0,425	ns ns ns
t: W in E	0,983	0,124	1,024	0,141	1,074	0,399	0,177 0,176 0,311	ns ns ns
t:EP	0,987	0,131	1,012	0,127	1,077	0,399	0,280 0,175 0,254	ns ns ns
DOMINANT LEG, 270°/s, value at wk 8 value at wk 0								
ptE	1,045	0,257	1,080	0,249	1,076	0,263	0,338 0,349 0,490	ns ns ns
20: W in E	1,060	0,215	1,261	0,400	1,148	0,331	0,032 0,175 0,190	ns ns ns
20: EP	1,079	0,274	1,240	0,457	1,163	0,322	0,100 0,205 0,289	ns ns ns
EER	1,084	0,290	1,160	0,428	1,252	0,453	0,260 0,097 0,273	ns ns ns

TEST	WATER GROUP (W)		LAND GROUP (L)		CONTROL GROUP (C)		p-values	
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	W vs L W vs C L vs C	
t: W in E	1,096	0,258	1,297	0,492	1,151	0,323	0,063 0,290 0,160	ns ns ns
t:EP	1,071	0,249	1,231	0,458	1,148	0,313	0,096 0,212 0,273	ns ns ns

bl* = no. of blocks (1 x 1,5 mm²)

s** = significant (Two-tailed t-test)

ns# = not significant

the values were obtained by dividing the value at week 4 by the value at week 0. Any value of the ratios in Table H4 above 1 therefore indicates an improvement over the baseline value.

Table M5 Comparison of the number of times thigh muscle soreness was reported on the weekly questionnaire over eight weeks in the land and water groups

	WATER GROUP	LAND GROUP	p - value #
NUMBER OF REPORTS OF <u>THIGH MUSCLE SORENESS</u>	42	46	0,306 ns*
NUMBER OF REPORTS OF <u>NO THIGH MUSCLE SORENESS</u>	107	89	
TOTAL NUMBER OF REPORTS	149**	135***	

ns* = not significant

** This is less than 152 (8 questionnaires x 19 subjects) because one subject did not complete the full 8 weeks of exercise

*** This is less than 144 (8 questionnaires x 18 subjects) because 3 subjects did not complete the full 8 weeks of exercise

2-Tail Fisher's Exact Test

APPENDIX M

Table M6 Analysis of where pain was felt during exercise

WEEK	PAIN LOCATION	WATER		LAND	
		NO.*	PERCENTAGE	NO.	PERCENTAGE
1	knee and thigh area	2	50	7	87,5
	ankle area	1	25	1	12,5
	other (stomach)	1	25	0	0
2	knee and thigh area	2	100	6	75
	ankle and calf area	0	0	1	12,5
	other (stomach)	0	0	1	12,5
3	knee and thigh area	2	100	8	72,73
	ankle and calf area	0	0	3	27,27
	other	0	0	0	0
4	knee and thigh area	4	100	8	88,89
	ankle and calf area	0	0	1	11,11
	other	0	0	0	0
5	knee and thigh area	6	100	9	81,82
	ankle and calf area	0	0	1	9,09
	other (stomach)	0	0	1	9,09
6	knee and thigh area	6	85,71	9	90
	ankle and calf area	1	14,29	1	10
	other	0	0	0	0
7	knee and thigh area	6	100	7	87,5
	ankle and calf area	0	0	1	12,5
	other	0	0	0	0
8	knee and thigh area	4	100	9	81,82
	ankle and calf area	0	0	2	18,18
	other	0	0	0	0

NO.* = number of subjects

APPENDIX M

Table M7 Correlation between 10 RM values and isokinetic extension values of the dominant leg at 60°/s at week 0

	10 RM WEEK 0 r (Pearsons correlation coefficient) r ² (Coefficient of determination)
ptE: week 0	r = 0,175 r ² = 0,031
20: W in E: week 0	r = 0,382 r ² = 0,146

Table M8 Correlation between 10 RM values and isokinetic extension values of the dominant leg at 60°/s at week 4

	10 RM: WEEK 4 r (Pearsons correlation coefficient) r ² (Coefficient of determination)
ptE: week 4	r = 0,149 r ² = 0,022
20: W in E: week 4	r = 0,330 r ² = 0,109

Table M9 Correlation between 10 RM values and isokinetic extension values of the dominant leg at 60°/s at week 7 or 8

	10 RM: WEEK 7 r (Pearsons correlation coefficient) r ² (Coefficient of determination)
ptE: week 8	r = 0,186 r ² = 0,035
20: W in E: week 8	r = 0,393 r ² = 0,154

APPENDIX N

APPENDIX N

REASONS FOR WITHDRAWAL

1. Volunteers who started the project but did not complete four weeks (not taken as subjects)

The reasons for withdrawal of the volunteers who did not complete four weeks are given in Table N1

Table N1 Reasons for subjects completing less than four weeks of exercise or for data being excluded from analysis

REASON FOR WITHDRAWAL	NUMBER OF VOLUNTEERS		
	WATER GROUP	LAND GROUP	CONTROL GROUP
Illness	4	2	0
Personal reasons	3	0	0
Eczema on legs (due to chlorine)	1	0	0
Went on holiday	1	0	0
Developed pain in feet	0	1	0
Taken out by researcher (unable to discontinue sport while participating in this research)	0	1	3
TOTAL	9	4	3
TOTAL EXPERIMENTAL MORTALITY	16/69 = 23,2%		

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2. Reason for withdrawal of the four subjects who
completed more than four, but less than eight
weeks

One subject in the water group went home for one week's study leave and was therefore unable to attend the daily exercise sessions during that week. Three subjects in the land exercise group completed a minimum of four weeks, but not the full eight weeks. Of these, one found participation too tedious or boring to complete eight weeks, one had to stop due to illness while another subject went home for one week's leave and could therefore not attend the exercise sessions.

APPENDIX O

APPENDIX O

CORRELATIONS BETWEEN MANUALLY CALCULATED
AND DATA REDUCTION COMPUTER ISOKINETIC
VALUES

Table O1 Isokinetic tests of dominant leg at 60°/s: Correlation between manually calculated values and values from Cybex II data reduction computer print-outs

TEST	MANUAL VALUE (S.D.)	COMPUTER PRINT- OUT VALUE	r^{2**}
week 0: ptE	101,70 (14,24) Nm	117,08 (18,29) Nm	0,557
week 0: 20: W in E	936,74 (187,15) b	1809,70 (418,76) J	0,568
week 0: 20: EP	6,126 (1,181) b/mm	66,95 (20,61) W	0,515
week 4: ptE	98,79 (15,77) Nm	117,64 (21,53) Nm	0,780
week 4: 20: W in E	952,68 (163,50) b	1921,10 (447,97) J	0,502
week 4: 20: EP	6,229 (0,998) b/mm	65,74 (19,22) W	0,489 ##
week 8: ptE	96,67 (16,21) Nm	115,50 (20,05) Nm	0,768
week 8: 20: W in E	947,98 (163,57) b***	1921,19 (398,39) J	0,728
week 8: 20: EP	6,201 (1,120) b/mm#	66,02 (15,54) W	0,546

- r^{2**} = (Pearson correlation coefficient)²
 b*** = blocks on graph paper (1 x 1,5mm) of area under the curve, used as the measure of work
 b/mm# = blocks per millimetre, i.e. the number of blocks of area under the curve divided by the distance the graph paper moved, used as a measure of power
 ## = the only r^2 value < 0,50, i.e. it is just below the value for an acceptable correlation

There was no significant difference between the three groups in the knee extension peak torque at 60°/s of the dominant knee in any of the tests ($p > 0,05$).

APPENDIX P

APPENDIX P

COMPARING THE COST OF WATER WEIGHTS AND
SANDBAGS

Table P1 Comparing the cost of water weights and sandbags as needed for one person on an eight week programme, starting at a 10 RM of 50 N (5 kg) (October 1996)

WATER WEIGHTS		SANDBAGS			
ITEM	COST	STRAP- ON		DURABLE HOME-MADE	
		ITEM	COST	ITEM	COST
11 empty plastic bottles - 3 for side of pool - 8 for water weights (available in most house holds/ from friends)	R 0,00	strap-on weights	R 504,67	1 packet of plastic bags to hold sand before it is put into canvass bags	R12,00
1 roll of string	R 7,30			24,5 kg of sand	R 7,04
50 cm of plastic tubing	R 1,17			3 m of canvass material	R36,00
3 pieces of stockinat - 1 for foot noose - 1 for leg - 1 to tie around bottles	R10,20			2 reels of cotton thread	R 4,30
2 towels - 1 around leg - 1 over side of the pool (available in household)	R 0,00			1 needle	R 1,00
TOTAL	R18,67	TOTAL	R504,67	TOTAL	R60,34

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References and citations in this research report were done according to the Vancouver style, following the University of the Witwatersrand Style Guide for theses, dissertations and research reports, Faculty of Dentistry and Medicine, 1995.

LIST OF CORRECTIONS

A comparison between quadriceps muscle strengthening on land and in water: a study on young females – Monika Petrick

Corrections

A note on numbering of sections, figures, tables, appendices and page numbering

The corrections described here refer to the section numbering used in the version of the research report, which was handed in on 25/9/97 (which the examiners marked). Subsequent to the corrections made by the researcher, numbering changed. For this reason, the name of the section is included with the "old" number of the section in this description of the corrections done.

Where "new" numbering is given next to the "old" numbering, it is given in bold italics in brackets.

Reference numbers: The reference numbers refer to the new reference list, with the previous reference number in brackets, if this reference had appeared in the previous reference list, eg. 23 (was 103) means that the previous reference number 103 is now number 23.

A. Corrections according to requirements of Mr. F. Cohen (his report is given in italics)

GENERAL

This research project is certainly adequate. A fortune of work has gone into this research, often misdirected. I feel this project is too long and could be markedly shortened. This project is not focused and could be improved by including only the relevant (that is to the title) information.

The literature review on strength training and muscle strength was taken out. The terms used in this part of the literature review only, were taken out of the "glossary of terms".

Table 5.21 and related text referring to the number of subjects who experienced pain on exercising in week 8 was taken out.

Section "5.6: One way ANOVA for testers" was shortened and put into "method"

Sections "5.7.1.3: Variables showing no significant differences" and "5.7.4.2: Thigh muscle soreness" were shortened.

Sections 5.10, 5.11, 6.1.1 and 6.1.2 and Tables 5.45, 5.46, 5.47 and 5.48 were taken out:

Comparing subjects with prior leg injury to those without injury and comparing subjects with prior sports participation to those without. The paragraph describing the statistical analysis of these two comparisons was taken out of section "4.4.1: Statistical testing".

All flexion results in "results" and "discussion" were taken out.

"6.1.4: Randomly dividing subjects into two groups" and "6.1.5: Difficulties getting subjects to volunteer for control group" were taken out.

Section "7.3: Method of testing" was taken out.

Section "5.9.1: Correlation between extension peak torque and extension work" (including tables 5.39, 5.40 and 5.41) was taken out.

The whole of section "6.1: The subjects" was taken out.

Appendix I: "Admission fees to some public pools in the Johannesburg and Springs areas" was taken out.

If the candidate required some examples of shortening certain sections, I have compiled a detailed critique of this research project, which she is most welcome to have.

This critique was obtained from Mr. Cohen. Corrections from the suggestions it contains are found at the end of the corrections from Mr. Cohen's examiners report.

The methodology is the weakest section of this report and should have been the strongest. It could have been tightened up and more scientific in approach, especially since prior pilot studies were performed. For example, the randomness of subject selection and the use of isokinetic equipment to measure isotonic strengthening to name a few.

See specific corrections that follow.

Not all the variables, it was felt, related directly to the purpose of this study.

Sections 5.10, 5.11, 6.1.1 and 6.1.2 and Tables 5.45, 5.46, 5.47 and 5.48 were taken out: Comparing subjects with prior leg injury to those without injury and comparing subjects with prior sports participation to those without. These sections did not directly relate to the purpose of the study.

See all other sections taken out, mentioned before.

Subjects and instrumentation should have been described in more detail and more operational definitions used.

Subjects and their selection were described in more detail in the beginning of the methods chapter. Instrumentation and calibration was explained in more detail, see corrections to method section. More definitions were added to the glossary.

Data analysis was adequately performed.

Referencing of articles was poorly done and very inconsistent. Only 3 authors should be mentioned in the text, otherwise first author, followed by et al.

Referencing was done in the Vancouver style, following the "University of the Witwatersrand Style Guide for theses, dissertations and research reports: Faculty of Dentistry and Faculty of Medicine, 1995". On p 10 it states that "more than one author should be cited as 'Hart & Mitchell', or 'Hart, Mitchell & Rogers' for the first time in the text only. After the first citation it is possible to refer to 'Hart, et al.' in the text." As the style guide is

unclear about how to refer to more than 3 authors in the text, using the Vancouver style, the researcher obtained information from one of the authors of the style guide, Mrs. Glenda Myers. She suggested that conventionally more than 3 authors are referred to as Peters, et al. in the Vancouver style.

The researcher followed these guidelines, i.e. after the first citation, which includes all authors (if these are 3 or less), subsequent citations mention the first author only, followed by et al. (Comment 1).

Corrections were made where the referencing had been done incorrectly.

Also do not require et al in the reference list, as a full list of authors is required.

Page 10 of the "University of the Witwatersrand Style Guide for theses, dissertations and research reports: Faculty of Dentistry and Faculty of Medicine, 1995" states that all authors should be listed in the reference list, except if the number exceeds six. In such a case the first six authors are listed, followed by et "al." . The researcher followed this. (Comment 2)

Reference 2 (was 76) was corrected from "Edlich et al." to:

"2. Edlich RF, Towler MA, Goitz RJ, Wilder RP, Buschbacher LP, Morgan RF et al. Bioengineering principles of hydrotherapy. J Burn Care Rehabil 1987;8(6):580-584."

The following note was added to the end of the reference list:

"References and citations in this research report were done according to the Vancouver style, following the University of the Witwatersrand Style Guide for theses, dissertations and research reports, Faculty of Dentistry and Medicine, 1995."

