CHAPTER 4
RESEARCH RESULTS

4.1. INTRODUCTION

This chapter deals with the results of the all the different phases of the research covered by the thesis. In the first section the results of the exploratory phase is covered. The section is followed by a section that deals with the new theoretical framework which has been developed as a result of the exploratory research. This new theoretical model plays a cardinal role in the research which follows.

In the third section the results of the explanatory research phase is covered. This section is followed by a section that deals with the experimental research which provides new perspectives on the new theoretical model which has been developed.

4.2. EXPLORATORY RESEARCH PHASE

4.2.1. Introduction to the exploratory research

The following section deals with the research results of the exploratory phase of the research. It covers the results of the first three individual case studies. The level of understanding is gradually increased during the research process which leads to a progressive refinement of theoretical propositions.

4.2.2. CASE STUDY 1

4.2.2.1. Introduction

Case Study 1 forms part of a group of three case studies that deal with the exploratory research phase of this project. The case study consists of four distinct phases.

The first two phases consisted of exploratory research based on the current theoretical understanding of the condition. In phase 1 the interventions were based on conventional physiotherapy. During phase 2 this was supplemented by calf muscle strengthening and proprioceptive retraining.

In phases three and four the interventions were expanded to include soft tissue mobilization in the lower leg which in turn was expanded to include the more proximal soft tissue.

Although the research started out as exploratory, as the knowledge and insight gained expanded, the case studies eventually provided the basis for the explanation of the new theoretical perspectives developed during the research.

4.2.2.2. Subject

The subject in Case Study 1 was a 36 year old female athlete who had been participating in road running for the previous three and a half years. At the time of her first consultation (24/01/02), she participated mainly in ten kilometre races and averaged a running pace of six and a half minutes per kilometre.

Inclusion criteria

During December 2001, she was clinically diagnosed with CPCS by a general practitioner who specializes in sport injuries. She complained of pain over the posterior-medial aspects of both lower legs whilst running. This pain usually occurred within the first kilometre of running, gradually grew worse as the run continued and abated with rest.

Exclusion criteria

With regard to the exclusion of nerve entrapments, it was noted that the plantar aspect of her feet often turned numb during a run (which could possibly be an indication of nerve entrapment), affecting the placing of her feet, but there was no tingling or burning sensation. She also did not experience any pain behind the knee.

4.2.2.3. The research question

"Does the existing theoretical model for the pathogenesis of CPCS provide for a logical model for describing causal relationships that could be used as the basis for the development of a conservative treatment approach for the condition?"

4.2.2.4. Theoretical framework

The model of Clanton & Solcher (1994) which has been discussed in Chapter 2 (Figure 2.3, page 55) is reproduced below with minor cosmetic changes. In terms of the model, CPCS is due to the increased muscle volume and the non-compliant fascial boundaries, which in turn leads to a decrease in tissue blood flow. The initial premise was that the blood-flow to the posterior compartment could be restored through conventional physiotherapy. Such conventional physiotherapy interventions would include massages, cross-friction techniques, ultrasound and interference therapy, and stretches that would lead to a reduction in the pressure in the calf area.

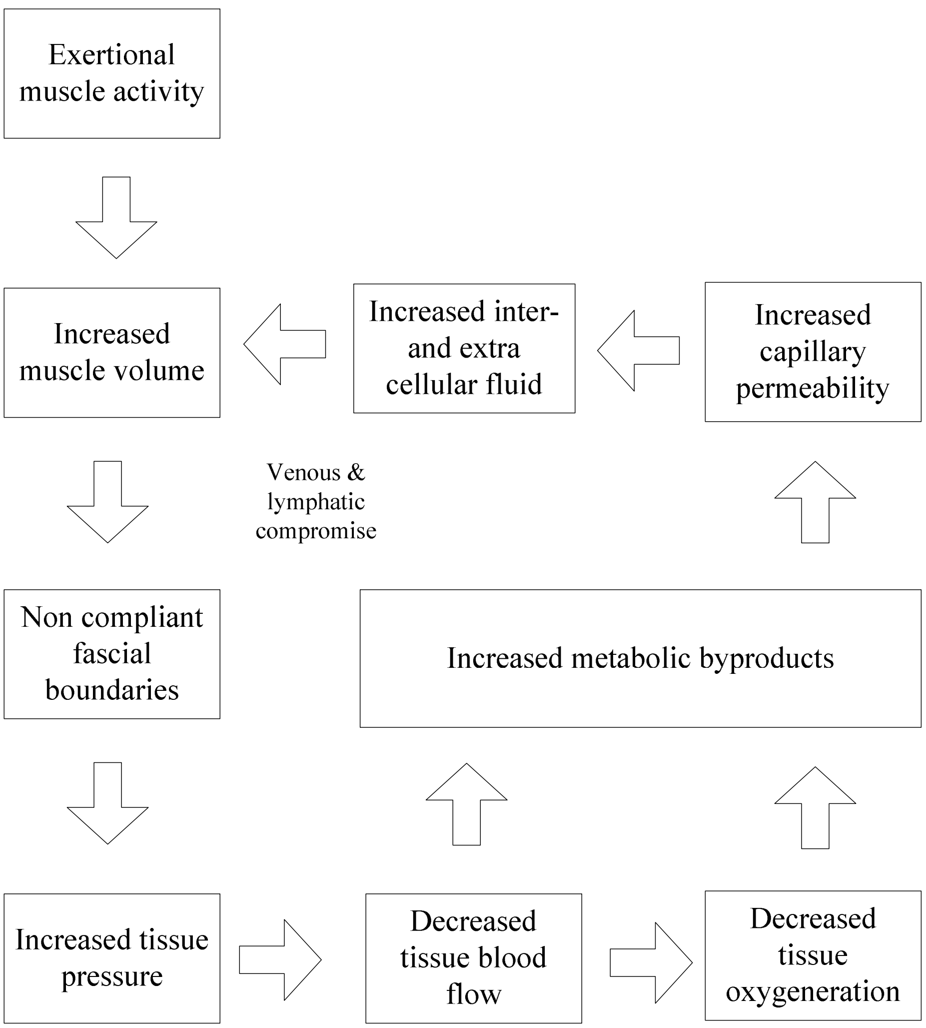


Figure 4.1: Pathogenesis of CPCS (Clanton & Solcher, 1994)

4.2.2.5. Propositions

The conventional treatment of the posterior compartment of the lower leg will lead to a disappearance in symptoms of CPCS through:

- *reduction in the pressure in calf area which in turn will lead to the alleviation of the symptoms of CPCS; and/or*
- *an increase in tissue blood flow and associated oxygenation that will reverse the process.*

4.2.2.6. Rival theories

The following rival theories can be postulated:

- *The rival proposition is that the conventional treatment of the posterior compartment of the lower leg will not lead to the alleviation of the symptoms of CPCS, as a different theoretical framework is responsible for the pathogenesis of the condition.*
- *The alleviation of the symptoms of the condition is purely due to chance and the intervention has nothing to do with it.*
- *The interventions have not been applied long enough in order to generate the required response.*
- *The researcher is incapable of applying the intervention techniques in an effective manner.*

4.2.2.7. Schedule and reviews

The schedule for the first case study and associated reviews was handled on an ad hoc basis due to the unpredictability of the exploratory nature of the research.

4.2.2.8. Criteria for interpreting results

The criteria for interpreting results were the degree of conformance to the propositions made from the theoretical framework.

4.2.2.9. The Research Procedure

Subjective assessment - Interview

- ***Running history***

The subject in Case Study 1 was a female athlete who had been participating in road running for the previous three and a half years. She participated mainly in ten kilometre races and averaged a running pace of six and a half minutes per kilometre. Her training programme consisted of a very gradual build up. She initially started by running for one minute, followed by walking for one minute. The running time was gradually increased over time to a stage where the total training distance reached a distance of five kilometres, where after the walking time was gradually reduced. This training programme was repeated three times a week.

She started off running with a slight anti-pronation shoe, but changed to a neutral shoe after consulting a podiatrist during February 2001. She had been paying careful attention to the number of kilometres she ran with the shoes and had to date never run more than 800 kilometres with a pair of shoes.

- ***Previous running injuries***

No other injuries apart from the calf muscle pain had been experienced.

- ***Symptoms noted***

Her first consultation with the researcher was on the 24th of January 2002. She complained of pain over the posterior-medial aspects of both lower legs with a pain rating of 20 out of 100 on a 100 mm VAS. This pain usually occurred within the first kilometre of running. The plantar aspect of both feet turned numb, during most of her runs (at least 70% of the runs) within the first four kilometres of the run. This made running very difficult, as she was not always sure of the placing of her feet.

o *History of symptoms and treatment received*

The subject first experienced the above mentioned symptoms towards the end of December 1998. During February 2001, she consulted a biokineticist who, in turn, recommended her to consult a podiatrist.

The podiatrist measured the degree of hind foot pronation as eight degrees in the right foot and six degrees in the left foot, after which he advised her to change her running shoes from a slight anti-pronation shoe to a neutral shoe. She also underwent six physiotherapy sessions consisting of massage of the calf muscles, stretch exercises for the calf muscles, ultrasound and interferential therapy over the indicated symptomatic calf muscles. She continued running, but despite the physiotherapy, her symptoms gradually became worse.

During September 2001, she consulted a general practitioner who specializes in sport injuries. The practitioner determined, by means of a Isokinetic dynamometer test, that both her plantar flexor muscles and her dorsi flexor muscles were weak and felt that these weaknesses were the cause of her symptoms. She underwent eight supervised strengthening sessions of the plantar- and dorsi flexor muscles on the Isokinetic dynamometer. Through all of this she continued to run, yet her symptoms progressively deteriorated to such an extent that towards the end of January 2002, she was unable to walk a distance of 100 metres. At this stage she presented at the researcher’s practice.

In summary, the subjective outcome measures as measured before the intervention:

- The intensity of pain / discomfort was 20 on the 100 mm VAS after a one kilometre run.
- The pain/ discomfort started within the first kilometre of running.
- She averaged a weekly distance of 12 kilometres per week at a pace of six and a half minutes per kilometre (she did not stop running the moment she felt the pain, which was within the first 100 metres. She continued as far as she could tolerate the pain).

Objective assessment – Physical examination

o ***Muscle strength tests***

The muscle strength of the plantar- and the dorsi flexor muscles was not retested, since this has been tested on a Isokinetic dynamometer by a biokineticist four months prior to the researcher seeing the subject. These measurements were accepted for baseline purposes. According to the referring practitioner, the strength of these two muscle groups was significantly lower compared to the norm at the time of testing.

o ***Analysis of running gait, including movement patterns***

The following movement patterns deviated from the normal/ ideal (Table 4.1):

- Throughout the running phases, the pelvis on the right remained slightly more posteriorly rotated in comparison to the left. The pelvis on the right also never seemed to move into a position of anterior rotation as one would normally expect during the initial contact phase.
- During the terminal stance and pre-swing phases, the right hip moved into more lateral rotation and extension compared to the left. Occasionally on every fourth or fifth stride, there was an additional lateral rotation and extension of the hip on the right, followed by an increased amount of medial rotation on the forward movement of the right hip in an attempt to counteract this.
- There was no heel toe action and during the mid stance phase, the calcaneus sunk into more of a valgus position than normal. This also appeared to be more on the right side than on the left. During the pre-swing phase the calcaneus on both sides moved into more inversion as though there was a slight weight shift from the second metatarsal head to the third metatarsal head. During the initial swing phase, there was hardly any push-off to be noticed on both sides.
- It was noticed from the posterior that the tendon Achilles was slightly curved convexly to the medial side in both legs.

From the description of the running movement patterns and the results tabled in Table 4.1, it is clear that abnormalities and asymmetries were present in the running movement patterns, compared to the norm.

Table 4.1: Outcomes of the running gait analysis for Case Study 1 prior to intervention

Running gait analysis: Case Study 1 (24/01/2002)								
	Weight Acceptance		***Single Leg Support***			***Swing Leg Advancement***		
Joint	*Initial Contact*	*Loading Response*	*Mid-stance*	*Terminal Stance*	*Pre-swing*	*Initial Swing*	*Mid-swing*	*Terminal Swing*
Pelvis	On the left side, the pelvis is in anterior rotation. On the right, the pelvis is in a neutral position.		Both sides are in slight posterior rotation. The right side more so than the left side.	Both sides are in posterior rotation; right side more than left side. Vertical movement of the pelvis on the right side is greater in comparison to the left.	Both sides are in posterior rotation; right side more than left side.		Both sides move out of posterior rotation.	The right side moves into a neutral pelvic position and the left side moves into anterior pelvic rotation.
Hip				The right hip is in more lateral rotation and extension compared to the left side.	The right hip is in more lateral rotation and extension compared to the left side.	Both hips start to move into internal rotation from the externally rotated position. Every now and then there is an irregularity on the right side with an increased amount of right hip external rotation and posterior pelvic rotation on the right.	Both hips are in flexion and internal rotation. Increased medial rotation in on the right side, following the occasional irregularity described in the previous column.	Both hips are in flexion.
Knee	Both knees: almost full extension with the tibia in external rotation.	The amount of knee extension decreases slightly in both knees.	The amount of extension in both knees increase slightly again with the tibia being in external rotation.	The tibias move into more external rotation with the knees in extension.	Both knees are extended with some external rotation of the tibias.	Both knees move out of extension and external rotation into flexion.	Both sides: Flexion and internal rotation.	Both sides: Extension and external rotation .
Ankle	Both ankles: no heel – toe action. Lands with both the ankles in a slightly inverted position, fractionally first on the lateral side of the foot (the base of the 5th metatarsal).	On both sides, there is a weight shift to the medial side of the foot (it moves into a more everted position).	The hind foot is in pronation. The left and right calcaneus sinks further into valgus, more so on the right than on the left. Both feet are in a position of abduction.	The hind foot moves out of the pronated position into a neutral position. The ankle starts to move into PF.	The hind foot moves into inversion, more on the right than on the left. Ankles are in plantar flexion.	Hardly any push-off. The hind foot moves into more inversion, especially on the right side. There is a weight shift from the 2nd metatarsal head to the 3rd metatarsal head.	Both ankles are in a position of plantar flexion and slight inversion of the hind foot.	Again: slight plantar flexion and inversion.

o ***Soft tissue palpation***

- ***Sole of the foot*:**

On palpation the area underneath the foot, namely the plantar fascia, felt tight bilaterally compared to the norm, but the left side felt tighter in comparison to the right side.

- ***Left calf:***

On palpation, the posterior-medial aspect of the calf felt very tight in comparison with the adjacent tissue, especially the area against the medial aspect of the tibia where the soleus muscle is palpable. The medial part of the Achilles tendon felt tight and swollen. A tight area was also palpated over the peroneus longus muscle in the middle one third of the lower leg.

- ***Right calf*:**

On palpation there was tightness in the upper central part of the calf, in the area between the two heads of the gastrocnemius muscle as well as on the medial part of the Achilles tendon. This area again appeared swollen but to a lesser extent than the left.

The motivation and description for the interventions used during this case study will be addressed in each of the phases as described hereafter.

o ***Flexibility/ length of the soleus muscle***

- Right soleus muscle: Big toe six mm from the wall.
- Left soleus muscle: Big toe four mm from the wall.

4.2.2.10. Intervention and data recording

The interventions used during the first case study, were changed during the treatment period based on the response of the subject. If an intervention did not lead to any improvement in the symptoms of CPCS, an alternative approach was adopted. The interventions applied in Case Study 1 consisted of four different phases.

Phase 1

Approach followed

The first phase consisted of intervention by means of conventional physiotherapy. This entailed the application of massage techniques; stretches of the soleus, and the gastrocnemius muscles; ultrasound; heat; myofascial release techniques of the tight calf muscles; and electrical stimulations to the area of the calf muscles (Biedert & Marti, 1997; Styf, 1998; Micheli *et al.*, 1999; Garcia-Mata *et al.*, 2001).

Treatment period

24th January 2002 to the 15th February 2002 (three weeks)

***Number of treatments sessions*:**

Ten

Initially conventional physiotherapy techniques were applied for the period 24th January 2002 to 15th February 2002 to treat the symptoms of CPCS. The area of the calf muscles was targeted during the treatment sessions and use was made of massage techniques, cross frictions (where the adhesions could be felt), ultrasound- and interferential therapy, and stretches of the calf muscles.

Outcome measures *(as measured on the 15th February 2002)*

The following outcome measures demonstrated no improvement on reassessment:

- The intensity of pain / discomfort at rest as well as the amount of pain/discomfort at the end of every training session as plotted on a 100 mm visual analogue scale (VAS). Throughout this period, she rated the pain as a 20 to a 40 on the 100 mm VAS.

- The distances run before the commencement of the symptoms with every training session. The distance varied from one to three kilometres.
- The total weekly distance run. This varied between six and nine kilometres.
- The palpation findings of the soft tissue of the posterior lower leg. This was tight exactly in the same places as with the first assessment.

Discussion

Since this approach did not lead to an improvement in any of the outcome measures, a different approach was selected. Varelas *et al*. (1993) proposed a strengthening programme of the calf muscles and Chandler & Kibler (1993) proposed proprioceptive retraining as intervention approaches for injuries of the lower limb. Varelas *et al.* (1993) have evaluated muscle function in compartment syndrome and concluded by saying that strengthening may be useful in very mild cases of CPCS or in post fasciotomy patients.

Proprioceptive retraining is recommended after ankle and knee injuries (Lentell *et al*., 1995; Osborne *et al*, 2001; and Risberg *et al.*, 2001.) as well as after plantar fasciitis (Chandler & Kibler, 1993). Although these two approaches were not described specifically for the treatment of symptoms of CPCS in the literature, it was decided to apply these two approaches as intervention techniques for CPCS. This decision was based on the fact that all the injuries occur in the lower limb, and both CPCS and plantar fasciitis are fascia-related injuries.

The choice of proprioceptive retraining as an intervention technique was based on the evidence found in the literature that some of the proprioceptive receptors are located in the fascia (Brown, 1980). The researcher thought it was possible that dysfunctional fascia might lead to abnormal feedback via the proprioceptive receptors located in the dysfunctional fascia. If the proprioceptive feedback can be improved by proprioceptive rehabilitation, it might have a positive effect on the symptoms of CPCS by decreasing or alleviating the symptoms.

Phase 2

Approach followed

The same conventional intervention approach was followed as described during phase 1, together with an eccentric- and concentric strengthening programme of the calf muscles (Varelas *et al.*, 1993) as well as proprioceptive retraining programme (Chandler & Kibler, 1993) to improve the subject's balance reactions.

Treatment period

15th April 2002 to the 3rd May 2002 (just more than three weeks)

Number of sessions

Five

The subject received a training programme for the strengthening exercises. Calf muscles were strengthened concentrically by doing calf raises, one leg at a time. Calf raises were done daily in sets of three with 15 repetitions in each set. Eccentric calf muscle strengthening was combined with proprioceptive retraining on a balance board. The calf muscles were strengthened eccentrically by doing proprioceptive retraining on a balance board, with the knees in a degree of flexion. The subject spent two minutes twice a day on the balance board, throwing a ball against a wall at slightly different angles and catching it. One minute was spent standing with both legs on the balance board, while the remaining time on the board was divided between the left and the right leg (30 seconds per leg).

Outcome measures

The following outcome measures on the 3rd May 2002 showed no improvement:

- The intensity of pain/discomfort at rest as well as the amount of pain / discomfort at the end of every training session as plotted on a 100 mm visual analogue scale (VAS): 20 – 40 mm.
- The distance run before the commencement of the symptoms with every training session: one to three km.
- The total weekly-distance run: six to nine kilometres.
- The palpation findings of the soft tissue of the posterior lower leg. This was tight exactly in the same places as with the first assessment.

Synthesis/discussion

The interventions did not result in the desired outcome, namely the alleviation of the symptoms of CPCS. At this point most of the findings are inconclusive. It is however possible to eliminate some of the issues raised. For convenience the rival theories will be addressed first.

The rival proposition that the treatment of the soft tissue in the calf-area will not lead to the alleviation of the symptoms of CPCS, as a different theoretical framework is responsible for the pathogenesis of the condition, can thus not be discarded.

Similarly, the rival theory that the alleviation of the symptoms of the condition will be due purely to chance, i.e. the intervention has nothing to do with it, can also be discarded. The soft tissue mobilization would in all probability have improved blood flow in the area, but insufficiently to reverse the condition.

The rival theory that the interventions have not been applied long enough also seems unlikely. During the interventions no positive response had been achieved. If interventions are successful, one would expect an incremental response to the application thereof.

The last of the rival theories, which challenges the competence of the researcher, is only of academic importance. It does however need to be addressed. The researcher is nationally acclaimed by the physiotherapy community for her applied skills and this theory is here forth discarded.

The proposition formulated has two components. The first addresses the reduction of pressure in the calf area which clearly has not been achieved. As was shown during the literature review, the surgical release of the pressure in the calf-area is the only intervention that had any degree of success. The second deals with increased blood flow to the area, which has as been stated earlier, insufficient to reverse the situation.

Conclusion

The current theoretical model does not provide an obvious mechanism for forecasting replication results in the application of treatment interventions for CPCS and calls for further exploration.

Propositions

Based on the aforementioned the propositions were adapted to the following:

"An intervention technique that will lead to a reduction in the pressure in posterior compartment will lead to the alleviation of the symptoms of CPCS".

Rival theories

The rival theory was adapted as follows:

The rival theory is that the treatment of the soft tissue in the calf-area will not lead to the alleviation of the symptoms of CPCS, as a different theoretical framework is responsible for the pathogenesis of the condition.

Phase 3

Approach followed

Interventions were then focused on the fascia and the release of associated muscles. The methodology as described in chapter four was applied (4.3.16 - mobilizations 1 to 3). Specific soft tissue mobilizing techniques were applied to the various fascia septa in the lower leg (such as the posterior inter-muscular septum and the deep transverse fascia). These interventions were supplemented by stretches for the soleus- and the gastrocnemius muscles.

Treatment period

10th May 2002 to the 2nd July 2002 (seven weeks).

Number of sessions

Five

During the first week of July 2002, the subject had insoles made by a podiatrist. These however caused severe blistering during running underneath her medial foot bridge. Video assessment of her gait while running on the treadmill with the insoles revealed an increase in abnormal movement patterns. Reassessment the running gait on the treadmill demonstrated an exaggeration of all the previously described gait abnormalities recorded on the video clips, especially the degree of inversion at the calcaneus during the pre-swing phase. During the phase of initial swing, her ankles went into an increased degree of inversion (shifting the weight from the second to the fourth metatarsal head), followed by an increased amount of eversion (seemingly uncontrolled) during the mid- to terminal swing phase in an attempt to correct the exaggerated inversion position. After one week the athlete stopped using the insoles.

Outcome measures *(as measured on the 2nd July 2002)*

- The intensity of pain / discomfort at rest as well as the amount of pain/discomfort at the end of every training session as plotted on a 100 mm visual analogue scale (VAS) improved slightly: 20 to 10 mm.
- The distance run before the commencement of the symptoms with every training session improved slightly: two to four kilometres
- The total weekly distance run improved slightly: 9 to 12 kilometres.
- The palpation findings of the soft tissue of the posterior lower leg demonstrated the following changes: The previously described tight area over the peroneus longus muscle in the middle one third of the lower leg on the left side was less tight on palpation.

As can be seen from the above, the interventions generated improvements for the first time. This could be attributed to the fact that the treatment was aimed more specifically at the fascia. This indicated that the solution to the symptoms of CPCS lies in the release of the tightness in the fascial web which is responsible for constricting the function of the muscles enclosed in the posterior compartment. This raised the question as to what the most effective manner would be for releasing the restricting/limiting fascia.

The literature search revealed fascia as a continuum that surrounds, encapsulates, and is intertwined with the muscles. One can thus hypothesise that inflammation, muscle spasm and trigger points in the muscles, etc. would in effect generate stresses on the fascial-web. Such stresses will be transmitted through the web to areas such as the calf area, and could indeed trigger the CPCS condition. This argument is supported by the success with the release of some of the more proximal muscles that are also linked via the fascial chain.

Since the fascia is a continuum, it is possible that there might be an anatomical relation between the muscles encapsulated in the fascia of the posterior compartment and the more proximal soft tissue, i.e. the soft tissue above the knee.

The formation of a non-functional scar, following a period of inflammation, could result in excessive cross-link formation or shortening of the involved connective tissue. Intervention techniques can be used to either break down excessive cross-links or to gain length in the myofascial tissue. These techniques have been described in chapter three.

Conclusion

Based on these findings and deductions made, the treatment interventions will be adapted as follows:

In addition to the fascial mobilization techniques applied during the third phase, all the tight muscles in the leg and lower back identified during the assessment will be mobilized. The following techniques will be applied:

- The trigger point therapy techniques (Travell & Simons, 1999);
- The myofascial release techniques (Barnes, 1990; Manheim, 1994); and
- Specific soft tissue release techniques (Hunter, 1998).

Phase 4

Approach followed

The approach followed was based on intervention by means of the mobilization of the more proximal posterior soft tissue. During this period, the subject followed her exercise programme (stretches of the calf muscles, strengthening of the calf muscles and proprioceptive retraining). The tight posterior soft tissue proximal and distal to the calf muscles was identified through the soft tissue assessment and mobilized. In addition to the calf muscle, the following soft tissue was found to be tight and was mobilized:

- The plantar fascia;
- The hamstring muscles;
- The sacrotuberous ligament and the piriformis muscles.

The plantar fascia was released through a myofascial release technique (Barnes, 1990); the semimembranosus, semitendinosus, biceps femoris and the sacro-tuberous ligament were released using specific soft tissue release techniques (Hunter, 1998) and a trigger point in the piriformis muscle was released (Travell & Simons, 1999).

Treatment period

5th July 2002 to the 25th September 2002 (11 weeks).

