reliable muscle strength test by many researchers today (64 (was 15), 48 (was 29), 50 (was 35), 51 (was 42)."

and in section "6.3.2 Reliability of isokinetic testing":

"In order to enhance the reliability of isokinetic testing in this project, the researcher ensured that a strict testing protocol was followed (57 (was 41), 40 (was 62), 5 (was 56))."

The following was added to section "6.4:The lack of strength improvement on isokinetic testing while strength improved isotonically":
"Smith and Melton (71 (was 36)) 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."

The following was added to section "6.4: The lack of strength improvement on isokinetic testing while strength improved isotonically":
"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 (55 (was 9), 65 (was 26), 4)."

The following paragraph in section "6.3.1.1 Significant improvements"

was changed and more references were added to it:

"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 (was 39)). A number of studies have demonstrated strengthening at the training velocity and below (61 (was 13), 68 (was 48), 69 (was 68)), while others have indicated that torque increases can be found at both higher and lower velocities than the training velocity (70 (was 22), 67 (was 39)). 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 (was 39)). The better test performance at week 8 was probably as a result of familiarisation with the test.

The following paragraph in section "6.3.1.2 Significant differences" was changed as follows:

"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 6.3.1.1 before)."

The following paragraphs in section "6.3.1.1 Significant improvements"
was changed and more references were added to it:

1. "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 (57 (was 41), 40 (was 62)). Absolute endurance measures, such as the total work done over 25 repetitions or the work done over the last five repetitions (57 (was 41), 40 (was 62)) 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 (was 41))."

2. "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 (was 61)). The problems with interpreting endurance ratios have been mentioned before."

Again, using the first person in reports must be avoided; p 167 "I am of the opinion",

This was changed to: "Nevertheless, the researcher is of the opinion that adherence to the strict test protocol prevented bias." (section 6.2.2: Reliability of 10 RM testing)

"my study", on p 180

This was changed to "this present study" (section 6.4: The lack of strength improvement on isokinetic testing while strength improved isotonically)

"when I recalculated" on p 181.

This was changed to "When recalculating the results from their raw data, the researcher came to the same conclusion." (section 6.4: The lack of strength improvement on isokinetic testing while strength improved isotonically)

Underlining is also unnecessary, p 174.

The underlining was removed here (section 6.3.1.2: Significant differences)

Statement s such as "this can only have been due to the familiarisation with the test procedure", p 171, without any reference is also unacceptable and shows a lack of understanding of scientific reporting.

The following paragraphs in section "6.3.1.1 Significant improvements" was changed and more references were added to it:

"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 (was 61)). The problems with interpreting endurance ratios have been mentioned before."

On p 172, first paragraph, conclusions are reached without any references.

This paragraph was taken out as it deals with a flexion value and all flexion results and discussions were taken out.

On the same page the researcher claims deconditioning led to weakening of the control group's hamstrings and then conveniently suggests that lack of motivation on initial testing led to increases in their extension ratios. This indicated a lack of overall understanding and too many irrelevant variables. Again, no references are provided for these conclusions.

The argument around the possible deconditioning of the hamstrings was taken out, together with all the other flexion variables. The extension endurance ratio argument in section "6.3.1.2: Significant differences" was changed to:

"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 6.3.1.1 before)."

This referred to the following argument in "6.3.1.1: Significant improvements" in which the problems interpreting endurance ratios is given as follows:
"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 (57 (was 41), 40 (was 62)). Absolute endurance measures, such as the total work done over 25 repetitions or the work done over the last five repetitions (57 (was 41), 40 (was 62)) 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 (was 41))."

The lack of isokinetic strength increases despite significant increases in 10 RM is indeed "unexpected" and needs more thoughtful analysis and discussion. References are required before, not after, statements such as "isokinetic testing should not be used in healthy people to determine strength increases due to an isotonic strengthening programme". Dogmatic statements such as these need very strong scientific support; at best the researcher should use words such as "it would appear" or "further research is needed to explain these findings". Subsequent to this statement the researcher quotes studies which found isokinetic strength *increases following isotonic training. This section is not well- constructed and needs major revision.*

Section "6.4: The lack of strength improvement on isokinetic testing, while strength improved isotonically" was changed as follows:

"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 (was 91)). 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 (71 (was 36), 65 (was 26), 72 (was 25), 41 (was 89), 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 (71 (was 36), 65 (was 26), 72 (was 25), 41 (was 89), 73).