One reference (no 33) does not have a date of publication.

July 1969 was added to reference no 86 (was 33).

SPECIFIC

Title

Good, identifies key words, reflects the essence of the research project.

Page 3, 4th paragraph

Questionnaires not referenced i.e. appendix D, E and F.

The questionnaires were referenced: "Questionnaires were completed before (Appendix D) (Appendix A) and at the end of the trial (Appendix F) (Appendix B), with the exercise groups completing additional weekly questionnaires (Appendix E) (Appendix C)".

Page 5, isometric contraction

Not a very clear definition. Should read "when muscle length does not change because contractile force is equal to resistive force".

Text was changed to: "**Isometric contraction:** A muscle contraction during which the muscle length does not change and no joint movement occurs because the contractile force is equal to the resistive force (6 (was 8))."

Page 6, no 9, Peak Torque

Not a clear definition. Could read "torque (turning moment) – the magnitude of a force multiplied by the length of its moment arm. The degree to which a force tends to rotate an object around a specified fulcrum".

The definition of peak torque was changed to:

"Peak torque: Torque is the magnitude of a force multiplied by the length of its moment arm (6 (was 8)). It is the ability of a force to produce rotation about an axis (7 (was 61), 4). Torque can be measured using isokinetic dynamometers (6 (was 8)). Peak torque is the highest point on the torque curve, a tracing of the torque over the range of movement (6 (was 8), 3) (see Figure 2.1). Peak torque gives an indication of muscle strength (3)."

Page 7, Figure 2.1

Area under the curve = rotational work = torque x angular displacement

The definition of rotational work was added to the glossary of terms:

10. Rotational work

Rotational work is work done during rotation about an axis. It is equal to torque x angular displacement and is represented by the area under a torque curve obtained by isokinetic testing (3) (see Figure 2.1).

The subheading of Figure 2.1 was changed to read "rotational work" instead of "work". The joint and movement tested was also included: "knee flexion and extension"

Page 8 – Literature review

Could add to glossary of terms:

- a) *Definition of force: "Muscle force generated by biochemical activity that tends to draw the opposite ends of a muscle towards each other".*

The following was added to the glossary of terms: "Muscle force: A force generated by biochemical activity in a muscle that tends to draw the opposite ends of a muscle towards each other (6 (was 8)).

- b) *Definition of muscular endurance: "Ability of a muscle or muscle group to perform repeated contractions against a submaximal load for an extended period of time."*

The following was added to the glossary of terms: "Muscular endurance

Muscular endurance is an indication of how long a person can maintain a specific isometric force or a certain power level of consecutive isotonic contractions (4)."

Page 12 – Muscle strength

For completeness, other determinants of muscle strength that could have been included are:

- a) strength to mass ratio*
- b) muscle contraction velocity and*
- c) joint angular velocity*

Page 12 – First paragraph

No such word as "basing"

Page 16 – Principles of strength training

Not mentioned were:

- a) "individual differences principle" i.e. individual differences at the start of training. Also individuals respond differently to training, and*
- b) Reversibility principle, i.e. detraining*

These principles are important and could have been discussed in the discussion.

Page 21 – Closed Kinetic Chain Exercise

Any cycling can be used and not stair climbing (only if the leg you are trying to strengthen does not leave the step).

Page 35

Cannot just say "fair", require the actual inter-test reliability scores.

Pages 8 – 39 were taken out of the research report in an attempt to shorten it on advice of the other examiner.

Page 44

As this study focuses on women, could add physical principles applicable to exercise in water - Buoyancy: Men versus Women

Women possess on average significantly more total body fat than men. Because fat floats and muscle and bone sink in the water, the average woman, therefore, gains a hydrodynamic lift and floats more easily than her male counterpart.

The following changes were made to section 3.2.3.1: Buoyancy:

1. The definition of specific gravity was written differently, i.e. "The specific gravity of an object is the mass of 1 ml of that substance divided by the mass of 1 ml of water, i.e. its density relative to the density of water (20)."
2. The following was added: "The specific gravity of tissues in the body varies (6 (was 8)). Fat has a specific gravity of less than one and therefore floats, while bone has a specific gravity of more than one and sinks (6 (was 8), 4). As women have a higher percentage body fat than men, they are more buoyant (2 (was 76)). Women therefore expend less energy to stay afloat than men (4). The specific gravity of the body and therefore the ease of floating, also

changes with age (it is 0,86 in a child, 0,97 in an adolescent/ young adult and 0,86 later in life) (20)."

Page 48

Require definitions of a) buoyancy – assisted, b) buoyancy – neutral, c) buoyancy – resisted exercises to add to glossary of terms

The following definitions were added to the glossary of terms and all the terms were put into alphabetical order:

1. **Buoyancy – assisted movement:** A movement in water in the direction of the force of buoyancy, i.e. upwards to the water surface, so that buoyancy assists it (1 (was 2))
2. **Buoyancy – neutral movement:** A movement in water that occurs at 90 degrees to the force of buoyancy, i.e. parallel to the surface of the water, so that buoyancy neither assists or resists the movement, but supports the limb (1 (was 2))
3. **Buoyancy – resisted movement:** A movement in water that occurs opposite to the direction of the force of buoyancy, i.e. downwards away from the water surface, so that buoyancy resists it (1 (was 2))

The aims of the literature review were clearly stated and the value of this research was made evident. However, it was felt more definitions and greater depth of discussion was needed.

The definitions of muscular force, rotational work and buoyancy-assisted, -neutral and -resisted movements were included in the glossary. See changes to "discussion" following suggestions by Dr. Diesel.

The relevant literature in this field of research appeared to be adequately covered.

Page 62 – Method

Need to say which Cybex was used. That is, model, year, etc.

More detail on the Cybex was included in the second paragraph of Chapter 4: METHOD and in section "4.2.6 Cybex isokinetic machine and dual channel recorder":

"A Cybex II+ Isokinetic Dynamometer (serial number C105-0165, 1983 model), a electromechanical dynamometer (Figure 4.5) was used as a means of testing muscle strength in this project."

Sampling - convenience sampling (JHB hospital)
 - non-probability sampling method. That is subjects were not selected randomly

The sampling method was fine for this study as criteria other than randomness were the basis for selecting this group.

The disadvantage of this method:

- a) *the unrepresentative nature of this group with respect to the general population of females 17 – 30 years of age*
- b) *the results could be biased as entire sections of the population are likely to be omitted from the selection process, and*
- c) *sampling error cannot be quantified*

The following was added to section "4.1 Sample":

"Convenience sampling, using a non-probability sampling method, was used, i.e. the subjects were not randomly selected. Subjects belonged to a wide variety of professions within the Johannesburg Hospital, thereby constituting a fair representation of healthy, young females working at that hospital. Convenience sampling as opposed to random selection was done as subjects had to be healthy, free of knee pathology, able to get to the hydrotherapy area of the Johannesburg Hospital five times a week during the exercise period and willing to exercise for the full eight week period.

A disadvantage of this sampling method was the unrepresentative nature of this group with respect to the general population of females 17 – 30 years of age. The results could also have been biased, as entire sections of the population were likely to have been omitted from the selection process. In addition, the sampling error could also not be quantified."

The heading of 4.1.1 "Method of selection of project participants" was changed to "recruitment of subjects and assigning them to the land, water or control group"

Page 63 – Sample

There is no mention of the number of subjects taking part in the study. Also, there is no mention of inclusion or exclusion criteria used, and also what "healthy" means.

The beginning of section "4.1 Sample" was changed as follows:

"Sixty nine healthy females, without knee pathology and in the age group 17 to 30 years (mean = 24,4, standard deviation = 3,9) volunteered for the project. Forty nine of these completed the full eight weeks of training. The final sample size of 53 subjects included these 49 as well as four subjects who completed more than 4 weeks, but not the full eight weeks. There was thus an experimental mortality of 23,2 per cent. Subjects were classified healthy if they considered themselves healthy and not suffering from any disease. Absence of knee pathology meant that there was nothing wrong with the knees at the beginning of the exercise trial, that the knees were not painful and that there had been no previous knee surgery. Subjects who had been unable to discontinue their sports activity during the eight weeks of the exercise project (n = 4) were excluded from the study."

Page 65 – Instrumentation

Sandbags

How were the sandbags weighed? What was used to weigh the sandbags? How sensitive is the instrument? What weights were used? What is meant by accurately, that is, compared to what gold standard? Proper calibration is vital for this research to be valid and reliable.

The following paragraph was changed, putting in more detail on how the sandbags were made, weighed and how the scale was calibrated:

“4.2.2 Sandbags

Sandbags were manufactured by putting fine sand into plastic bags and these into canvass covers (Figure 4.2). The sandbags were weighed on a Krupps Type 844 kitchen scale while the correct amount of sand was added to make 0,5 kg, 1 kg, 2 kg, 4 kg and 5 kg weights, before the last seam of the sand bags was sewn closed. The sand bags were then marked at their respective levels using a permanent marking pen. The Krupps scale was found to register 10 g too little throughout when calibrated using standard G+G Ltd weights (Table H1, Appendix H), which constitutes a 1% error. The sandbags were thus 1% lighter than what they were marked, which constitutes a small difference only. Sandbags were used for the land exercise group and for the weekly 10 RM tests of all subjects.”

Page 67 – Instrumentation

Water weights

The opening in the center of the water weights is not obvious in the text or picture. It is very unclear how this works.

Figures 4.3a and Figure 4.3b were added to the section “4.2.3 Water weights” to make it clearer where the opening for the subjects’ leg was (see the sections in bold and look at the figures and their subscripts):

“ Eight 2 litre bottles were bound together with string, leaving an opening in the centre for the subject's leg (**Figure 4.3a and Figure 4.3b**). A loop of material was attached to the bottles to serve as an anchor for the foot (**Figure 4.3b**).“

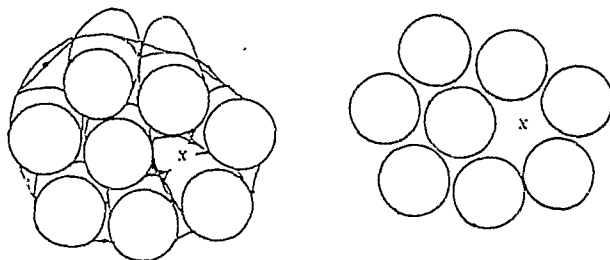


Figure 4.3a View of top end of water weights (bottle bases)
X = opening to place foot and leg through to apply water weights

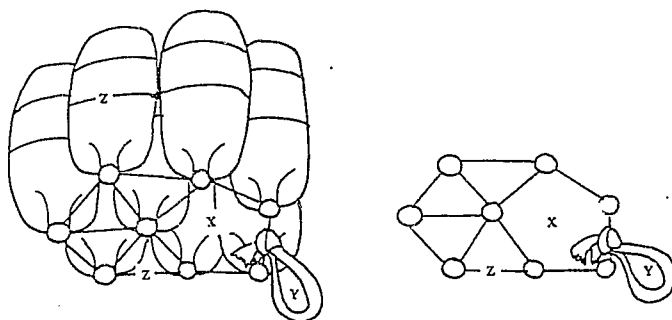


Figure 4.3b View of bottom end of water weights (bottle lids)

X = Opening for leg: Foot will stick out here once water weights are applied.

Y = Noose to put foot through to secure water weights on leg

Z = String to hold bottles together

If referring to weight, measurement is in Newton, not kilograms

a) Throughout the research report, resistance levels were changed from kilograms to Newtons, where the text referred to weight, e.g. in "4.2.3.1: Resistance offered by the water weights", 16 kg was changed to 160 N: "As the maximum weight the subjects would exercise against was not expected to be higher than 160 N (a mass of 16 kg), eight 2 litre bottles (resistance of about 160 N) were used for the purpose of this exercise trial."

b) In this way, the subscript to Figure 4.3 was changed to:

"Figure 4.3 A set of bottles used as water weights: equivalent to 30 N (3 kg)

(1 = water,

2 = A 2 litre bottle with 300 ml water inside (to compensate for viscous drag force), resistance of 20 N (2 kg),

3 = bottle half-filled, resistance of 10 N (1 kg))"

c) Both kilograms and Newtons were used where this seemed appropriate, e.g. in section 6.2.2 (Reliability of 10 RM testing):

"Moreover a standardised test protocol was followed, in which the 10 RM test was always started at 5 N more weight (a mass of 0,5 kg) than the maximum the person had exercised with during that week, and not at any arbitrary higher level."

No mention about the methodology of how the "viscous drag force" of 300 g was calculated.

The whole explanation of the magnitude of the viscous drag force for this research was deleted, i.e. "... the set of eight bottles was dragged through water at a constant slow velocity with the bottle tops facing the direction of movement, i.e. when the set was most streamlined. A force of 300 g was found when the bottles were dragged with their bases first. The value of 300 g was taken as the viscous drag force most likely to represent that which would occur in the water exercises, as the orientation of the bottles would change throughout the range of movement"

and was changed to

"To calculate the viscous drag force on the water weights, empirical measurements were done on these in the pool. The bottle sets were hooked to a Capacity Spring Balance and then dragged through the water with the long axis of the bottles at a 90 degree angle to the direction of the movement (Figure 4.3c). (During knee extension at 60°/s, the bottles would also move with their long axes at 90 degrees to the direction of movement.) They were dragged at velocities of 0,09 m/s, 0,252 m/s and 0,415 m/s respectively (Figure 4.3c). These velocities represent the velocities at which the top, the middle and the bottom of the water weights would move during knee extension at 60°/s (For calculations, see Appendix J). Readings on the spring balance were taken at each of these velocities (Appendix J). The velocities were obtained by dragging the bottles through a distance of 6 m in 14,5 s (to get a velocity of 0,414 m/s), in 23,8 s (to get 0,252 m/s) and in 66,7 s (to get 0,09 m/s) respectively. The time was determined with an Electronic Timer Clock (design registered number 1049496)(Appendix J). The resultant resistance at the middle of the sets of water bottles was found to be 3 N (300 g) (Appendix J) and was taken as the magnitude of the viscous drag force resisting knee extension in water for the purpose of this research.