Number of sessions

14.

Outcome measures *(as measured on the 25th September 2002)*

- The intensity of pain/discomfort at rest as well as the amount of pain/discomfort at the end of every training session as plotted on a 100 mm VAS demonstrated good improvement: 0 mm – no pain.
- The distance run before the commencement of the symptoms improved: she could run ten kilometres without pain, discomfort or numbness of the feet.
- The total weekly distance run improved to 27 kilometres. She was still able to run 21 kilometres symptom free, 35 months after the last physiotherapy session.
- The palpation findings of the soft tissue of the posterior lower leg improved slightly: The medial parts of both Achilles tendons were not swollen any more and the alignment more normal (no convex curving any more). Although still tight on palpation bilaterally, the plantar fascia felt less tight.
- Flexibility of the soleus muscles improved: From four to 30 mm on the left side and from six to 32 mm on the right side.

Despite the improvements in the outcome measures, the athlete still felt the need to work hard at her stretches and proprioception in order to remain symptom free. She said that, although she experienced no symptoms, she felt as though the tightness in her calf muscles gradually increased after a two week period of doing no exercises.

Synthesis/discussion

The intervention by means of the mobilization of the more proximal posterior soft tissue was responsible for the first improvements of the symptoms of CPCS. These improvements created a direct link between the research outcomes and the emerging theoretical reasoning. Although the subject was involved with exercise programme (stretches of the calf muscles, strengthening of the calf muscles and proprioceptive retraining) during this period, it could not have made any significant contribution towards the release of the constraining fascia border within the posterior compartment. Similar to the surgical release of the involved fascia, the intervention had resulted in a loosening of the "non-compliant fascia border", which alleviated the symptoms.

Conclusion

These interventions based on the release of fascia through the mobilization of the more proximal posterior soft tissue appear to provide a logical framework for predicting replication of results.

New theoretical framework

The entrapment/restriction of the fascia external to the calf area could be responsible for the pathogenesis of CPCS and the release of tightness in more proximal posterior soft tissue will lead to a reduction in the pressure in the calf area, which in turn will lead to the alleviation of the symptoms of CPCS.

Proposition

Based on the aforementioned, the propositions were adapted to the following:

Interventions based on the release of fascia through the mobilization of the more proximal posterior soft tissue will reduce the pressure in the posterior compartment, which in turn will lead to the alleviation of the symptoms of CPCS.

Rival theories

The rival proposition that the treatment of the soft tissue in the calf-area will not lead to the alleviation of the symptoms of CPCS, as a different theoretical framework is responsible for the pathogenesis of the condition, must be accepted.

4.2.2.11. Conclusion

The first case study has revealed that the current theoretical framework does not provide a logical framework for predicting the effects of treatment interventions. The research has indicated a strong possibility that the condition might be resolved by focussing on the fascial web, and particularly at releasing the fascia that are intertwined with more proximal posterior muscles. The chronological development of the first case study is reflected in Figure 5.2.

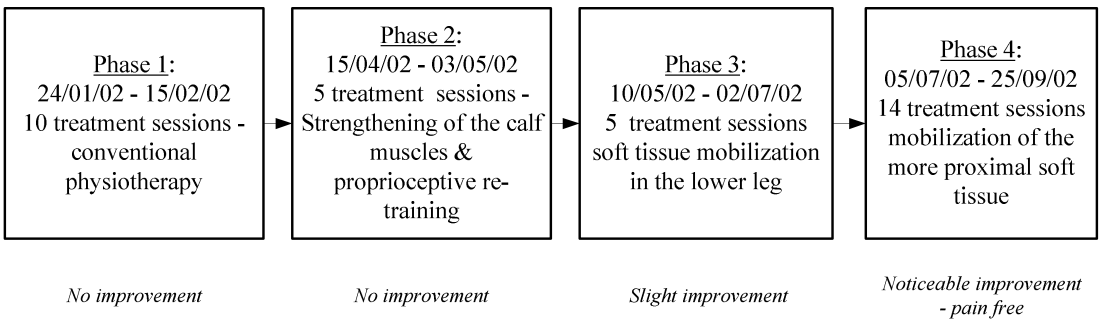


Figure 4.2: The chronological development of Case Study 1.

Note: Subject 1 was discharged in 2002. In 2006 she completed the Comrades marathon without any problems. The researcher saw her again at the Skukuza half-marathon in August 2007 and she was still running pain free.

4.2.2.12. Knowledge integration

The exploratory research has revealed that the fascia, and in particular the impingement thereof in the more proximal posterior muscles play a significant role in the perpetuation of the condition.

Knowledge gained from this study that will be applied in the next case study:

- *The subjects should run bare foot on the treadmill during the video assessment of the running gait to allow surface anatomical markings on the legs to be identified clearly. It might be informative to measure the degree of hind foot pronation in other subjects. The objective is to determine whether the degree of hind foot pronation plays as big a role in the symptoms of CPCS as it does in other running injuries (Hintermann & Nigg, 1998).*
- *It may be necessary to mobilize the other tight proximal soft tissue (myofascial) structures since the subject only started to improve once the hamstring muscles, the piriformis muscles as well as the sacrotuberous ligament have been released. It may therefore be important to identify other more proximal muscles that are tight and that might lead to a further decrease in symptoms when mobilized.*

The modified theoretical framework as a result of these findings is reflected in Figure 4.3.

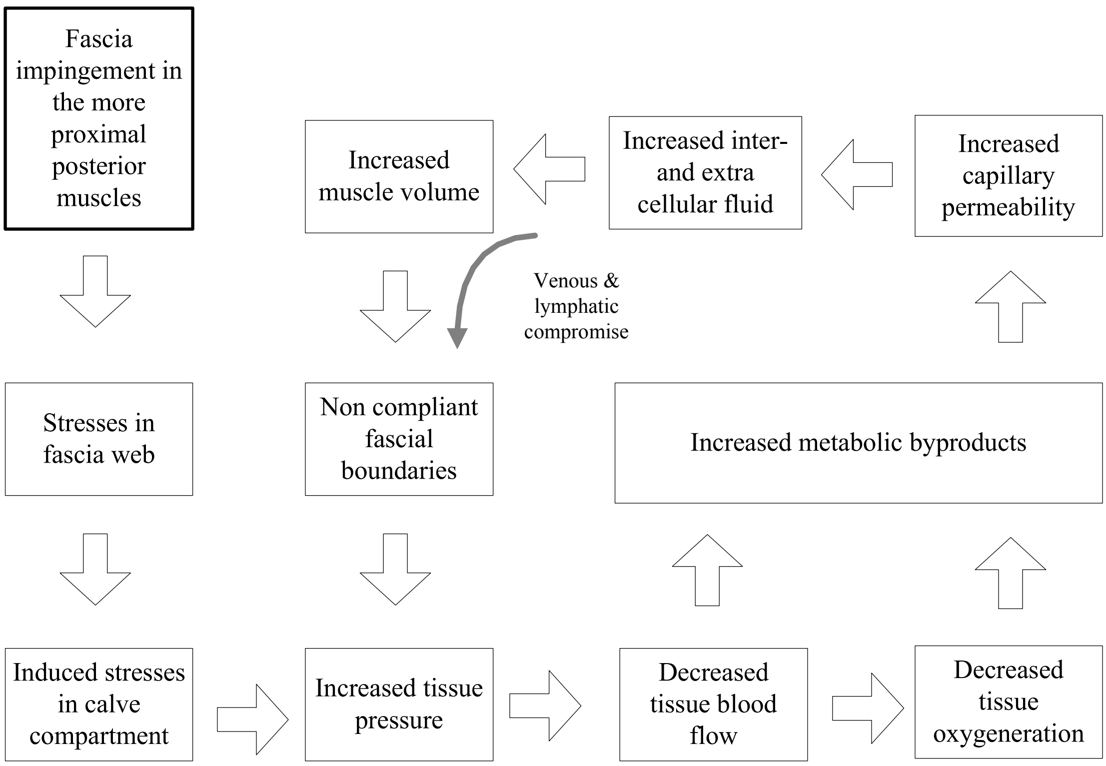


Figure 4.3: Modified theoretical framework (Case Study 1)

4.2.3. CASE STUDY 2

4.2.3.1. Introduction

Case Study 2 is the second of the exploratory research cases. This case study is more focused than the first based on the realization from the results of the first that the solution to the problem might lay external to the calf compartment.

4.2.3.2. Subject

The subject in Case Study 2 was a 40 year old male athlete who had been participating in road races for the previous eight years.

Inclusion criteria

He experienced pain in the centre of the posterior aspect of his lower leg on the left together with a constant feeling of tightness/swelling in the calf, which abated with rest. During October 1997 he was diagnosed with CPCS by a general practitioner who specializes in sport injuries.

Exclusion criteria

All the necessary physical tests as described in Chapter 3 were performed to confirm that no exclusion criteria were present. The subject however did not experience lumbar nerve root pain. Although the pain was primarily on the left side, the right calf was also tight/ swollen and he had previously experienced the same symptoms on the right side.

4.2.3.3. The research question

Could the entrapment/constriction of the fascia external to the calf area be responsible for the pathogenesis of CPCS and will the release of tightness in more proximal posterior *soft tissue lead to a reduction in the pressure in the calf area, which in turn will lead to the alleviation of the symptoms of CPCS?*

4.2.3.4. Theoretical framework

The revised theoretical framework is reflected in Figure 4.3.

4.2.3.5. Propositions

Interventions based on the release of fascia through the mobilization of the more proximal posterior soft tissue will reduce the pressure in the calf area, which in turn will lead to the alleviation of the symptoms of CPCS.

4.2.3.6. Rival theories

The following rival theories can be postulated:

- *The exercise programme was responsible for the alleviation of the symptoms.*
- *The interventions responsible for the alleviation of the symptoms of CPCS are not limited to the more proximal posterior soft tissue but extend to other areas as well.*

4.2.3.7. Criteria for interpreting results

The criteria were the degree of conformance to the propositions made.

4.2.3.8. The Research Procedure

Subjective assessment - Interview

- ***Running history***

The subject had been participating monthly in road races for the previous eight years. The distances varied from 10 to 91 kilometres. His average running pace was five and a half minutes per kilometre. He never increased his training programme by more than ten percent per week. He had been running in the same brand of neutral running shoe for the past six years and never ran more than 800 kilometres with a pair.

o ***Previous running injuries***

He was involved in a motorbike accident during 1984 which resulted in reconstructive surgery (1985) for the anterior cruciate ligament of his right knee. Whilst at school, he injured some of the tendons/ ligaments around his right ankle.

o ***Symptoms noted***

Muscle strength was tested by a biokineticist on a calibrated Isokinetic dynamometer, using a standardized testing protocol. The results are shown in Table 4.2. Statistical significant differences between left and right are reflected in italics.

Table 4.2: Muscle strength results prior to intervention: Case Study 2

Movement tested **	***Peak torque (Nm)***			***Work per repetition(Nm/s)***		
	Right	***Left***	***Deficit***	***Right***	***Left***	***Deficit***
Hip extensors	132	113	*-14*	158	135	*-15*
Hip flexors	75	84	*-11*	87	90	-3
Hip internal rotators	17	24	*-29*	13	22	*-41*
Hip external rotators	24	27	*-11*	17	27	*-37*
Hip abduction	68	110	*-38*	38	65	*-42*
Hip adduction	118	153	*-23*	80	100	*-20*
Knee extensors	113	182	*-38*	111	193	*-42*
Knee flexors	69	115	*-40*	79	142	*-44*
Knee internal rotation	20	28	*-29*	15	20	*-25*
Knee external rotation	21	26	*-19*	17	20	*-15*
Ankle inversion	37	36	-3	31	46	*-33*
Ankle eversion	26	38	*-32*	23	49	*-53*
Ankle plantar flexors	67	89	*-25*	41	53	*-23*
Ankle dorsi flexors	22	37	*-41*	16	24	*-33*

o *History of symptoms and treatment received*

The symptoms had first been experienced on a training run in October 1997, two weeks prior to the Berlin Marathon. His left calf muscles were very sore and felt swollen. He rested for the remaining two weeks prior to running the Berlin Marathon. While participating in the race, his left calf muscles felt tight from the beginning of the race and the associated pain gradually grew worse throughout the race. After the race, his left calf muscles were very sore for a couple of months and the calf muscles of both his left and right legs felt tight and swollen.

Back in South Africa, a couple of weeks after the Berlin Marathon, he consulted a general practitioner, who specializes in the treatment of sport injuries. The practitioner diagnosed him with CPCS and recommended that he rested for eight weeks and during these eight weeks he was instructed to undergo a strengthening programme on the Isokinetic dynamometer for the dorsi flexor - and the plantar flexor muscles of the ankles.

Eight weeks later, he resumed his training programme. During February 1998, he felt fit enough to participate in a 32 kilometre race. About six kilometres into the race, he felt a pain in his right calf muscles. The further he ran the more painful and the tighter his right calf muscles became. Although he completed the race, he was forced by the pain in his right calf to walk a great part of it. After the race, his right calf muscles were very sore and both calves felt very tight. Following this second incident of calf muscle pain, he tried a variety of treatment approaches namely:

- Physiotherapy, consisting of massage of the muscles of the lower leg, cross-frictions of “adhesions” in the calf muscles, ultrasound- and interferential therapy over the area involved as well as calf muscle stretches. The physiotherapy had no beneficial effects and the stretches made his symptoms worse.
- After a number of physiotherapy sessions, he underwent a programme on the Isokinetic dynamometer to strengthen the plantar- and dorsi flexor muscles of the ankles. After confirmation that his plantar- and dorsi flexor muscles were again of normal strength, he had still not experienced any relief from the symptoms of PCS.

He decided to rest again for eight weeks, after which he resumed his training. He followed a very conservative running programme, increasing the distance by not more than ten percent every second week. On the 10th of February 2003, a pain in his left calf forced him to walk after he had been running a distance of three and a half kilometres. He commenced running again on the 24th of February 2003, but was forced to walk due to pain in the left calf after running four kilometres. He rested his injury until he could walk comfortably again. He ran again on the 6th of March 2003. After two and a half kilometres he was forced by pain in his left calf to walk. On the 10th of March 2003 after a screening assessment, he was included into the study. In summary, the subjective outcome measurements as measured before the intervention:

- The intensity of pain/discomfort at rest was 60 on the 100 mm VAS.
- He could not run at all.

The Objective assessment - Physical examination

o ***Muscle strength tests***

Muscle strength was tested by a biokineticist on a calibrated Isokinetic dynamometer, using a standardized testing protocol. The results are shown in Table 4.2.

o ***Analysis of running gait, including movement patterns***

The subject was videotaped while running, from both sides as well as from posterior. The subject ran bare footed on the treadmill during the videotaping. Details of the observations found during the gait analysis are provided in Table 4.3. The following movement patterns deviated from the normal/ideal running patterns:

Table 4.3: Outcomes of running gait analysis for Case Study 2 prior to intervention

Running gait analysis: Case Study 2 - 10/03/2003)								
	Weight Acceptance		***Single Leg Support***			***Swing Leg Advancement***		
Joint	***Initial Contact***	***Loading Response***	***Mid-stance***	***Terminal Stance***	***Pre-swing***	***Initial Swing***	***Mid-swing***	***Terminal Swing***
Pelvis						Occasionally, there is an increased degree of posterior pelvic rotation on the left compared to the right.		
Hip				The left hip is in more lateral rotation and extension in comparison to the right side.	The left hip is in more lateral rotation and extension in comparison to the right side.	Both hips start to move into internal rotation from the externally rotated position. Every 3rd or 4th stride, there is an irregularity on the left side with an increased amount of left external rotation accompanied with more of a posterior pelvis rotation on the left.	Both hips are in flexion and internal rotation. An increased degree of internal rotation on the left follows on the occasional increased lateral rotation on the left.	
Knee	Both knees: almost full extension with the tibias in external rotation. A slightly greater right knee extension in comparison to the left.	The degree of knee extension decreases slightly in both legs.	The amount of knee extension increases slightly again with the tibia being in external rotation.	The tibias move into more external rotation with the knees in extension.	Both knees are extended with some external rotation of the tibias.	Both knees move out of extension and external rotation into flexion.	Both sides: flexion and internal rotation.	Both sides: extension and external rotation.
Ankle	Both ankles: no heel-toe action. Lands with both the feet fractionally first on the lateral side of the foot (5th metatarsal bone).	On both sides, there is a weight shift to the medial side of the foot.	Both hind feet are in pronation. The eccentric control is less on the left side; after weight acceptance, the hind foot on the left side sinks further into valgus. Both feet are in a position of abduction.	The hind foot move out of a pronated position into neutral.	The hind foot on the right moves more into inversion in comparison to the left side.	The hind foot on the right moves more into inversion in comparison to the left.	Both ankles are in slight plantar flexion and slight inversion.	Slight plantar flexion and inversion.
Toes				The subject rises higher onto his fore foot than normal.				The extensor tendons of the lateral 4 toes are very active.

- Throughout the running phases, the pelvis on the left side remained slightly more posteriorly rotated in comparison to the right side.
- During terminal stance and pre-swing phases, the left hip moved into more lateral rotation and extension in comparison to the right side. Occasionally, every third or fourth stride, there was an increase in the amount of lateral rotation and extension on the left, followed by an increased medial rotation on the forward movement of the left hip as counter action. This phenomenon was observed as a "wobble" in the left ankle.
- There was no heel toe action and during mid stance, the calcaneus sunk into more of a valgus position on the left than would normally be expected. During the pre-swing phase the calcaneus on the right sides moved into inversion as though there was a slight weight shift from the second metatarsal head to the third metatarsal head.
- The subject had a greater degree of metatarsophalangeal extension in the forefoot during the push off than what one would normally expect.

o ***Measurement of specific biomechanical angles***

The measurements of the degree of dorsi flexion at the ankle joint, and the degree of extension at the first metatarsophalangeal joint was done as described respectively in Chapter 3 sections 3.4.2.8. The biomechanical measurements are provided in Table 4.4.

Table 4.4: Biomechanical angles: Case Study 2 during intervention – (15/05/2003)

Movement	***Joint Range of Movement (degrees)****	
	Mid stance	***Terminal stance***
Dorsi flexion left	7, 33°	15, 33 °
Dorsi flexion right	10, 33 °	18, 00 °
Metatarsophalangeal extension left		47, 00 °
Metatarsophalangeal extension right		40, 33 °
Hind foot pronation left		9, 00 °
Hind foot pronation right		9, 00 °

* *Averages of three measurements*

- ***Soft tissue palpation***

The left and right sides of the body were compared to each other, and all the soft tissue palpated in order to assess the extent of tightness.

Left side:

The plantar fascia felt tight as well as the lateral side of the calf muscles (gastrocnemius muscle). The soleus muscle, palpated from anterior, felt tight. The iliotibial band and the central part of the hamstring felt tight. This palpated tightness extended into the gluteus maximus muscle on the left side. Higher up, the fascia- junction between the latissimus dorsi muscle and the trapezius muscle in the vicinity of T8 felt tight. In the trunk area, the quadratus lumborum and the erector spinae muscles felt tight.

Right side:

The lateral part of the calf muscles felt tight (tighter compared to the left side, but along a smaller area). The soleus muscle, palpated from the anterior also felt tighter than the left side. The right iliotibial band felt tight as well as the fascia-junction of the latissimus dorsi muscle and the trapezius muscle in the vicinity of T8. This fascia junction seemed tighter on the right than the left side. In the area of the trunk, the quadratus lumborum and the erector spinae felt tighter on the right than on the left.

- ***Flexibility/length of the soleus muscle***

  - *Right soleus muscle: Big toe ten mm from the wall*
  - *Left soleus muscle: Big toe 12 mm from the wall*

4.2.3.9. Intervention and data recording

With this subject, the mobilizing of the distal and the more proximal tight soft tissue structures were included from the start. All the tight soft tissue identified during the assessment was mobilized.

Phase 1

Approach followed: Intervention by means of the mobilizing of the distal and the more proximal posterior soft tissue.

The following soft tissues were mobilized:

- plantar fascia (myofascial release according to Barnes, 1990),
- the gastrocnemius and soleus muscles. The soleus muscle was mobilized through specific soft tissue techniques according to Hunter (1998), working from the anterior aspect medial to the tibia. The gastrocnemius muscle was released with myofascial release techniques (Mannheim, 1994),
- the pes anserine (myofascial release technique of the adductor muscles) (Mannheim, 1994),
- the ilio tibial band (myofascial release techniques) (Manheim, 1994),
- the hamstring muscles (specific soft tissue mobilization techniques) (Hunter, 1998),
- the gluteus maximus (trigger point release) (Travell & Simons, 1999),
- the piriformis muscles (trigger point release) (Travell & Simons, 1999),
- the sacrotuberous ligament (specific soft tissue mobilization techniques) (Hunter, 1998),
- the quadratus lumborum muscle (trigger points release) (Travell & Simons, 1999),
- the erector spinae (myofascial release technique) (Mannheim, 1994) and
- the fascial link between the latissimus dorsi- and the lower fibres of the trapezius muscle in the vicinity of T8 (Hunter, 1998).

Stretches for the piriformis muscle, as well as the hamstring muscles was introduced at this stage. This was in addition to stretches of the calf muscles introduced in the initial treatment programme. These stretches did not aggravate his symptoms. The descriptions of the newly introduced stretches are as follows:

Piriformis stretch

- The supine subject crossed the leg on the side to be stretched over the opposite thigh, and rested the opposite hand on the knee of the uppermost limb to be stretched.
- This hand is used, when needed, to assist gravity in adducting the leg to be stretched, which is flexed 90°.
- The subject stabilizes the hip on the side to be stretched by pressing down on the iliac crest with the ipsilateral hand. (Travell & Simons, 1999)

Hamstring stretch in sitting

- Sit on the floor with the leg to be stretched extended, and the other leg bent with the foot towards the body.
- Reach out with the hands, lean the upper body forwards, and bring the chest towards the thigh.
- Care must be taken not to round the upper back; the lower back should be slightly curved.
- Get to the point of a mild stretch and hold.
- Repeat for each leg.

Hamstring stretch in supine

- Lie on the back with the legs out.
- Raise the leg to be stretched with the knee bent.
- Grasp the calf or thigh and gently pull the leg towards the body.
- Get to the point of a mild stretch and hold.
- Repeat for each leg.

o ***Treatment period***

10th March 2003 – 28th May 2003 (six weeks)

- ***Number of sessions***

11 treatments were performed between the 10th March 2003 and the 28th May 2003.

- ***Outcome measures** (as measured on the 28th May 2003)*

At the end of May, he was running 12 kilometres per week without any pain. A videotape of his running gait was repeated at this stage. His running gait had improved in terms of symmetry and abnormal movement patterns. The increased lateral hip rotation, followed by an increased medial rotation upon hip flexion that occurred on the left side with every third or fourth stride, disappeared. His calf (soleus) muscle flexibility improved from ten mm to 28 mm on the right and from 12 mm to 29 mm on the left (distance of toe from wall in knee-to-wall test).

- ***Synthesis/discussion***

Subject two has had symptoms of CPCS since October 1997 and had previously tried physiotherapy, strengthening of the plantar flexor muscles on the Isokinetic dynamometer, and stretches of the calf muscles to no avail. With the new approach of mobilizing the more proximal soft tissue, the subject was pain free within a period of two and a half months (11 treatment sessions).

- ***Conclusion***

This led to the notion that the anterior soft tissue distally as well as proximally might also be tight and that the mobilizing of these soft tissue links might further aid the outcomes of the treatment approach. Working additionally on the anterior tight soft tissue (myofascial links) might cause the symptoms of CPCS to disappear more quickly. With the next subject the anterior myofascial tissue would be mobilized additionally. The exercise programme as a possible causal factor for success can safely be discarded as a rival theory in the light of that with Case Study 2, no strengthening programmes were utilised.

- ***New theoretical framework***

The entrapment/constriction of the fascia external to the calf area could be responsible for the pathogenesis of CPCS and the release of tightness in more proximal posterior as well as the anterior soft tissue will lead to a quicker response to the interventions.

- ***Propositions***

Based on the aforementioned the proposition was adapted to the following:

Interventions based on the release of fascia through the mobilization of the more proximal posterior as well as anterior soft tissue will lead to a quicker response to treatment interventions.

- ***Rival theories***

  - *The positive response to the interventions is due to the stretching programmes.*
  - *The improvements are purely by chance and there is a different theoretical framework responsible for the pathogenesis of CPCS.*

An argument that could have been raised with Case Study 1 is that the improvements were due to the fact that the interventions had been applied long enough in order to be effective. The quick response of Case Study 2 with its focus on the more proximally muscles, defeats this argument.

4.2.4. CASE STUDY 3

4.2.4.1. Introduction

Case Study 3 is the last of the exploratory case studies and is more focused than the first two due to the realization that the solution to the problem lay external to the calf compartment.

4.2.4.2. Subject

The subject was a 32 year old female athlete participating in ten kilometre road races.

Inclusion criteria

She complained of symptoms of CPCS in both legs that increased during running and decreased with rest. She complained of pain and stiffness over the posterior-lateral and especially over the posterior-medial aspect of the middle one-third of the posterior part of both lower legs. She also experienced stiffness, but to a lesser extent, over the anterior-lateral and the anterior-medial aspect of both the lower legs. She experienced constant discomfort with walking and climbing stairs. She rated the intensity of the pain as a 65 on a 100mm VAS.

Exclusion criteria

None.

4.2.4.3. The research question

Would the release of tightness in more proximal posterior as well as anterior soft tissue lead to a quicker response in the alleviation of the symptoms of CPCS?

4.2.4.4. Theoretical framework

The theoretical framework that evolved from the exploratory research is reflected in Figure 4.4.