Smith and Melton (71 (was 36)) 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 (was 26)) 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 (was 25)), who conducted a very similar study to that of Frontera, et al. (65 (was 26)) on elderly men, also found that the 12 week weight lifting programme led mostly to isotonic strengthening.

Reynolds, Worrel & Perrin (41 (was 89)) 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 lar weights with their knee extensors after an eight week low-intensity isotonic strengthening p. gramme, 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 (34). 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)). 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 (was 8)). 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 (73, 72 (was 25)). 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 (was 8)). 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 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 (62 (was 10), 61 (was 13), 64 (was 15), 63 (was 16), 32).

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 (55 (was 9), 65 (was 26), 4, 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 (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. 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 (was 8), 60 (was 55)). 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 (was 8), 60 (was 55)).

In the undergraduate study by Mandelbaum and Novick (43 (was 91)), 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. 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."

This also applies to section 6.9 para. 1.

Section 6.9 was moved to "conclusion" and the sentences referring to isokinetic and isotonic testing were taken out, in line with suggestions made by the examiner later.

Discussions regarding the difference in resistance through range between the two exercise groups, p 182 —185, is important but needs to be incorporated into the findings of this study. The fact that maximal resistance occurs at opposite ends of the knee extension exercise needs to be explained in terms of the results; more specifically the lack of any significant differences in the 10 RM test results.

The following was added to section "6.5 Difference in resistance through range between the two exercise groups":
"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."

The researcher, on p 186, in her opinion regards the visual analogue scale as being very accurate suggests she is an "authority" on such matters. References other than the researcher's opinion are needed.

The sentence "The researcher is also of the opinion that the results obtained in this trial using the visual analogue scale to determine pain and muscle soreness were very accurate" in section "6.6.1: The degree of comfort while exercising" was taken out.

A clear explanation needs to be provided as to why the water-based subjects reported less discomfort whilst exercising but significantly greater degree of muscle soreness. Speculation by the researcher as to why this happened is not adequate. Severe muscle soreness may also have been due to overload or even eccentric quads in controlling the buoyancy on returning to knee flexion.

The following parts of section "6.6.1: The degree of comfort while exercising" were changed:

"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 water 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 (was 72), 20) and the slightly smaller resistance to knee extension in the water group could have led to this finding."

Section "6.6.2: Significant differences in the degree of muscle soreness" was changed as follows:

"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 water 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, the participants may have indicated the severity of their general muscle soreness on the visual analogue scale, as this part of the question did not ask specifically for the severity of "thigh" muscle soreness (see Appendix E and F, question 1)*(Appendix C and B)*. 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, as the upper body was out of water. Nevertheless, the subjects had to isometrically contract their hip flexors and abdominals during the exercises in order to maintain the starting position. 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."

Currently, in Cape Town there is a huge outcry over the closure of many of our public swimming pools – perhaps physiotherapists involved in community projects should be made aware of these findings and approach the necessary authorities (reference to p193).

The following was added to section "6.7.2: Advantages and disadvantages of water exercises":

"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."

References needed for the lack of awareness of perspiration during water-based exercises (p 194).

The following was included in "6.7.3: Advantages and disadvantages of land exercises":

"During exercise in a heated pool, one looses 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."

Implications of findings, p 196, chapter 6.9 should go to CONCLUSIONS, as once again the researcher failed to provide a single reference.

Section "6.9: Implications of findings", was put into CONCLUSIONS. References 12 (was 3), 15 (was 5) and 39 were added to "Conclusion".

The most important aspects of this report were discussed between p 176 – 196. This section should receive more attention, in particular regarding appropriate references.

Section "6.4" was revised (see above).

In section "6.5.1: Knee extension against an ankle weight", reference 9 (was 11) was added.

Section "6.5.2 Water group: knee extension in prone lying over the edge of the pool" was changed as follows:

Reference 9 (was 11) was added.
The head-down under water position was described slightly differently and Dr. Diesel's suggestion of using the same starting position for both groups was added to the end of this section:

"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 (was 11)).