The Capacity Spring Balances (able to measure up to 1 kg and marked in 10 g intervals) were calibrated using standard 500 g and 1 kg G+G weights (Table H3, Appendix H). These weights were placed in a plastic bag, which was hung on the spring balances. A small 2% error was found.

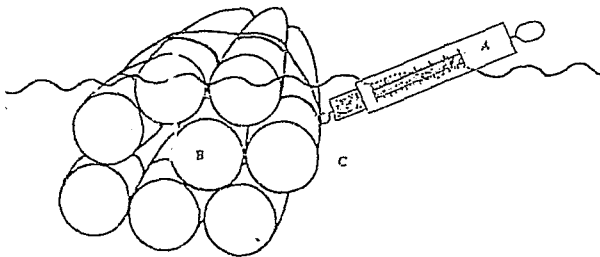


Figure 4.3c Dragging a set of bottles through water with a spring balance to establish viscous drag force (A = spring balance, B = water weights, C = water)"

Page 69

Can add definitions of: a) resistance force, b) inertia, c) internal force to the glossary of terms

The following definitions were added to the glossary of terms:

Resisting force

A force resisting movement (6 (was 8))

Inertia and inertial forces

Inertia is the absence of movement. Inertial forces are forces which occur due to changes in the direction of a moving body. They are exerted to change an object's velocity. Inertial force is equal to the mass of the object times its acceleration (2 (was 76)).

Internal force

A force generated by a muscle (6 (was 8))

2nd paragraph

Where does this assumption come from? Surely varying the depth of submersion varies the hydrostatic pressure.

The explanation of the effects of hydrostatic pressure on the water weights (section 4.2.3.1) was changed from:

"The volume of water displaced when a plastic bottle filled with 2 050 ml of air was forcefully submerged was taken as 2 litres (the missing 50 ml would equal the amount of compression that would occur due to hydrostatic pressure)."

to:

"The compression due to hydrostatic pressure of an empty bottle when displaced under water was determined empirically. A 2050 ml plastic bottle, such as those used for the water weights, was filled with 400 ml of water. A rubber stop, which was large enough to seal off the opening of the plastic bottle, was selected and a hole drilled through it. The hole was big enough to allow a long glass tube with an internal diameter of 5 mm to just pass through. A long glass tube was passed through the rubber stop in such a way that the tube ended just above the bottom of the bottle, but not touching it and inside the 400 ml of water once the rubber stop was secured in the opening of the bottle (Figure 4.3d). To extend the length of the tube (so that the end would be higher than the water level once the bottle was submerged), a piece of plastic tubing (8 mm diameter) was attached to the end of the glass tube outside the bottle (Figure 4.3d). The level of the water in the glass tube was marked before the bottle was submerged (V1). The bottle and tube were then submerged until the base of the bottle was at 64,2 cm below the water level, which is comparable to the depth of displacement during the water exercise. Hydrostatic pressure now pushed some of the water out of the bottle into the thin tube. The top of the tube was then closed with a finger while the bottle was taken up to the water surface, out of the water and onto the side of the pool. With the finger still in place, the stopper-tube combination was carefully removed and the contents of the tube emptied into a glass measuring cylinder (100/1 ml at 20° C, LMS Germany). The volume of water already in the tube (V1) was subtracted from this volume (V2), the resultant volume (V3) being an indication of volume change on air-filled submerged bottles making up the water weights (Figure 4.3d). The bottle was refilled with 400 ml of water and the whole procedure was repeated 10 times, showing a mean volume loss of 9,65 ml when one bottle is submerged (Appendix I).

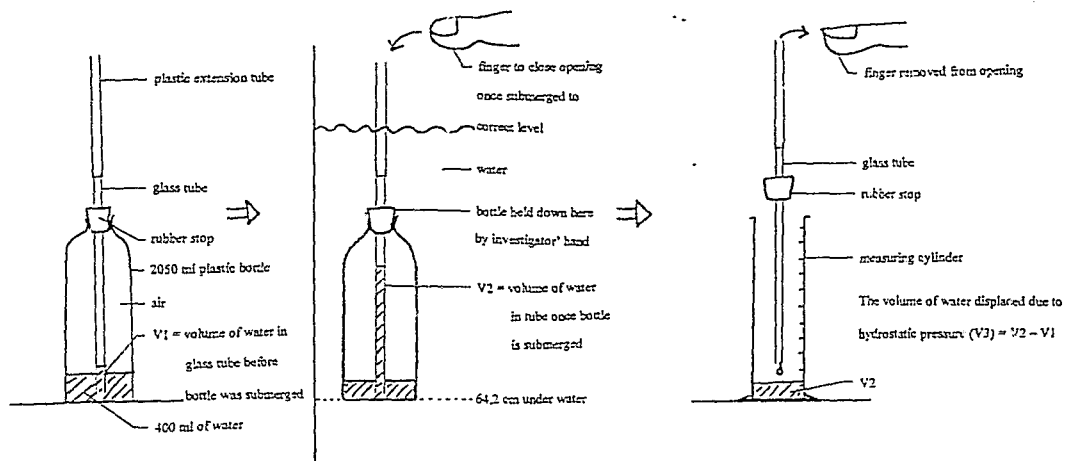


Figure 4.3d Establishing volume loss of an air-filled plastic bottle when submerged under water."

3rd paragraph

How was the speed of 60°/s maintained or even controlled?

Section "4.2.5 Metronome" was done in more detail and changed to the following:

"In order to make sure that all exercises would occur at an angular velocity of 60°/s, a Wittner wooden metronome with a pendulum (range of 40 – 208 beats per minute) was set on 40 beats per minute and a 90 minute tape recording was made of this. Subjects would extend the knee on one beat, flex on the next, extend again on the next beat, etc. To work out how many beats per minute to set the metronome at, in order to get an angular velocity of 60°/s, the following calculation was made: The knee travelled through 90 degrees in one beat. To achieve 60°/s the knee needed to move through 60 degrees in one second. In one second, 60/90 th of a beat would occur. In sixty seconds, $60/90 \times 60$ beats = 40 beats would occur. The metronome was therefore set at 40 beats per minute.

All exercises and 10 RM tests were done to the beat of the metronome on this tape recording. A Blaupunkt model SZ60 portable stereo two band radio cassette recorder was used to play the tape with the metronome recording throughout the trial. The subjects just had to switch on the tape when they exercised. When the metronome was calibrated against the second hand of a wrist watch, a 5% error was found, the metronome being slightly slower (Table H6, Appendix H)."

Inertial forces can occur in any direction and is equal to the mass (kg) multiplied by the acceleration (velocity/ time) of the limb. The inertial forces, thus, can be found. The mass of an object is a direct measure of the inertia of the object.

In section "4.2.3.1: Resistance offered by the water weights" the part explaining the inertial forces due to changes in direction was changed to the following:

"The inertial forces encountered due to changes in the direction of movement (2 (was 76)) ($F = ma$, F : force, m : mass, a : acceleration) did not produce a substantial amount of resistance to knee extension, as the direction changes were not abrupt and the training speed of 60°/s was relatively slow. These forces would only have had an effect for a fraction of each knee extension movement, as acceleration only occurred for a fraction of a second. Ninety degrees of knee extension took only 1,5 s at a speed of 60°/s. These inertial forces from direction changes would therefore only have occurred for a short duration at the beginning of each knee extension movement. The heavier the resistance apparatus, the larger these inertial forces would have been. For this reason, the inertial forces would have been greatest as the water exercise subjects commenced the programme, as most of their bottles would have been filled with water at this stage, which made the resistance apparatus heavier. Techniques such as underwater time frame photography or high speed photography (stroboscopic photographs) (6 (was 8)) would have been needed to accurately calculate acceleration. If one assumes that acceleration occurred during the first 0,1 s of knee extension and that the weights had to accelerate from 0 m/s to 0,252 m/s (the velocity that the middle of the water weights travelled at, Appendix J) in this time, then $\text{acceleration} = \text{velocity} / \text{time} = 0,252 / 0,1 = 2,52 \text{ m/s}^2$.

If a set of water weights with 1 empty and 7 water-filled bottles is accelerated (20 N resistance), then

$$F = ma = 14 \text{ kg} \times 2,52 \text{ m/s}^2 = 35,28 \text{ N}$$

Page 70

Where did this arbitrary volume come from to take viscous drag into account, and how does it operate?

See the explanation in response to the comments on p 67 above. Also, in "4.2.3.1: Resistance offered by the water weights" the section explaining that viscous drag force was taken account of by putting 300 ml of water into the first air-filled 2 l bottle of each set of water weights and the marking of the bottles was changed to:

"The viscous drag force was taken into account by leaving 300 ml of water in the first empty 2 litre bottle of each set of water weights. Despite the 300 ml of water in it, this bottle then represented a resistance of 20 N (or 2 kg). To mark the bottles, the researcher used a 1 000 ml glass measuring cylinder (1 000/1 ml at 20° C, LMS Germany) to pour the correct volumes of water into the first bottle (300 ml, 500 ml, 1 000 ml and 1 500 ml) and mark this bottle accordingly. All other bottles in the water weights were then marked using tape measure readings of the distances between the marks on the first bottle."

Where does the resistance of 20 N come from? How was buoyancy calculated?

The fact that 20 N is the resistance due to buoyancy of one 2 litre bottle displaced under water (upthrust = weight of water displaced, 2 litres of water weigh 20 N) and the way buoyancy was calculated should now be apparent from the first part of "4.2.3.1 Resistance offered by the water weights":

"As the maximum weight the subjects would exercise against was not expected to be higher than 160 N (a mass of 16 kg), eight 2 litre bottles (resistance of about 160 N) were used for the purpose of this exercise trial. The figure of 160 N was obtained as follows: The upthrust of buoyancy is equal to the weight of the water displaced by the object that is displaced under water. If eight empty 2 litre bottles (16 l) are displaced under water, the upthrust they experience

is equal to the weight of the water they displaced, which is 160 N (8×20 N), as 2 litres of water weigh 20 N.

The biggest resistance to the submersion of the water weights was due to the effect of buoyancy, as mentioned above. The upthrust on the eight submerged bottles stayed constant throughout the exercise trial, but the amount of water in the bottles, i.e. the downward force due to the weight of the water inside the bottles, became less as water was let out of the bottles. The force resisting submersion of the weights (upthrust minus weight of the water in the bottles) was, therefore, in effect, equal to the weight of the water displaced by the empty bottles. A set of eight bottles containing 3 litres of air would experience an upwards force of 30 N (upthrust - weight of water inside bottles = $160 \text{ N} - 130 \text{ N} = 30 \text{ N}$).

Page 71

How was the hydrostatic pressure measured? It must be clear to the reader.

See explanation on changes to section 4.2.3.1 in response to comments on p 69 above.

3rd paragraph – arbitrary assumption

This is an assumption, but probably realistic. See also the changes to the summary of the resistance of the water weights:

“c) inertial forces due to changes in direction of movement

(only acted for a fraction of each knee extension, while there was acceleration)

= Could have varied from 35,28 N (if acceleration was $2,52 \text{ m/s}^2$ and 7 bottles were filled with water) to 7,56 N (acceleration of $2,52 \text{ m/s}^2$ and 1,5 bottles filled with water)”

Also see above, how the author attempted to gain an understanding of the magnitude of these forces. A detailed assessment of the inertial forces due to direction changes was not done as the use of underwater high speed photography was not seen as within the scope of this research report, as these forces are small compared to the resistance offered by buoyancy. Detailed assessment of acceleration under water would, however, have made the calculation of resistance to the water weights more accurate. This is acknowledged in the corrections to section 4.2.3.1. (see the response to the examiner's next suggestion).

5th paragraph – a preliminary study should have been set up to accurately assess the resistance at the water weights. Simple physic and mathematical models could give you the answer to this problem.

The fact that a preliminary study should have been set up to accurately assess the resistance at the water weights was acknowledged. Section 4.2.3.1 “resistance offered by the water weights” was changed considerably to provide more information and clarity (see above). The summary of the resistance of water weights was changed to the following:

“A summary of the maximal resistance offered by one set of water weights moved at $60^\circ/\text{s}$ follows.

A preliminary study should have been set up to accurately assess the resistance of the water weights and the lack of this is a shortcoming of this research project.

Even though the water weights were 2% heavier and the sandbags 1% lighter (section 4.2.2) than planned, a 3% difference (30 g in each 1 000 g) was still small enough for the water and land weights to be comparable. A 10 N resistance from the sand bags was thus taken to be the same as a 10 N resistance from the water weights."

Other factors to consider when calculating resistance to exercise to water were also added to section "4.2.3.1: Resistance offered by water weights":

"Person- specific resistance to knee extension in water

In addition to the resistance to knee extension due to the water weights, some person- specific factors also resisted knee extension in the water group: These were the viscous drag force on the lower leg moving in the water, the lower leg weight and lower leg buoyancy and varied from person to person, as these depend on lower leg shape, volume and weight.

In an attempt to quantify the viscous drag force on the lower leg (resisting knee extension), an artificial leg with similar shape to that of a lower leg was dragged through the pool, following the same procedure as that of determining the viscous drag force on the water weights (Appendix J). At the velocity that the centre of the projecting surface of the water weights would travel, the viscous drag force on the artificial leg was 0,75 N (Appendix J). The determination of the viscous drag force on each subject's lower leg was beyond the scope of this research, but would warrant further investigation.

Lower leg weight assisted knee extension in the water exercise while lower leg buoyancy resisted knee extension. It was a shortcoming of this research that these two variables of each subject were not measured. In order to gain an understanding of the forces likely to have been involved, the lower leg volumes and lower leg weights of 12 healthy women (age range 21 – 42) were determined subsequent to the exercise trial. The methods used and values obtained are found in Appendix L. The calibration of the Addis measuring jug and the EKS scale are found in Table H4 and Table H5, Appendix H respectively. The weights of the lower legs were higher than the upthrust of buoyancy, leaving the water group with an additional force assisting knee extension. In contrast, the land group had to perform knee extension against the weight of the lower leg as well. In order to equalise the starting resistance level of the water and the land groups, the water exercise group should have been given additional empty bottles in their water weights. This additional volume of air should have equalled each individual's lower leg weight plus the difference between this weight and the weight of the water displaced by the empty bottles (calculated from leg volume). Slightly larger water weights (consisting of 9 or 10 bottles each) would have been needed.