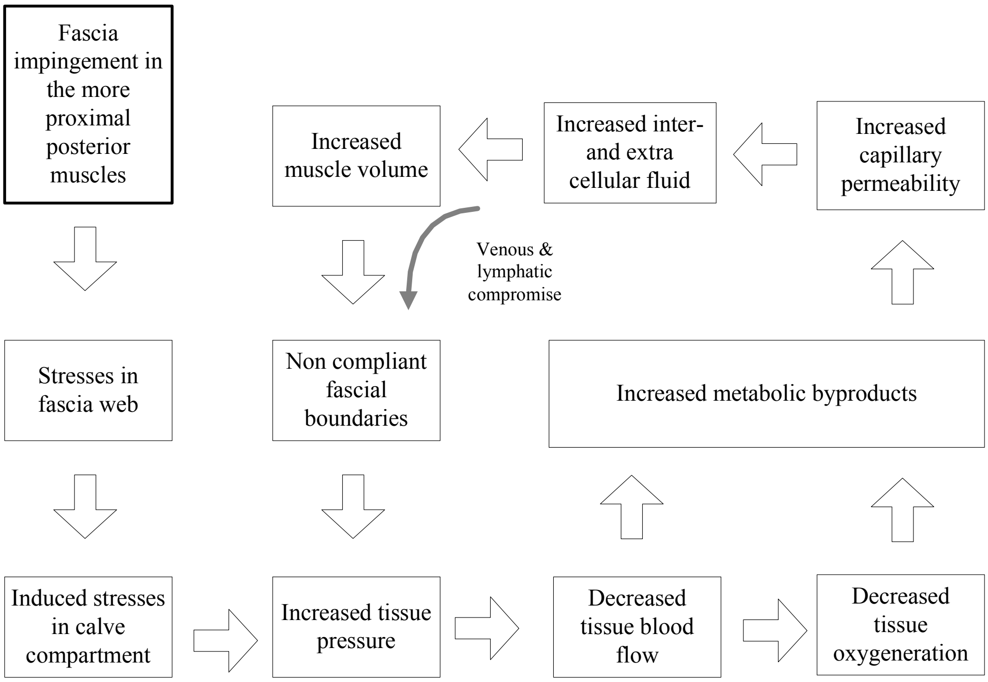


Figure 4.4: The evolved theoretical framework

4.2.4.5. Propositions

Interventions based on the release of fascia through the mobilization of the more proximal posterior soft tissue will reduce the pressure in the calf area, which in turn will lead to the alleviation of the symptoms of CPCS.

4.2.4.6. Rival theories

The following rival theories can be postulated:

- *The exercise programme of the subject in Case Study 1 was responsible for the alleviation of the symptoms of CPCS.*
- *The interventions responsible for the alleviation of the symptoms of CPCS are not limited to the more proximal posterior soft tissue but extend to other areas as well.*

4.2.4.7. The Research Procedure

Subjective assessment - Interview

- ***Running history***

The subject in case 3 was a 32 year old female athlete who had been participating in road races. She ran in ten kilometre races at an average pace of just over six minutes per kilometre. Her programme consisted of a gradual build-up of running distance. She started on the walk/ run programme and her running time gradually increased to the point where she was running for a full five kilometres. This programme was followed three times a week. She was running in slight anti-pronation shoes.

- ***Previous running injuries***

The subject had no history of any previous running injuries. She had had an operation for the removal of bunions on both feet two years previously.

- ***Symptoms noted***

She was assessed on the 13th May 2003. She complained of pain and stiffness over the posterior-lateral and especially over the posterior-medial aspect of the middle one-third of the posterior aspect of both lower legs. She also experienced stiffness, but to a lesser extent over the anterior-lateral and the anterior-medial aspect of both the lower legs. At the time of her first consultation, she found it too painful to run. She experienced constant discomfort with walking and climbing stairs. The intensity of the pain was 65 on a 100 mm VAS.

- ***History of current symptoms and previous treatment received***

She had experienced the symptoms for a period of four months. When she reached the stage where her calves became too painful to run, she exchanged the running for a two-week programme of stretching and strengthening work in the gymnasium. Her calves improved and she could resume the running again, which was followed by a gradual build-up of pain and tightness. She had no treatment. Subjective outcome measures were:

- The intensity of pain / discomfort at rest was 65 on the 100 mm VAS.
- She could not run at all.

Objective assessment – Physical examination

o ***Muscle strength tests***

Muscle strength was tested on a calibrated Isokinetic dynamometer, using a standardized testing protocol.

Table 4.5: Muscle strength results* prior to intervention: Case Study 3

	Peak torque (Nm)			***Work per repetition(Nm/s)***		
Movement tested*	***Right***	***Left***	***Deficit***	***Right***	***Left***	***Deficit***
Hip extensors	85	99	*-14*	123	144	*-14*
Hip flexors	46	39	*-15*	60	62	-4
Hip internal rotators	5	5	*0*	4	5	*-25*
Hip external rotators	8	9	*-14*	7	8	*-17*
Hip abduction	30	43	*-31*	11	20	*-47*
Hip adduction	4	26	*-84*	1	11	*-88*
Knee extensors	71	79	*-10*	81	84	*-3*
Knee flexors	46	43	*-6*	61	56	*-9*
Knee internal rotation	9	8	*-14*	8	8	*0*
Knee external rotation	12	11	*-11*	12	11	*-11*
Ankle inversion	15	11	*-27*	22	14	*-38*
Ankle eversion	15	12	*-18*	22	14	*-38*
Ankle plantar flexors	57	53	-7	39	34	*-14*
Ankle dorsi flexors	18	19	-7	14	12	*-10*

*Statistically significant values between the left and the right sides are reflected in *italics*
** Tested at a speed of 30/30 and with five repetitions

o ***Analysis of running gait, including movement patterns***

A summary of the gait analysis is provided in Table 4.6.

Table 4.6: Outcomes of the running gait analysis for Case Study 3 prior to intervention

Running gait analysis: Case Study 3 (13/05//2003)								
	Weight Acceptance		*Single Leg Support*			*Swing Leg Advancement*		
Joint	***Initial Contact***	***Loading Response***	***Mid-stance***	***Terminal Stance***	***Pre-swing***	***Initial Swing***	***Mid-swing***	***Terminal Swing***
Pelvis	On the left side, the pelvis is in anterior rotation. On the right, the pelvis is also in an anteriorly rotated position, but less compared to the left side.			Both sides are in posterior rotation; right side more than left side.	Both sides are in posterior rotation; right side more than left side.		Both sides move out of posterior rotation.	Both sides move into anterior rotation. Left more than right.
Hip			The hip on the left side is in slightly more adduction than on the right side.	The right hip is in a greater lateral rotation and extension compared to the left side.	The right hip is in a greater lateral rotation and extension in comparison to the left side.	Both hips start to move into internal rotation from the externally rotated position. A periodic irregularity on the right side with an increased amount of external right hip rotation and posterior pelvic rotation on the right.	Both hips are in flexion and internal rotation. Increased medial rotation in on the right side, following the occasional irregularity described in the previous column.	Both hips are in flexion.
Knee	Both knees: almost full extension with the tibia in external rotation.	The amount of knee extension decreases slightly in both knees.	The amount of extension in both knees decrease further with the tibia being in external rotation.	The tibias move into a greater external rotation. With the knees in extension.	Both knees are extended with some external rotation of the tibias.	Both knees move out of extension and external rotation into flexion.	Both sides: Flexion and internal rotation..	Both sides: Extension and external rotation.
Ankle	Definite heel- toe action.	A weight shift to the medial side of the foot on both sides (it moves into a greater everted position).	Hind foot is in pronation. Left and right calcaneus sinks slightly further into valgus, more on the right than on the left. Both feet are in abduction.	The hind foot moves out of the pronated position into a slightly everted position, more on the right. The ankle starts to move into PF.	The hind foot moves into inversion. Ankles are in plantar flexion.	Hardly any push-off. The hind foot moves into greater inversion.	Both ankles are in a position of plantar flexion and a neutral position of the hind foot.	Again: slight plantar flexion in a neutral position of the hind foot.
Toe							Extension, especially of the big toe.	Extension, especially of the big toe.

The following movement patterns deviated from the normal/ ideal running patterns:

- Throughout the running phases, the pelvis on the right side remained slightly more posteriorly rotated in comparison to the left. Although the pelvis on the right moved into anterior rotation during the initial contact phase, the degree of anterior rotation was still less than that on the left.
- During the terminal stance and pre-swing phases, the right hip moved into more lateral rotation and extension compared to the left. Occasionally a further increase in lateral rotation and extension on the right side occurred, followed by increased medial rotation on the forward movement of the right hip.
- During the phase of mid stance, the calcaneus on the right sunk into more of a valgus position than would normally be expected. Both feet were in a position of abduction. During the initial swing phase, there was hardly any push-off on both sides.
- During the mid swing and the terminal swing phase, the tendon on both the big toes appeared very active.

o ***Measurement of biomechanical angles***

The Biomechanical angles as measured with Corel Draw are provided in Table 4.7.

Table 4.7: Biomechanical angles for Case Study 3 during intervention – (15/05/2003)

Movement	***Joint Range of Movement (degrees)****	
	Mid-stance	***Terminal stance***
Dorsi flexion left	5,25^{o}	11,67 ^{o}
Dorsi flexion right	4,67 ^{o}	12,33 ^{o}
Metatarsophalangeal extension left		45,67 ^{o}
Metatarsophalangeal extension right		53,00 ^{o}
Hind foot pronation left		10,67 ^{o}
Hind foot pronation right		7,67 ^{o}

**Averages of three measurements*

- ***Flexibility/ length of the soleus muscle***

- Right soleus: Big toe five mm from the wall.
- Left soleus: Big toe seven mm from the wall.

- ***Soft tissue palpation***

The left and right sides of the body were compared to each other and all the soft tissue palpated in order to assess the tightness.

- ***Posterior soft tissue assessment***

- The plantar fascia as well as the soleus muscles felt tight on both sides.
- The gastrocnemius muscles felt very tight on both sides.
- The iliotibial band, the gluteus medius-, gluteus maximus- and quadratus lumborum muscles felt tight on both sides, right more than left.
- The hamstring muscles felt tight on both sides, left more than right.

- ***Anterior soft tissue assessment***

- The pes anserine felt tight on both sides, right more than left.
- Both soleus muscles felt very tight.
- The tensor fascia lata felt tight on the right side.
- Iliopsoas muscles felt tight on both sides, but left more than right.
- The pectoralis major muscle felt tight on the left side.

4.2.4.8. Intervention and data recording

Phase 1:

The release of the posterior tight myofascial links, as described in Case Study 2, was done during this phase together with stretches of the calf muscles, the hamstring muscles and the piriformis muscles.

o ***Treatment period***

14th May 2003 to 13th June 2003 (four weeks).

o ***Number of session*:**

Six.

o ***Interventions***

During the first six sessions only the posterior links were treated in order to determine the effect of the release of the anterior links. During the first six treatments, the researcher mobilized:

- the plantar fascia (myofascial release according to Barnes, 1990);
- the gastrocnemius and soleus muscles (the soleus muscle was mobilized through specific soft tissue techniques according to Hunter (1998), working from the anterior aspect; medial to the tibia. The gastrocnemius muscle was released with myofascial release techniques (Mannheim, 1994);
- the ilio tibial band (myofascial release techniques according to Manheim (1994);
- the hamstring muscles (specific soft tissue mobilization techniques according to Hunter);
- the gluteus maximus (trigger point release according to Travell and Simons (1999);
- the quadratus lumborum muscle (trigger point release according to Travell & Simons, 1999); and
- the sacrotuberous ligament (specific soft tissue mobilization techniques according to Hunter, 1998).

All the muscles that were mobilized were followed up by stretches in order to try and maintain the length that had been gained with the soft tissue mobilization. The following stretches were also added to the stretches of the soleus-, the gastrocnemius, the piriformis and the hamstring muscles:

- ***The quadratus lumborum muscle***

Side lying: the lower limb on the side involved was uppermost and extended behind the other lower limb. The subject anchored the ribcage in an elevated position by raising the arm and grasping the head of the treatment table. A pillow underneath the lumbar region further increased the stretch (Travell & Simons, 1999).

- ***Outcome measures** (as measured on the 13th June 2003)*

The subject improved and she was able to run faster (she managed a personal best time during a ten kilometre race) and the distance that she ran per week, increased from nought to 15 to 20 kilometres per week. She ran pain free every second or third run, but during the other runs, she still experienced pain during the run. The pain as indicated on a 100mm VAS, decreased from a 65 to a 40 during a run.

Phase 2

- ***Treatment period***

26th June 2003 to 1st September 2003

- ***Number of sessions***

Five

During the last five treatments, the following tight anterior soft tissue was also mobilized in addition to the posterior muscles:

- both soleus muscles from anterior (specific soft tissue mobilization techniques according to Hunter, 1998);
- the tensor fascia lata on the right (trigger point release according to Travell and Simons (1999) as well as myofascial release technique according to Mannheim (1994);

- both iliopsoas muscles (trigger point release according to Travell and Simons (1999) and myofascial release technique according to Mannheim (1994); and
- the pectoralis muscle on the left (trigger point release according to Travell and Simons (1999); and myofascial release technique according to Mannheim (1990).

Stretches for the iliopsoas muscles and the pectoralis muscles were added:

- ***Iliopsoas muscle***

In side-lying: The subject extended the hip of the upper leg and grasped the upper leg with the uppermost hand. Very carefully without rolling backwards, the subject then increased the amount of hip extension in the uppermost leg by pulling the leg as far backwards as possible (Travell & Simons, 1999).

- ***Pectoralis muscle***

The in-doorway stretch exercise was useful to stretch all of the adductors and internal rotators at the shoulder. To achieve this, the subject stood in a narrow doorway with the forearms against the doorjambs. One foot was placed in front of the other, and the forward knee was bent. The subject held the head erect looking straight ahead, neither craning the head forward nor looking down at the floor. As the forward knee bent and the subject leaned through the doorway, a slow, gentle passive stretch was exerted bilaterally on the pectoralis muscles. The hand position against the door jambs was adjusted to vary the stretch on different sections of the muscle. Fibres of the clavicular section were best stretched in the low hand position. By raising the hands to the middle hand-position with the upper arms horizontal, the sternal section was stretched. By moving the hands as high as possible, while keeping the forearms against the doorjambs, the costal and more vertical abdominal fibres that form the lateral margin of the muscle were stretched (Travell & Simons, 1999).

- ***Outcome measures** (as measured on the 1st of September 2003)*

The following noticeable changes took place in the parameters following the five treatment sessions in phase two:

- After the second treatment discomfort in the lower legs disappeared after five kilometres.
- After the third treatment, the pain on a 100 mm VAS went down to ten. The area of discomfort reduced to a small area located over the medial aspect of the posterior calf.
- After the fifth treatment she was running pain free for the whole ten kilometres.
- The outcome measures after a total of 11 treatment sessions during the period 13th of May 2003 to the 1st of September 2003 were:
  - She was running 17, 5 kilometres per week pain free and also completed her first 21 kilometre race on the 1st of September 2003. (In 2005 she was still running pain free and had completed her first 32 kilometre race.)
  - Her calf mobility improved from five mm to 30 mm on the right and from seven mm to 30 mm *on the left.*

The knowledge gained from this study which would be applied in the next Case Study, is as follows: Working on the anterior tight muscles accelerated the rate at which the symptoms improved. It was also important to establish which physically palpable muscles are linked via the fascia to the involved calf muscles. If these muscles could be identified through a literature study, they would form the basis of the soft tissue assessment and the soft tissue mobilizations. If these were tight, they might have an influence on the symptoms of CPCS.

4.2.4.9. Integration

Pain/discomfort

The symptoms of the subjects progressively improved as the interventions were adapted to include the mobilization of the more proximal muscles. In terms of pain/discomfort all the subjects were symptom free at the end of the interventions. The intensity of pain/ discomfort as measured prior- and post intervention is summarized in Table 4.8.

Table 4.8: The intensity of pain/ discomfort before and after intervention

Case Studies	***Intensity of Pain VAS- 100mm (visual analogue scale)***		
	1	**2**	**3**
Prior to intervention	*20*	*60*	*65*
Post intervention	*0*	*0*	*0*

Distance run before commencement of symptoms

The distance run before commencement of symptoms is reflected in Table 4.9 below.

Table 4.9: The distance run before commencement of symptoms

Case Studies	***Distance run (km)***		
	1	**2**	**3**
Prior to intervention	*1*	*0*	*0*
Post intervention	*21*	*21*	*21*

Total weekly distance run

The same argument applies in terms of the third outcome measure used, namely the total weekly distance run. The cross case results for this measure are reflected in Table 4.10.

Table 4.10: The total weekly distance run before and after intervention.

Case Studies	***Total weekly distance run (km)***		
	1	**2**	**3**
Prior to intervention	*12*	*0*	*0*
Post intervention	*17*	*12*	*18*

Conclusion

The improvements in all three of the outcome measures were significant.

Muscle imbalances

A comparison of the abnormalities in muscle imbalances between case studies 2 and 3, based on *peak torque performance* is reflected in Table 4.11.

Table 4.11: Muscle imbalances in peak torque performance prior to intervention

Movement tested ** Peak torque	***Imbalances between Left and Right (Nm)***	
	CS 2	***CS 3***
Hip extensors	*-14*	*-14*
Hip flexors	*-11*	*-15*
Hip internal rotators	*-29*	*0*
Hip external rotators	*-11*	*-14*
Hip abduction	*-38*	*-31*
Hip adduction	*-23*	*-84*
Knee extensors	*-38*	*-10*
Knee flexors	*-40*	*-6*
Knee internal rotation	*-29*	*-14*
Knee external rotation	*-19*	*-11*
Ankle inversion	-3	*-27*
Ankle eversion	*-32*	*-18*
Ankle plantar flexors	*-25*	-7
Ankle dorsi flexors	*-41*	-7
Total per Case Study	*14*	*12*

*Statistically significant differences are reflected in *italics*

** Tested at a speed of 30/30 and with five repetitions

4.2.5. Conclusion

During the interventions with these three case studies better outcomes were achieved through treatment techniques applied distally, further proximally, as well as anteriorly from the posterior compartment. This implied that the more proximal and the anterior soft tissue could be connected to the soft tissue of the calf muscles. Based on this argument the anatomical links between the calf muscles and the more proximal anterior and posterior myofascial structures were explored. The progressive improvements in outcomes are reflected in Table 4.12.

Table 4.12: A summary of the chronological progression of case studies 1 to 3

Subjects	***Main approach used***	***Main outcome***
Subject 1	***Phase 1: 24/01/02 - 05/02/02*** - Conventional physiotherapy ***Phase 2: 15/04/02 –03/05/02*** - Calf muscle strengthening and proprioceptive retraining ***Phase 3: 10/05/02 - 02/07/02*** - Soft tissue mobilization aimed specifically at the fascia ***Phase 4: 05/07/02 - 25/09/02*** - Mobilization of the more proximal soft tissue plus stretches	No improvement No improvement Slight improvement Noticeable improvement
Subject 2	***Phase 1: 10/03/03 –28/05/03*** - Mobilization of the more proximal posterior soft tissue plus stretches	Progressive improvement
Subject 3	***Phase 1: 14/05/03 -13/06/03*** - Mobilization of the more proximal posterior soft tissue plus stretches ***Phase 2: 26/06/03 -01/09/03*** - Mobilization of the more proximal anterior and posterior soft tissue plus stretches	Noticeable improvement Noticeable improvement

4.3. THE DEVELOPMENT OF THE CONCEPT OF CLINICALLY SIGNIFICANT MUSCLES

4.3.1. Introduction

The relative successes which were achieved with the mobilization of muscles external to the calf area, led to the exploration of the relationships that exist between these muscles and the fascia that link them to the fascia surrounding the muscles of the posterior compartment. The required knowledge with regard to these relationships however did not exist at the outset of this research. Information on fascia obtained from the literature research covered in Chapter 2, was fragmented. In order to create a holistic perspective of these relationships the contributions of various researchers had to be integrated into a bigger picture.

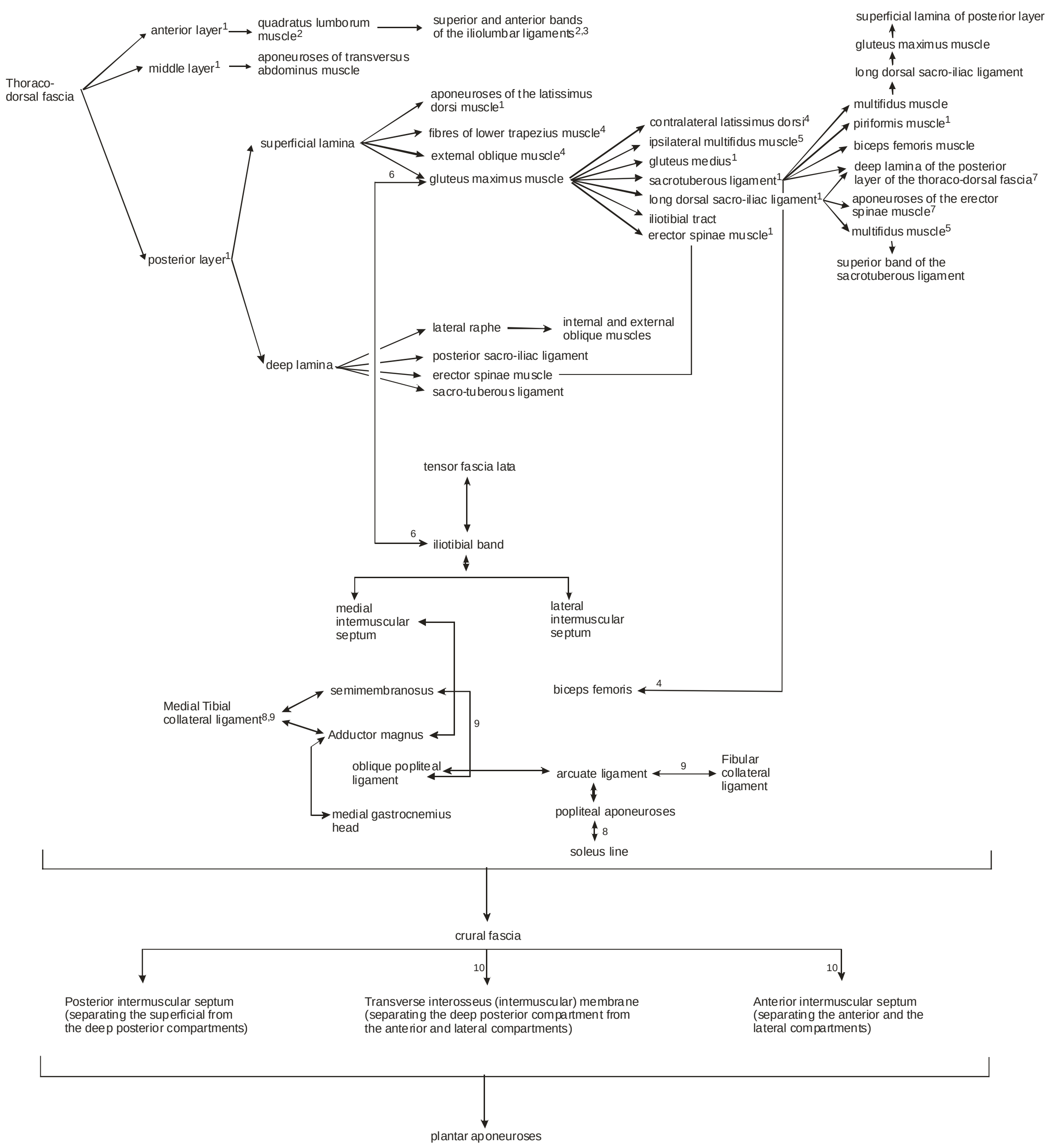
4.3.2. Myofascial links and clinically significant muscles

Comprehensive maps were created through the integration of information from various researchers that reflects these relationships that exist between the muscles and the myofascial web. This led to a clearer understanding of the relationships between the muscles external to the calf-area and the fascia surrounding the posterior compartment, and how these links could influence stresses in the fascia of the posterior compartment. The results of the knowledge integration of these myofascial links of the trunk and the leg are summarized in Figures 4.5 and 4.6. These figures represent a significant and original contribution of the research project. The muscles that could influence the stress in the fascia of the posterior compartment were classified as the *clinically significant muscles* and are reflected in Table 4.13

4.3.3. Significance of the myofascial links

Through these links, restrictions of the fascia in any of these muscles could have an effect on the fascia that surrounds the posterior compartment. The mobilizing of these muscles could thus release the stress in the fascia surrounding the posterior compartment As these *clinically significant* muscles are all linked to each other and ultimately to the muscles of the posterior compartment of the lower leg via the myofascial web, the release of restrictions of the fascia in other muscles external to the calf-area, could normalize the length of the myofascial chain which could influence the root cause of the problem, namely stress in the surrounding fascia of the posterior compartment. The clinically significant muscles thus formed the basis for the soft tissue assessment and treatment of the next three subjects.