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."

Section "6.6.1: The degree of comfort while exercising" was changed as mentioned in the corrections before.

Section "6.6.2: Significant differences in degree of thigh muscle soreness" was changed as mentioned in the corrections before. Reference 1 (was 2) was added.

Section "6.6.3: Significant differences in pain on exercising" was changed to:

"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 (12). 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 6.6.1 and 6.6.2 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 (81 (was 98), 20). 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 (was 23), 83 (was 95)). Two subjects in the study by Gerberich, et al. (83 (was 95)) 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, et al. (82 (was 23)) 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."

In addition to the changes to section "6.7.2: Advantages and disadvantages of water exercises" described before, references 1 (was 2) and 58 (was 92) were added. The first part of the paragraph referring to pool maintenance was changed to:

"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 (92). Correct chlorine and acid levels need to be maintained (1 (was 2), 58 (was 92)). 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 (was 92)). More careful monitoring and chlorine dosing is needed when a larger number of people use the pool (58 (was 92))."

In addition to the changes to section "6.7.3: Advantages and disadvantages of land exercises" described before, references 16 (was 6), 18 (was 72), 2 (was 76) and 27 (was 78) were added. The following paragraph was changed slightly:

"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 6.6.1 and 6.6.2 before) and had more transient anterior knee pain during exercise than the water group."

CONCLUSION

The method of quadriceps training used in this study appears to be both awkward and impractical. Perhaps a simpler option would have been to assume the same seated position in the water, as on land, but use heavier water-proof weights, non-buoyant material, to negate the effects of buoyancy i.e. water could be added instead of letting out water. In which case maximal resistance would occur at terminal extension in both land and water-based exercise programmes, making comparisons between "discomfort levels" more acceptable.

Adding water instead of letting water out would not have worked as there would have been no resultant resistance from buoyancy to knee extension with all the bottles filled with water, using this starting position. The upthrust of buoyancy (weight of water displaced) would have been approximately equal to the downward force of gravity, i.e. the weight of the water in the bottles. One would have to use very dense material as water weights to provide resistance in this starting position, so that the weight would be larger than the upthrust of buoyancy.

The suggestion of using the same starting position in both groups was added to section "6.5.2: Water group: knee extension in prone lying over the edge of the pool" as described in the corrections to section 6.5.2 above.

The arguments against using isokinetic testing for measuring strength gains, following isotonic training, is incorrect (p 201). The researcher has already referenced studies showing the opposite to be true (Smith and Melton(36), Tovin et al. (5), Danneskiold-Samsoe (77)), in fact she even admits to being one of the subjects in the trial (p 181). The research can only say that her findings support literature which suggests that isokinetic testing is perhaps not as sensitive to strength gains as is isotonic testing, following isotonic training.

The findings of Smith and Melton (71 (was 36)) support the use of isotonic rather than isokinetic testing for measuring strength gains after isotonic training. Although they found significant strength gains on isometric, isotonic and isokinetic testing (which differs from the results of the present study), 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. Their sample of 12 adolescents, who were divided into four groups, one of which was a control group, was rather small. The discussion of their findings was added to section "6.4: The lack of strength improvement on isokinetic testing, while strength improved isotonically".

The findings of Tovin, et al. (15 (was 5)) may show a tendency towards supporting the specificity of training, but do not present strong evidence in an argument against using isokinetic testing for measuring strength gains, following isotonic training. They used isometric and isokinetic testing eight weeks after the commencement of their closed chain isotonic strengthening programmes in water and on land in their patients who had undergone anterior cruciate reconstruction. These two tests were done to compare the two exercise groups and not to assess strengthening, as no initial strength test was done. Their study, however, revealed smaller peak torque values than other studies. The authors say that this could have been 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 (15 (was 5), 41 (was 89)).

Danneskiold-Samsoe (24 (was 77)) does not provide enough information about the sample and programme design to warrant any conclusions about the advisability or not of using isokinetic testing for measuring strength gains, following isotonic training.

The undergraduate study by Mandelbaum, et al. (43 (was 91)) did show isokinetic strengthening in both the isotonic and isokinetic exercise groups, contrary to the findings of this study, which is difficult to explain, but could be related to the fact that the isotonic exercise group of Mandelbaum, et al. (43 (was 91)) exercised against a Westminster pulley, while the exercises in this study were done with ankle weights. This was explained in section "6.4: The lack of strength improvement on isokinetic testing, while strength improved isotonically".