In this project the exercise groups did not start off with the same amount of resistance. The exercise progression (i.e. resistance provided by sandbags or water weights), however, was the same in both groups. For land exercise it is not customary to mention the lower leg weight in addition to the weight of the sandbag to be lifted. When comparing water and land progressive resistance exercise, lower leg weight (for water and land groups) and the effect of buoyancy on the leg should, however, be included in determining similar resistance levels. Knowledge of the lower leg weight and volume of each subject would have helped the researcher equalise the level

of the resistance for the land and water groups at the beginning of the exercise trial. It was a shortcoming of this research that these two variables of each subject were not measured."

After consultation with the Department of Physics, the author was told that the resistance to the water weights could not be derived by using simple physics and mathematical models, as the water weights had a complex shape. The Department of Physics advised the author to determine the viscous drag force and volume loss due to hydrostatic pressure empirically.

Page 73

Figure 4.4 – numbers 1-6 not labelled

The following labels were added to Figure 4.4 and label no. 4 on figure B was changed to no. 3:

(1 = water, 2 = side wall of pool, 3 = plastic bottle to fill up trough, 4 = water weight, 5 = plastic bottles used as "spacing" between thigh and side wall of pool, 6 = weight tied to bottles)

– more information is required on how the patient was instructed to move the metronome

See explanation in response to comments on p 69 above.

Page 76

Although the time of day was mentioned as important and should be standardised in the literature review, it was not kept constant in this research.

The following was added to "4.3.1: Procedure of Cybex test":

"Testing was not always done at same time of day, as is recommended by some (68, 57), as a more recent literature review of 224 articles on factors that affect isokinetic testing (56) does not mention the time of day. Many of the tests were performed at the same time of day, however, as many subjects who did not work shifts preferred to attend their exercise and test sessions during their lunch times."

Was the warm-up and stretch arbitrarily chosen?

The following was added to "4.3.1: Procedure of Cybex test":

A warm-up is done to prevent injury from the test or exercise procedure (56). Although there is probably not such a thing as an optimal warm up procedure, a warm up, if done in a standard way before a test procedure, helps to ensure that test data is accurate (56). The warm-up and stretch chosen for this research aimed to increase the circulation in the muscles that would be used for exercising or testing. Stretching of hamstrings and quadriceps was done to maintain flexibility. The same warm-up procedure was used throughout, to standardise exercise and testing procedures.

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Page 78

No mention of how the axis of the knee joint was measured. For example the top of the patella in extension.

The following was added to "4.3.1: Procedure of Cybex test":

"The axis of the knee was taken as the centre of the lateral joint line with the knee in 90° flexion. The lateral joint line was found by palpation."

and

"The dynamometer position was noted and all subsequent tests for that subject were done with the dynamometer in that position."

Page 87

The picture displayed is different from that on page 83. Also, it was noted that the non-dominant leg was flexed. This is different from the testing of the 10RM. This was not mentioned.

The following was added to "4.3.3: Exercise regimen" to describe the position of the subjects in the land group when exercising:

"The position of their arms was not specified. In contrast to the 10 RM test, where the nondominant knee was extended (Figure 4.12), the nondominant knee was relaxed in a flexed position with the lower leg hanging over the edge of the plinth during the land exercises (Figure 4.15)."

Page 91

It is not clear whether the weights used in the water were equal to that on land. 5 kg should have been 4 kg and the amount of repetitions should have been 20 and not 10.

The resistance offered by land and water weights was equal; see the changes made to section "4.2.3.1: resistance offered by the water weights" described above and especially the following paragraph: "Even though the water weights were 2% heavier and the sandbags 1% lighter (section 4.2.2) than planned, a 3% difference (30 g in each 1 000 g) was still small enough for the water and land weights to be comparable. A 10 N resistance from the sand bags was thus taken to be the same as a 10 N resistance from the water weights."

The 5 kg was changed to 40 N. The corrected sentence reads: "So, for example, the person with the lowest weight of 20 N, the middle weight of 30 N and the highest weight of 40 N would have had to take out 1 litre of water to change the resistance from 20 N to 30 N."

Two sets of 10 repetitions, as mentioned in the text of the research report, is correct.

In summary, the method was not described in enough detail to allow replication of this study. Only the Cybex was calibrated, and the reliability of each machine was not measured. The quality of this section needs to be improved.

1. The method is now described in more detail, which should allow replication of this study.

2. Calibration of the apparatus used is now included:

a. The calibration of the Krupps type 844 kitchen scale can be found in the corrections to section "4.2.2: Sandbags" and in Table H1, Appendix H.

b. The calibration of the Seca Paediatric scale (model QD35 ed 177, no. 776624) can be found in the following paragraph in section "4.2.3.1: Resistance offered by the water weights" and in Table H2, Appendix H:

"The mass of the empty bottles plays a role in determining the resistance and was therefore measured on a Seca Paediatric scale, model QD35Ed177, no. 776624. The mass of one set of eight bottles and string was 655 g. The scale was calibrated (Table H2, Appendix H) and found to have a 0,5 % error at the masses of 3 and 4 kg, but to be 100 % accurate in the 0,5 kg – 1 kg range, in which the mass of the bottles fell."

c. The calibration of the Capacity spring balance can be found in the corrections to section "4.2.3.1: Resistance offered by water weights" where viscous drag force is described and in Table H3, Appendix H.

d. The calibration of the Addis 1,5 l measuring jug can be found in the corrections to section "4.2.3.1: Resistance offered by water weights" relating to determination of lower leg weight and volume and in Table H4, Appendix H.

e. The calibration of the EKS Doctor's Scale can be found in the corrections to section "4.2.3.1: Resistance offered by water weights" relating to determination of lower leg weight and volume and in Table H5, Appendix H.

f. The calibration of the Wittner wooden metronome with pendulum can be found in the corrections to section "4.2.5: Metronome" and in Table H6, Appendix H.

3. The apparatus showed no or small errors, which made the use of the equipment reliable.

The following was added to "4.2.6: Cybex isokinetic machine and dual channel recorder":

In an attempt to establish the test-retest reliability of the Cybex II+ Isokinetic Dynamometer (serial number C105-0165, 1983 model) at the Johannesburg Hospital, two identical isokinetic tests, involving six reciprocal repetitions of knee extension and flexion at 60°/s were done on 4 subjects (the control group) 8 – 9 days apart during trial 1 (Appendix A)(Appendix D). The knee extension peak torque of the dominant leg improved significantly in the second test, while that of the nondominant leg stayed the same. These unusual results are probably due to a small sample size. This test-retest reliability should have been established using more subjects. It has also been found that subjects may perform better the second time they undergo an isokinetic test, as they would be more familiar with the test the second time round (46 (was 46), 47 (was 65)). If

familiarisation had happened here, both the dominant and nondominant legs should have performed better the second time round. However, in order to rule out the possible effect of familiarisation, two initial Cybex test could have been done, and the value of the second test taken, in order to give subjects an optimal chance to familiarise themselves to the testing procedure. The fact that this was not done is a minor shortcoming of this research."

The following was added to section "4.3: Procedure":

"Test-retest reliability of the 10 RM test was not established before the start of this project, which is a shortcoming of this research. 1 RM testing has, however, been documented to be reliable (48 (was 29), 49 (was 30), 50 (was 35), 51 (was 42), 52 (was 45)), while multiple RM testing has also been used (53 (was 44)). Determination of the 1 RM could lead to injury if done in an unsupervised way by people not used to weight lifting (55 (was 9), 4, 54). DiNubile (55 (was 9)) recommended that a number of repetitions, such as the 10 RM, be used as this was much safer (55 (was 9)). The 10 RM test was used in the present research project, as it was considered safer than the 1 RM test."

Page 93 – Data analysis

How were the tracings for peak torque, work, power and endurance ratios calculated without the dual channel recorder? Was it working but with no values observed?

The beginning of section "4.4: Data analysis" was changed as follows:

"Following the completion of the clinical trial, the data obtained from the Cybex tests was analysed. Due to the fact that the computer part of the Cybex Dual Channel Recorder had broken down half way through the trial (even though the repairs were completed in three weeks) a number of Cybex tests were done without the computer's numerical print-outs. The part of the dual channel recorder drawing the torque curves was functional throughout the test sessions. Graph tracings were therefore obtained for all the tests. Peak torque, work, power and endurance ratios could therefore still be determined by calculating them from the torque curve tracings on the graph paper and all the Cybex graph tracings were therefore analysed manually."

The following changes were also made to this section:

"From the tracings of the Dual Channel Recorder, the peak torque, work, power and endurance ratios for both knee flexion and extension were calculated.

The manual calculations were done as follows: The flexion and extension curves were marked and analysed separately. A grid (grid D on the CYBEX II+ Chart Data Card, see Figure 4.22) was used to read off peak torque (the mean of the first five peak torques). The number of 1, 5 x 1 mm blocks under 20 curves or under the curves completed in 56 s or 17 s (for traces at 60°/s and 270°/s respectively) was counted to provide an indication of rotational work done. The work done was divided by the time taken to complete the work to get an indication of power. The endurance ratio was determined by dividing the number of blocks under the last 5 curves by the number of blocks under the first 5 curves, i.e. the work done over the last 5 contractions divided by the work done under the first 5 contractions.

The manual calculations were time-consuming, as this included the counting of the 1,5 mm x 1

mm blocks under the graphs (rotational work done) of about 132 m of graph tracings."

Figure 4.22 was added to the text and included in the list of figures.

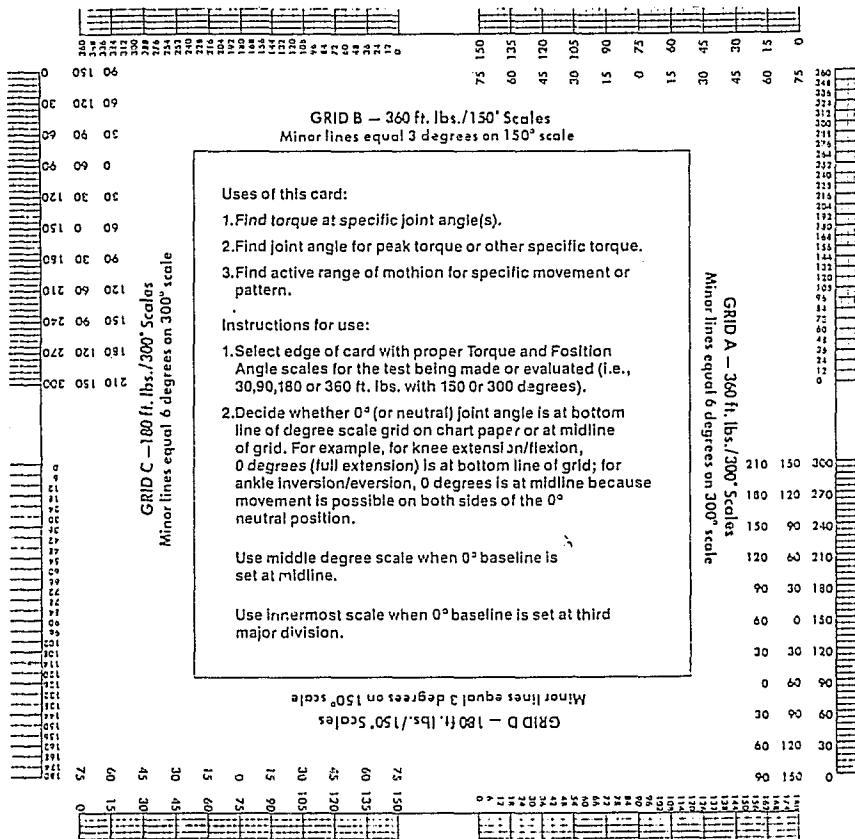


Figure 4.22 CYBEX II+ Chart Data Card (Grid D on a similar card calibrated in Nm instead of ft. lbs. was used to read off peak torque from the torque curves, 1 ft. lb. = 1,35 Nm (8 (was 58)))

Page 96

What is SAS?

The following was added to section "4.4.1: Statistical analysis":

"The SAS^a (Statistical Applications Systems), version 6.07, statistical computer software programme was used for statistical analysis.)

(^aSAS Institute, Inc., SAS Campus Drive, Cary, USA)

RESULTS

Figures should have included totals for clarity

mm blocks under the graphs (rotational work done) of about 132 m of graph tracings.”

Figure 4.22 was added to the text and included in the list of figures.

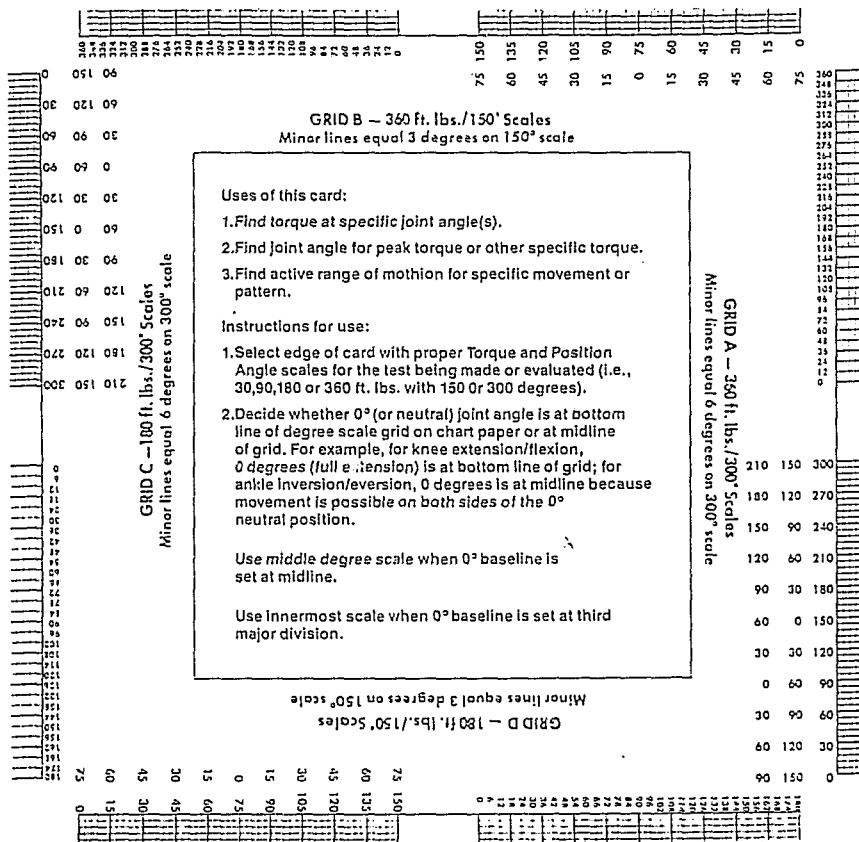


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Totals and explanations (where necessary) were included in tables 5.1, 5.3, 5.4, 5.5, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13, 5.14, 5.22, 5.25, 5.26, 5.27, 5.28, 5.29, 5.30, 5.31, 5.32, 5.33, 5.33 and HH1.