Posterior Myofascial Links



References:

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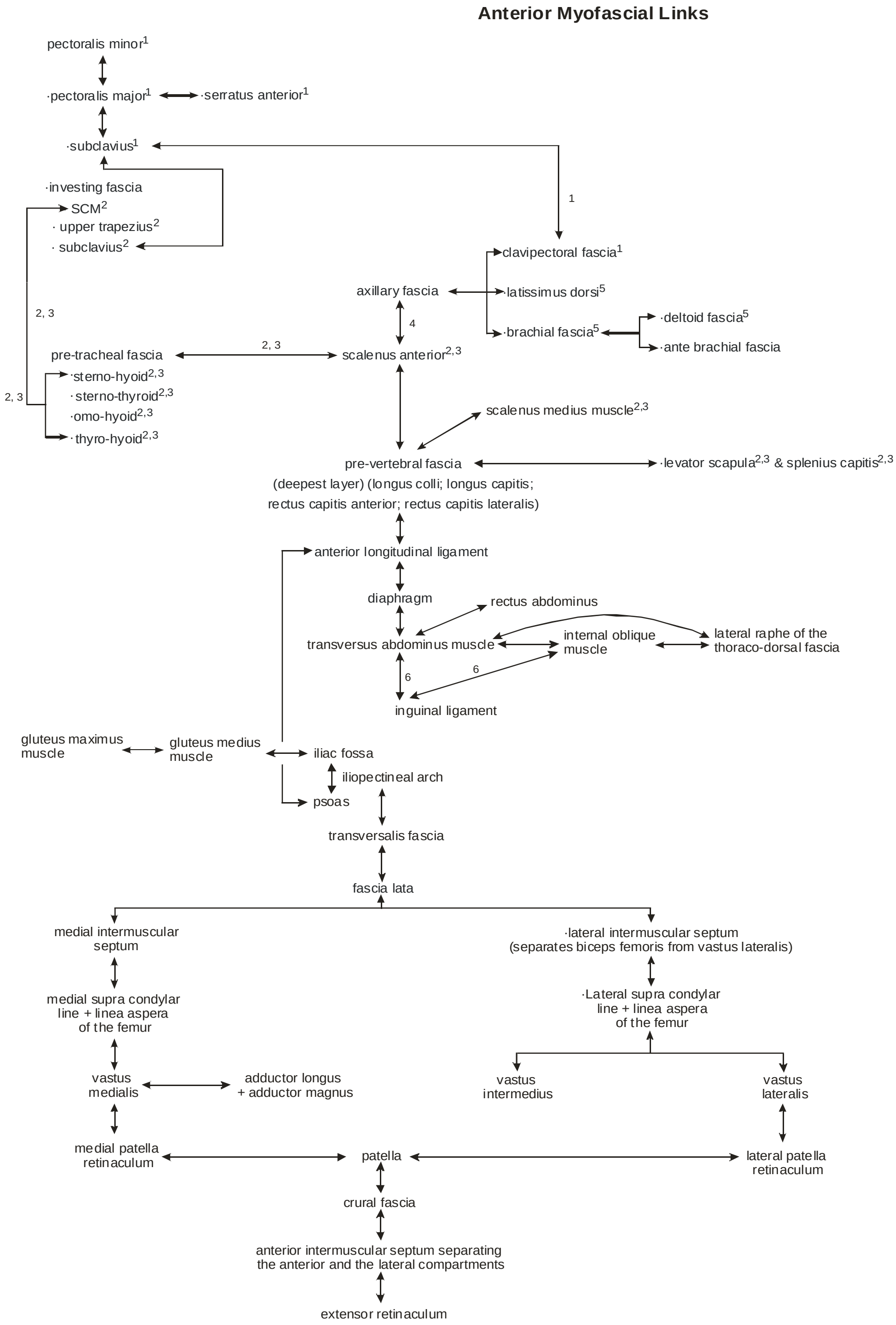
Figure 4.5: A summary of the different posterior myofascial links



References
[1]Lockhart R.D., Hamilton G.F. and Fyfe F.W. 1974: Anatomy of the human body, Faber and Faber, London.
[2]Romanes G.J. 1981: Cunningham's Textbook of Anatomy, 12th Ed., Oxford University Press.
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Figure 4.6: A summary of the different anterior myofascial links

Table 4.13: Clinically significant muscles

Posterior fascia links	***Anterior fascia links***
Levator scapula	*Sternocleidomastoid*
Trapezius	*Scalenii*
Latissimus dorsi	*Pectoralis major*
Erector spinae	*Pectoralis minor*
Quadratus lumborum	*Serratus anterior*
Gluteus medius	*Subscapularis*
Gluteus maximus	*External oblique*
Piriformis	*Rectus abdominus*
Semimembranosus	*Psoas- umbilicus head*
Semitendinosus	*Psoas- iliac head*
Biceps femoris	*Psoas- groin*
Gastrocnemius	*Iliotibial band*
Soleus	*Vastus lateralis*
Plantar fascia	*Vastus medialis*
	Adductor longus
	Adductor magnus
	Pes anserinius

4.3.4. Conclusion

In the first literature review it was established that fascia exposed to physical trauma, scarring or inflammation loses its pliability. Any restriction somewhere along the myofascial chain will cause a decrease in the effective length of the myofascial chain. Such a restriction in length will induces stresses in the web during activities which require extended movement patterns such as running. These stresses will be transmitted via the inelastic myofascial web to areas such as the posterior compartment where it will induce pressure in the posterior compartment. During running, the additional forces exerted on an already compromised myofascial chain, will cause micro trauma and inflammation. The fascia will then become tight, restricted and a source of tension to the rest of the body due to the continuous nature of the myofascial web that links muscle and ligaments of various parts of the body with each other. It is therefore conceivable that a restriction or tightness in any of the more proximal muscles linked to that of the posterior compartment might contribute to the stresses in the fascia which will lead to associated pressure in the compartment.

4.4. THE REVISED THEORETICAL FRAMEWORK

4.4.1. Introduction

The role of a theoretical model that reflects causal relationships is vital to qualitative research (Yin, 2003). He proclaims that theory development as part of the design phase is essential. The complete research design embodies a “theory” of what is being studied and the goal is to have some theoretical basis for formulating theoretical propositions that are to be tested by means of experimentation.

With the initial exploratory research the interventions which were primarily based on the current perspectives of CPCS, did not lead to any successes. This resulted in an additional literature study which was directed to the characteristics and properties of fascia. Although the role that fascia plays in creating pressure within the enclosed compartment is acknowledged in the current theory, the nature and characteristics of this variable are not explored.

This chapter reviews the current theoretical framework for CPCS and highlights the gap that exists. A modified model is proposed which provides a more credible basis for causal relationships of the condition.

4.4.2. The current theoretical model

In order to create a broader contextual framework for a discussion of the current model, some of the viewpoints as emerged during the literature research in chapter 2 will be briefly recaptured. The following reflect the wide acceptance of the model, or at least elements which are encapsulated in the model:

- With repeated contraction, an exercising muscle can increase its volume by 20% (Bourne & Rorabeck, 1989; Eisele & Sammarco, 1993);
- If this occurs with compartment surrounded by a non-compliant fascia envelope (Clanton & Solcher, 1994; Nicholas & Herschman, 1995b), compartment pressures are expected to increase;
- This increase in pressure impedes blood flow and produces ischemic pain (Nicholas & Herschman, 1995b). The elevated compartment pressure increases pressure within intra-compartmental veins which reduces blood flow within the compartment;
- The circulation and function of the muscles and the neurovascular components are compromised in the closed anatomical space of the posterior compartment of the lower leg (Reneman, 1975);
- People presenting with the syndrome are predominantly runners (Detmer *et al.*, 1985);
- The propagation that the whole cycle is initiated by exertional muscle activity (Clanton & Solcher, 1994), and
- The role of fascia in perpetuating the condition has been adequately demonstrated with the relative success of a fasciotomy or a fasciectomy (Howard *et al.*, 2000; Slimmon *et al.*, 2002; Turnipseed, 2002; Shah *et al.*, 2004).

This model proposes that symptoms are caused by exertional muscle exercise, creating abnormally high intramuscular pressure as the result of non-compliant fascial borders. It is suggested that this high pressure occurs during exercise or shortly thereafter. The syndrome then allows several deleterious processes to develop. Circulation to the microvasculature is impeded, and the metabolic demands of the intra-compartmental musculature are compromised. Pressure is then thought to develop secondary to increased intra- and extracellular fluid accumulation within a non-compliant fascial space. There is often venous and lymphatic compromise that contributes to the vicious cycle of increasing tissue pressure resulting in further vascular compromise.

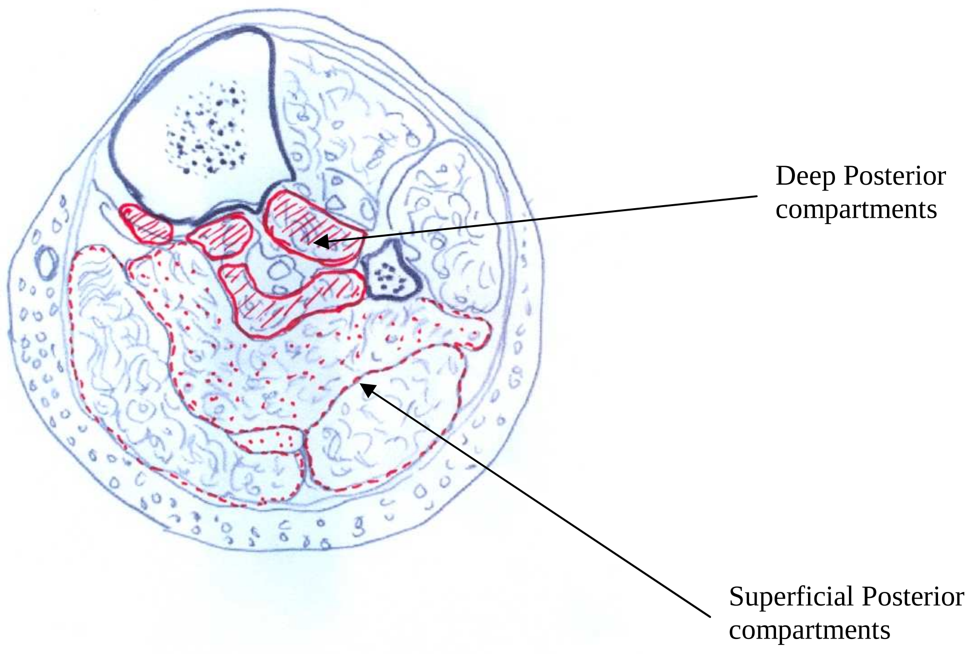

Figure 4.7: Posterior compartments

4.4.3. The theoretical gap

There is however one question that vividly reflects the lack of a comprehensive understanding of the condition, namely:

"Why do only a selected few runners develop this syndrome, if it is caused by muscle exertional exercises?"

In order to answer this question it is necessary to review the shortcomings of the current theoretical base. The glaring shortcoming which emerged from the literature review is the fact that the nature and the characteristics of fascia have largely been ignored in the theoretical approach towards the syndrome. The current model proposes that symptoms are caused by *exertional muscle exercise*, creating abnormally high intramuscular pressure as the result of non-compliant fascial borders. It is suggested that this high pressure occurs during exercise or shortly thereafter. The syndrome then allows several deleterious processes to develop. Circulation to the microvasculature is impeded, and the metabolic demands of the intra-compartmental musculature are compromised. Pressure is then thought to develop secondary to increased intra- and extracellular fluid accumulation within a *non-compliant fascial space*. There is often venous and lymphatic compromise that contributes to the vicious cycle of increasing tissue pressure resulting in further vascular compromise. The role of the non-compliant fascial space has been adequately demonstrated by the success of a fasciotomy or a fasciectomy (Turnipseed, 2002; Shah *et al.*, 2004).

The one aspect of the model that has however not been verified is the assumption that the condition is triggered by muscle exertion. In the revised or modified model that is presented in the next paragraph, a more credible rationale for the development of CPCS is presented.

4.4.4. A revised theoretical model for CPCS

The fact that non-compliant fascia, surrounding muscle compartments, play a crucial role in CPCS is widely accepted. This is also illustrated by the fact that the only successful treatment to date, results from the surgical release of the involved fascia (Froneck *et al.*, 1987; Melberg & Styf, 1989; Biedert & Marti, 1997). The surgical release leads to a decrease in the intra-compartmental pressure which in turn leads to the restoration of circulation and the decrease of symptoms.

The long term result of this approach is however not successful, since symptoms often re-occur shortly after the athlete resumes training (Shah *et al.*, 2004). The fact that running re-induces this condition implies that the root cause for the condition has not been addressed. From the literature review it became evident that the continuous nature and non-elasticity of fascia have been ignored in the theoretical deliberation of the condition. The characteristics of fascia as an 'integrated continuum' suggest that the cause of the symptoms of CPCS might lie somewhere outside the enclosure of the posterior compartment. With the continuous nature of the fascia and its relative inelasticity it seem logical to assume that a restriction anywhere along the myofascial chain could influence an area remotely distant from the source of the restriction. To illustrate this argument, the analogy of an insect in a spider web can be used. The entangled insect will induce forces along the links, destroying the symmetry of the web. If the spider web was inelastic, the length in the remaining part of the web will also be affected. Likewise any restrictions in the myofascial chain will induce longitudinal stresses in the myofascial web. This will be especially relevant during exercises where extended movement ranges are required during activities such as running. Such restrictions of the fascia will decrease the available fascial length which will prevent the myofascial chain from working optimally. These induced stresses in the fascial web will be transmitted along the chain and can be reflected at any point in the continuous web.

The fact that the surgical release of the involved fascia reduces the pressure in the posterior compartment to such an extent that circulation is restored, supports the deduction that the induced intra-compartmental pressure caused by stresses in the fascial web could be sufficient to trigger the condition in the first place. The fact that the condition reoccurs after surgical release once the subject starts to run again, implies that running somehow triggers the condition again. In other words the running creates a process that interferes with the microcirculation to the extent that the symptoms reoccur. This implies that sufficient pressure has been induced in the posterior compartment to impede the microcirculation again.

A critical analysis of the running activity reveals that during running the stresses in the fascial web will be increased due to an increased range of movement and dynamic forces induced by the weight bearing nature of the running exercise. It is thus argued that the pressure induced in the posterior compartment as a result of running following surgical release is sufficient to increase the intra-compartmental pressure to such an extent that the symptoms recur. It is also argued that if the induced stresses caused by running in these subjects are sufficient to impede microcirculation, the same argument can be applied to subjects with a compromised fascial length. The pressure that is induced in the posterior compartment could be sufficient to impede the micro circulation. This in turn creates the currently accepted conditions for the development of the symptoms of CPCS as proposed by Clanton & Solcher (1994). In the previous chapter the continuous nature of fascia has been explored which led to the identification and classification of the "significant muscles". It is postulated that a restriction or tightness in any of these proximal muscles that are linked to the posterior compartment might have an effect on the fascia of the posterior compartment. In exercises such as running the range of movements are more accentuated and a greater degree of stresses are therefore induced in the fascia. These longitudinal forces in the fascia web that surrounds the muscle compartments induce abnormal high intramuscular pressure within the compartments. The pressure is thus not only as the result of non-compliant fascial borders, but also due to the fact that these fascial borders create the initial conditions for the development of the said deleterious processes. The proposed longitudinal forces in the myofascial web which could be responsible for the initiation of CPCS are depicted in Figure 4.8.

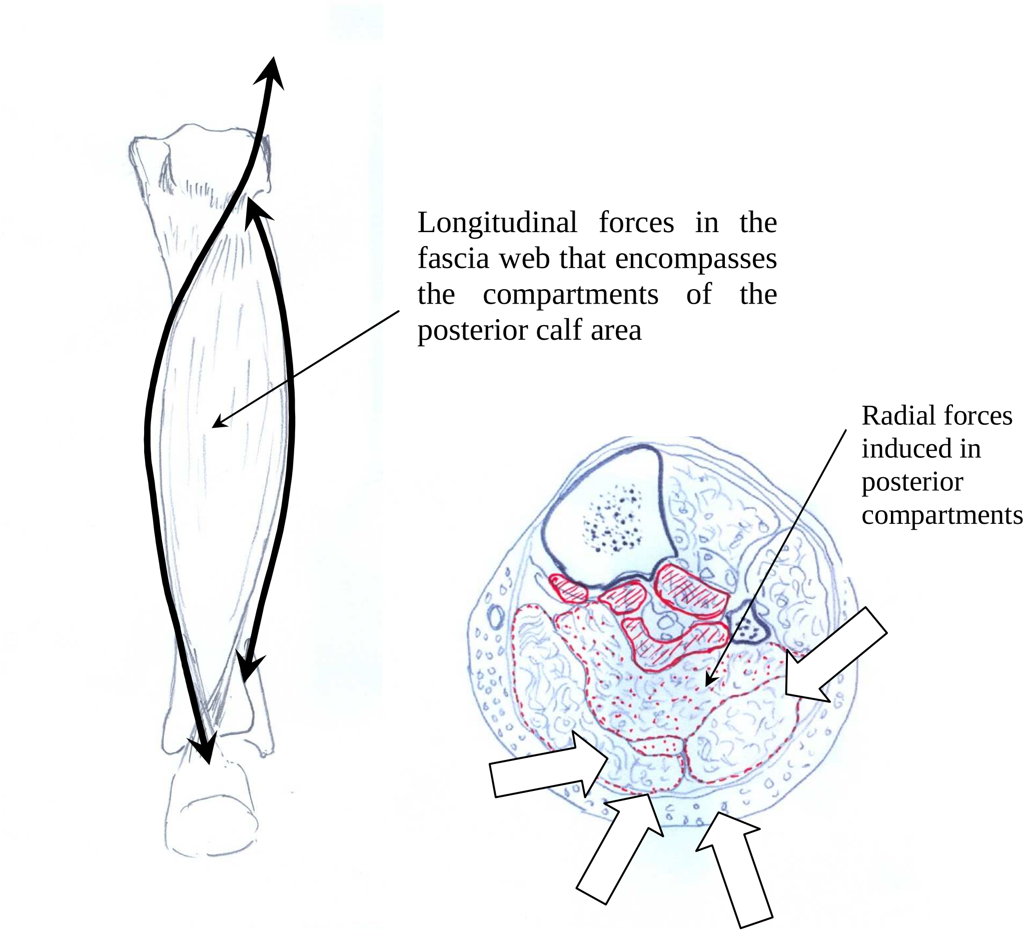

Figure 4.8: Induced stresses in posterior compartments

It is proposed that the injury and inflammation of any of the clinically significant muscles could compromise the myofascial web, which in turn could lead to the initiation of CPCS through the involvement in weight bearing exercises such as running. The proposed modified model for the pathogenesis of CPCS is depicted in Figure 4.9. It should be noted that the only modification to the current model is the initiating conditions. The root cause thus in al probability lies external to the posterior compartment.

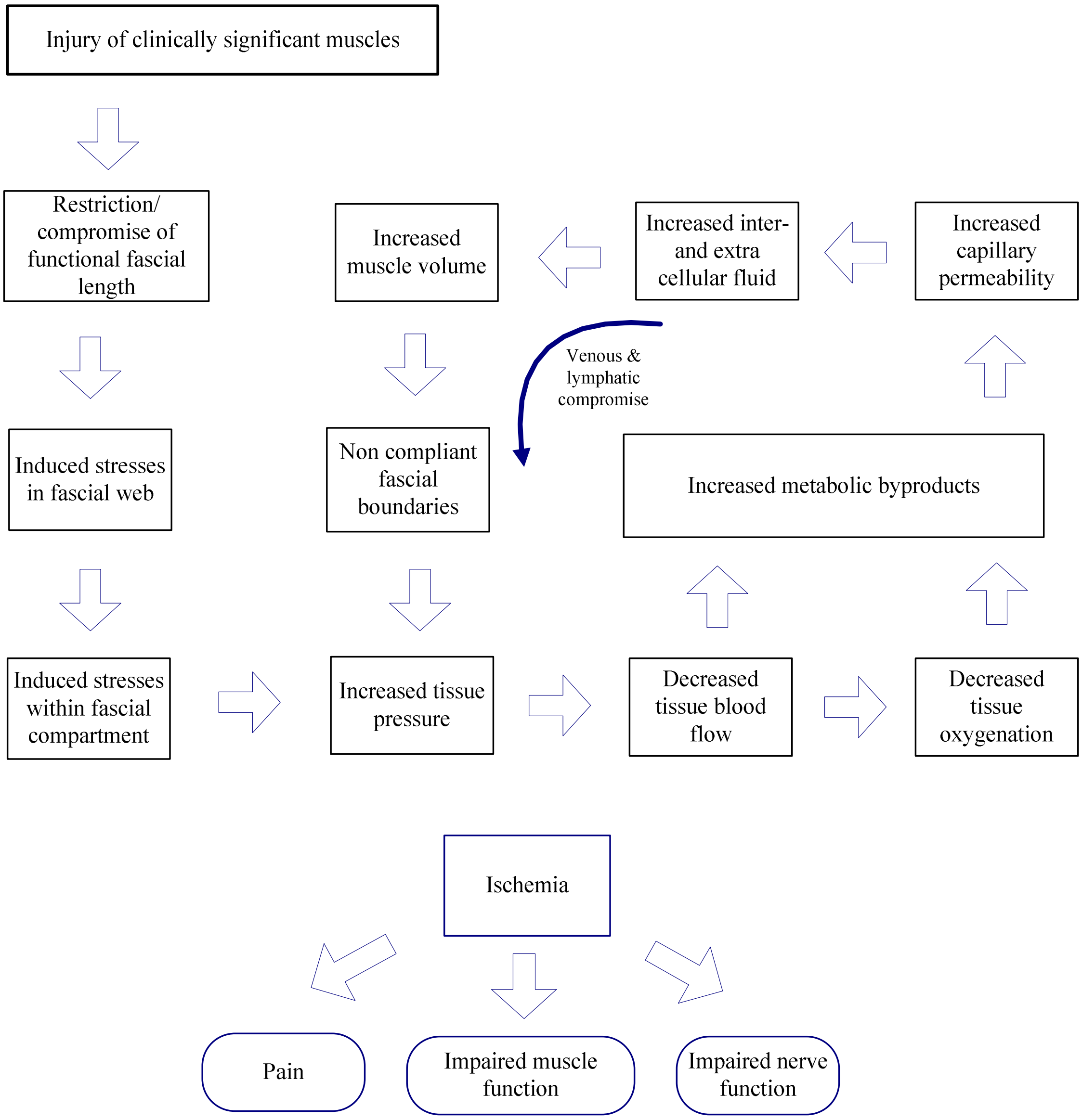

Figure 4.9: Modified model for the pathogenesis of CPCS

4.4.5. Rationale for the treatment approach

If the proposed model or framework is a fair reflection of the pathogenesis of CPCS, a number of deductions should be valid. Any distortions in the fascial web should be evident from tightness in the 'clinically significant' muscles.

Stresses in the fascial web and a compromised myofascial chain should also lead to altered movement patterns and biomechanical measures. These should be evident during exercises such as running, especially where extended or full ranges of movement are required.

Similarly it can be argued that if the root cause for the condition is indeed determined by injuries in the clinically significant muscles. The alleviation of the condition will also lead to the normalisation of such movement patterns and biomechanics.

4.4.6. Conclusion

The problem with the current model for the pathogenesis of CPCS of Clanton & Solcher (1994), is that based on clinical experience, exertion of muscle activity does not lead to CPCS in the majority of athletes. Exertional muscle activity is thus not solely responsible for the precipitation of symptoms of CPCS.

It was hypothesized that it is probable that the cause of the symptoms of CPCS might lie somewhere outside the involved compartment. This would imply tightness in the clinically significant muscles as far proximally as where the restriction in the myofascial web lies. Due to the fact that such restrictions might lie anywhere along the continuum, it can be expected that the patterns of associated tightness in the 'clinically significant' muscles would in all probability differ from subject to subject. This would imply that the patterns of muscle tightness of the subjects will differ from subject to subject, depending on where the restriction in the web lies.

It could also be argued that tightness in the soft tissue would lead to altered running movement patterns and altered biomechanics. It is also possible that if the mobilization of the 'clinically significant' muscles leads to the clearance of the symptoms of CPCS, the restoration of the functional length of the fascial web will also lead to an improvement in running patterns and biomechanics.

4.5. EXPLANATORY RESEARCH RESULTS

4.5.1. Introduction

This section deals with the results of case studies 4 to 6 of the explanatory research phase. The objective of the research is primarily the validation of the model for the pathogenesis of CPCS as developed towards the end of the exploratory research phase. A number of quantitative measurements were done during the explanatory research phase. The assessments of these results will also be covered in group context.

Case Study 4 is the first of the case studies dealing with the validation of the theoretical model as discussed in the previous section. To some extent it also reflects the transition from the exploratory to the explanatory. In the initial interventions these have not been fully developed and only in the latter part of the interventions were the theory fully applied. In terms of this model, the basic proposition is that the cause of the condition lies outside the posterior compartment and that the mobilization of soft tissue (myofascial tissue) of the clinical significant muscles involved will lead to a disappearance in symptoms. This proposition relies to a large extent on the existing knowledge base as reflected by the model for the pathogenesis of CPCS (Clanton & Solcher, 1994) and supplemented by the findings in the literature research. In terms of this knowledge (Reneman, 1975; Detmer *et al.*, 1985; Clanton & Solcher, 1994; Nicholas & Herschman, 1995a; Howard *et al.*, 2000; Turnipseed, 2002; Slimmon *et al.*, 2002; Shah *et al.*, 2004), healing is effected by a reduction in the pressure in the posterior compartment. These claims are adequately demonstrated by the success of the release of pressure by means of fasciectomy which increases tissue blood flow and associated oxygenation which reverse the process.

With regard to the measures employed during this research, none have the sophistication to actually measure the pressure within the posterior compartment, nor the increase in tissue blood flow. The measurement of pressure in the posterior compartment is based on the palpation findings which to some extent is a qualitative measure. Some degree of reliance is thus placed on the current understanding of the healing process as was demonstrated during the literature research with the surgical release of the fascia.

The propositions

Main proposition

The main proposition of this explanatory phase of the research is that the root cause of CPCS lies outside the posterior compartment-compartment and this manifests through tightness in the clinically significant muscles. The mobilization of the soft tissue (myofascial tissue) of these "clinical significant muscles" will lead to a disappearance in symptoms of CPCS through:

- *a reduction in the pressure in calf area which in turn will lead to the alleviation of the symptoms of CPCS; and/or*
- *an increase in tissue blood flow and associated oxygenation that will reverse the process.*

Secondary propositions

As a result of the continuous nature of the fascia and its relatively inelasticity the condition will reflect in a number of movement abnormalities which will be restored once the condition of CPCS has been eliminated.