Section "7.3: Method of testing" was taken out, as this was not part of the initial objectives of the study (see before).

The absolute statements concerning the unsuitability of isokinetic testing to measure isotonic strengthening were changed to indicate that the researcher's findings support literature which suggests that isokinetic testing is not as sensitive to strength gains as is isotonic testing, following isotonic training, e.g.:

Section "6.4: The lack of strength improvement on isokinetic testing, while strength improved isotonically" was changed as follows:

"The two tests used for determining quadriceps strength, isokinetic peak torque at 60°/s and the 10 RM test, therefore most likely do not measure the same thing."

"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. 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 (was 8), 60 (was 55). 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 (was 8), 60 (was 55))."

The reference to muscle strength testing in the abstract was changed to:

"Isokinetic testing does not seem to be ideal following isotonic muscle strengthening in this population."

The researcher is advised to check her opening paragraphs in the introduction and make sure the conclusions resulting pertain to the objectives of the study. The impression is created, in the introduction, that part of the problem with strengthening in water is not knowing what resistance is being used and whether or not this type of exercise is effective. The conclusion should therefore deal primarily with these issues. The study was not designed to compare isokinetic to 10 RM testing. Refer to 1.2 Objectives of the study on p 3.

Section "7.3: Method of testing" (to compare isokinetic to 10 RM testing) was taken out of the conclusion.

The conclusion was changed to:

"7.1 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 (39, 15 (was 5)), may benefit from the isotonic strengthening programme used in this project.

7.2 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 (was 3)). 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 (was 3)). 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 (was 3)). 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."

D. Additional Corrections

DECLARATION

The date in the declaration was changed to 1999:

"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.

....

..........day of............., 1999"

ACKNOWLEDGEMENTS

Added: "Ms. E. Viljoen of the Medical Research Council kindly assisted me with further statistical testing for the corrections of this research report."
Help received from Mr D. Roworth, Huntleigh Akron, was also acknowledged.
The words "physiotherapy and physiotherapy assistant colleagues" were changed to "rehabilitation colleagues and students".
RSG was written out in full, i. e. "Radio Sonder Grense".

TABLE OF CONTENTS

Table of contents was updated and changed according to the sections, figures and tables taken out or added.

LIST OF FIGURES

List of figures was updated and changed according to the figures added.

LIST OF TABLES

List of tables was updated and changed according to the tables taken out or added.

2. GLOSSARY OF TERMS

The glossary of terms was moved to the initial pages of the research report, after the list of tables.

The definition of an isokinetic dynamometer was changed as follows:

"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)."

The following definitions were added here:

7. **Isokinetic endurance tests**

These tests are recommended for test speeds of 180 or 240°/s (5 (was 56)).

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 (5 (was 56), 3).

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 (5 (was 56), 3).

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 (was 56)).

3. LITERATURE REVIEW

More references were added to the literature review on exercise in water.

The following information on recent studies was added to section "3.2.1: Benefits of exercise in water":

"A number of studies on patients with rheumatoid arthritis have shown that water exercise improved muscle strength as well as quality of life (14 (was 4), 24 (was 77)), although Sanford Smith, MacKay-Lyons and 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."

"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."

The formula for viscous drag force was added to "3.1.3.2: 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 (was 76)) and can be calculated using the following formula:
$F_{drag} = 0,5 \times C_d A \rho v^2$ (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 (was 76))"

The following correction was made to "3.2.7: Quadriceps rehabilitation in water":

"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 (was 89))."

The following was added to "3.2.7: Quadriceps rehabilitation in water":

"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 (25, 21)."

4. METHOD

In the introduction of the method chapter, the name "Ethics Committee" was changed to the more correct "Committee for Research on Human Subjects".

The following sentences in 4.1.1: Method of selection of project participants" were changed slightly:

"Volunteers needed to be healthy, have no knee pathology, be 17 – 30 years old and able to attend 20 minute exercise sessions five times a week, for eight consecutive weeks. They were asked to discontinue all sporting activities during the time of the project."