Page 101

Seem to be missing 1 subject (total = 53)

The following sentence was added to the paragraph on right leg dominance in section "5.3:

Baseline values: Findings at week 0":

"One person did not answer this question in the questionnaire."

Page 102

Text is very unclear. The numbers do not correlate with the table, and you have not mentioned whether the sports participation is current or past.

The numbers were not meant to correlate with the table, as these results were not given in table format. This part of the text in section "5.3: Baseline values: Findings at week 0" was changed as follows:

"The participation in sport or other regular physical activity at the beginning of the trial was relatively low, with no significant difference ($p > 0,05$) between the three groups. Only 13 out of 53 subjects (24,5 per cent) participated in sport and eight out of 50 subjects (16 per cent) participated in other regular physical activity. Three subjects did not answer the question on current participation in other regular physical activity (see Appendix D, Pre-Trial questionnaire, question 7)(Appendix A)."

Detail such as the type of sport/ activity participated in, time spent on sport and the number of sports per person was left out as not relevant in light of the low sport participation, large variety of sports and lack of significant differences in sport participation between the groups.

Page 105

Annova reliability test was good.

Page 120 – Table 5.19

Where did the number of subjects, or should it read observations come from? Water group = $8 \times 18 = 144$ readings? Land group = $8 \times 15 = 120$ readings?

Table 5.19 was changed to Table HH1. The legend of the table now explains that the total of 149 reports in the water group was less than the expected 152 (8 questionnaires x 19 subjects) because one subject did not complete the full 8 weeks of exercise. The total of 135 in the land group was also less than the expected 144 (8 questionnaires x 18 subjects) because 3 subjects did not complete the full 8 weeks of exercise.

*Page 121 – Table 5.20**Why was the first week omitted?*

Week 1 was initially not included in the table as there was no significant difference in muscle soreness this week. For completeness, it is now included in the table again. The heading of the table was changed to: "Differences in severity of muscle soreness between water and land groups, all significant ($p < 0,05$) except week 1."

Page 123 – Table 5.22

Should read number of observations of pain/ no pain over 8 weeks. However, the areas where pain was felt during exercise is not a significant part of this study's aims and should certainly be noted, and perhaps commented on in the discussion, but, I feel omitted in the results. Could have a table in the Appendix.

In Table 5.22 the "number of participants who had pain" and "number of participants who did not have pain" was changed to "NUMBER OF REPORTS OF PAIN" and "NUMBER OF REPORTS OF NO PAIN" respectively.

The text referring to this table in section "5.7.4.3: Pain on exercising" was changed as follows: "When the number of reports of pain on exercising (found on the weekly questionnaires) was taken as a total over eight weeks, a significant difference between the land and water groups was found (see Table 5.22). Significantly more reports of pain had occurred in the land than in the water group."

Table 5.23 describing the areas where pain was felt during exercise was moved to the appendix (Table M6, Appendix M).

The text referring to this table in section "5.7.4.3: Pain on exercising" was changed as follows: "Due to low numbers no statistical analysis was possible to compare the areas where pain was felt during exercise between the three groups. Table M6 (Appendix M) summarises the comparison between the areas where pain was felt."

*Page 128 – Table 5.29**Total number of subjects exceeds total for this group.*

The total number of subjects exceeds the total for this group, as subjects could give any number of advantages of water exercise. This was added as a footnote to the table.

Page 131 – Table 5.33

Total number of subjects complaining about skin irritation was 6. Number of complaints = 9, therefore, some subjects complained of 2 reactions?

Some subjects complained of more than one reactions as subjects could give any number of reactions. This was added as a footnote to the table.

Page 138

Could include the meaningfulness of correlation values, that is, the coefficient of determination (r^2)

Tables 5.39, 5.40 and 5.41 were taken out (not relevant to the study). In tables 5.42, 5.43 and 5.44 (now in Appendix M and called tables M7, M8 and M9 respectively) the r^2 -value (coefficient of determination) was added. The p-value was left out on advice of the statistician, as correlations need to be analysed using the r or r^2 values and not the p-value.

Page 140 – 5.9.2.1 and Page 141 – 5.9.2.3

Weak correlation, but is certainly not meaningful.

In section 5.9.2.1: "Correlations at week 0", using the r^2 value (0,15) it became apparent that there was no correlation between the 10 RM tests and the extension work in 20 s of the dominant leg at 60°/s (A r^2 value of 0,5 or above indicates that there is a correlation. A r^2 value of 0,5 means that in 50% of the cases you can predict what the other variable will be).

Similarly, in section 5.9.2.3: "Correlations at end of study", using the r^2 value (0,15) it became apparent that there was no correlation between the 10 RM tests and the extension work in 20 s of the dominant leg at 60°/s.

This whole section "5.9.2: Correlation between 10 RM and isokinetic test values" was thus shortened, the tables were moved to Appendix M and the text condensed to:

"No correlation was found between the 10 RM values and the isokinetic test values at 60°/s for peak extension torque and extension work of the dominant leg at weeks 0, 4 or 8 (see Tables M7, M8 and M9, Appendix M)."

Section "5.9: Correlations" was also shortened as follows:

Section "5.9.1: Correlation between extension peak torque and extension work" (including tables 5.39, 5.40 and 5.41) was taken out, as it was not relevant to the aims of this study.

Page 143 – 5.10.1, Page 143 - 5.10.2

Is this amount of detail necessary to the significance of this study?

Sections 5.10 and 5.11: "Comparing subjects with prior leg injury to those without injury and comparing subjects with prior sports participation to those without" were taken out.

Page 143 – 5.10.2

The chi-squared test statistic is used to test the hypotheses that the outcomes of a random variable follow specific pattern. The data in this study were not truly randomly chosen. It is also advisable that when table totals are less than 20 to use Yate's correction for the chi-squared statistic.

Following discussions with a statistician, the researcher was advised that Yate's correction should not be used. She was advised to use a 2-Tail Fisher's Exact Test on all 2 x 2 tables. This was done and the new p – values also inserted (see "Table 5.8 Reported "feeling at ease" in

water: significant difference between water and land groups", "Table 5.19 Comparison of the number of subjects who had experienced thigh muscle soreness over eight weeks in the land and water groups", "Table 5.22 Comparison of pain while exercising over eight weeks", "Table 5.25 The perceived degree of benefit of the exercises"). The Chi-squared test is the best test to use for 3 x 2 tables and was therefore retained for these tables.

In summary, the results section could have been simplified and less laborious. Confidence levels and table totals could have been included throughout to make for easier reading.

A confidence level of $p = 0,05$ was used throughout the study and this was stated in section "4.4.1: Statistical analysis": "A confidence level of $p = 0,05$ was selected and used throughout the study."

Confidence levels were inserted in the text of the method and results chapters.

Table totals were included.

Only the results and not the methodology are required in this section.

Sections taken out of "results" into "discussion"

In section "5.9.2: Correlation between 10 RM and isokinetic test values" the following sentence was removed, as this belongs to "discussion":

"The two tests used for determining quadriceps strength, isokinetic peak extension torque at 60°/s and the 10 RM test, do not correlate well and therefore, most likely, do not measure the same thing."

Sections taken out of "results" into "method"

All the data pertaining to information obtained from the initial questionnaire was taken out of "results" and put into "method", i.e.

5.2: Subject compliance and selection for analysis

5.3: Baseline values: Findings at week 0 (except for "5.3.1: Isokinetic test values at week 0" and "5.3.2: 10 RM test values at week 0")

5.6: One way ANOVA for testers

5.7.1: Results obtained when comparing the information from the pre-trial questionnaires.

5.5: Pool and ambient temperature

The method chapter was then re-arranged to present the information in a logical order. To prevent repetition, the pre-trial characteristics of all subjects together and the comparisons between the groups of these characteristics were placed together and some tables left out (tables 5.3, 5.4 and 5.5). The sections on the type, date and side of injuries were left out, as well as the type of sports, number of sports per person and time on sport, including the corresponding tables.

The following paragraph in "5.7.6: Comparing the final questionnaire of the land and water groups" was changed by excluding references to the methodology:

"The advantages and disadvantages of having been in the water exercise group are found in Tables 5.29 and 5.30. Similarly, the advantages and disadvantages of having been in the land exercise group are listed in Tables 5.31 and 5.32."

References to the final questionnaire were left out in the sentence referring to Table 5.9, so that it reads as follows:

"The reasons for having indicated that their thigh muscles had strengthened are found in Table 5.9."

DISCUSSION

No discussion about why people with leg injuries perform better.

Section "6.1.1: Comparing those with previous leg injuries to those without" was taken out.

Page 155 – 6.1.3

The females could also have been matched regarding the body size and composition as these factors might also contribute to muscle strength.

Section "6.1.3: Differences between the three groups at the start of the trial" was taken out.

Page 162 – 1st paragraph, last sentence

This is not necessarily so, because, as you said before, mild weakening might have occurred due to not participating in sport, over and above the mild strengthening due to the programme. That is to say more complex physiological mechanisms might be at play.

Section "6.1.2: Comparing those who took part in sport to those who did not" was taken out of the results and the discussion chapters. This paragraph was also taken out.

Page 174 – 3rd paragraph

The validity of the test was poor. For a test to be valid, a critical analysis must be made as to the nature of the activity it is to measure.

The following was added to the paragraph referred to in "6.3.1.2: Significant differences", referring to isokinetic testing:

"The validity of isokinetic testing for this isotonic strengthening programme was poor. For a test to be valid, a critical analysis must be made of the activity it is to measure. Isotonic strengthening was to be measured and therefore isotonic strength testing (10 RM), was more appropriate than isokinetic testing."

Page 175 – 6.3.2

A reliability study should have been performed.

A small test-retest reliability study was performed as part of trial 1 (see addition to "4.2.6: Cybex isokinetic machine and dual channel recorder").

The text of "6.3.2: Reliability of isokinetic testing" was changed as follows:

"In order to enhance the reliability of isokinetic testing in this project, the researcher ensured that a strict testing protocol was followed. The researcher and one other tester performed all the Cybex tests. The second tester was included to improve the objectivity of the testing. Although inter-tester reliability between these two testers was not established, the adherence to the testing protocol served to standardise the testing. The other tester, also a physiotherapist, had been well instructed in the testing procedure and was competent in doing the Cybex tests. She did not know which exercise group the subjects were in and followed the protocol for isokinetic testing strictly.

The reliability of the isokinetic testing in this research would have been enhanced even more if two initial Cybex tests had been done for each subject. The data from the second test would then have been used, following the results of the test-retest reliability during trial 1, where the second Cybex test showed a higher knee extension peak torque value (see section 4.2.6), as well as those of other studies (46 (was 46), 47 (was 65)). For subsequent tests this would not have been necessary, as subjects had been familiar with the test by then."

Page 178 – 1st paragraph

Good, specificity is important

Page 183 – 1st paragraph

There is definitely compressive force in the direction of the femur, as the effort force exerted by the patella tendon has both horizontal and vertical components attached to it. Shear forces during knee flexion and extension also occur.

The second paragraph of section "6.5.1 Land exercise group: knee extension against an ankle weight" was changed as follows:

"At the starting position, with the knee flexed to 90 degrees, there is virtually no resistance to quadriceps (9 (was 11)). As the knee is extended, the resistance is increased until maximum resistance is reached at full knee extension (9 (was 11)) (see Figure 6.1). In full knee extension the ankle weight does not exert a compressive force in the direction of the shaft of the femur (9 (was 11)). The compressive and shear forces that do occur are due to the force exerted by the patellar tendon in the direction of the shaft of the femur."

Page 203 – no 6

Well recognised. Perhaps could have been more researched in this project.

Research into the resistance provided by water for a number of different water exercises at different speeds was not seen to be within the scope of this research project.

Suggestion number 6 was changed as follows:

- "6. Research on the resistance provided by water for specific exercises at specific speeds, in order to establish normative data for use in rehabilitation. Strain gauges or pressure sensors would have to be attached to resistance devices or the body part to be moved. The gauges/ pressure sensors would have to be connected to a chart recorder/ computer

for continuous recording of the values obtained. The research by Hillman, et al. (37) could serve as a guideline. Research could include:

- A. An accurate assessment of the resistance of water resistance devices such as the water weights used in this project, including the effects of viscous drag force, and inertial forces due to acceleration.
- B. The determination of the viscous drag force on body parts moving through water during exercise."

In summary, the discussion contains a lot of repetition about the methodology and the results.

This was corrected, see before.

The first paragraph of "6.2: 10 Repetition maximum tests" was taken out and the first section of 6.2.1 was worded as follows:

"The exercises in both exercise groups were equally effective, as both groups showed considerable isotonic (10 RM) strength increases, but no significant differences."