In terms of these propositions, the main proposition and its associated rivalry theories will be discussed on a case-by-case basis.

4.5.2. CASE STUDY 4

4.5.2.1. The subject

The subject in Case Study 4 was a 24 year old male athlete who had been forced by pain to focus on ten kilometre races and duathlon events.

Inclusion criteria

- He experienced constant discomfort in both Calves, over the posterior-medial aspect in the middle one third of both lower legs. His discomfort rated as a 25 on the 100mm VAS. This discomfort steadily increased to reach a pain level of 75 as indicated on a 100mm VAS, at the end of a seven kilometre run.
- He was diagnosed with CPCS after intra-compartmental pressure measurements were taken by an orthopaedic surgeon at the beginning of 1996.

Exclusion criteria

With regard to the exclusion of vascular conditions:

- He already had two popliteal artery entrapment release operations (November 1994), one in each leg.

4.5.2.2. Research Procedure

Subjective assessment – Interview

- ***Running history***

This 24-year old male subject had been a competitive athlete since high school (1994). He participated in 800 m and 1500 m track events. During recent years, he had been forced by injuries to focus on ten kilometre races and duathlon events. These consist of standard and mini duathlon. The duathlon consists of a ten kilometre run followed by 40 kilometres cycling, and then a five kilometre run; while the mini duathlon consists of a five kilometre run followed by a 30 kilometre cycling, and then a five kilometre run. At the time of his inclusion into the study, he managed to run a distance of seven kilometres twice a week, providing that he had a period of at least two days rest in between. He ran at a pace of four-and-a-half minutes per kilometre. He increased his fitness by following a cross-training programme. He cycled a distance of 55 to 120 kilometres twice a week and also attended a gymnasium for weight training three times a week. At the time of inclusion into the study, he was running with strong motion control shoes. His hind foot pronation was 20° on the left and 18° on the right as measured by a podiatrist in the early half of 2002. He used different shoes (clip-on) for cycling.

o ***Previous running injuries***

Previous injuries that he had encountered included:

- A right-sided iliotibial band syndrome;
- Runner’s knee on the right side; and
- Mid thoracic pain during cycling.

o ***Current symptoms***

He experienced a constant discomfort in both calves, over the posterior-medial aspect in the middle one-third of both lower legs. He rated this constant discomfort as a 25 on the 100mm VAS. This discomfort steadily increased to 75 as indicated on a 100mm VAS towards the end of a seven kilometre run. He ran in the late afternoons and the intensity of pain would remain at that level for a couple of hours. If he attempted to run more than twice a week without the break, the pain would remain at a level of 75 on a 100mm VAS for a period of two to three days thereafter. With his entrance into the study, he was averaging a running distance of 14 kilometres per week.

o ***History of symptoms and previous treatment received***

He first experienced symptoms during 1994 whilst he was participating in 800 m and 1500 m track events. He described the symptoms as deep sharp pains behind the posterior-medial aspect of both tibias. At times, he also experienced a numb sensation or a sensation of pins and needles in both feet. His symptoms commenced within ten to 20 minutes after the commencement of the training session. The pain would then continue for a couple of hours after the cessation of the exercise session. He also complained of a sensation of weakness in his calf muscles.

When the symptoms appeared for the first time, he received conventional physiotherapy treatment that consisted of ultrasound, interferential, massage and stretch exercises, all aimed locally at the area of the calf muscles. He also underwent a calf muscle strengthening programme on the Isokinetic dynamometer. Despite this treatment, his symptoms remained unchanged. He was then referred for further investigations which included: a bone scan, a Doppler test and an arteriogram. The results of the bone scan and the Doppler test were negative, but the arteriogram was indicative of a bilateral popliteal entrapment syndrome with a stenosis developing in the popliteal artery.

During November 1994, he underwent a bilateral popliteal entrapment release. Post-operatively, he started to train gradually, but his symptoms re-appeared two to three weeks after the commencement of his training programme. Intra-compartmental pressure measurements were taken. The pressure was found to be raised significantly enough to be indicative of posterior compartment syndrome. A bilateral posterior compartment release was done during April 1996. The symptoms again re-appeared two to three weeks after he had started to train, the only difference being a decrease in the frequency of pins and needles in the feet. He again received three to four sessions of physiotherapy consisting of ultrasound, interferential, massage and stretch exercises over the area of the lower leg, which once more had no effect on his symptoms.

During May 1998, he underwent a revised surgical posterior compartment release (bilaterally). Thereafter he experienced no symptoms with cycling, but with running, his symptoms became progressively worse, despite the fact that he was receiving conventional physiotherapy for his calf muscles on a daily basis. The physiotherapy consisted of massage, ultrasound- and interferential treatment over the area of the calf muscles, calf muscle stretches and calf muscle strengthening exercises. The latter consisted of both concentric as well as eccentric exercises.

During the latter half of 2001, he reached the stage where he had constant pain and a sensation of weakness in his calf muscles. He was again referred for further tests of the lower legs. These tests included ultrasonic imaging, an arteriogram, an electromyographic test (EMG) as well as magnetic resonance imaging (MRI). The test results were normal.

In summary, the subjective outcome measurements as measured before the intervention:

- The intensity of pain / discomfort at rest was 25 on the 100mm VAS and 75 on the 100mm VAS after a seven kilometre run.
- He averaged a distance of 14 kilometres per week at a pace of four and a half minutes per kilometre.

Objective assessment – Physical examination

- ***Muscle strength tests***

Muscle strength was assessed by a biokineticist on a calibrated Isokinetic dynamometer, using a standardized testing protocol (Date: 22/11/2002). The subject presented with several significant differences in muscle strength between the left and the right sides as reflected in Table 4.14.

Table 4.14: Isokinetic dynamometer test results* prior to intervention: Case Study 4.

Movement tested**	***Peak torque (Nm)***			***Work per repetition (Nm/s)***		
	Right	***Left***	***Deficit***	***Right***	***Left***	***Deficit***
Hip extensors	175	152	*13*	223	183	*18*
Hip flexors	92	110	*-16*	108	117	-8
Hip internal rotators	28	21	*25*	31	19	*39*
Hip external rotators	26	20	*23*	28	19	*32*
Hip abduction	104	121	*-14*	55	59	-7
Hip adduction	120	176	*-32*	69	91	*-24*
Knee extensors	192	173	*10*	194	176	9
Knee flexors	107	100	7	130	132	-2
Knee internal rotation	34	35	-4	33	33	0
Knee external rotation	26	27	-5	30	31	-4
Ankle inversion	33	32	3	27	26	4
Ankle eversion	21	21	0	23	17	*26*
Ankle plantar flexors	85	79	7	47	47	0
Ankle dorsi flexors	34	36	-6	21	20	5

**Statistically significant differences between the right and the left sides are given in italic*

*** Tested at a speed of 30/30 and with five repetitions*

o ***Analysis of running gait, including movement patterns***

The following movement patterns deviated from the normal/ ideal running patterns (see Table 4.15 for full description):

- The right shoulder moved into more extension and retraction than the left shoulder. It was swinging more than the left. It was also more depressed than the left.
- There was more thoracic rotation towards the left compared to the right side.
- The pelvis on the right side moved into anterior rotation during initial contact whilst the pelvis on the left only moved into a position of neutral. During the single leg support phase, the left pelvis dropped more in comparison to the right.

Table 4.15 (a): Running gait analysis: Case Study 4 prior to intervention (Upper body)

Running gait analysis: Case Study 4 (28/01/2003)								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Shoulders	Left leg: right shoulder in more extension and retraction than left shoulder with right leg initial contact. During this phase the right shoulder-blade is swinging more than the left and is also in more depression than the left.							
Thoracic region	There is more thoracic rotation to the left (initial contact left leg) than to the right (initial contact right leg).							
Pelvis	Right pelvis is in anterior rotation. The left pelvis is in a neutral position.		Both sides are in slight posterior rotation. The left side more so than the right side. The left side seems to drop more than the right side.	Both sides are in posterior rotation; left side more than right side.	Both sides are in posterior rotation; left side more than right side.		Both sides move out of posterior rotation.	The left side moves into a neutral pelvic position and the right side moves into anterior pelvic rotation.
Hip	Right hip: flexion plus slight adduction. Left hip: flexion plus slight external rotation.		The right hip is in neutral. The left hip is in slight abduction. The subject has an uneven gait. He seems to have more of a push-off action on the right side and a landing action on the left side.	Both hips are in extension and external rotation. The left hip is in more external rotation than the right.	Both are in extension and external rotation. The left side is in more external rotation than the right side.	Both hips start to move into internal rotation from the externally rotated position.	Both hips: Flexion and internal rotation.	Both hips: Flexion.

Table 4.15 (b): Running gait analysis: Case Study 4 prior to intervention (Lower body)

Running gait analysis: Case Study 4 (28/01/2003)								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Knee	Both knees: almost full extension with the tibia in external rotation.	The amount of knee extension decreases slightly in both knees.	The amount of extension in both knees increase a bit again with the tibia being in external rotation.	The tibias move into more external rotation with the knees in extension.	Both knees are extended with a degree of external rotation of the tibias.	Both knees move out of flexion and external rotation into flexion. There is a frequent irregularity on the left side with an increased amount of left hip external rotation and posterior pelvic rotation.	Both sides: Flexion and internal rotation.	Both sides: Extension and external rotation.
Ankle	Right ankle: no heel –toe action. Lands with the ankle in a neutral position, fractionally first on the lateral side of the foot. Left ankle: lands in a slightly inverted position; laterally on the 5th metatarsal. No heel-toe action.	Left and right sides: shift the weight to the medial side of the foot (moves into a greater everted position).	The hind foot is in pronation. The left and the right calcaneus sink further into valgus (loss of eccentric control). This occurs more on the left than the right. Both feet are in abduction.	The hind foot moves out of the pronated position into neutral. The right calcaneus starts to move earlier than the left one. The ankle moves into plantar flexion.	Left and right sides are in a neutral hind foot position with plantar flexion.	There is no real push-off. It is initiated (more so on the left than on the right) by a backward rotation of the pelvis, hip extension and external rotation. With the push-off the weight is shifted from the 2nd to the 3rd metatarsal head so that the foot moves into inversion. It returns to the position of the 2nd metatarsal head as soon as the weight is off. Less subtle on the right side than on the left side.	Left and right sides: slight inversion and plantar flexion.	Left and right sides: slight inversion and plantar flexion.
Toes	Excessive MTP extension, especially of the big toes.	Less extension.	Toes in neutral position.	Toes move into extension.	Extension.	Extension.	Extension.	More extension.

- The left hip was in slight abduction in comparison to the right side. It was almost as thought the subject had an uneven push-off (right side) and landing (left side) gait. The hip on the left side was throughout in a position of increased lateral rotation.
- There was no heel-toe action and during the mid stance phase, the calcaneus on both sides, sank into an increased degree of valgus. This was more noticeable on the left side. Both feet were in a position of abduction. During the terminal stance phase, the right calcaneus started to move earlier out of the valgus position in comparison to the left side.
- There was no push-off. There was again an irregularity noticeable when the weight was shifted from the 2nd to the 3rd metatarsal heads during the phase of terminal stance. This was less subtle on the right than on the left.

o ***Flexibility/ length of soleus muscle (28/01/2003)***

Right soleus muscle: Big toe 120 mm from the wall.

Left soleus muscle: Big toe 140 mm from the wall.

o ***Biomechanical angles (28/01/2003)***

The biomechanical angle measurements are provided in Table 4.16.

Table 4.16: Biomechanical angles: Case Study 4.

Movement	***Joint Range of Movement (degrees)****	
	Mid stance	***Terminal stance***
Dorsi flexion left	9, 33^{o}	19, 00^{o}
Dorsi flexion right	5, 67^{o}	20, 75^{o}
Metatarsophalangeal extension left		50, 67^{o}
Metatarsophalangeal extension right		48, 50^{o}
Hind foot pronation left	20, 00	
Hind foot pronation right	18, 00	

** Averages of three measurements*

Table 4.17: Tightness of clinically significant muscles: Case Study 4 prior to intervention: (Date: 28/01/2003)

Muscle	***Left Side***			***Right Side***			***Muscle***	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula		1				2	*Sternocleidomastoid*		1				2
Trapezius		1				2	*Scalenii*		1				2
Latissimus dorsi		1				2	*Pectoralis major*		1				2
Erector spinae		1				2	*Pectoralis minor*			2		1	
Quadratus lumborum			2			2	*Serratus anterior*		1				2
Gluteus medius		1				2	*Subscapularis*		1				2
Gluteus maximus			2			2	*External oblique*		1				2
Piriformis			2			2	*Rectus abdominus*			2			2
Semi-membranosus		1				2	*Psoas- umbilicus head*		1				2
Semitendinosus		1			1		*Psoas- iliac head*		1				2
Biceps femoris			2			2	*Psoas- groin*		1				2
Gastrocnemius			2			2	*Iliotibial band*		1				2
Soleus			2			2	*Vastus lateralis*	0				1	
Plantar fascia		1			1		*Vastus medialis*	0				1	
							Adductor longus	0				1	
							Adductor magnus	0				1	
							Pes anserinius			2			2

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

o *Soft tissue palpation (clinically significant muscles)*

All the clinically significant muscles were palpated for tightness and spasm and rated on a scale from 0 to 2. These outcomes are reflected in Table 4.17.

4.5.2.3. Interventions

All the clinically significant muscles with a relative tightness rating of one or two were mobilized. Different soft tissue mobilising techniques were used, depending on the muscle involved. Myofascial release techniques were applied according to the approach of Barnes (1990) and Manheim (1994). Trigger point release techniques were applied according to the approach of Travell & Simons (1999) and specific soft tissue mobilization was applied according to Hunter's approach (1998).

The subject was seen twice a week during the first two weeks. Thereafter the frequency decreased to once every seven to 14 days for a period of one year. The objective was an intervention period of every ten days but the schedule was influenced by external commitments of the subject. He was instructed to stretch on a daily basis. Stretches were provided for the following muscles:

- the trapezius
- the levator scapula
- the pectoralis
- the abdominal muscles
- the iliopsoas
- the piriformis
- the hamstrings
- the gastrocnemius and
- the soleus muscles

He was instructed to hold each stretch for 30 seconds and to repeat it.

Clinical observations during the intervention period:

- During the first half of the intervention period (23/08/02 – 25/10/03), on eight different occasions there were so many tight clinically significant muscles that it was impossible to mobilize all effectively during the 45 minute intervention. During the 2nd, the 4th, the 6th and the 8th occasions, only the tight clinically significant muscles of the pelvis and the area above the pelvis were mobilised. During the 1st, the 3rd, the 5th and the 7th occasions only the tight clinically significant muscles of the legs were mobilized. The differences in the subjective outcome measurements between these two were then compared. In the week following the mobilization of the legs, there was no improvement in the measures (i.e. pain as indicated on a 100mm VAS; the distance run before the commencement of the pain; or the total weekly distance run). In the week following the intervention where the clinically significant muscles of the pelvis area and above were mobilized, a noticeable improvement was recorded in terms of all three the measures. This was an indication that the release of the more proximal tight myofascial links played a very important role in the amelioration of the symptoms of CPCS in the fourth subject.
- As can be seen in the Figures 2.5 (posterior myofascial links), the superficial lamina of the posterior layer of the thoraco-dorsal fascia links both to the aponeurosis of the latissimus dorsi muscle and also to the lower fibres of trapezius muscle. Clinically, the fascia overlap between these two muscles could be felt bilaterally at the T8 spinous level. It could also be observed when the subject was asked to lift the arms up in elevation, adduction and lateral rotation while lying in prone. Specific soft tissue mobilizations as developed by Hunter (1998) in the area where the fascia of the two muscles overlap, led to the disappearance of the thoracic pain that he previously experienced every time that he cycled a distance of more than 70 km. This was not mentioned earlier since it did not occur while running and seemingly had no direct correlation with the symptoms of CPCS.
- The link between the semimembranosus, the medial tibial ligament and the adductor magnus is also reflected in Figure 4.5. Palpation of his right semimembranosus initially reproduced his right knee pain (so called "*runners knee*") and the

mobilization of this muscle with Hunter's specific soft tissue mobilizations led to the disappearance of his right knee pain. In addition to this, it also improved the range of his straight leg raise.

- It was noted throughout the intervention period that his symptoms increased slightly, despite the interventions, whenever he had to spend more time sitting and studying; or when he trained on loose sea sand during the holiday periods. It seemed as though posture plays a definite role in the symptoms of CPCS. Whenever he spent more time in a seated position, slumping as during examination times, his symptoms increased. A plausible explanation for this is that the sitting and slumping positions probably places a bigger demand on the already compromised myofascial chain. As for the training on loose sea sand, a greater force is required for forwards propulsion in the loose sand which also requires a greater range of movement with associated increased stresses in the fascial chain.

o ***Treatment period***

(23rd August 2002 – 25th October 2003)

Final assessment results (Date: 25/10/2003)

Interview

- The intensity of pain / discomfort at rest as well as the intensity of pain / discomfort at the end of every training session was plotted on a 100 mm VAS: he had no discomfort at rest (0 on the 100mm VAS). He experienced occasionally a discomfort of ten in the right calf muscle on the 100 mm visual analogue scale after 15 minutes of running; or at the end of a ten kilometre run; or once cooled down.
- He ran pain free most of the time.
- He ran a weekly distance of 20 kilometres.
- He ran at a pace of less than four minutes per kilometre.
- He received provincial colours for triathlon during 2004, for duathlon during 2005, and represented South Africa in duathlon during the 2005 world championships.

Physical examination

o ***Muscle strength tests***

The strength of the hip extensors, the hip flexors, the hip abductors, the hip adductors, the medial- and lateral rotators of the hip, the knee extensors, the knee flexors, the medial- and lateral rotators of the knee, the invertors and evertors of the ankle as well as the dorsi- and plantar flexors of the ankle were assessed by a biokineticist on a calibrated Isokinetic dynamometer, using a standardized testing protocol. The results of the tests as measured on 25/10/2003 are provided in Table 4.18.

Table 4.18: Isokinetic dynamometer test results* after intervention: Case Study 4.

Movement tested**	***Peak torque (Nm)***			***Work per repetition (Nm/s)***		
	Right	***Left***	***Deficit***	***Right***	***Left***	***Deficit***
Hip extensors	133	155	*-14*	181	195	-7
Hip flexors	102	104	-2	140	117	*16*
Hip internal rotators	37	48	*-23*	34	68	*-50*
Hip external rotators	30	33	-9	37	41	*-10*
Hip abduction	129	135	-4	119	114	4
Hip adduction	104	139	*-25*	117	135	*-13*
Knee extensors	197	192	3	187	204	-8
Knee flexors	115	117	-2	142	178	*-20*
Knee internal rotation	***	***	***	***	***	***
Knee external rotation	***	***	***	***	***	***
Ankle inversion	58	50	*14*	74	49	*34*
Ankle eversion	34	33	3	53	37	*30*
Ankle plantar flexors	109	90	*17*	61	53	*13*
Ankle dorsi flexors	46	36	*22*	33	24	*27*

**Statistically significant differences between right and left are given in italics*

***Tested at a speed of 30/30 and with 5 repetitions *** Not measured*

o ***Reassessment of running gait and movement patterns***

Running gait and movement patterns were reassessed and the results are reflected in Table 4.19.

Table 4.19: Running gait analysis: Case Study 4 after intervention (Date: 13/07/2003)

Running gait analysis: Case Study 4 (13/07/2003)								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre- swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Shoulders	Left leg: right shoulder in more extension and retraction than left shoulder with right leg initial contact, but less than on the 28/01/03.							
Thoracic region	Left pelvis in more anterior rotation than previously.							
Pelvis	Left pelvis in more anterior rotation than previously.		Pelvis on the left and right in neutral. Still tends to drop a bit on the left side.	The amount of posterior rotation of the pelvis is equal on the left and the right.	The amount of posterior rotation is equal on the left and the right.			The left side now also moves into anterior rotation.
Hip	Left and right sides are in flexion.							
Knee	All movements were normal.							
Ankle	All movements were normal.							
Toes	All movements were normal.							

- ***Flexibility/ length of soleus muscle (25/10/2003)***

Right soleus muscle: Big toe 160 mm from the wall.
Left soleus muscle: Big toe 180 mm from the wall.

- ***Biomechanical measurements***

The biomechanical measurements for subject 4 were done twice, the first measurement after six months and the second measurement after a further three months. This was due to the fact that the treatment period for subject 4 was far longer than the other subjects and provided for an interim reflection on results. The measurements made on 15/05/2003 are reflected in Table 4.20.

Table 4.20: Biomechanical angles: Case Study 4

Date	***Joint Range of Movement (degree)***			
	13/07/2003		***25/10/03***	
	Stance		***Stance***	
	Mid	***Terminal***	***Mid***	***Terminal***
Dorsi flexion left	9,67	15	10,75	16,5
Dorsi flexion right	8,67	20	5,33	16,67
MTP extension left		47,33		47
MTP extension right		47,33		38
Hind foot pronation left	13		11,3	
Hind foot pronation right	13		12	

- ***Soft tissue palpation (clinically significant muscles)***

All the clinically significant muscles were palpated for tightness and spasm and rated on a scale from 0 to 2. These results appear in Table 4.21.

Table 4.21: Tightness of clinically significant muscles: Case Study 4 after intervention: (Date: 25/10/2003)

Muscle	***Left Side***			***Right Side***			***Muscle***	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula	0				<1		*Sternocleidomastoid*	0				<1	
Trapezius	0				1		*Scalenii*	0				<1	
Latissimus dorsi	0				1		*Pectoralis major*		<1			1	
Erector spinae	0				1		*Pectoralis minor*		1			<1	
Quadratus lumborum		<1			<1		*Serratus anterior*		<1			1	
Gluteus medius		<1			1		*Subscapularis*		<1			1	
Gluteus maximus		1			<1		*External oblique*		<1			1	
Piriformis		<1			<1		*Rectus abdominus*		1			1	
Semimembranosus	0				1		*Psoas- umbilicus head*	0				1	
Semitendinosus							*Psoas- iliac head*	0			0		
Biceps femoris	0			0			*Psoas- groin*	0			0		
Gastrocnemius		<1			<1		*Iliotibial band*	0				1	
Soleus	0			0			*Vastus lateralis*	0			0		
Plantar fascia	0				<1		*Vastus medialis*	0				<1	
							Adductor longus	0				<1	
							Adductor magnus	0				<1	
							Pes anserinius	0			0		

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

4.5.2.4. Synthesis/discussion

The discussion will be limited to the conclusions drawn in terms of the main proposition and associated rival theories.

o ***The proposition***

The mobilization of soft tissue (myofascial tissue) of the tight clinical significant muscles did lead to a disappearance in symptoms of CPCS. This was accompanied with a reduction in the pressure in the posterior compartment manifested by means of the palpation of the posterior compartment area. This reduction in pressure in posterior compartment in all probability led to the alleviation of the symptoms of CPCS. This includes the increase in tissue blood flow to the posterior compartment area and associated oxygenation which reversed the process.

o ***Rival theories***

- The subject had significant tightnesses in the clinical significant muscles. This negates the rival proposition that subjects will not have any significant tightness in the clinically significant muscles. At this point it does not exclude the possibility that a different theoretical framework could be responsible for the pathogenesis of the condition.
- The treatment of the tightness in the clinical significant muscles did lead to the alleviation of the symptoms of CPCS. This is however not a conclusive fact that this was solely responsible for the alleviation of the symptoms. It could be as a result of chance, and that a different theoretical framework is responsible for the pathogenesis of the condition.
- The rival theory that the alleviation of the symptoms of the condition is purely due to chance and the intervention has nothing to do with it can not be ruled out at this stage.
- The rival theory that the interventions have not been applied long enough in order to generate the required response is ruled out as the desired response has been achieved.

- Similarly the last rival theory that the researcher is incapable of applying the intervention techniques in an effective manner is also ruled out as the desired response has been achieved.

4.5.3. CASE STUDY 5

4.5.3.1. The subject

The subject in Case Study 5 was a 35 year old male athlete who participated competitively in road running races, duathlon- and cycling events.

Inclusion criteria

He complained of a constant bilateral calf pain over the posterior-medial aspect of the middle one-third of his lower legs. The pain therefore increased with exercise and decreased with rest.

Exclusion criteria

The pins-and-needles sensation that he occasionally experienced after sitting for a prolonged period of time behind the computer was present in both feet and affected the whole foot; it was not in the distribution area of a specific nerve.

4.5.3.2. Research Procedure

Subjective assessment - Interview

o ***Running history***

The subject was a 35 year old male athlete who participated competitively in road running races, duathlon- and cycling events. He had won the Cullinan Duathlon event (6 km run; 30 km cycle; 6 km run) the previous year and had also won a two year bursary to cycle in Belgium during the Nineties. He usually cycled a distance of between 60 and 120 kilometres on a Sunday and was running a total of 28 kilometres per week when he was seen by the researcher for the first time. At the time of inclusion into the study, he was running with mild anti-pronation shoes. He used different shoes (clip-on) for cycling.

o ***Previous running injuries***

Previous injuries that he had encountered included:

- bilateral iliotibial band syndromes (18 months before)
- left sided hip pain (18 months before)
- right knee pain following a hit and run accident during 1989 whilst he was cycling
- a left ankle pain

o ***Current symptoms***

He complained of a constant bilateral calf pain with an intensity of 40 on a 100mm VAS over the posterior-medial aspect of the middle one-third of his lower legs. He also experienced pain over the anterior-lateral aspects of both lower legs which developed during running, but was never as bad as the calf pain. The pain was rated as a 50 on the 100mm VAS directly after a run. The pain in the left lower leg was worse than that in the right leg. After a hard run, when the pain increased, a haematoma always appeared over the superior-lateral aspect of his left leg in the vicinity of his superior tibio-fibula joint. He often experienced pins and needles in both feet after sitting behind the computer for a prolonged period of time. He also complained of experiencing abdominal cramps (stitches) during hard runs.

o ***History of symptoms and previous treatment received***

He had first experienced these symptoms six months before, when he increased his training from eight kilometres to 28 kilometres per week. Since then the symptoms in his legs, had grown gradually worse. He stopped training for a period of three weeks in order to recuperate but with his first training run all symptoms returned immediately. In summary, the subjective outcome measures before the intervention were as follows:

- Pain/discomfort at rest was 40 on the 100mm VAS and 50 after a training session.
- He averaged a weekly distance of 28 kilometres per week.