The calibration of equipment was added.

4.2.3.1 Resistance offered by the water weights

A. The order of the paragraphs in this section was changed, to make for easier reading.

B. The following sections were added:

"The biggest resistance to the submersion of the water weights was due to the effect of buoyancy, which is equal to the weight of the water displaced. As some bottles in the water

weights were filled with water, the force resisting submersion of the weights was, in effect, equal to the weight of the water displaced by the empty water bottles.
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 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)."

C. The following paragraph was simplified and the reference to Appendix K was added:

"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".

4.2.6 Cybex isokinetic machine and dual channel recorder

The following was taken out: "Provided that some precautions are taken and a strict test protocol is followed, isokinetic testing of peak torque, work and power has been found to be highly reliable and reproducible, especially for testing of the knee (84 (was 59), 7 (was 61), 40 (was 62))."

The calibration of the Cybex was taken out of "4.3.1 Procedure of Cybex test" and put into this section.

References 57 (was 41) and 5 (was 56) were added to "4.3.1: Procedure of Cybex test". The following sentence was also shortened: "All subjects received the following identical instructions (as suggested by Davies, 5 (was 56)) by either of the testers throughout all Cybex tests:"

The first paragraph of "4.3.3: Exercise regimen" was changed as follows:

"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)."

The following sentence in "4.3.1: Procedure of Cybex testing" was changed and now reads:

"The lever length and dynamometer position were noted and kept the same for all subsequent tests for that subject (57)."

A reference to Appendix "A4: Trial 4"***(D4: Trial 4)*** was added to "4.3.3: Exercise regimen" where the modified, more strenuous version of the deLorme strengthening programme is discussed.

The page number reference to Cybex test procedure in "4.3.3: Exercise regimen" was taken out.

4.4 Data Analysis

The following clarifying sentence was added to the problems with leg weighing and motivation for manual analysis:
"The lower leg weight measurements would have affected the computer's numerical print-outs, as these were gravity corrected."
"Limb weight measurements" was also changed to "lower leg weight measurements"

The first sentence of "4.4.1: Statistical analysis" was taken out:
"Means and standard deviations were obtained for the baseline values and initial questionnaires of all the subjects."

The following was added to section "4.4.1: Statistical analysis"
"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."

Two paragraphs in "4.4.1: Statistical analysis" were changed as follows:

"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."

"Correlation analyses were done of peak extension torque and extension work of the dominant leg at 60°/s at weeks 0, 4 and 8, and the corresponding 10 RM, using Pearsons correlation coefficients and the coefficient of determination."

5. RESULTS

The abbreviations were moved to the initial pages of the research report, i.e. following LIST OF TABLES and GLOSSARY. The following was inserted under the heading of the "results" chapter:
"(For the abbreviations used in this chapter, refer to ABBREVIATIONS, p xxvi)"

Small corrections were made to the style of tables:

1. *NO. changed to NO.*, in line with s**, or p#, and symbols also put after the letters (i.e. in the same order) in subscript of tables

2. Subscripts of tables "S.D. = standard deviation" taken out as S.D. appears in the list of abbreviations

3. The symbol "±" taken out of table 5.20, as this notation of standard deviation is incorrect.

Sections 5.4 and 5.7.5 (both concerning attendances) were put together in the beginning of results as follows:

"**5.2 Attendance**

The mean number of attendances for both exercise groups was 36,22 (standard deviation = 3,91), which means they attended 95% 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)."

The paragraph describing the skin irritation experienced by some in the water group (section "5.7.6: Comparing the final questionnaire of the land and water groups") was shortened as follows:
"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 5.13."

Tables **5.39, 5.40, 5.41, 5.42, 5.43, 5.44** had the r^2 (coefficient of determination) values added.

Table 5.19: For more clarity, the table heading was changed to "Comparison of the number of times thigh muscle soreness was reported on the weekly questionnaire over eight weeks in the land and water groups". Row headings were changed from "number of participants who had thigh muscle soreness" to "number of reports of thigh muscle soreness" and from "number of participants who had no thigh muscle soreness" to "number of reports of no thigh muscle soreness"

The word "weight" was changed to "body mass" in Table 5.2, section 5.3.