Section "6.3.3: Problems in isokinetic testing during this project" was taken out of "discussion" and put into "method" ("4.3.1: Procedure of Cybex test"), as it pertains to methodology. Both paragraphs were also shortened as follows:

"The subjects could choose a time of day that was convenient for them to have their tests. Testing was not always done at same time of day, as is recommended by some (68, 57), as a more recent literature review of 224 articles on factors that affect isokinetic testing (56) does not mention the time of day. Many of the tests were performed at the same time of day, however, as many subjects who did not work shifts preferred to attend their exercise and test sessions during their lunch times."

and

"A graph tracing speed of 25 mm/s would have been better for testing at 270°/s to make sure the curves are not too small, which makes manual analysis more difficult (5), but was not done due to the high cost of the graph paper."

The author explored findings in the discussion, discussed pitfalls and made judgements about the worth and usefulness of her finding. I felt more interrelation and less repetition was necessary in the discussion with the findings of the other authors in the introduction and the results of the study.

A number of other references were added and changes were made (see corrections done following Dr. Diesel's examiners' report).

The author states correctly what she might do differently next time, and gave interesting and plausible ideas for future research.

This research project has good potential, but requires more focus and brevity.

A number of sections were left out, all chapters were revised to make them more focused.

B. Further corrections as advised by Mr. F. Cohen in his detailed critique (aspects mentioned in addition to the report)

Page 5 Isometric contractions: Also, the resistance does not have to be fixed.

The definition was changed to: Isometric contraction: A muscle contraction during which the muscle length does not change because contractile force is equal to resistive force (6 (was 8)).

Page 7, figure 2.1 – area under the curve is work ? require definition of work. Unsure whether author knows if this is linear or rotational work. Linear work = force x distance. Rotational work = torque x angular displacement

The definition of rotational work was added to the glossary of terms

“Rotational work

Rotational work is work done during rotation about an axis. It is equal to torque x angular displacement and is represented by the area under a torque curve obtained by isokinetic testing (8 (was 58), 3) (see Figure 2.1).”

The subheading of Figure 2.1 was changed to read “rotational work” instead of “work”. The joint and movement tested was also included: “knee flexion and extension”

Literature review, p 8: Does not have to say the literature review follows, it is obvious. Rather...in this literature review we focus on the principles etc

The introductory sentence was taken out and the literature review starts with, “ Muscle strengthening in water”. The section “3.1: Strength training and muscle strength testing” was taken out and the remainder of the literature review numbered accordingly.

Page 9 and 10 for completeness of neural factors. The force output of a muscle is also determined by the rate at which the motor units are fired (rate coding).

*Page 12 for completeness: Other determinants of muscle strength are:
Strength to mass ratio – in sprinting and jumping, the ratio of the strength of the muscles involved in the movement to the mass of the body parts being accelerated is critical.
Muscle contraction velocity – as the velocity of contraction increases, the muscle force decreases.
Joint angular velocity – muscle torque varies with joint angular velocity according to the type of muscular action eg. concentric, isometric and eccentric muscle action. However, this was mentioned briefly on page 15.*

Page 13 3rd paragraph – no reference for statement in first sentence of isometric strengthening

Page 18 3rd paragraph, 2nd sentence reference 35. Do not require et al in reference list as full list of authors is required. But do require et al in text i.e. HUNTER et al (35), if more than 3 authors.

Page 20, reference 38, 2nd paragraph – no et al in reference list! Should read KRAMER et al (38). 2nd paragraph 1st sentence of text.

Page 24, second paragraph – irrelevant

Page 27, 1st line, 1st paragraph – FIATERONE et al (42) only mentions 3 authors – incorrect ? should be et al if more than 3 authors

Reference on p 27 – TREUTH et al (45) incorrect. Only 3 authors mentioned. Articles by Taaffe and Charette should read – TAAFFE et al (29)
- CHARETTE et al (30)

Page 29, 4th paragraph, 2nd sentence: Reference should read MAFFROID et al (33)

Page 30, 2nd paragraph 1st sentence reference again should read “many investigators”... (33, 41, 46 etc.) Left out “investigators”

2nd paragraph, 3rd sentence should read ROTHSTEIN, LAMB AND MAYHEW (62).

Page 33, 3rd paragraph, last sentence should read ROTHSTEIN, LAMB AND MAYHEW (62)

Page 34 1st paragraph 1st sentence DURAND et al (59)
2nd paragraph 2nd sentence should read FRONTERA et al (46)

Page 36, 1st paragraph 2nd sentence. No reference

4th paragraph, 2nd sentence. Do not require 2 references for the same sentence i.e. (46)

4th paragraph 3rd sentence. Reference should read THORSTENSSON et al (67)

The section “3.1: Strength training and muscle strength testing” (p 8 – 39) was taken out on the advice of the other examiner.

Page 47 1st paragraph 5th sentence. Reference should read TOVIN et al (5)
1st paragraph 7th sentence. Should read FORT et al (83)

This was changed to “Tovin, et al. (15 (was 5))” and to Fort, et al. (33 (was 83))

Page 49 Reference 85 – no et al! in reference, as full list of authors is required

See Comment 2 to Mr. Cohen’s examiner’s report.

Page 49, 4th paragraph 1st sentence Reference should read ABIDIN et al (85)

This was changed to Abidin, et al. (35 (was 85))

Page 50, figure 3.2 not necessarily "new" (1988!)

Should read ...authors (85) upgraded hydrofitness device with large handle for arm strengthening.

The words "a new" were replaced by "the upgraded" in the legend for Figure 3.2. Abidin, et al. (35 (was 85)) subsequently designed an upgraded light-weight hydrofitness device with a large handle for arm strengthening (Figure 3.2).

Page 51, 1st paragraph 1st sentence. Reference should read GOITZ et al (81)

This was changed to Goitz, et al.(30 (was 81)).

2nd paragraph 1st sentence – seems out of text

The text was clarified as follows:

"Another hydrofitness device that could be applied to the foot, which Goitz, et al. (30 (was 81)) evaluated, was an inflatable arm band type of device applied to the lower leg. It was found to be too close to the knee and had the potential risk of punctures (30 (was 81)). The third type of device investigated, had flat disc-like paddles (Figure 3.4) and could also be attached to the foot (30 (was 81)). The strapping was found to be inadequate for exercises performed vigorously (30 (was 81)). This device could also not be used for walking re-education and could only be used on one leg at a time (30 (was 81)).

Page 52, 1st paragraph 1st sentence. reference should read GOITZ et al (86)

This was changed to Goitz, et al. (36 (was 86)).

Page 55, 3rd paragraph 1st sentence. reference should read GOITZ et al

This was changed to Goitz, et al. (30 (was 81)).

Page 58, 4th paragraph 1st sentence. Reference should read TOVIN et al (5)

This was changed to Tovin, et al. (15 (was 5)).

Page 61 mentions the English literature frequently. Is there information available that is significant to this study in other languages ?

The word "English" was taken out of the text of the research report where used in this context ("1.1 Significance of the study" and "3.2.7 Quadriceps rehabilitation in water"), as no muscle strengthening trial utilising progressive resistance exercise in water has been recorded in other languages, either. Index Medicus literature searches, which the author used, search for other languages apart from English as well and none of the English articles on hydrotherapy or exercise in water had references to relevant articles in other languages.

Sampling method of this research project is useful to obtain the characteristics of the random variable under study.

Sampling method was described better (see comments made in response to Mr. Cohen's examiner's report).

Appendix C

For a questionnaire the subject should be free to deny answer to specific items or questions. Also, confidentiality should have been addressed.

The following was added to "4.1.1: Recruitment of subjects and assigning them to the land, water or control groups":

"Written informed consent was obtained (see Appendix C)(Appendix F) if the volunteer agreed with all the requirements of the project. Although the information handout (Appendix B)(Appendix E), the statement of consent (Appendix C)(Appendix F) and the questionnaires (Appendices D – F)(Appendices A – C) had been approved by the Committee of Research on Human Subjects, the statement of consent (Appendix C)(Appendix F), would have been improved if it had also stated that the subject would be free to deny answer to specific items or questions on the questionnaires. The confidentiality of questionnaires and test results should also have been stated on the statement of consent (Appendix C)(Appendix F). Although not stated, subjects were free to leave out any questions on the questionnaires that they did not want to answer, which also occurred occasionally (see Table 4.10)."

Page 63 Sample: Method of selection of subjects should have been more carefully looked at prior to this study.

The following was added to "4.1 Sample":

"A random selection of young females aged 17 – 30 years working at the Johannesburg Hospital would have made the results of this study more representative of the population of young females working at this institution. The researcher could also have used a random selection of young females living within 5 km of the hospital would have made the results representative of a more varied and larger population. This was, however, not feasible within the constraints of this research report. In both cases, subject compliance might, however, seriously have been affected and the researcher would have had to carry out the experimental part of this research project over a number of years in order to gather enough data. In both

cases there would still have been bias towards very motivated individuals, who would have been more likely to attend for eight weeks."

4.2.3.1: Unclear where this resistance (~16 kg) come from ? accommodating resistance in water p 46.

This was already explained in answer to Mr. Cohen's examiners report. For clarity, here it is again (this section was added to the explanation of the water weights):

The figure of 160 N (16kg) is the resistance due to buoyancy and is explained in the first part of "4.2.3.1 Resistance offered by the water weights":

"As the maximum weight the subjects would exercise against was not expected to be higher than 160 N (a mass of 16 kg), eight 2 litre bottles (resistance of about 160 N) were used for the purpose of this exercise trial. The figure of 160 N was obtained as follows: The upthrust of buoyancy is equal to the weight of the water displaced by the object that is displaced under water. If eight empty 2 litre bottles (16 l) are displaced under water, the upthrust they experience is equal to the weight of the water they displaced, which is 160 N (8×20 N), as 2 litres of water weigh 20 N.

The biggest resistance to the submersion of the water weights was due to the effect of buoyancy, as mentioned above. The upthrust on the eight submerged bottles stayed constant throughout the exercise trial, but the amount of water in the bottles, i.e. the downward force due to the weight of the water inside the bottles, became less as water was let out of the bottles. The force resisting submersion of the weights (upthrust minus weight of the water in the bottles) was, therefore, in effect, equal to the weight of the water displaced by the empty bottles. A set of eight bottles containing 3 litres of air would experience an upwards force of 30 N (upthrust - weight of water inside bottles = $160 \text{ N} - 130 \text{ N} = 30 \text{ N}$)."

Page 69, 1st paragraph: Weight mentioned, but given in grams? Weight = mass x acceleration = Newtons

All weight values were changed from kg to N.

Page 69, 3rd paragraph, 3rd sentence: ? commencing programme resulting in increased inertial forces. Surely any changes in direction will result in increases in inertial forces?

The inertial forces were already described in response to Mr. Cohen's examiners report. As he says quite correctly, any changes in direction will lead to inertial forces.

In section "4.2.3.1: Resistance offered by the water weights" the inertial forces that are largest during the first few weeks of the exercise trial were explained as follows:

"The heavier the resistance apparatus, the larger these inertial forces would have been. For this reason, the inertial forces would have been greatest as the water exercise subjects commenced the programme, as most of their bottles would have been filled with water at this stage, which made the resistance apparatus heavier."

Last sentence of p 70: Weight is always written as Newtons. Is this the weight of each bottle (should then read weight of each bottle) or all the bottles including the string?

This sentence was changed to:

"a) weight of bottle set, string and noose = 6,55 N (mass of 0,655 g)"

Page 74: 4.2.6:

- 1. Exact details of the Cybex is required i.e. where manufactured, model etc*
- 2. Was the reliability measured in other experiments measured on the same machine?*
- 3. Was the reliability of this machine measured?*
- 4. Were the machines calibrated? Only the Cybex (p 76)*

These details were already given in response to Mr. Cohen's examiners report. For clarity, here they are again:

1. More detail on the Cybex was included in the second paragraph of Chapter 4: METHOD and in section "4.2.6 Cybex isokinetic machine and dual channel recorder":

"A Cybex II+ Isokinetic Dynamometer (serial number C105-0165, 1983 model), a electromechanical dynamometer (Figure 4.5) was used as a means of testing muscle strength in this project."

2. A lot of literature exists on the Cybex II Isokinetic Dynamometer (40 (was 62)). The following was added to 4.2.6: "Cybex isokinetic machine and dual channel recorder":

"The reliability of the Cybex II Isokinetic Dynamometer has been investigated extensively and found to be high for peak torque, work and power of knee flexion and extension if some precautions are taken and a carefully structured test protocol is followed (7 (was 61), 40 (was 62))."

3. The following was added to "4.2.6: Cybex isokinetic machine and dual channel recorder": In an attempt to establish the test-retest reliability of the Cybex II+ Isokinetic Dynamometer (serial number C105-0165, 1983 model) at the Johannesburg Hospital, two identical isokinetic tests, involving six reciprocal repetitions of knee extension and flexion at 60°/s were done on 4 subjects (the control group) 8 – 9 days apart during trial 1 (Appendix A)(Appendix D). The knee extension peak torque of the dominant leg improved significantly in the second test, while that of the nondominant leg stayed the same. These unusual results are probably due to a small sample size. This test-retest reliability should have been established using more subjects. It has also been found that subjects may perform better the second time they undergo an isokinetic test, as they would be more familiar with the test the second time round (46 (was 46), 47 (was 65)). If familiarisation had happened here, both the dominant and nondominant legs should have performed better the second time round. However, in order to rule out the possible effect of familiarisation, two initial Cybex test could have been done, and the value of the second test taken, in order to give subjects an optimal chance to familiarise themselves to the testing procedure. The fact that this was not done is a minor shortcoming of this research."

4. All the other equipment and machines were calibrated (see comments made to Mr. Cohen's examiners report before), except for the Akron isokinetic machine used in trial 3.

Page 78: No calibration of the "dual channel recorder" was done

The dual channel recorder was calibrated with the Cybex machine at the beginning of the trial. Calibration of this recorder is an essential part of the Cybex calibration procedure. The text was changed as follows in section 4.2.6:

"The Cybex II+ dynamometer and dual channel recorder were calibrated by technicians from the local Cybex agents before the start of the project, using the calibrated weights supplied with the machine and following the calibration procedures in the operating manual (Cybex, Division of Lumex, Inc., 2100 Smithtown Ave, PO Box 9003, Ronkonkoma, New York, USA)."