Objective assessment – Physical examination

o ***Muscle strength tests***

Muscle strength was measured by a biokineticist on 14/06/2003 on a calibrated Isokinetic dynamometer, using a standardized testing protocol. The results are reflected in Table 4.22.

Table 4.22: Isokinetic dynamometer test results* prior to intervention: Case Study 5.

Movement tested*	***Peak torque (Nm)***			***Work per repetition(Nm/s)***		
	Right	***Left***	***Deficit***	***Right***	***Left***	***Deficit***
Hip extensors	252	237	-6	325	312	-4
Hip flexors	115	108	-6	144	137	-5
Hip internal rotators	47	47	0	46	50	-8
Hip external rotators	35	43	*-19*	38	49	*-22*
Hip abduction	130	137	-5	99	95	-4
Hip adduction	134	145	-7	111	119	-7
Knee extensors	217	188	*-13*	241	213	*-12*
Knee flexors	137	132	-4	165	156	-6
Knee internal rotation	42	50	*-16*	33	34	-4
Knee external rotation	47	42	*-11*	30	34	*-12*
Ankle inversion	46	50	27	35	46	***
Ankle eversion	24	36	51	22	28	***
Ankle plantar flexors	89	103	*-13*	49	57	*-14*
Ankle dorsi flexors	34	38	*-11*	18	24	*-28*

**Statistically significant differences between right and left are given in italic*

[**]Tested at a speed of 30/30 and with 5 repetitions

****Not determined.*

Table 4.23(a): Running gait analysis: Case Study 5 prior to intervention (Upper body)

Running gait analysis: Case Study 5:24/05/03								
Joint	***Weight acceptance***			***Single leg support***		***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre- swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Shoulders	Left leg: right shoulder in more extension and retraction than left shoulder with right leg initial contact. During this phase there is also a swing at the right shoulder blade. The right shoulder is in more depression than the left.							
Thoracic region	There is more upper thoracic rotation to the left (initial contact left leg) than to the right (initial contact right leg).							
Pelvis	The pelvis on the right moves into more anterior rotation than on the left.	Left: anterior rotation. Right: anterior rotation.	Left: mid position. Right: mid position.	The pelvis on the right moves into less posterior rotation than on the left.	Left: posterior rotation. Right: posterior rotation (less than on the left.)	Both move out of posterior rotation.	Both are in a neutral position.	Both in anterior rotation: right more than left.
Hip	Both are in flexion.	Both are in flexion and slight external rotation.	Both are in slight flexion and external rotation.	Both are in extension and external rotation. The left is in more external rotation than the right.	Both are in extension and starting to move out of external rotation.	Both moves into flexion and out of external rotation.	Both are in flexion and internal rotation. The right hip is in more internal rotation than the left.	Both are in flexion.

Table 4.23(b): Running gait analysis: Case Study 5 prior to intervention (Lower body)

Running gait analysis: Case Study 5:24/05/03								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre- swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Knee	Both are in very slight flexion.	Slightly more flexion on both sides.	Slightly more flexion and external rotation on both sides.	Extension and external rotation on both sides. The right side is more externally rotated than the left.	Still in external rotation. Flexion is initiated.	On both sides the amount of flexion is increased and both start to move into internal rotation.	Both are in flexion and starting to move into external rotation and extension. There is more external rotation on the right than on the left.	Both are in slight flexion and external rotation.
Ankle	On both sides there is a definite heel contact. The ankles are in neutral with the feet a little in abduction.	Both ankles are in neutral: midway between supination and pronation and both feet are in abduction.	The degree of dorsi flexion at the ankle is 0 degrees. Both feet moves into hind foot pronation.	There is an irregularity in the right foot. Both feet are in plantar flexion. On the left, the push-off is in line with the 2nd metatarsal head. On the right., it is in line with the 3rd metatarsal and the foot moves slightly into inversion.	Both are in plantar flexion.	Both are in plantar flexion.	Both are in plantar flexion.	Both are in dorsi flexion.
Toes	Both are in extension. Very active tendons.	Both are in extension.	Both are still slightly in extension.	Both are in extension. He is very high on the toes. Seems to be higher on the toes of the left foot.	Both are in extension, but less.	Both are in extension, but less.	Almost neutral: both sides.	Both sides move into a lot of extension.

o *Analysis of running gait, including movement patterns*

Movement patterns which deviated from the normal/ ideal running patterns are:

- The right shoulder moved into more extension and retraction than the left shoulder. There was more thoracic rotation towards the left compared on to the right side.
- The pelvis on the right side moved into anterior rotation during initial contact whilst the pelvis on the left side only moved into a neutral position.
- The hip on the left side was in a position of increased lateral rotation throughout compared to the right side.
- There is an irregularity in the right foot. On the left side, the push-off is in line with the second metatarsal head. On the right side, it is in line with the third metatarsal and the foot moves slightly into inversion.

o *Flexibility/ length of soleus muscle 24/05/2003*

Right soleus muscle: Big toe 80 mm from the wall.
Left soleus muscle: Big toe 90 mm from the wall.

o *Biomechanical angles 24/05/2003*

The biomechanical angles as measured on 24/05/2003 are reflected in Table 4.24.

Table 4.24: Biomechanical angles: Case Study 5 during intervention

Movement	***Joint Range of Movement (degrees)****	
	Mid stance	***Terminal stance***
Dorsi flexion left	11, 67^{o}	18, 00^{o}
Dorsi flexion right	4, 33^{o}	14, 67^{o}
Metatarsophalangeal extension left		56, 67^{o}
Metatarsophalangeal extension right		49, 33^{o}
Hind foot pronation left	11, 67^{o}	
Hind foot pronation right	9, 33^{o}	

**Average of three measurements*

Table 4.25: Tightness of clinically significant muscles: Case Study 5 prior to intervention (Date: 24/05/03)

Muscle	***Left Side***			***Right Side***			***Muscle***	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula		1				2	*Sternocleidomastoid*		1				2
Trapezius		1				2	*Scalenii*			2			2
Latissimus dorsi		1				2	*Pectoralis major*		1				2
Erector spinae		1				2	*Pectoralis minor*			2		1	
Quadratus lumborum			2		1		*Serratus anterior*			2		1	
Gluteus medius		1				2	*Subscapularis*	0				1	
Gluteus maximus		1				2	*External oblique*			2		1	
Piriformis		1				2	*Rectus abdominus*			2			2
Semimembranosus			2		1		*Psoas- umbilicus head*			2		1	
Semitendinosus			2		1		*Psoas- iliac head*			2		1	
Biceps femoris		1				2	*Psoas- groin*			2		1	
Gastrocnemius			2		1		*Iliotibial band*			2		1	
Soleus			2		1		*Vastus lateralis*	0			0		
Plantar fascia	0			0			*Vastus medialis*	0			0		
							Adductor longus			2		1	
							Adductor magnus			2		1	
							Pes anserinius			2		1	

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

o *The tightness of the clinically significant muscles*

All clinically significant muscles were palpated for tightness and rated on a scale of 0 – 2. The outcomes are provided in Table 4.25.

4.5.3.3. Intervention

All the tight clinically significant muscles were released. Different release techniques were used, depending on the muscle involved. Myofascial release techniques were used according to Mannheim (1994) and Barnes (1990). Trigger point release techniques were done according to Travell & Simons (1999) and specific soft tissue mobilization were done according to Hunter (1998).

The subject was seen twice a week during the first two weeks. Thereafter the frequency decreased to once every ten days for a period of five months. The intervals however varied from seven to fourteen days due to uncontrollable events.

He was instructed to stretch the following muscles on a daily basis:

- the trapezius
- the levator scapula
- the pectoralis
- the abdominal muscles
- the iliopsoas
- the piriformis
- the hamstrings
- the gastrocnemius and
- the soleus muscles

He was instructed to hold each stretch for 30 seconds and to repeat it.

The following clinical observations were made during the intervention period:

- the sensation of pins-and-needles in both feet which occurred after spending prolonged periods of time behind the computer disappeared.
- he could run hard without afterwards noticing any signs of haematomas over the superior tibio-femoral joint on the left.
- the release of the external oblique muscles led to the disappearance of the abdominal stitches he experienced whilst running hard. This was observed with the first run after these muscles were released.

Treatment period

24 May 2003 to 25 October 2003.

Final assessment results (25/10/2003)

Interview

- He had no discomfort/pain at rest or during or after a run anymore.
- He ran a weekly distance of 55 to 65 kilometres.
- He ran a personal best time of 45 minutes for a ten kilometre run; as well as a best time of 94 minutes for a 21 kilometre run during November and October 2003 respectively.

Physical examination

o ***Re-assessment of running gait and movement patterns***

The following movement patterns deviated from the normal/ideal running patterns (see Table 4.26 for more detail):

- The pelvis was still slightly more posteriorly rotated on the left than on the right, but the difference was much less than with the initial assessment.
- The external hip rotation on the left was less. Both sides were more equal.

Table 4.26: Running gait analysis: Case Study 5 after intervention (Date: 25/10/2003)

Running gait analysis: Case Study 5: 25/10/2003								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre- swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Shoulders	As above but to a lesser extent.							
Thoracic region	As above but to a lesser extent.							
Pelvis	The right side of the pelvis still moves into more anterior rotation than the left but the difference between the 2 sides are much less.				The pelvis is still slightly more posteriorly rotated on the left than on the right., but the difference is much less than with the previous assessment.			
Hips							The left and right sides are more equal. There is less medial rotation of the left hip.	
Knees							The external rotation on the left side is less. Both sides are more equal.	
Ankles		The right foot is less in abduction than with the previous assessment.		With the right foot's push-off, there is now only a slight inclination towards the 3rd metatarsal head.				Appears not to go so high on the toes. The amount of dorsi flexion is less.
Toes								Appears not to go so high on the toes. The amount of MTP extension is less.

- With the right foot's push-off, there was now only a slight inclination towards the third metatarsal head.
- He did not rise as high as previously onto his front foot during the terminal phase. The measurements of the degree of metatarsophalangeal extension at the first metatarsophalangeal joint angle confirmed this observation (see Table 4.27).

o ***Flexibility/ length of soleus muscle***

Right soleus muscle: Big toe 100 mm from the wall.

Left soleus muscle: Big toe 110 mm from the wall.

o ***Biomechanical angles***

The biomechanical angles as measured on 25/10/2003 are reflected in Table 4.27.

Table 4.27: **Biomechanical angles: Case Study 5**

Movement	***Joint Range of Movement (degrees)****	
	Mid stance	***Terminal stance***
Dorsi flexion left	13, 33^{o}	18, 33^{o}
Dorsi flexion right	5, 50^{o}	14, 33^{o}
Metatarsophalangeal extension left		52, 66^{o}
Metatarsophalangeal extension right		40, 33^{o}
Hind foot pronation left	9, 67^{o}	
Hind foot pronation right	7, 00^{o}	

** Averages of three measurements*

o ***The tightness of the clinically significant muscles***

The tightness of the clinically significant muscles was again rated on a scale of 0 – 2 as indicated in Table 4.28.

Table 4.28: Tightness of clinically significant muscles: Case Study 5 after intervention: (Date: 15/10/2003)

Muscle	*Left Side*			*Right Side*			*Muscle*	*Left Side*			*Right Side*		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula	0			0			*Sternocleidomastoid*		<1			1	
Trapezius	0				1		*Scalenii*	0			0		
Latissimus dorsi	0				1		*Pectoralis major*		<1			1	
Erector spinae	0				1		*Pectoralis minor*		1			<1	
Quadratus lumborum		1		0			*Serratus anterior*		1		0		
Gluteus medius	0			0			*Subscapularis*	0			0		
Gluteus maximus	0			0			*External oblique*		1			<1	
Piriformis	0			0			*Rectus abdominus*		1			1	
Semi-membranosus		1		0			*Psoas- umbilicus head*		1		0		
Semitendinosus	0			0			*Psoas- iliac head*		1		0		
Biceps femoris	0			0			*Psoas- groin*		1		0		
Gastrocnemius		1		0			*Iliotibial band*		1		0		
Soleus		1		0			*Vastus lateralis*	0			0		
Plantar fascia		1		0			*Vastus medialis*	0			0		
							Adductor longus		1		0		
							Adductor magnus		1		0		
							Pes anserinius		1		0		

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

4.5.3.4. Synthesis/discussion

The discussion will again be limited to the conclusions drawn in terms of the main proposition and associated rival theories.

o ***The proposition***

The mobilization of the tightness (myofascial tissue) of the clinical significant muscles did lead to a disappearance in symptoms of CPCS. This was accompanied with a reduction in the pressure in the posterior compartment as manifested by means of the palpation of the posterior compartment area. This reduction in pressure in posterior compartment in all probability led to the alleviation of the symptoms of CPCS. This reduction in pressure can in all probability be contributed to the normalisation of the myofascial chain.

This normalisation leads to a reduction in the stresses in the chain and the pressure which these stresses induce into the posterior compartment. The pressure relief is associated with an increase in tissue blood flow to the posterior compartment area and an associated oxygenation which reversed the process.

o ***Rival theories***

- The subject had significant tightnesses in the clinical significant muscles. This negates the rival proposition that subjects will not have any significant tightness in the clinically significant muscles as a different theoretical framework is responsible for the pathogenesis of the condition.
- The treatment of the tightness in the clinical significant muscles did lead to the alleviation of the symptoms of CPCS. This is however not a conclusive fact that this was solely responsible for the alleviation of the symptoms. It could be as a result of chance, and that a different theoretical framework is responsible for the pathogenesis

of the condition. In the light of the replication of the previous case study results this is considered to be highly unlikely.

- The rival theory that the alleviation of the symptoms of the condition is purely due to chance and the intervention has nothing to do with it can be considered as highly unlikely.

4.5.3.5. Quality assurance measures

The review of the quality assurance measures will be done on a collective basis with regard to the explanatory research involving the main propositions at the end of this chapter.

4.5.4. CASE STUDY 6

(24 May 2003 – 25 October 2003)

4.5.4.1. The Subject

The subject in Case Study 6 was a 35 year old male athlete, who had participated competitively in duathlon, cycling and running events for the previous four years.

Inclusion criteria

He complained of symptoms of CPCS. The pain was situated over the posterior-medial aspect of the middle third of both calves. He described the pain as an intense cramp. Once he experienced this pain, it became impossible to run; he completed the race by walking. The pain increased with exercise and abated with rest.

Exclusion criteria

Nothing abnormal was noted whilst testing the exclusion criteria.

4.5.4.2. Research procedure

Subjective assessment - Interview

- ***Running history***

The subject in Case Study 6 was a 35 year old male athlete. He had participated competitively in standard duathlon events, 100 km cycling events and ultra distance running events for the previous four years. His weekly training programme included a 100 kilometre bicycle ride on a Sunday, two spinning sessions in the gymnasium and a total of 40 kilometres of running. Whenever he participated in a long run such as a 42 km race over a weekend, he did very little running during the remainder of the week (at the most, distances of eight kilometres and no later than Wednesday). He did a ‘brick session’ twice a week, i.e. a spinning session followed by an eight kilometre running session.

At the time of inclusion into the study, he was running with strong anti-pronation shoes.

- ***Previous running injuries***

He had right sided iliotibial band syndrome (2002).

He had left sided plantar fasciitis (2002).

He had received cortisone injections for both of the above injuries, which had left him pain free until the commencement of the intervention.

- ***Current symptoms***

His symptoms usually started 35 to 40 kilometres into a race or towards the end of a brick session. He found that running over hilly terrain or on a treadmill, caused the symptoms to appear more quickly. The pain was situated over the posterior-medial aspect of the middle third of both calves. He described the pain as an intense cramp. Once he experienced this pain, it became impossible to run; he completed the race by walking. On photographs that had been taken during one of his previous races, dentations caused by a cramp in the vicinity of the soleus muscles were clearly visible. He rated the intensity of the pain as 80 on a 100mm VAS. He also often experienced cramps in his adductors during a longer cycling race of 70 kilometres plus.

o ***History of symptoms and previous treatment received***

The symptoms had started three years previously. He had previously received massage of the legs as a treatment and had been stretching the calf muscles (gastrocnemius- as well as soleus muscles); the hamstring muscles, the adductor muscles, the quadriceps-, the iliopsoas- and the piriformis muscles on a daily basis (each stretch was maintained for 30 seconds).

In summary, the subjective outcome measures before the intervention were:

- He had no pain at rest.
- The intensity of pain/ discomfort was rated as an 80 on the 100mm VAS and appeared after a brick session or 35 to 40 kilometres into the race.
- He averaged a running distance of 40 kilometres per week.

Objective assessment – Physical examination

o ***Muscle strength tests***

Muscle strength was assessed by a biokineticist on a calibrated Isokinetic dynamometer, using a standardized testing protocol. It is clear from the measurements made on 06/06/2003 reflected in Table 4.29 that there were some muscle imbalances between the left and right sides of the athlete.

Table 4.29: Isokinetic dynamometer test results* prior to intervention: Case Study 6.

*Movement tested***	*Peak torque (Nm)*			*Work per repetition (Nm/s)*		
	Right	*Left*	*Deficit*	*Right*	*Left*	*Deficit*
Hip extensors	106	115	-8	141	154	-8
Hip flexors	78	71	9	90	90	0
Hip internal rotators	14	12	*14*	14	13	7
Hip external rotators	14	14	0	16	16	0
Hip abduction	66	76	*-13*	33	42	*-21*
Hip adduction	66	61	8	35	38	-8
Knee extensors	137	122	*11*	150	146	3
Knee flexors	81	72	*11*	97	89	8
Knee internal rotation	23	23	0	21	22	-5
Knee external rotation	17	15	*12*	18	17	6
Ankle inversion	21	12	***	18	9	***
Ankle eversion	16	12	***	14	9	***
Ankle plantar flexors	45	45	0	32	29	9
Ankle dorsi flexors	17	17	0	13	13	0

**Statistically significant differences between the left and right legs are given in italic*
***Tested at a speed of 30/30 and with 5 repetitions*
****Not calculated*

o ***Analysis of running gait, including movement patterns (24/05/03)***

The following movement patterns as summarised in Table 4.30 deviated from the normal/ ideal running patterns:

- The left shoulder moved into more extension and retraction than the right.
- There was more thoracic rotation towards the right in comparison to the left side.
- The pelvis on the left side moved into anterior rotation during initial contact whilst the pelvis on the right only moved into a neutral position.
- The right hip was throughout in an increased lateral rotation in comparison to the left.
- There is an irregularity in the right foot. On the left, the push-off is in line with the 2nd metatarsal head. On the right, it is in line with the 3rd metatarsal and the foot moves slightly into inversion.

Table 4.30 (a): Running gait analysis: Case Study 6 prior to intervention (Upper body)

***Running gait analysis: Case Study 6** (24/05/2003)*								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre- swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Shoulders	Right leg: left shoulder in more extension and retraction than left leg with right shoulder (phase of initial contact). There is a bit of swinging of the right shoulder with extension of the right shoulder.							
Thoracic region	There is more thoracic rotation to the right than to the left.							
Pelvis	The pelvis on the left rotates more anteriorly than the pelvis on the right side.	The left pelvis is in anterior rotation, while the pelvis on the right side moves into a neutral position.	The pelvis on the left is in anterior rotation while the pelvis on the right is in a neutral position.	The pelvis on the right side is in more posterior rotation than the pelvis on the left side.	Both sides are in posterior rotation.	Both sides are in posterior rotation.	Both sides move into a position of neutral.	Left side of the pelvis moves into anterior rotation. The right side stays in neutral.
Hip	Both hips are in flexion. The left hip is slightly in adduction.	The left hip is lower than the right. Both hips are in flexion.	Both hips are in flexion.	Right hip in more extension and external rotation than the left. The left hip only moves into a neutral position.	Right hip: extension and external rotation. Left hip: neutral and external rotation.	The right hip starts to move into internal rotation. The left hip is in neutral.	The left hip is lower than the right hip. Both hips move into flexion.	The left hip is lower than the right. Both hips are in flexion.

Table 4.30 (b): Running gait analysis: Case Study 6 prior to intervention (Lower body)

***Running gait analysis: Case Study 6** (24/05/2003)*								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre- swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Knee	Both are almost fully extended.	Slightly more flexion in both knees.	A further slight increase in the amount of knee flexion in both knees.	Both knees: almost full extension.	Left knee: slightly more flexion. Right knee: slightly more flexion and external rotation.	Both knees: external rotation and flexion.	Both knees: external rotation and flexion.	Both knees: almost full extension.
Ankle	Definite heel contact first (both feet) with very active extensor. Tendons.	Both feet in abduction.	Dorsi-flexion – both feet.	Plantar flexion – both feet.	Slight plantar flexion –both feet. Right foot: tends to shift weight to the 3rd metatarsal head, the foot then moves into a position of inversion. This happens much less in the left foot. The amount of inversion is also less in the left foot.	Plantar flexion: left and right sides.	Right side: plantar flexion. Left side: neutral.	Right side: dorsi-flexion. Left side: slight dorsi-flexion.
Toes	Strong extension action on both sides.	Somewhat less extension on both sides.	Left and right sides are in neutral.	High on toes with push-off.	Extension.	Very slight extension on both sides.	Extension: left and right sides.	Extension: left and right sides.

o ***Flexibility/ length of soleus muscle***

Right soleus muscle: big toe 92 mm from the wall.

Left soleus muscle: big toe 86 mm from the wall.

o ***Biomechanical angles (Date: 24/05/2003)***

The biomechanical angles that were measured are provided in Table 4.31.

Table 4.31: Biomechanical angles: Case Study 6 prior to intervention

Movement	***Joint Range of Movement (degrees)****	
	Mid stance	***Terminal stance***
Dorsi flexion left	5, 40^{o}	15, 00^{o}
Dorsi flexion right	9, 50^{o}	20, 00^{o}
Metatarsophalangeal extension left		54, 00^{o}
Metatarsophalangeal extension right		51, 00^{o}
Hind foot pronation left	11, 67^{o}	
Hind foot pronation right	9, 00^{o}	

** Averages of three measurements*

o ***The tightness of the clinically significant muscles***

Tightness of clinically significant muscles before intervention is reflected in Table 4.32.

Table 4.32: Tightness of clinically significant muscles: Case Study 6 prior to intervention (Date: 24/05/2003)

Muscle	***Left Side***			***Right Side***			***Muscle***	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula		1			1		*Sternocleidomastoid*		1			1	
Trapezius		1				1,5	*Scalenii*		1				2
Latissimus dorsi		1				2	*Pectoralis major*		1			1	
Erector spinae			2			2	*Pectoralis minor*			2		1	
Quadratus lumborum			2		1		*Serratus anterior*		1			1	
Gluteus medius			2			2	*Subscapularis*		1				2
Gluteus maximus			2		1		*External oblique*			2			1,5
Piriformis			2			2	*Rectus abdominus*		1			1	
Semimembranosus			2			2	*Psoas- umbilicus head*			1,5			2
Semitendinosus		1			1		*Psoas- iliac head*	0			0		
Biceps femoris	0			0			*Psoas- groin*	0			0		
Gastrocnemius			2		1		*Iliotibial band*		1			1	
Soleus			2			1,5	*Vastus lateralis*	0			0		
Plantar fascia			2		1		*Vastus medialis*		1			1	
							Adductor longus		1				2
							Adductor magnus		1				1,5
							Pes anserinius			2	0		

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

4.5.4.3. Intervention

All the tight clinically significant muscles were mobilized. Different release techniques were used, depending on the muscle involved. Myofascial release techniques were used according to Barnes (1990) and Mannheim (1994), Trigger point release techniques were done according to Travell & Simons (1999) and Cross-frictions were done according to Cyriax (1988).The subject was for the first two weeks treated twice a week, thereafter once every ten days for a period of five months. These intervals again varied between seven and 14 days due to factors beyond the control of the subject or the researcher.

He was instructed to stretch the following muscles on a daily basis:

- the trapezius
- the levator scapula
- the pectoralis
- the abdominal muscles
- the iliopsoas
- the piriformis
- the hamstrings
- the gastrocnemius and
- the soleus muscles

He was instructed to hold each stretch for 30 seconds and to repeat it.

- ***Clinical observations during the intervention period:***

No new knowledge/ observations came to the fore.

- ***Treatment period***

32 weeks.

Interim results (25/10/2003)

Interview

- The intensity of pain was still rated as 80 on a 100mm VAS scale when he experienced the symptoms 35 to 40 km into a run.
- He no longer experienced cramps after a brick session and his adductors also did not cramp during cycling races.
- He averaged a weekly distance of 60 kilometres.
- The subject ran a 42 kilometre race during the second week in October 2003. It was a hilly course, partly on loose sand and from the 16 kilometres mark onwards the runners were running against a very strong head wind. The subject started cramping very badly at 16 kilometres.

Note: In Case Study 4 a similar situation was experienced where loose sand triggered cramping faster than normal.

In general the situation improved and he no longer experienced cramps during or after a brick session. He averaged a distance of 60 kilometres per week versus 40 kilometres. The subject also started out running harder than normal in order to improve his times.