6. DISCUSSION

The first sentence of "6.2: 10 repetition maximum tests" was taken out, as it wasn't relevant.

"6.2: 10 repetition maximum tests" was changed to: "6.1 Isotonic strength increases"

The following was changed in "6.3.1.1: Significant improvements", to avoid repetition:
"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 first part of "6.3.1.2: Significant differences" was changed as follows:
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 6.3.1.1 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."

In the first paragraph of "6.3.2: Reliability of isokinetic testing" the words "two students of the University of the Witwatersrand" were taken out, as this was a repetition.

The first sentence in "6.4 The lack of strength improvement on isokinetic testing, while strength improved isotonically" was taken out, as these results had been taken out of the results section (not relevant):
"A strong correlation was found between peak extension torque and extension work in 20 s of the dominant leg at 60°/s at weeks 0, 4 and 8, which is in accordance with the findings of other researchers (57 (was 41), 8 (was 58), 45 (was 66))."

The reference to pool admission fees in section 6.7.2: "Advantages and disadvantages of water exercises" was changed as follows:

"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.)"

The following paragraph in section 6.7.2: "Advantages and disadvantages of water exercises" was shortened to:

"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."

The paragraph on the cost of water weights was taken out of "6.7.3: Advantages and disadvantages of land exercises" to avoid repetition.

The words "of which water weights are the cheapest" were added to the description of the costs of water weights, home made sand bags and strap-on weights in "6.8: The design of progressive resistance ankle weights in water". The last 2 sentences of this section were joined together as follows: "A rubber encasement that would hold eight bottles may prove to be the answer, as this would prevent the bottles from slipping out."

7. CONCLUSION

The following was taken out of section "7.1: Comparing an isotonic strengthening programme on land to in water" as it would have duplicated the statements of 6.9 (now moved to "Conclusion"):

"Both groups were comfortable initially on exercising. The water group maintaining the same level of comfort throughout the trial, while the land group experienced a significant reduction in comfort between the first and last weeks."

The following was taken out of section "7.2: The design of the water weights":

"Knowledge of the exact resistance a person is exercising against in water is important for rehabilitation and for research purposes. In the previously mentioned study by Tovin, et al. (15 (was 5)), rehabilitation programmes on land and in water were compared, even though the amount of resistance to the water exercise was not known. Conclusions drawn from their findings may therefore have been inaccurate."

8. SUGGESTIONS FOR FURTHER STUDY

The following was added:

"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:
   C. 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.
   D. The determination of the viscous drag force on body parts moving through water during exercise.

8. An investigation into muscle soreness following exercise in water."

APPENDIX

The following change was made to Appendix A, section "A.1.4 Possible faults identified in TRIAL 1"*(Appendix D, section D.1.4)*:

" 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."

The following was taken out of appendix A *(Appendix D)*:

"A.3.3.1 Similarities between the Akron and Cybex tests

In none of the extension tests did both the Cybex and Akron isokinetic machines show a significant improvement ($p < 0,05$). "

The following new appendices H, I, J, K, L, N and O were added:

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 x 100 = 2%	%ERROR = 10/500 x 100 = 2%

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

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 X 100 = 5%

APPENDIX I

HYDROSTATIC PRESSURE MEASUREMENTS

Table I1 volume loss in a 2050 ml air-filled bottle submerged under water (as a result of hydrostatic pressure)

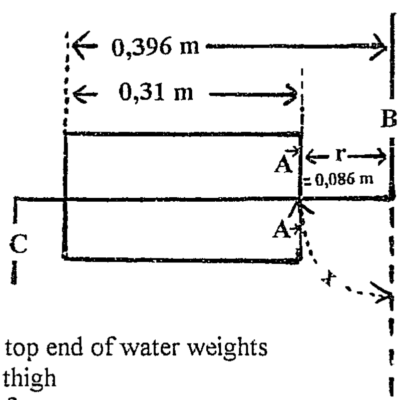
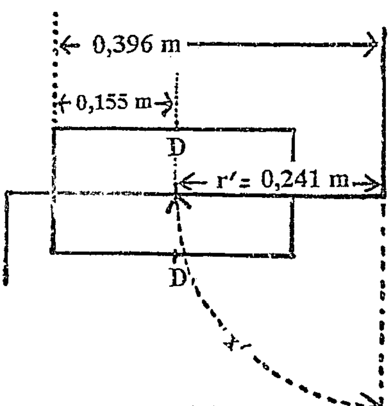
TRIAL	VOLUME (ml)	MEAN VOLUME (ml)
1	16.5	
2	9	9,65
3	10	
4	9	
5	10	
6	10,5	
7	10	
8	9	
9	9	
10	9,5	