Page 99, table 5.1: could have included totals for each group and total Experimental mortality

Table 5.1 was changed to Table MO.1. A column for the control group, totals for each group and total experimental mortality were included:

Table MO.1 Reasons for subjects completing less than four weeks of exercise or for data being excluded from analysis

REASON FOR WITHDRAWAL	NUMBER OF VOLUNTEERS		
	WATER GROUP	LAND GROUP	CONTROL GROUP
Illness	4	2	0
Personal reasons	3	0	0
Eczema on legs (due to chlorine)	1	0	0
Went on holiday	1	0	0
Developed pain in feet	0	1	0
Taken out by researcher (unable to discontinue sport while participating in this research)	0	1	3
TOTAL	9	4	3
TOTAL EXPERIMENTAL MORTALITY	16/69 = 23,2%		

Page 101, table 5.3: Graphs should be separated i.e. type of injury, date of injury and side of injury. Not immediately clear. Totals could be added for clarity, as well.

Table 5.3 was taken out and 2 tables with comparisons between the groups used instead (tables 4.3 and 4.4 (the old 5.10 and 5.11)).

Totals were added.

Table 5.5: Number of subjects and number of sports per person should be made much clearer.

This table was left out.

P 103: 2nd paragraph: What happened to the other 3 subjects

The following sentence was added to this section:

"Three subjects did not answer the question on current participation in other regular physical activity (see Appendix D, Pre-Trial questionnaire, question 7)(*Appendix A*)."

Appendix H, p 237 – table H: leg and speed, 15th line – should read 270 °/s

The 60°/s was changed to 270°/s.

The following tables could include totals: p 109 table 5.9, p 110 tables 5.10 and 5.11, p 111 table 5.12, p 112 table 5.13, p 113 table 5.14

This was done.

p 113: 5.7.1.3: Need to state other variables

The absence of significant differences (except for age) between the groups at the beginning of the trial and the variables used to establish this were put into the "method" section in "4.1.3: *Characteristics of sample*".

Results section could have been simplified and less laborious, eg.

Example 1: p 105: Reliability tests: one way ANOVA for testers

There was no significant difference ($p > 0,05$) between the 10 RM measurements performed by the six testers on subject M and J respectively (See Appendix A1. Could put table in here.)

"Section 5.6: One way ANOVA for testers" was shortened as suggested above and put into method (4.3.2: "Procedure of 10 RM test"). The table was put into Table M1, Appendix M.

Example 2: p 114

No significant differences were found when comparing all previous leg injuries sustained by the three groups or the ability to swim between the groups. (See appendix A2)

As described above, the absence of significant differences (except for age) between the groups at the beginning of the trial and the variables used to establish this were put into the "method" section in "4.1.3: *Characteristics of sample*". This was shortened and tables 5.15 and 5.16 were taken out.

Example 3: 5.7.4.2: p 119: Thigh muscle soreness

On 42 occasions out of 149 in the water group and on 46 occasions out of 135 in the land group, muscle soreness was recorded (Appendix A3). By totaling each week's scores, no significant difference in thigh muscle soreness was found between the water and land groups over the 8 week period ($p > 0,05$) (Appendix A4). However, a significant difference ($p < 0,05$) was noted in the severity of muscle soreness between the land and water group during each of the exercise weeks, except for the first week ($p > 0,05$) (Appendix A5)

The above mentioned section was changed as follows: "On 42 occasions out of 149 in the water group and on 46 occasions out of 135 in the land group, thigh muscle soreness was recorded (Table M5, Appendix M). There was thus no significant difference in the number of subjects reporting thigh muscle soreness between the water and land groups over the 8 week period ($p > 0,05$). However, the water group experiences significantly more muscle soreness than the land group ($p < 0,05$) during each of the exercise weeks, except for the first week ($p > 0,05$) (Table 5.20)."

Table 5.19 was changed to Table M5.

Section 5.7.2.2 Should say – see table H2, Appendix H. Require probability levels.

"(see table M2, Appendix M)" and " $p < 0,05$ " were added to 5.7.2.2: "Changes over eight weeks in exercised leg".

5.7.2.3 Should say – see table H2, Appendix H.

"(see table M2, Appendix M)" and " $p < 0,05$ " were added to 5.7.2.3: "Changes over initial four weeks in exercised leg".

Could include confidence levels throughout results section. It makes for easier reading.

This was done.

Page 119, 5.7.4.1

Only require results in results section. The methodology has or should already have been mentioned. Require probability levels. 5.7.4.2: Only results required

Methodology was taken out of sections "5.7.4.1, 5.7.4.2 and 5.7.4.3" and " $p < 0,05$ " added. These methodology sections were put into "4.3.3: Exercise regimen", where the weekly questionnaire is described.

Page 122 – table 5.21: should include totals:

19 in water – 1	= 18
18 on land – 3	= 15
16 in control – 0	= 16
Total 53	49

This table was left out.

P 126: Table 5.26 and Table 5.27: Include totals

Totals were added

p 127: Table 5.28: : Include totals

Totals were added

P 128, table 5.29: Total number of subjects exceeds total for this group. Was more than 1 advantage in water allowed?

The following subscript was added to the table: "***subjects could give any number of advantages"

p 134, table 5.35: Bottom of page. Last result should be on next/ following page.

The lay-out of Table 5.35 was improved.

p150, 5.11.2, 2nd paragraph, 1st sentence: Surely at the end of weeks 1 and 7 means the same as between week 0 – 1 and week 6 – 7.

This section was taken out of the research report.

(These do not mean the same. "At the end of each week" is a value in kg. "Between week 0 – 1" is a ratio of "value at week 1/ value at week 0")

Use Yates's correction for the chi-squared statistics e.g. table 5.21, p 122

Following discussions with a statistician, the researcher was advised that Yate's correction should not be used. She was advised to use a 2-Tail Fisher's Exact Test on all 2 x 2 tables. This was done and the new p – values also inserted (see "Table 5.8 Reported "feeling at ease" in water: significant difference between water and land groups", "Table 5.19 Comparison of the number of subjects who had experienced thigh muscle soreness over eight weeks in the land and water groups", "Table 5.22 Comparison of pain while exercising over eight weeks", "Table 5.25 The perceived degree of benefit of the exercises"). The Chi-squared test is the best test to use for 3 x 2 tables and was therefore retained for these tables. Table 5.21 was left out of the results as there was no significant difference following the 2-Tail Fisher's Exact Test and this information was thus not important.

P 159, 3rd sentence: Should read AGRE et al (94).

Section "6.1.5: Difficulties getting subjects to volunteer for control group" was taken out.

p 161, 2nd paragraph, 2nd sentence should read GERBERICH et al (95)

Section "6.1.6: Standardising the activity level of subjects while on a muscle strengthening programme" was taken out.

p 162: 6.1.7.1: Only 49 subjects completed the study therefore, the compliance rate is less.

The discussion on the compliance rate in section "6.1.7.1: Ability to complete the 8 week exercise trial" was changed to:

"A good overall compliance rate of 76,8 percent (including the four subjects who completed more than four but less than eight weeks of exercise, as their data was included in the analysis) was found."

Lots of repetition about the methodology and results in the discussion.

References to methodology were taken out. Where results were mentioned at the start of a section, it served to make the section easier to read and grasp.

P 166: 6.2.2, 2nd paragraph: reference should read De LATEUR, LEHMANN and FORDYCE (21).

This was changed to DeLateur, Lehmann & Fordyce (66 (was 21)).

p 170: An important distinction can be made between a muscle loaded isokinetically and a muscle loaded with a standard weight-lifting exercise. As with all joints of the body, the muscle force exerted against an external resistance varies with the bony lever configuration as the joint moves through its normal range of motion. Therefore, when training with weights, the resistance is usually fixed at the greatest load that allows completion of the movement. Consequently, the resistance can be no greater than the maximum strength of the weakest joint position in the range of motion. Otherwise, the movement would not be completed. This is not the case in an isokinetically loaded muscle. Thus, the peak power output generated on the Cybex is greater throughout the range than training with weights, which might account for no improvement at 60%.

The above explanation was added to section "6.4: The lack of strength improvement on isokinetic testing, while strength improved isotonicity" as follows:

"An important distinction between a muscle loaded isokinetically and a muscle loaded with a standard weight-lifting exercise is the position of resistance in the range of movement. As with all joints of the body, the muscle force exerted against an external resistance varies with

the bony lever configuration as the joint moves through its normal range of motion (6 (was 8)). Therefore, when training with weights, the resistance is usually fixed at the greatest load that allows completion of the movement. Consequently, the resistance can be no greater than the maximum strength of the weakest joint position in the range of motion. Otherwise, the movement would not be completed (6 (was 8)). This is not the case in an isokinetically loaded muscle, where the resistance changes according to the muscles' ability throughout the range of movement, thereby loading the muscle maximally throughout the range of movement (76 (was 17)). Training isotonicly, i.e. increasing the strength at the weakest joint position, may therefore not yield results that are measurable on maximal muscle strength testing through full range of motion, as in isokinetic testing."

p 178, first paragraph: Good. Specificity is important as an improvement in a muscle's force production is related to adaptations in the muscle itself, neural organisation and excitability, and thus related to the type of exercise, for example, isotonic exercise.

The following was added to "6.4: The lack of strength improvement on isokinetic testing, while strength improved isotonicly":

"Specific neural adaptations will occur in muscle as a result of isotonic strength training. The improvement in a muscle's force production is related to enhanced neural organisation, excitability and efficiency of muscle contraction, and thus related to the type of exercise (62 (was 10), 61 (was 13), 64 (was 15), 63 (was 16), 32)."

p 178 4th paragraph: reference should read LINDEMAN et al (96)

This paragraph in section "6.4: The lack of strength improvement on isokinetic testing, while strength improved isotonicly" was taken out.

P 190, 2nd paragraph, 5th sentence: Reference should read ROSE, RADZYMINSKI and BEATTY (23).

This reference was changed to "Rose, Radzynski & Beatty (82 (was 23)).

It was felt that the discussion was a repetition of the results and methodology section.

More discussion and interrelation to other literature was put into this chapter.

P 219: Appendix A, 3rd paragraph: Need to back up these statements with references

The information regarding the superiority of the Cybex to the Akron in this paragraph could not be substantiated with literature and was therefore left out. This paragraph and the surrounding paragraphs were changed as follows:

"As neither the Akron nor the Cybex machines showed strengthening of the trained leg at the exercise speed, it was evident that the failure of isokinetic testing to show strengthening of the quadriceps at the exercise speed was not due to a faulty Cybex machine. It was consequently

decided to continue using the Cybex machine at the Johannesburg Hospital for subsequent trials, but to include the weekly 10 RM as an additional test, as this seemed to be highly specific to the strengthening that occurred.

The Akron and Cybex machines produce their resistance differently, the Akron with a hydraulic component (personal communication with Mr D. Roworth, Huntleigh Akron) and the Cybex with the use of an electric motor (7 (was 61), 4). Ideally, this trial should therefore have compared the results on two Cybex machines and not a Cybex and an Akron machine. At the time of the research, very few of these expensive Cybex machines were available and the researcher consequently only had access to one Cybex machine in the Johannesburg area."

Surely, when deciding on the adequacy of the Cybex machine, the reliability and reproducibility of this machine should have been done by performing the same test on subjects at the same time of day on consecutive days and comparing statistics applied to the data.

This was done, using 4 subjects (see addition to "4.2.6: Cybex isokinetic machine and dual channel recorder" discussed before: "In an attempt to establish the test-retest reliability of the Cybex II+ Isokinetic Dynamometer (serial number C105-0165, 1983 model) at the Johannesburg Hospital, two identical isokinetic tests, involving six reciprocal repetitions of knee extension and flexion at 60°/s were done on 4 subjects (the control group) 8 – 9 days apart during trial 1 (Appendix A)(Appendix D). The knee extension peak torque of the dominant leg improved significantly in the second test, while that of the nondominant leg stayed the same. These unusual results are probably due to a small sample size. This test-retest reliability should have been established using more subjects. It has also been found that subjects may perform better the second time they undergo an isokinetic test, as they would be more familiar with the test the second time round (46 (was 46), 47 (was 65)). If familiarisation had happened here, both the dominant and nondominant legs should have performed better the second time round. However, in order to rule out the possible effect of familiarisation, two initial Cybex test could have been done, and the value of the second test taken, in order to give subjects an optimal chance to familiarise themselves to the testing procedure. The fact that this was not done is a minor shortcoming of this research.").

The following addition was made to Trial 1 "A.1.3: Discussion":

"It is a shortcoming of this research that test-retest reliability was not established using a larger sample. In the light of a number of other studies having established test-retest reliability of Cybex testing of knee flexion and extension torque, work and power using specific protocols (84 (was 59), 7 (was 61), 40 (was 62)), test-retest reliability was not pursued further in this study."

If the mechanism of function of these two machines is different, how could a comparison be made, especially if the Cybex is supposed to be more reliable.

The following text was added to section "A3.3.2: Differences between the Akron and Cybex tests":

"Ideally, the performance of subjects on two different Cybex machines should have been compared and not on a Cybex and an Akron machine. At the time of the research, the researcher, however, only had access to the one Cybex machine in the Johannesburg area, as very few of these expensive machines were available."

Note: It is grossly apparent that the CONSTRUCT VALIDITY, i.e. the degree to which performance on a test corresponds to the abilities or the traits that the test purports to measure, was inadequate. The Cybex isokinetic test was thus not valid in the testing of isotonic exercise. The constructs underlying quadriceps strength training needed to be evaluated properly, and the appropriate tests to measure this instituted.