Physical examination

o ***Re-assessment of running gait and movement patterns***

With regard to the movement patterns which are summarised in Table 4.33:

- In general his running movement patterns in the pelvic and hip area had improved.
- The anterior rotation on the right improved during the initial contact phase. During terminal stance, the lateral rotation of the hip was less.

Table 4.33: Running gait analysis: Case Study 6 after intervention

Running gait analysis: Case Study 6 (25/10/2003)								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre--swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Shoulders	As above.							
Thoracic region	As above.							
Pelvis	The amount of anterior rotation on the left side is more, although it is still less than on the right.			The pelvis on the left is in less posterior rotation than before, but it is still more than that on the right hand side.				
Hip	The left hip is in less adduction than before.			The left hip now moves into extension but it is still less than that on the right side.				
Ankle				Left push-off is in line with the 2nd metatarsal head. With the push-off on the right, there is still a weight shift towards the 3rd metatarsal head.				

o *Flexibility/length of soleus muscles*

Right soleus muscle: big toe 95mm from the wall (was 92).
Left soleus muscle: big toe 92mm from the wall (was 86).

o *Biomechanical measurements*

The biomechanical measurements as measured on 25/10/2003 are given in Table 4.34.

Table 4.34: Biomechanical angles: Case Study 6 after intervention

Movement	***Joint Range of Movement (degrees)****	
	Mid stance	***Terminal stance***
Dorsi flexion left	12, 00 °	17, 33 °
Dorsi flexion right	7, 67 °	17, 67 °
Metatarsophalangeal extension left		50, 00 °
Metatarsophalangeal extension right		42, 67 °
Hind foot pronation left	10, 33 °	
Hind foot pronation right	8, 67 °	

** Averages of three measurements*

o *The tightness of the clinically significant muscles*

From Table 4.35 it can be seen that the tightness of the clinically significant muscles at the end of October 2003, have improved except for the tightness of the pectoralis minor- and the external oblique muscles. The pectoralis minor muscle still rated as a two on the left side and a one on the right. The external oblique muscle rated as a two on the left, and as 1,5 on the right. It was thus decided to mobilize only these two muscles whilst the subject continued with all the stretches. The objective was to determine whether the tightness in these two muscles caused the perpetuation of the symptoms.

Table 4.35: Tightness of clinically significant muscles: Case Study 6 after intervention (Date: 25/10/2003) (Interim)

Muscle	***Left Side***			***Right Side***			***Muscle***	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula	0			0			*Sternocleidomastoid*		<1			1	
Trapezius	0				1		*Scalenii*	0			0		
Latissimus dorsi	0				1		*Pectoralis major*		<1			1	
Erector spinae	0				1		*Pectoralis minor*			2		1	
Quadratus lumborum		1		0			*Serratus anterior*		1		0		
Gluteus medius	0			0			*Subscapularis*	0			0		
Gluteus maximus			2		1.5		*External oblique*			2			1.5
Piriformis		1		0			*Rectus abdominus*		1			1	
Semimembranosus		1		0			*Psoas- umbilicus head*		1		0		
Semitendinosus	0			0			*Psoas- iliac head*		1		0		
Biceps femoris	0			0			*Psoas- groin*		1		0		
Gastrocnemius		1		0			*Iliotibial band*		1		0		
Soleus		1		0			*Vastus lateralis*	0			0		
Plantar fascia		1		0			*Vastus medialis*	0			0		
							Adductor longus		1		0		
							Adductor magnus		1		0		
							Pes anserinius		1		0		

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

After two more treatment sessions during November and two during December 2003, the subject ran a difficult, hilly marathon at the end of January 2004. He completed this race without any incidence in a time of 4h08, compared to 4h53 for the race in October 2003. The release of the remaining two tight muscles led to the alleviation of all symptoms.

Final results (January 2004)

- ***Interview***

He participated in a difficult and hilly 42 kilometre race the last weekend in January on a day during which the maximum temperature increased to 28 degrees Celsius and completed the distance symptom free. He averaged a running distance of 76 kilometres per week.

- ***Physical examination***

The tightness of the clinically significant muscles at the end of January 2004 is presented in Table 4.36.

4.5.4.4. Synthesis/discussion

The discussion will again be limited to the conclusions drawn in terms of the main proposition and associated rival theories.

- ***The proposition***

The mobilization of the clinical significant muscles did lead to a disappearance in symptoms of CPCS. This was accompanied with a reduction in the pressure in the posterior compartment as manifested by means of the palpation of the calf area. This reduction in pressure in the posterior compartment in all probability led to the alleviation of the symptoms of CPCS by an increase in tissue blood flow to the posterior compartment area and associated oxygenation which reversed the process.

Table 4.36: Tightness of clinically significant muscles: Case Study 6 (Final) (Date: 24/01/2004)

Muscle	***Left Side***			***Right Side***			***Muscle***	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula	0			0			*Sternocleidomastoid*	0			0		
Trapezius	0			0			*Scalenii*	0			0		
Latissimus dorsi	0			0			*Pectoralis major*	0			0		
Erector spinae	0			0			*Pectoralis minor*		1		0		
Quadratus lumborum	0			0			*Serratus anterior*	0			0		
Gluteus medius	0			0			*Subscapularis*	0			0		
Gluteus maximus	0			0			*External oblique*		1		0		
Piriformis		1		0			*Rectus abdominus*	0			0		
Semimembranosus	0			0			*Psoas- umbilicus head*	0			0		
Semitendinosus	0			0			*Psoas- iliac head*	0			0		
Biceps femoris	0			0			*Psoas- groin*	0			0		
Gastrocnemius		1		0			*Iliotibial band*	0			0		
Soleus	0			0			*Vastus lateralis*	0			0		
Plantar fascia	0			0			*Vastus medialis*	0			0		
							Adductor longus	0				1	
							Adductor magnus	0				1	
							Pes anserinius	0			0		

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

o ***Rival theories***

- The subject had significant tightness in the clinical significant muscles. This again negates the rival proposition that subjects will not have any significant tightness in the clinically significant muscles and that a different theoretical framework is responsible for the pathogenesis of the condition.
- The treatment of the tightness in the clinical significant muscles did lead to the alleviation of the symptoms of CPCS. With three replications it appears as a reasonable conclusion that the interventions of releasing the tightness in the clinically significant muscles are responsible for the alleviation of the symptoms. This perspective is further enforced by the fact that the only other intervention with some degree of success is the surgical release of the involved fascia in the posterior compartment. It is highly unlikely that a totally different healing mechanism applies. It is also highly unlikely that the results are due to chance.

4.6. CROSS CASE STUDY COMPARISON

4.6.1. Introduction

In previous sections the focus was on the individual case studies. In this chapter the focus will be on the consolidation of these observations in the form of cross case comparisons. With regard to the symptoms of CPCS, five measures were elected. These measures consisted of the *Intensity of pain/discomfort prior to running; Intensity of pain/discomfort post running; Distance run prior to symptoms; Total weekly distance run; and Palpation findings*. These measures were supplemented by observations made during the pre-assessment of the subjects, as well as post intervention assessments.

Although the explanatory research phase theoretically only dealt with case studies 4 to 6, the final results of case studies 1 to 3, are also included as supplementary evidence to the findings of the explanatory phase. Due to the additional interventions during the exploratory phase, these results do not bear the same significance as the findings of case studies 4 to 6. From an ethical perspective however, the success that were achieved with the new interventions based on the new theoretical model for the pathogenesis of CPCS had to be shared with the first three subjects.

This section reviews the collective outcomes of the individual case study experiments discussed in previous sections. These outcomes consist of both quantitative and qualitative results. It includes the qualitative observations made during the initial assessment as well as those at the end of the interventions.

Some of these abnormal movement observations triggered the supplementary biomechanical experimentation covered in this section. A summary of the chronological progression of the case studies are presented in Table 4.37 for the ease of relating outcomes to the chronological sequencing of the interventions that were applied. Subject 4, as can be seen from Table 4.37, provided some overlap with the previous three case studies. In this regard it is important to note the gradual progression from pure exploration to explanation of new theoretical concepts formalised. This progression is graphically illustrated in Figure 4.10.

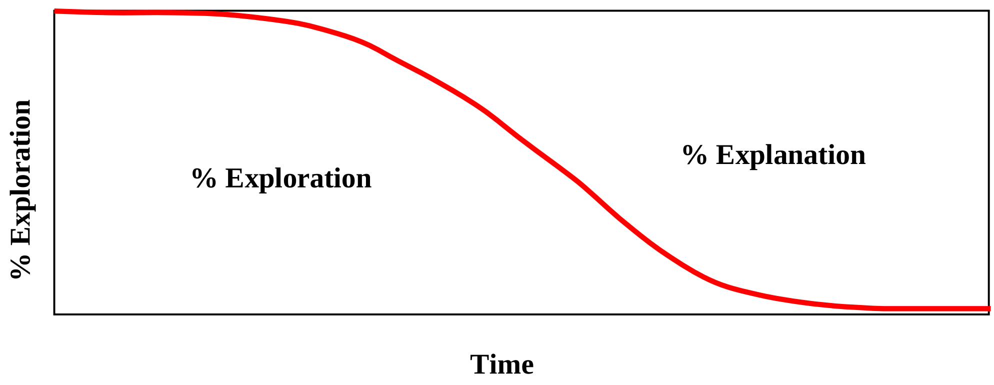

Figure 4.10: Progressive change from *Exploration* to *Explanation*

Table 4.37: A summary of the chronological progression of case studies 1 to 6

Subjects	***Main approach used***	***Main outcome***
Subject 1	***Phase 1: 24/01/02 - 05/02/02*** - Conventional physiotherapy ***Phase 2: 15/04/02 –03/05/02*** - Calf muscle strengthening and proprioceptive retraining ***Phase 3: 10/05/02 - 02/07/02*** - Mobilization aimed specifically at the fascia of the lower leg ***Phase 4: 05/07/02 - 25/09/02*** - Mobilization of the more proximal soft tissue*	No improvement No improvement Slight improvement Pain free
Subject 2	***Phase 1: 10/03/03 –28/05/03*** - Mobilization of the more proximal posterior soft tissue*	Progressive improvement
Subject 3	***Phase 1: 14/05/03 -13/06/03*** - Mobilization of the more proximal posterior soft tissue * ***Phase 2: 26/06/03 -01/09/03*** - Mobilization of more proximal anterior and posterior soft tissue*	Noticeable improvement Noticeable improvement
Subject 4	***Phase 1: 23/08/02 -10/03/03*** - Mobilization aimed specifically at the fascia of the lower leg - Mobilization of the soft tissue of the trunk and pelvis* ***Phase 2: 10/03/03 -25/10/03*** - Mobilization of the clinically significant muscles*	No improvement Noticeable improvement Pain free
Subject 5	***Phase 1:24/05/03 – 25/10/03*** - Mobilization of the clinically significant muscles*	Pain free
Subject 6	***Phase 1: 24/05/03 -25/10/03*** - Mobilization of the clinically significant muscles* (pectoralis minor- and external oblique not mobilized effectively) ***Phase 2: 25/10/03 -04/12/03*** - Mobilization of all the clinically significant muscles*	Initial improvement Pain free

* Plus stretches

4.6.2. The symptoms prior and post interventions

Pain/discomfort

All the subjects had symptoms of *pain and discomfort* prior to the interventions. These symptoms progressively responded positively to the interventions as more of the 'clinically significant' muscles were mobilized. In terms of pain/discomfort all the subjects were symptom free at the end of the interventions. The intensity of pain/ discomfort as measured on a 100mm VAS prior- and post intervention is summarized in Table 4.38

Table 4.38: Intensity of pain and discomfort before and after intervention

	Intensity of pain VAS- 100mm (Visual analogue scale)					
Case Studies	**1**	**2**	**3**	**4**	**5**	**6**
Prior to intervention	*20*	*60*	*65*	*75*	*50*	*80*
Post intervention	*0*	*0*	*0*	*0*	*0*	*0*

The fact that all the subjects were pain free after the interventions is considered to be a significant improvement.

Distance run before commencement of symptoms

The second outcome measure used was the *distance run before commencement of symptoms*. The results of this second outcome measure are given in Table 4.39.

Table 4.39: Commencement of symptoms before and after intervention

	Distance run before commencement of symptoms (km)					
Case Studies	**1**	**2**	**3**	**4**	**5**	**6**
Prior to intervention	*1*	*0*	*0*	*0*	*0.5*	*35**
Post intervention	*21*	*21*	*21*	*10***	*32*	*42*

** Or after a brick session*

*** Sometimes a slight discomfort after 10 km.*

These results represent a significant improvement with the exception of subject 6 who's distances did not increase, but whose symptoms decreased.

Total weekly distance run

The results for the third outcome measure used, namely the *total weekly distance run*, are reflected in Table 4.40.

Table 4.40: The total weekly distance run before and after intervention.

Case Studies	*Total weekly distance run (km)*					
	1	**2**	**3**	**4**	**5**	**6**
Prior to intervention	*12*	*0*	*0*	*14*	*28*	*40*
Post intervention	*17*	*12*	*18*	*20*	*60*	*60*

The minimum improvement listed in Table 10.4 was 42% (from 12 km to 17 km).

Conclusion

The improvements in all three of the outcome measures were significant.

4.6.3. Tightness in the clinically significant muscles

The last of the quantitative measure used, is the palpation findings. In the previous sections it was seen that the successes of the interventions correlated well with the release of tightness in the 'clinically significant' muscles. In this section the pre- and post soft tissue intervention measurements will be reviewed on a comparative cross-case basis. The "clinically significant" muscles as shown earlier can be grouped according to their posterior and anterior fascia links. The posterior and anterior fascia links consists of 14 and 17 muscles respectively. With regard to these groups, two aspects will be reviewed in this section. The first is the number of muscles that were tight prior to the interventions. The second is the extent, or degree of tightness in the muscles. The tightness as indicated earlier, were measured on a scale of 0 to 2. The overall extent of tightness in a subject can therefore be expressed as the product between the number of tight links, and the degree of tightness in the muscles. The review of the cross case results will firstly be done between the left and right sides, and thereafter between the posterior and anterior links.

4.6.3.1. Relative tightness on the left

<u>Posterior fascia links – prior to intervention</u>

Each of the subjects had 14 posterior links that could have been tight. Collectively this provides a possible 42 posterior *fascia links* that could be tight. As seen from Table 4.41 (a), 39 out of these possible 42 links were tight. This represents ninety three percent (93%) of the posterior muscles. The average tightness per subject varied between 1.29 and 1.57, with an average tightness for the three subjects of 1.40.

Table 4.41 (a): Relative tightness of posterior links prior to intervention (left)

Muscle	*Relative Tightness*				
<u>Posterior fascia links</u>	*Case 4*	*Case 5*	*Case 6*	*Qty*	*Average*
Levator scapula	1	1	1	3	1.00
Trapezius	1	1	1	3	1.00
Latissimus dorsi	1	1	1	3	1.00
Erector spinae	1	1	2	3	1.33
Quadratus lumborum	2	2	2	3	2.00
Gluteus medius	0	1	2	2	1.00
Gluteus maximus	2	1	2	3	1.67
Piriformis	2	1	2	3	1.67
Semimembranosus	1	2	2	3	1.67
Semitendinosus	1	2	1	3	1.33
Biceps femoris	2	1	0	2	1.00
Gastrocnemius	2	2	2	3	2.00
Soleus	2	2	2	3	2.00
Plantar fascia	1	0	2	2	1.00
Number of tight posterior links	**13**	**13**	**13**	**39**	**13**
Average posterior tightness rating	**1.36**	**1.29**	**1.57**		**1.40**

The *product* of the *average tightness rating* (1.40) and the *average number of tight muscles* (13) thus provides an *overall tightness measure* of 18.2. The Overall tightness rating can thus be expressed as follows:

Overall tightness rating = average tightness rating x average number of tight muscles

In subjects 4 to 6, the Quadratus lumborum, Gastrocnemius and Soleus muscles as highlighted in Table 4.41(a), were very tight with ratings of 2. With weight bearing exercises such as running, the most stress is expected in these muscles. The Quadratus lumborum is a stabilising muscle. With weakness of the Gluteus medius muscles, which acts as a stabiliser during weight bearing, the Quadratus lumborum muscle takes more strain. This leads to tightness in the Quadratus lumborum muscle.

Anterior fascia links – prior to intervention

Table 4.41 (b): Relative tightness of anterior links prior to intervention (left)

Muscle	***Relative Tightness***				
Anterior fascia links	***Case 4***	***Case 5***	***Case 6***	***Qty***	***Average***
Sternocleidomastoid	1	1	1	3	1.00
Scalenii	1	2	1	3	1.33
Pectoralis major	1	1	1	3	1.00
Pectoralis minor	2	2	2	3	2.00
Serratus anterior	1	2	1	2	1.33
Subscapularis	1	0	1	2	0.67
External oblique	1	2	2	3	1.67
Rectus abdominus	2	2	1	3	1.67
Psoas- umbilicus head	1	2	1,5	3	1.50
Psoas- iliac head	1	2	0	2	1.00
Psoas- groin	1	2	0	2	1.00
Iliotibial band	1	2	1	3	1.33
Vastus lateralis	0	0	0	0	0.00
Vastus medialis	0	0	1	1	0.33
Adductor longus	0	2	1	2	1.00
Adductor magnus	0	2	1	2	1.00
Pes anserinius	2	2	2	2	2.00
Number of tight anterior links	**13**	**14**	**15**	**42**	**14**
Average anterior tightness rating	**0.94**	**1.53**	**1.00**		**1.33**

The *anterior links* totalled 17 links per side as reflected in Table 4.41(b). This provides a grand total of 51 anterior links for the three subjects. Of these, 42 of the links were tight. This gives an average of 76% (82%) of the links that were tight. The *average tightness* of these links was 1.33. The *overall tightness rating* for the *anterior* left side is the product between the average number of tight links, namely 14, and the average tightness of 1.33. This provides an *overall tightness rating* of 18.62. In the case of the anterior links, only two muscles were very tight in all three subjects with ratings of 2. These muscles were Pectoralis minor and Pes anserinius.

Posterior fascia links – post intervention

The relative tightness for the Posterior fascia links, post intervention for the left side, is illustrated in Table 4.42(a).

Table 4.42 (a): Relative tightness of posterior links post intervention (left)

Muscle	*Relative Tightness*				
Posterior fascia links	*4*	*5*	*6*	*Qty*	*Average*
Levator scapula	0	0	0	0	0
Trapezius	0	0	0	0	0
Latissimus dorsi	0	0	0	0	0
Erector spinae	0	0	0	0	0
Quadratus lumborum	0.5	1	0	2	0.50
Gluteus medius	0.5	0	0	1	0.17
Gluteus maximus	0.5	0	0	1	0.17
Piriformis	0.5	0	0	1	0.17
Semi-membranosus	0	1	0	1	0.33
Semitendinosus	0	0	1	1	0.33
Biceps femoris	0	0	0	0	0
Gastrocnemius	0.5	1	0	2	0.50
Soleus	0	1	0	1	0.33
Plantar fascia	0	1	0	1	0.33
Number of tight posterior links	**5**	**5**	**1**	**11**	**5.5**
Average posterior tightness rating	**0.18**	**0.36**	**0.07**		**0.2**

As can be seen from the table the number of tight links after intervention, was reduced to 5, 5 for the posterior links. This is thirty-nine percent (39%) of the posterior 'clinically significant' muscles. The average tightness rating for the three subjects was reduced to 0,2. This provides an overall tightness measure of 1,1. Prior to intervention this figure was 18,2 which provides an improvement in the overall tightness measure of 17,1 or 94%.

Anterior fascia links – prior to intervention

The relative tightness for the anterior fascia links, post intervention for the left side, is illustrated in Table 4.42(b). As can be seen from the table the number of tight links after intervention, was reduced to 9,67. This is sixty-eight percent (68%) of the anterior 'clinically significant' muscles.

Table 4.42 (b): Relative tightness of the anterior links prior to intervention (left)

Muscle	***Relative Tightness***				
Anterior fascia links	***4***	***5***	***6***	***Qty***	***Average***
Sternocleidomastoid	0	0.5	1	2	0.88
Scalenii	0	0	1	1	0.50
Pectoralis major	0.5	0.5	1	3	0.67
Pectoralis minor	1	1	0	2	0.67
Serratus anterior	0.5	1	1	3	0.83
Subscapularis	0.5	0	1	2	0.88
External oblique	0.5	1	0	2	0.50
Rectus abdominus	1	1	1	3	1.50
Psoas- umbilicus head	0	1	0	1	0.50
Psoas- iliac head	0	1	0	1	0.33
Psoas- groin	0	1	0	1	0.33
Iliotibial band	0	1	1	2	0.67
Vastus lateralis	0	0	0	0	0.00
Vastus medialis	0	0	1	1	0.33
Adductor longus	0	1	1	2	1.00
Adductor magnus	0	1	1	2	0.67
Pes anserinius	0	1	0	1	0.33
Number of tight anterior links	**6**	**13**	**10**	**29**	**9.67**
Average anterior tightness rating	**0.24**	**0.71**	**0.59**		**0.62**

The relative tightness of the muscles changed from 1,33 to 0,62 after the intervention. The tightness of the 'clinically significant' muscles has thus improved by 86% for the posterior and 68% for the anterior muscles respectively.

4.6.3.2. Relative tightness on the right

Posterior fascia links – prior to intervention

As can be seen from Table 4.43(a) the average number of tight 'clinically significant' muscles on the right was 13,33 for the posterior links. Prior to intervention the average posterior muscle tightness rating was 1,54. This provides an *overall tightness rating* for the three subjects of 20,5 prior to intervention.

Table 4.43(a): Relative tightness of posterior links prior to intervention (right)

Muscle	*Relative Tightness*				
Posterior fascia links	*4*	*5*	*6*	*Qty*	*Average*
Levator scapula	2	2	1	3	1.67
Trapezius	2	2	1,5	3	2.00
Latissimus dorsi	2	2	2	3	2.00
Erector spinae	2	2	2	3	2.00
Quadratus lumborum	2	1	1	3	1.33
Gluteus medius	2	2	2	3	2.00
Gluteus maximus	1	2	1	3	1.33
Piriformis	2	2	2	3	2.00
Semi-membranosus	2	1	2	3	1.67
Semitendinosus	1	1	1	3	1.00
Biceps femoris	1	2	0	2	1.00
Gastrocnemius	2	1	1	3	1.33
Soleus	2	1	1,5	3	1.50
Plantar fascia	1	0	1	2	0.67
Number of tight posterior links	**14**	**13**	**13**	**40**	**13.33**
Average posterior tightness rating	**1.71**	**1.50**	**1.33**		**1.54**

Anterior fascia links – prior to intervention

For the anterior links reflected in Table 4.43(b) the average number of tight clinically significant muscles was also 13,33 with an average tightness rating of 1,45. This provides an *overall tightness rating* of 19,3 prior to intervention.

Table 4.43(b): Relative tightness of anterior links prior to intervention (right)

Muscle	***Relative Tightness***				
Anterior fascia links	***4***	***5***	***6***	***Qty***	***Average***
Sternocleidomastoid	2	2	1	3	2.00
Scalenii	2	2	2	3	2.25
Pectoralis major	2	2	1	3	1.67
Pectoralis minor	1	1	1	3	1.00
Serratus anterior	2	1	0	2	1.00
Subscapularis	2	1	2	3	2.00
External oblique	2	1	1,5	3	1.50
Rectus abdominus	2	2	1	3	2.00
Psoas- umbilicus head	2	1	2	3	2.00
Psoas- iliac head	2	1	0	2	1.00
Psoas- groin	2	1	0	2	1.00
Iliotibial band	2	1	1	3	1.33
Vastus lateralis	1	0	0	1	0.33
Vastus medialis	1	0	1	2	0.67
Adductor longus	1	1	2	3	1.75
Adductor magnus	1	1	1,5	3	1.00
Pes anserinius	2	1	0	2	1.00
Number of tight anterior links	**14**	**13**	**13**	**40**	**13.33**
Average anterior tightness rating	**1.71**	**1.50**	**1.33**		**1.45**

Posterior fascia links – post intervention

As can be seen from Table 4.44(a) the average number of tight ‘clinically significant’ muscles on the right was reduced from 13,33 for the posterior links to 5,44. Prior to intervention the average posterior muscle tightness rating was 1,54. This was reduced to an average rating of 0,40 for the posterior links. This provides an overall tightness rating for the three subjects of 2,2 post interventions. The overall tightness rating was thus reduced by 18,3. This is a reduction in the overall tightness rating of 89%.

Table 4.44 (a): Relative tightness of the posterior links post intervention (right)

Muscle	***Relative Tightness***				
Posterior fascia links	***4***	***5***	***6***	***Qty***	***Average***
Levator scapula	0.5	0	1	2	0.50
Trapezius	1	1	0	2	0.67
Latissimus dorsi	1	1	0	2	0.67
Erector spinae	1	1	0	2	0.67
Quadratus lumborum	0.5	0	1	2	0.50
Gluteus medius	1	0	0	1	0.33
Gluteus maximus	0.5	0	1	2	0.50
Piriformis	0.5	0	0	1	0.17
Semi-membranosus	1	0	0	1	0.33
Semitendinosus	0	0	1	1	0.33
Biceps femoris	0	0	0	0	0.00
Gastrocnemius	0.5	0	1	2	0.50
Soleus	0	0	0	0	0.00
Plantar fascia	0.5	0	1	2	0.50
Number of tight posterior links	**11**	**3**	**6**	**20**	**5.44**
Average posterior tightness rating	**0.57**	**0.21**	**0.43**		**0.40**

Anterior fascia links post intervention

For the anterior links, post interventions reflected in Table 4.44(b), the average number of tight clinically significant muscles was reduced to 8 with an average tightness rating of 0,5. This provides an overall tightness rating of 4 post interventions. This represents a reduction in this measure of 15,3. This is a 79% reduction in the overall tightness rating.