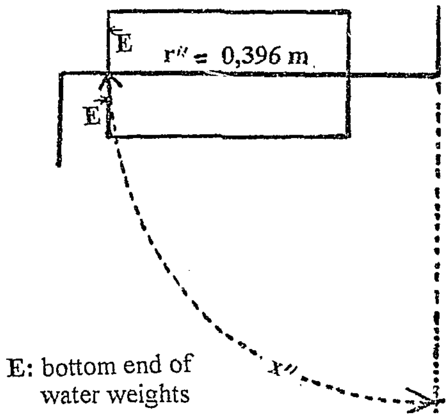
APPENDIX J

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°/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 m – 0,31 m = 0,086 m time (t) to complete 90° at a velocity of 60°/s = 1,5 s x = πr/2 = 3,142 x 0,086/2 = 0,135 m velocity (v) = x/t = 0,135/1,5 = 0,09 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 x length of bottle = 0,396 m – (0,5 x 0,31) m = 0,241 m time (t) to complete 90° at a velocity of 60°/s = 1,5 s x' = πr/2 = 3,142 x 0,241/2 = 0,379 m velocity (v') = x/t = 0,379/1,5 = 0,252 m/s

Velocity at the BOTTOM of the water weights (closest to the ankle) (v'')	
Drawing of lower leg with water weights	***Calculations***
	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°/s = 1,5 s x'' = πr/2 = 3,142 x 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°/s (v, see above)	66,7 s	first set 10 10 10	secondset 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°/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 set 500 450 400	second set 600 600 600	450 350 400

* See Table 5.2 for mean of the lower leg lengths

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

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

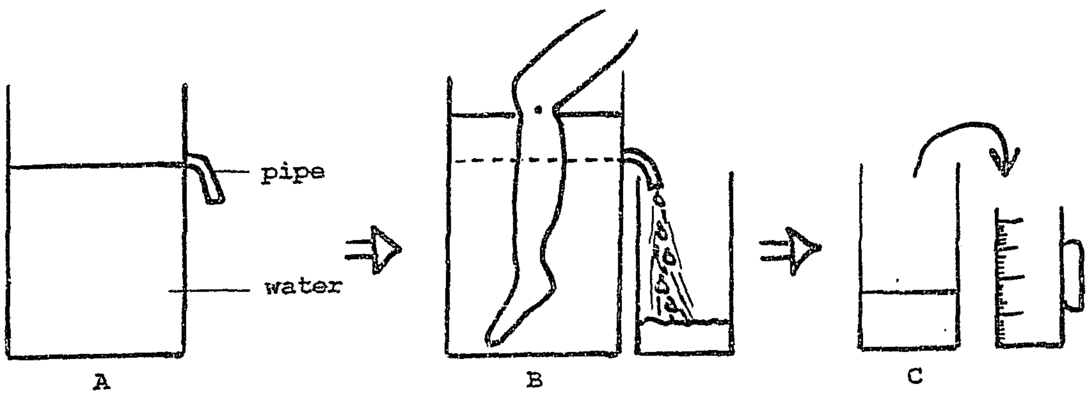


Figure L1 Measuring lower leg volume: **A**: Water just not overflowing through pipe, **B:** Right lower leg inserted up to level of the lateral epicondyle. Water overflows via the pipe into the bucket, **C:** The volume of water that overflowed into the bucket (lower leg volume) is measured using a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

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:

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

where L = distance between the supports for the board,

S1 – S2 = the difference in scale readings with knee flexed and extended, and

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

(See Figure L2)