The following was added to section "6.4: The lack of strength improvement on isokinetic testing, while strength improved isotonically":

"The construct validity, i.e. the degree to which performance on a test corresponds to the abilities or the traits that the test purports to measure, of the Cybex isokinetic test for this research was inadequate. The researcher's findings support the literature which suggests that isokinetic testing is not as sensitive to strength gains as is isotonic testing, following isotonic training (71 (was 36), 65 (was 26), 72 (was 25), 41 (was 89), 73). Isokinetic testing therefore does not seem to be valid in the testing of isotonic exercise and should not be the test of choice in healthy young females to determine strength increases due to an eight week isotonic strengthening programme such as that used in this study."

P 223: The Cybex test does not appear to be a sensitive technique for measuring isotonic strength. Muscle strength, or more precisely, the maximum force or tension generated by a muscle is generally measured by:

- 1. Tensiometry*
 - 2. Dynamometry*
 - 3. One repetition maximum and*
 - 4. Computer – assisted force and work output determinations using isokinetic dynamometry.*
- However, the one repetition maximum is the best criterion of overall muscle strength. It has been noted that even if 2 people have the same 1 RM score, the force-time curves could be quite dissimilar. Such differences in force dynamics may reflect an entirely different neuromuscular physiology.*

Certainly, isokinetic dynamometry allows us to study muscle dynamics.

References:

Number 13, 20, 30, 35, 38, 40, 76, 85, 95, 96 – NO et al should be given in the reference list, as a complete list of authors is necessary.

See **Comment 2** to Mr. Cohen's examiner's report.

C. Corrections according to requirements of Dr. W. Diesel (his report is given in italics)

Thank you for asking me to act as an external examiner for the above mentioned research report. The study was designed to compare the effectiveness between water and land-based incremental resistance quadriceps training in young females. The research report revealed a satisfactory acquaintance and understanding of research methodology as well as original research. However, my recommendation is that this report should be referred back to Monika for major revision as regard to the literary style and presentation.

The report is too lengthy and focuses too much attention on minor issues such as randomization of subjects.

The literature review on strength training and muscle strength was taken out. The terms used in this part of the literature review only, were taken out of the "glossary of terms".

Table 5.2.1 and related text referring to the number of subjects who experienced pain on exercising in week 8 was taken out. Section "5.6: One way ANOVA for testers" was shortened and put into "method"

Sections "5.7.1.3: Variables showing no significant differences" and "5.7.4.2: Thigh muscle soreness" were shortened.

Sections 5.10, 5.11, 6.1.1 and 6.1.2 and Tables 5.45, 5.46, 5.47 and 5.48 were taken out: Comparing subjects with prior leg injury to those without injury and comparing subjects with prior sports participation to those without. The paragraph describing the statistical analysis of these two comparisons was taken out of section "4.4.1: Statistical testing".

All flexion results in "results" and "discussion" were taken out.

"6.1.4: Randomly dividing subjects into two groups" and "6.1.5: Difficulties getting subjects to volunteer for control group" were taken out.

Section "7.3: Method of testing" was taken out.

Section "5.9.1: Correlation between extension peak torque and extension work" (including tables 5.39, 5.40 and 5.41) was taken out.

The whole of section "6.1: The subjects" was taken out.

Appendix I, the admission fees to public pools, was taken out.

The randomization of subjects was kept in the methods section, but was taken out of the discussion, i.e. sections "6.1.4: Randomly dividing subjects into two groups" and "6.1.5: Difficulties getting subjects to volunteer for control group" were taken out.

Another problem I have with her report is the lack of references throughout large sections of this study.

More references were added throughout.

INTRODUCTION

How does the researcher now that "most physiotherapists..." would or would not agree to (p1). Even if this is the case, this is a scientific report and claims such as these need to be supported by appropriate literature.

"Most physiotherapists" was taken out of this paragraph, so that the second sentence reads as follows:

"Golland (1 (was 2)) states that "the use of water in treating patients is one of the most valuable, and ... enjoyable, techniques in the physiotherapist's repertoire."

Using the first person in writing scientific reports should be avoided (p2 – in my experience).

Where the first person had been used before (except for the where it is used in the declaration, acknowledgement and information handout (Appendix B)(Appendix E)), the words "the researcher" were inserted instead or the passive voice was used.
e.g. on page 2 "in my experience" was changed to "in the experience of the researcher"

Paragraph 2 on p 2 starts by saying "many researchers..." but only 1 author is referenced.

References 12 (was 3) and 13 (was 73) were added to this paragraph in section "1.1: Significance of the study". It now reads as follows:

"Many authors (1 (was 2), 12 (was 3), 13 (was 73)) have described the basic principles of exercise progression in water..."

Chapter 2 – Glossary of terms has no references! (except Oxford Muscle Scale)

References were added to each term that appears in the glossary.

Chapter 3 – Poor reference of statements throughout the whole chapter, e.g. 3.1.1.1 Neural factors. Each and every sentence needs to be appropriately referenced.

The literature review on strength training and muscle strength (section 3.1) was taken out.

As a general observation, too much detail is given to topics not entirely relevant to the study. Most, if not all sections in this chapter can be significantly shortened. This study is a research report and not a dissertation. The possible exception to this is from Chapter 3.2 to the end of the introduction – which contains pertinent information to this research report.

The literature review on strength training and muscle strength (section 3.1) was taken out.

Page 58 – the researcher concludes that the difference in the strengthening programmes may explain the reduction in joint oedema. In order to reach such a conclusion the researcher must give reasons and explanations why and how differences in strengthening programmes

affect joint oedema. The researcher must refrain from giving her own opinions. The reason for having a literature review is to provide arguments for and against the hypothesis. This hypothesis is then tested and finally supported or rejected.

A critical review of the study by Tovin et al. (15 (was 5)) is indicated in this literature review, as the topic is related to the hypothesis of the present research project. A critical review of Tovin et al. (15 (was 5)) shows that they made an incorrect conclusion that the reduction in joint effusion in the water group was entirely due to the exercise medium. The present study aimed to make sure that the water and land groups followed the same strengthening programmes.

Reasons and explanations of why and how differences in strengthening programmes affect joint oedema were included as follows:

“Their conclusion that the water group had less joint effusion because they exercised in water (15, (was 5)) is, however, questionable, as the two exercise programmes in this trial were not identical, the resistance in water having been self-paced while the land groups used incremental weights. A less vigorous exercise programme in water could also have resulted in less joint irritation and joint swelling, both of which can occur following vigorous post-operative exercise (39).”

The reference DiNubile (9) is used very frequently and is relatively old – 1991. This is a review article and therefore the original research should be quoted.

Many references to DiNubile (55 (was 9)) occurred in section 3.1, which was taken out.

In other places, references to DiNubile were replaced by references to original articles or more recent publications, e.g. in a part added to section “4.3 Procedure”:

“Determination of the 1 RM could lead to injury if done in an unsupervised way by people not used to weight lifting (55 (was 9), 4, 54).”

and in “section 6.4: The lack of strength improvement on isokinetic testing, while strength increased isotonically”:

“In addition, the intensity was not so high that it would have resulted in the weakening effects of over-training (75, 4, 55 (was 9)).”

More recent literature pertaining to areas such as exercise-induced muscle soreness should also be reviewed by the researcher.

More literature on muscle soreness was included in the discussion, section “6.6.2: Significant difference in the degree of thigh muscle soreness”. This section was changed as follows:

“Although the number of subjects with thigh muscle soreness did not significantly differ between the two groups, the water group had more severe muscle soreness over the course of the trial.

On the questionnaire, a clear distinction was made between muscle soreness and pain. It is therefore unlikely that the subjects indicated the presence of muscle soreness when they meant pain. It remains unclear why the water group should have had muscle soreness of a greater severity than the land group.

Research has shown that eccentric muscle activity causes more muscle soreness than concentric activity (78, 79). This is as a result of damage to muscle fibres and connective tissue and elevation of fluid pressure in the muscle that has done the eccentric work (78).

Both the land and water groups had to perform eccentric quadriceps work when flexing the knee after knee extension, in order to control the lowering of the weights and upward movement of the empty plastic bottles respectively. The eccentric contractions only differed in that most eccentric control was needed with the knee close to extension in the land group (where the force of gravity is at 90 degrees to the direction of the muscle pull) and with the knee close to flexion in the water group (where buoyancy is at 90 degrees to the direction of muscle pull). This could possibly have led to differences in thigh muscle soreness between the two groups, but more research is needed.

Another explanation is that although the questionnaire asked specifically for the absence or presence of thigh muscle soreness in the first part of this question, the second part of the question with the visual analogue scale did not ask specifically for the severity of "thigh" muscle soreness (see Appendix E and F, question 1) (*Appendix C and B*). The participants may thus have indicated the severity of their general muscle soreness on the visual analogue scale. The researcher suspects that some of the subjects in the water group may have referred to abdominal muscle soreness. Some subjects in the water group complained of the effort required of their abdominal muscles to maintain the correct starting position during exercise.

Stabilisation becomes a problem when using a lot of buoyant material. The exercise in this project provided good stabilisation of the trunk, as the upper body was out of water. However, to stabilise the hip in 90 degrees of flexion and maintain this position throughout the exercises, the subjects had to isometrically contract their hip flexors and abdominals. Isometric contractions can, to a lesser degree than eccentric contractions, also lead to muscle soreness (4, 80). This added isometric muscular effort could possibly have led to those in the water group having experienced more severe muscle soreness."

METHODS

The method used to randomly select subjects, particularly for the control group, appears not to have been thought out very well.

This was identified as a shortcoming of the research in "4.1.1: Recruitment of subjects and assigning them to the land, water or control group":

"It is a shortcoming of this research that the subjects were not assigned to water, land or control groups in a consistent manner. Perhaps the subjects would have been willing to be randomly assigned to the control group if the researcher had been able to promise participation in a similar strengthening programme to them after the 8 week control period, as was done by Agre, et al. (44 (was 94))."

Convenience sampling of the subjects is further described in "4.1.2: Sampling method".

The data analysis (chapter 4.4 page 93) of the isokinetic tests needs re-assessment, especially due to the "unexpected" results obtained. Verification of the readings should be carried out by somebody other than the researcher.

Verifying the results obtained from block counting

On consultation with a statistician from the Medical Research Council, it became clear that results obtained by block counting could be verified in two ways:

Firstly, ten percent of the data could be recounted by another person (not the researcher), or, secondly, a correlation analysis between the values obtained manually and the values of the computer print-outs that were available could be done.

The researcher chose to verify the results using the second option. A good correlation was found and the statistician advised that the first option of having ten percent of the data recounted was then not necessary.

The following was added to the text of the research report (4.4: Data analysis):

"The procedure of counting the blocks and using a grid to calculate peak torque was found to be reliable, as a strong correlation was found between the values obtained manually and the values of the computer print-outs that were available (Appendix O). In view of this strong correlation and the fact that more data was available using the manual calculations, the data obtained manually was used for statistical analysis."

RESULTS

Tables too lengthy and contain variables not part of the study design; such as Cybex flexion results. I suggest these unnecessary variables be removed and focus kept on the research topic.

The following tables were taken out: 5.3, 5.15, 5.16, 5.21, 5.39, 5.40, 5.41, 5.45, 5.46, 5.47, 5.48.

All Cybex flexion results and discussions on these were taken out.

Avoid underlining sentences (p118) and highlighting words (p136).

The above underlining and highlighting as well as other unnecessary underlining and highlighting was taken out of the text.

Looking at every possible correlation coefficient and comparison is both unnecessary and confusing. Stick to relevant issues. Sorting out information from hundreds of test results is an important aspect of writing good concise research reports.

Section "5.9: Correlations" was shortened as follows:

Section "5.9.1: Correlation between extension peak torque and extension work" (including tables 5.39, 5.40 and 5.41) was taken out, as it was not relevant to the aims of this study.

In section 5.9.2.1: "Correlations at week 0", using the r^2 value (0,15) it became apparent that there was no correlation between the 10 RM tests and the extension work in 20 s of the dominant leg at 60°/s (A r^2 value of 0,5 or above indicates that there is a correlation. A r^2 value of 0,5 means that in 50% of the cases you can predict what the other variable will be).

Similarly, in section 5.9.2.3: "Correlations at end of study", using the r^2 value (0,15) it became apparent that there was no correlation between the 10 RM tests and the extension work in 20 s of the dominant leg at 60°/s.

This whole section "5.9.2: Correlation between 10 RM and isokinetic test values" was thus shortened, Tables 5.42, 5.43 and 5.44 were put into Appendix M and called Tables M7, 8 and 9 respectively. The text was condensed to:

"No correlation was found between the 10 RM values and the isokinetic test values at 60°/s for peak extension torque and extension work of the dominant leg at weeks 0, 4 or 8 (see Tables M7, 8 and 9, Appendix M)."

DISCUSSION

Tedious repetition of irrelevant issues, such as presence/ absence of leg injuries; sport participation, age of subjects, feeling "at ease" in water, extension work of non-dominant leg at 60°/s, occupations, randomisation, difficulty in recruiting volunteers, standardisation of activity levels, compliance, attendance, additional physical activities, etc. etc.

The whole of section "6.1: The subjects" was taken out, which includes section such as "6.1.1: Comparing those with previous leg injuries to those without", section "6.1.2: Comparing subjects with prior sports participation to those without", section "6.1.4: Randomly dividing subjects into two groups", section "6.1.5: Difficulties getting subjects to volunteer for control group".

Only 3 references in the first 14 pages of the discussion!

More references were added to the discussion, e.g. in "6.7.3: Advantages and disadvantages of land exercise":

"During exercise in a heated pool, one loses heat by sweating and evaporation of sweat in those parts of the body that are not submerged (31)."

and in section "6.2.1 10 RM results":

"Muscle strengthening in the present research project is most likely to have occurred as a result of neural factors (such as better muscle fibre recruitment and higher synchronisation (61 (was 13), 32)) since the isotonic strengthening programme of eight weeks was relatively short for muscle strengthening (62 (was 10), 61 (was 13), 63 (was 16), 64 (was 15), 32)."

and in section "6.2.2: Reliability of 10 RM testing":

"Despite the fact that the 10 RM test dates back to the time of DeLorme (1945)(9 (was 11), 10 (was 12)), testing of repetition maxima, such as the 10 RM or 1 RM, is still being used as a

Author Petrick M

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