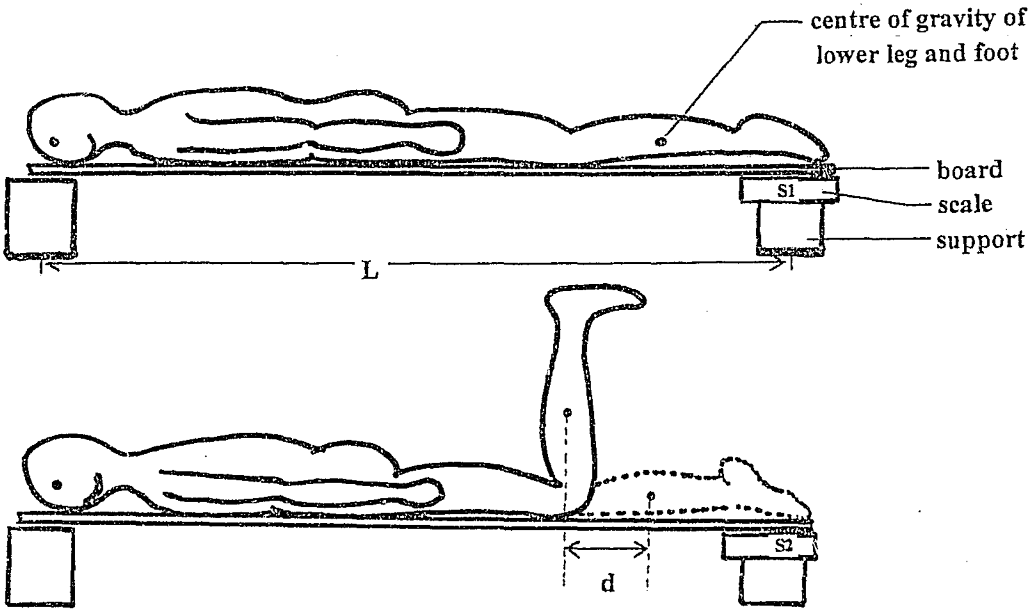


Figure L2 Measuring lower leg weight: **S1** = scale reading with knee extended, **S2** = scale reading with knee flexed to 90 degrees, **L** = distance between the supports for the board, **d** = horizontal distance the centre of gravity of the lower leg and foot moves from knee flexion to knee extension

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 (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 MEAN (S.D.)	BODY WEIGHT MEAN (S.D.)	6,4% BODY WEIGHT MEAN (S.D.)	MEASURED LOWER LEG WEIGHT MEAN (S.D.)	LOWER LEG VOLUME AND UPTHRUST 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).

APPENDIX M

APPENDIX M

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			
	MEAN	S.D.	MEAN	S.D.	p – VALUE	
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
ns** = not significant (Two-tailed two sample t-test)

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

AGE MEAN (S.D.)	BODY WEIGHT MEAN (S.D.)	6,4% BODY WEIGHT MEAN (S.D.)	MEASURED LOWER LEG WEIGHT MEAN (S.D.)	LOWER LEG VOLUME AND UPTHRUST MEAN (S.D.)
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NO. OF DOUBLE SESSIONS	3,63	3,24	2,22	2,10	0,064	ns

*The maximum number of exercise sessions possible = 38
ns** = not significant (Two-tailed two sample t-test)

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, 60°/s	t: W in E	887,9528 b	121,1285 b
Nondominant leg, 60°/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.

APPENDIX M

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)

	WATER GROUP (W)		LAND GROUP (L)		CONTROL GROUP (C)		p-values	
TEST	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	W vs L W vs C L 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	0,138	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	0,383 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	0,389	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	0,203	0,338 0,349 0,480	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	0,292	1,162	0,428	1,252	0,453	0,260 0,097 0,278	ns ns ns

	WATER GROUP (W)		LAND GROUP (L)		CONTROL GROUP (C)		p-values	
TEST	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	W vs L W vs C L vs C	
t: W in E	1,095	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 mm^2)
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 THIGH MUSCLE SORENESS	42	46	0,306 ns*
NUMBER OF REPORTS OF NO THIGH MUSCLE SORENESS	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

Table M6 Analysis of where pain was felt during exercise

		WATER		LAND	
WEEK	PAIN LOCATION	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

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

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 fo- 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%		

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

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).

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(Reference numbers given are the new numbers)

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The references that do not appear in the revised text any more were taken out and all references were re-numbered according to their order of occurrence in the text.

The following was put at the bottom 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."