Table 4.44 (b): Relative tightness of the anterior links post intervention (right)

Muscle	***Relative Tightness***				
Anterior fascia links	***4***	***5***	***6***	***Qty***	***Average***
Sternocleidomastoid	0.5	1	1	3	1.38
Scalenii	0.5	0	0	1	0.38
Pectoralis major	1	1	1	3	1.00
Pectoralis minor	0.5	0.5	1	3	0.67
Serratus anterior	1	0	0	1	0.33
Subscapularis	1	0	0	1	0.50
External oblique	1	0.5	0	2	0.50
Rectus abdominus	1	1	1	3	1.50
Psoas- umbilicus head	1	0	0	1	0.50
Psoas- iliac head	0	0	0	0	0.00
Psoas- groin	0	0	0	0	0.00
Iliotibial band	1	0	1	2	0.67
Vastus lateralis	0	0	0	0	0.00
Vastus medialis	0.5	0	1	2	0.50
Adductor longus	0.5	0	0	1	0.38
Adductor magnus	0.5	0	0	1	0.17
Pes anserinius	0	0	0	0	0.00
Number of tight anterior links	**13**	**5**	**6**	**24**	**8.00**
Average anterior tightness rating	**0.59**	**0.24**	**0.35**		**0.50**

4.6.3.3. Summary

From the previous section on the changes in the tightness of the clinically significant muscles, it can be seen that there is a strong correlation between this reduction in the tightness of the clinically significant muscles and the other outcome measures used.

4.6.4. Assessment of other abnormalities

4.6.4.1. Muscle imbalances

The abnormalities in terms of muscle imbalances were assessed based on the differences in muscle strength and peak torque performance of muscles between the left and right sides of the subjects. These measurements were made on an Isokinetic dynamometer.

Peak torque performance

The muscle imbalances based on *peak torque performance* is reflected in Table 4.45**.** The values in *italics* reflect statistically significant differences as determined by the imbedded software program resident in the Isokinetic dynamometer (Cybex, 1995). From Table 4.45 it can be seen that in 43 out of the 75 cases significant muscle imbalances existed. These imbalances represent 60% of the measurements. Significant differences existed for all subjects in terms of strength of the knee extensor muscles. In four out of the five there were significant differences in the strength of hip internal- and external rotator muscles as well as the knee external rotator muscles. The imbalances showed little correlation with each other. The correlation coefficients between case studies 2 and 3; 2 and 4; 5 and 6 are 0,127; 0,124; and 0,166 respectively. This indicates that muscle tightness of the subjects differed in terms of both location and the extent of tightness (Table 4.45).

Table 4.45: Muscle imbalances in peak torque performance (Prior to treatment)

Movement tested **	**Imbalances between Left and Right (Nm)**					**Number of**
Peak torque	**CS 2**	**CS 3**	**CS 4**	**CS 5**	**CS 6**	**imbalances**
Hip extensors	*-14*	*-14*	*13*	-6	-8	*3*
Hip flexors	*-11*	*-15*	*-16*	-6	9	*3*
Hip internal rotators	*-29*	*0*	*25*	0	*14*	*4*
Hip external rotators	*-11*	*-14*	*23*	*-19*	0	*4*
Hip abduction	*-38*	*-31*	*-14*	-5	*-13*	*4*
Hip adduction	*-23*	*-84*	*-32*	-7	8	*3*
Knee extensors	*-38*	*-10*	*10*	*-13*	*11*	*5*
Knee flexors	*-40*	*-6*	7	-4	*11*	*3*
Knee internal rotation	*-29*	*-14*	-4	*-16*	0	*3*
Knee external rotation	*-19*	*-11*	-5	*-11*	*12*	*4*
Ankle inversion	-3	*-27*	3	***	***	*1*
Ankle eversion	*-32*	*-18*	0	***	***	*2*
Ankle plantar flexors	*-25*	-7	7	*-13*	0	*2*
Ankle dorsi flexors	*-41*	-7	-6	*-11*	0	*2*
Total per case study	*14*	*12*	*7*	*6*	*5*	*43*

[*]Statistically significant differences are reflected in *italics;*

[**] Tested at a speed of 30/30 and with five repetitions; *** Not measured

Work performance per repetition

Muscle imbalances in terms of *work performance per repetition* are provided in Table 4.46.

Table 4.46: Muscle imbalances: work performance per repetition (Prior to treatment)

Movement tested **	Imbalances between Left and Right (Nm/sec)					Number of
Work per repetition	**CS 2**	**CS 3**	**CS 4**	**CS 5**	**CS 6**	**imbalances**
Hip extensors	*-15*	*-14*	*18*	-4	-8	*3*
Hip flexors	-3	-4	-8	-5	0	0
Hip internal rotators	*-41*	*-25*	*39*	-8	7	*3*
Hip external rotators	*-37*	*-17*	*32*	*-22*	0	*4*
Hip abduction	*-42*	*-47*	-7	-4	*-21*	*3*
Hip adduction	*-20*	*-88*	*-24*	-7	-8	*3*
Knee extensors	*-42*	*-3*	9	*-12*	3	*3*
Knee flexors	*-44*	*-9*	-2	-6	8	*2*
Knee internal rotation	*-25*	*0*	0	-4	-5	*2*
Knee external rotation	*-15*	*-11*	-4	*-12*	6	*3*
Ankle inversion	*-33*	*-38*	4	***	***	*2*
Ankle eversion	*-53*	*-38*	*26*	***	***	*3*
Ankle plantar flexors	*-23*	*-14*	0	*-14*	9	*3*
Ankle dorsi flexors	*-33*	*-10*	5	*-28*	0	*3*
Total per case study	*13*	*13*	*5*	*5*	*1*	*37*

*Statistically significant differences as determined by the Cybex in *italic;*

** Tested at a speed of 30/30 and with five repetitions; *** Not measured

The statistically significant differences represented 37 out of the 75 measurements, i.e. 60%. In four out of the five subjects there were a statistically significant difference in muscle strength of the right and the left hip external rotators. In three of the five subjects there were a statistically significant difference in muscle strength between the left and the right hip extensor, -hip internal rotator, -hip abduction, -hip adduction, knee external rotation, ankle eversion, -ankle plantar flexion and- ankle dorsi flexion muscles. Similar to the muscle imbalances as reflected by the measurements in terms of maximum torque performance, similar patterns existed with the imbalances reflected by the work performed per cycle. This was again reflected by the correlation between the measurements of the different subjects. The correlation coefficients between case studies 2 and 3; 2 and 4; 5 and 6 are 0,3; -0,38; and -0,25 respectively.

These observations suggest that distortions in the fascia affect muscle performance. The root cause of the distortions in the fascia is however tightness in the clinically significant muscles and it seems logical that such tightness would influence muscle performance.

Effect of intervention on muscle performance

The initial objective did not include the retesting of the subjects. It was however decided to retest subject 4 after 11-months. The objective was to determine whether the soft tissue mobilization techniques had any effect on the subject's muscle strength and imbalances. This retesting was considered to be specifically relevant due to the fact that subject four did not do any form of strengthening exercises during the preceding 11-month time period. Any differences in muscle performance could therefore only reflect the effect of the soft tissue mobilization techniques.

Peak torque performance

The comparison of pre- and post treatment results in terms of peak torque performance are listed in Table 4.47. The impact of the intervention on the muscle strength as reflected by peak torque performance is reflected in Figure 4.11. The fact that most of the data, as illustrated in Figure 4.11, fall to the right of the diagonal line imply a general improvement in muscle performance over a broad spectrum of muscles.

Table 4.47: The effect of the treatments on peak torque performance (Nm)

Peak Torque Measurements – Right			
Movement Tested	**Actual Measurements (Nm)**		
	Prior	***Post***	***%Change***
Hip extensors	175	133	-24%
Hip flexors	92	102	11%
Hip internal rotators	28	37	32%
Hip external rotators	26	30	15%
Hip abduction	104	129	24%
Hip adduction	120	104	-13%
Knee extensors	192	197	3%
Knee flexors	107	115	7%
Ankle inversion	33	58	76%
Ankle eversion	21	34	62%
Ankle plantar flexors	85	109	28%
Ankle dorsi flexors	34	46	35%

Peak Torque Measurements – Left (Nm)			
Movement Tested	**Actual Measurements**		
	Prior	***Post***	***%Change***
Hip extensors	152	155	2%
Hip flexors	110	104	-5%
Hip internal rotators	21	48	129%
Hip external rotators	20	33	65%
Hip abduction	121	135	12%
Hip adduction	176	139	-21%
Knee extensors	173	192	11%
Knee flexors	100	117	17%
Ankle inversion	32	50	56%
Ankle eversion	21	33	57%
Ankle plantar flexors	79	90	14%
Ankle dorsi flexors	36	36	0%

Figure 4.11: Correlations between peak torque performance pre- and post intervention

Work performance per cycle

The comparison of the pre- and post treatment results is listed in Table 4.48. As can be seen from the Table 4.48 muscle strengths have improved over a broad spectrum.

Table 4.48: Analysis of the effect of treatment on work performance (Nm/sec)

Work per Repetition – Right			
Movement Tested	**Actual Measurements (Nm)**		
	Prior	***Post***	***%Change***
Hip extensors	223	181	-19%
Hip flexors	108	140	30%
Hip internal rotators	31	34	10%
Hip external rotators	28	37	32%
Hip abduction	55	119	116%
Hip adduction	69	117	70%
Knee extensors	194	187	-4%
Knee flexors	130	142	9%
Ankle inversion	27	74	174%
Ankle eversion	23	53	130%
Ankle plantar flexors	47	61	30%
Ankle dorsi flexors	21	33	57%
Work per Repetition - Left			
Movement Tested	**Actual Measurements (Nm)**		
	Prior	***Post***	***%Change***
Hip extensors	152	155	7%
Hip flexors	110	104	0%
Hip internal rotators	21	48	258%
Hip external rotators	20	33	116%
Hip abduction	121	135	93%
Hip adduction	176	139	48%
Knee extensors	173	192	16%
Knee flexors	100	117	35%
Ankle inversion	32	50	88%
Ankle eversion	21	33	118%
Ankle plantar flexors	79	90	13%
Ankle dorsi flexors	36	36	20%

These improvements in muscle strength as reflected by the improvement in work performance per cycle are reflected in Figure 4.12

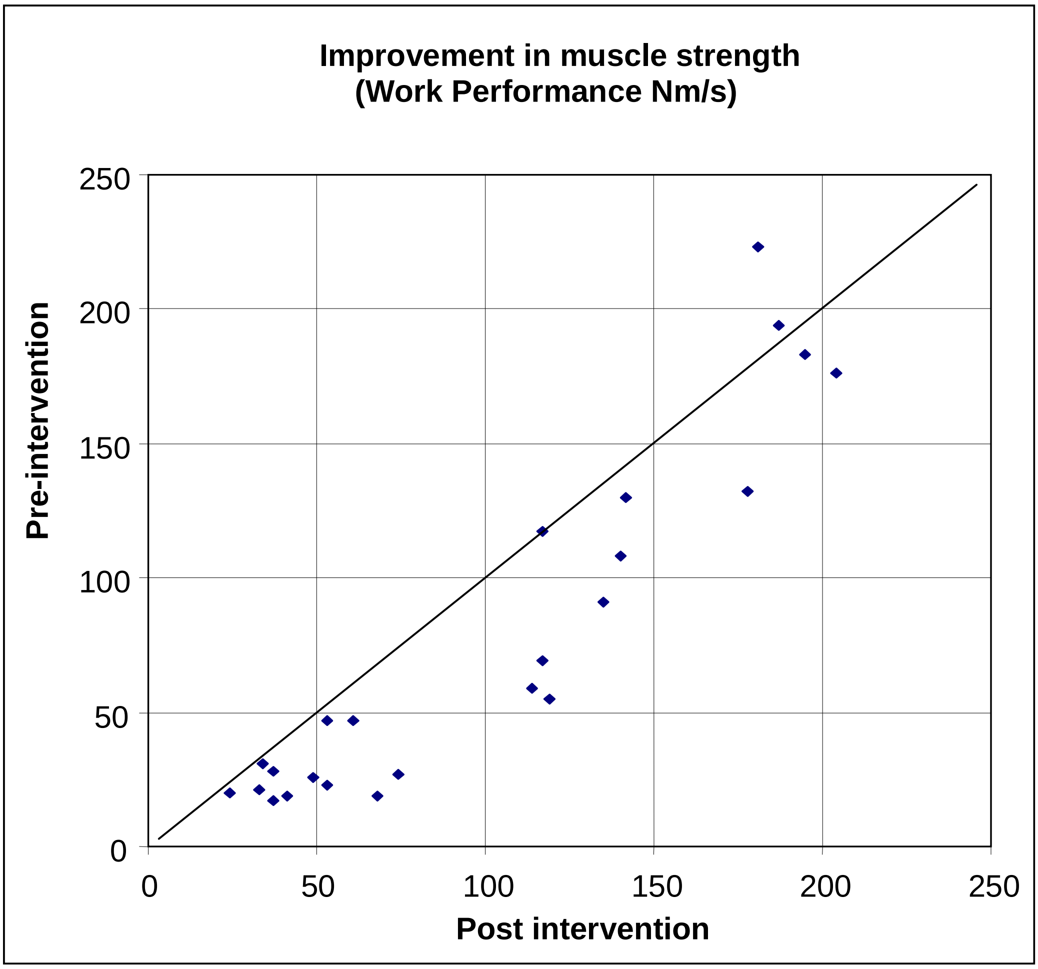

Figure 4.12: Correlation between work-performed per repetition pre- and post intervention

The fact that most of the data points fall to the right of the diagonal line again illustrates the spectrum of improvement in muscle performance.

4.6.4.2. Running movement pattern abnormalities

The movement abnormalities observed during running and the effect of the mobilization of the tight 'clinically significant' muscles on these are summarized in Tables 4.49 to 4.56.

Table 4.49 (a): A comparative summary of running gait analysis prior and post intervention: Weight acceptance phase – initial contact (Upper Body - Shoulder)

Prior Intervention	***Post Intervention***
Case Study 4 Left leg: Right shoulder in more extension and retraction than left shoulder with right leg initial contact. During this phase the right shoulder-blade is winging more than the left and is also in more depression than the left.	Left leg: right shoulder in more extension and retraction than left shoulder with right leg initial contact, but less than before.
Case Study 5 Left leg: Right shoulder in more extension and retraction than left shoulder with right leg initial contact. During this phase there is also some winging of the right shoulder-blade. The right shoulder is in more depression than the left.	The same movement patterns are observed but the differences between the left and the right sides are less.
Case Study 6 Right leg: Left shoulder in more extension and retraction than left leg with right shoulder (phase of initial contact). There is a bit of winging of the left shoulder blade with extension of the left shoulder.	As before.

Comment

Although no significant improvements were observed with Case Study 6, the improvements with the other two were noticeable. The symmetry of their movement patterns improved appreciably. The lack of improvement with the shoulder can be linked to the relative tightness in the pectoralis minor and external oblique muscles which were only effectively released during the last four treatment sessions.

Table 4.49(b): A comparative summary of running gait analysis prior and post intervention: Weight acceptance phase – initial contact (Upper Body - Thoracic region)

Prior Intervention	***Post Intervention***
Case Study 4 There is more thoracic rotation to the left than to the right.	The difference in the degree of rotation to the left- and the right side is less.
Case Study 5 More upper thoracic rotation to the left than to the right.	The difference in the degree of rotation to the left- and the right side is less.
Case Study 6 More thoracic rotation to the right than the left.	As before.

Comment

Similar to the shoulder, the movement patterns of the thoracic region were the same. Subject 6 showed no noticeable improvements while those of subjects 4 and 5 were much more symmetrical.

Table 4.49 (c): A comparative summary of running gait analysis prior and post intervention: Weight acceptance phase – initial contact (Upper Body - Pelvis)

Prior Intervention	***Post Intervention***
Case Study 4 Right pelvis in anterior rotation, the left in a neutral position.	Left pelvis in more anterior rotation than previously.
Case Study 5 The pelvis on the right moves into more anterior rotation than on the left.	The right still moves into more anterior rotation than the left but the difference between the two sides are much less.
Case Study 6 The amount of anterior rotation on the left side is more, although less than on the right.	The anterior rotation on the left side is more, although still less than on the right.

Comment

The movement patterns of all three the subjects normalised after the interventions.

Table 4.50(a): A comparative summary of running gait analysis prior and post intervention: Weight acceptance phase – initial contact (Lower Body - Hip)

Prior Intervention	***Post Intervention***
Case Study 4 Right hip: flexion plus slight adduction. Left hip: flexion plus slight external rotation.	Left and right sides are in flexion.
Case Study 5 Both are in flexion.	As before.
Case Study 6 Hips in flexion - left slightly in adduction.	The left hip is in less adduction than before.

Comment

The improvement in the adduction asymmetry of subjects 4 and 6 was noticeable.

Table 4.50(b): A comparative summary of running gait analysis prior and post intervention: Weight acceptance phase – initial contact (Lower Body - Knee)

Prior Intervention	***Post Intervention***
Case Study 4 Both knees: almost full extension with the tibia in external rotation.	All movements were normal.
Case Study 5 Both are in very slight flexion.	As before.
Case Study 6 Both are almost fully extended.	As before.

Comment

With the exception of subject 4, the interventions had little effect of the running gait.

Table 4.50(c): A comparative summary of running gait analysis prior and post intervention: Weight acceptance phase – initial contact (Lower Body -Ankle)

Prior Intervention	***Post Intervention***
Case Study 4 No heel –toe action –both ankles. Lands in a slightly inverted position on the left ankle; laterally on the 5th metatarsal.	All movements were normal.
Case Study 5 Both are in very slight flexion.	As before.
Case Study 6 Both are almost fully extended.	As before.

Comment

The heel-toe action of subject 4 normalized completely as a result of the interventions. In Subject 5, there was a decrease in the degree of fore foot abduction. Subject 6 was normal at the outset and showed no change.

Table 4.50(d): A comparative summary of running gait analysis prior and post intervention: Weight acceptance phase – initial contact (Lower Body -Toes)

Prior Intervention	***Post Intervention***
Case Study 4 Excessive MTP extension, especially of the big toes	All movements were normal.
Case Study 5 Both are in extension. Very active tendons	The extensor tendons are less active than before
Case Study 6 Very active extensor tendons.	Extensor tendons less active

Comment

The extensor tendons became less active in all three subjects.

Table 4.51(a): A comparative summary of running gait analysis prior and post intervention: Weight acceptance phase – loading response (Pelvis)

Prior Intervention	*Post Intervention*
Case Study 4 Greater anterior rotation on the right.	All movements were normal.
Case Study 5 Greater anterior rotation on the right.	All movements were normal.
Case Study 6 The left pelvis is in anterior rotation, while the pelvis on the right side moves into a neutral position.	All movements were normal.

Comment

There was more symmetry in the position of the pelvis in all the subjects.

Table 4.51(b): A comparative summary of running gait analysis prior and post intervention: Weight acceptance phase – loading response (Hip)

Prior Intervention	*Post Intervention*
Case Study 4 Normal - Both hips are on the same level.	Normal - Both hips are on the same level.
Case Study 5 Both are in flexion and slight external rotation.	Normal - Both hips are on the same level.
Case Study 6 Left hip lower than the right. Both in flexion.	Normal - Both hips are on the same level.

Comment

There was an improvement in the symmetry of the levels of the hips in subject 6.

Table 4.51(c): A comparative summary of running gait analysis prior and post intervention: Weight acceptance phase – loading response (Ankle)

Prior Intervention	***Post Intervention***
Case Study 4 Shift the weight to the medial side of the foot on both sides.	Moves into a lesser degree of eversion than before.
Case Study 5 Ankles neutral: midway between supination and pronation; both feet in abduction.	The right foot is less in abduction than with the previous assessment.
Case Study 6 Both feet in abduction.	A decrease in fore foot abduction.

Comment

The degree of eversion was less in subject 4 and the degree of fore foot abduction was less in subjects 5 and 6.

Table 4.52(a): A comparative summary of running gait analysis prior and post intervention: Single leg support – mid-stance phase (Pelvis)

Prior Intervention	***Post Intervention***
Case Study 4 Both sides are in slight posterior rotation. The left side more so than the right side.	Pelvis on the left and right in neutral. Still tends to drop a bit on the left side.
Case Study 5 Left: mid position Right: mid position.	Still the same.
Case Study 6 The pelvis on the left is in anterior rotation - pelvis on the right is in a neutral position.	Still the same.

Comment

The symmetry improved marginally.

Table 4.52(b): A comparative summary of running gait analysis prior and post intervention: Single leg support – mid stance phase (Hip)

Prior Intervention	***Post Intervention***
Case Study 4 The right hip is in neutral - left hip is in slight abduction. Gait uneven - more of a push-off action on the right side.	Gait more even. The left hip is now in a position of neutral.
Case Study 5 Hips in slight flexion and external rotation.	Still the same.
Case Study 6 Both hips are in flexion.	Still the same.

Comment

The gait became more even in subject 4.

Table 4.52(c): A comparative summary of running gait analysis prior and post intervention: Single leg support – mid stance phase (Ankle)

Prior Intervention	***Post Intervention***
Case Study 4 Hind foot in pronation. The left and the right calcaneus sink further into valgus (loss of eccentric control). Both feet in abduction.	The calcaneus sinks less into valgus than before. Both feet are in a lesser degree of abduction than before.
Case Study 5 The degree of dorsi flexion at the ankle is 0 degrees. Both feet moves into hind foot pronation.	The degree of hind foot pronation is less.
Case Study 6 Dorsi-flexion – both feet.	Still the same.

Comment

The symmetry improved marginally – an improvement in hind foot pronation.

Table 4.53(a): A comparative summary of running gait analysis prior and post intervention: Single leg support – terminal stance phase (Pelvis)

Prior Intervention	***Post Intervention***
Case Study 4 Both sides are in posterior rotation; left side more than right.	The amount of posterior rotation of the pelvis is equal on the left and the right.
Case Study 5 The pelvis on the right moves into less posterior rotation than on the left.	The degree of hind foot pronation is less.
Case Study 6 The pelvis on the right side is in more posterior rotation than the pelvis on the left.	The pelvis on the left is in less posterior rotation than before, but still more than right.

Comment

There was more symmetry with regard to the position of the pelvis.

Table 4.53(b): A comparative summary of running gait analysis prior and post intervention: Single leg support – terminal stance phase (Hip)

Prior Intervention	***Post Intervention***
Case Study 4 Both hips are in extension and external rotation, the left more than the right.	The amount of posterior rotation of the pelvis is equal on the left and the right.
Case Study 5 Both hips are in extension and external rotation, left hip more external than the right.	The degree of hind foot pronation is less.
Case Study 6 Right hip in more extension and external rotation than the left. Left hip only moves into a neutral position.	The left hip now moves into extension but it is still less than that on the right side.

Comment

The symmetry improved marginally.

Table 4.53(c): A comparative summary of running gait analysis prior and post intervention: Single leg support – terminal stance phase (Ankle)

Prior Intervention	***Post Intervention***
Case Study 4 The hind foot moves out of the pronated position into neutral. The right calcaneus starts to move earlier than the left one. The ankle moves into plantar flexion.	
Case Study 5 An irregularity in the right foot. Both feet are in plantar flexion. On the left, the push-off is in line with the 2^{nd} metatarsal head. On the right, it is in line with the 3^{rd} metatarsal and the foot moves slightly into inversion.	With the right foot's push-off, there is now only a slight inclination towards the 3^{rd} metatarsal head.
Case Study 6 Plantar flexion –both feet.	Left push-off is in line with the 2^{nd} metatarsal head.

Comment

The movement patterns in the ankles of subjects 5 and 6 have improved.

Table 4.53(d): A comparative summary of running gait analysis prior and post intervention: Single leg support – terminal stance phase (Toes)

Prior Intervention	***Post Intervention***
Case Study 4 Toes move into extension.	Less high on the toes.
Case Study 5 Both are in extension. He is very high on the toes. Seems to be higher on the toes of the left foot.	Less high on the toes.
Case Study 6 High on toes with push-off.	Less high on the toes.

Comment

After the intervention the decreases in the degree of extension at the metatarsophalangeal joints in subjects 5 and 6 were especially notable. It looked as if restrictions were removed that allowed for a greater range of movement. It was decided to investigate the phenomena further.

Table 4.54(a): A comparative summary of running gait analysis prior and post intervention: Single leg support – pre-swing phase (Pelvis)

Prior Intervention	***Post Intervention***
Case Study 4 Both sides are in posterior rotation; left side more than right side.	Posterior rotation equal on the left and right.
Case Study 5 The pelvis is more posteriorly rotated on the left than on the right.	Pelvis is still slightly more posteriorly rotated on left than on the right, difference is less.
Case Study 6 Both sides are in posterior rotation.	More symmetry with regard to the pelvis.

Comment

There is more symmetry with regard to the pelvis.

Table 4.54(b): A comparative summary of running gait analysis prior and post intervention: Single leg support – pre-swing phase (Hip)

Prior Intervention	***Post Intervention***
Case Study 4 Both are in extension and external rotation. Left in more external rotation than the right.	Normal.
Case Study 5 Normal.	Normal.
Case Study 6 Both are in extension and external rotation. The left in more external rotation than right.	Normal.

Comment

The symmetry improved marginally.

Table 4.54(c): A comparative summary of running gait analysis prior and post intervention: Single leg support – pre-swing phase (Ankle)

Prior Intervention	***Post Intervention***
Case Study 4 Left and right sides are in a neutral hind foot position with plantar flexion.	Normal.
Case Study 5 Normal.	Normal.
Case Study 6 Slight plantar flexion –both feet. Right foot: tends to shift weight to the 3rd metatarsal head, the foot then moves into a position of inversion. Much less in the left foot.	There is less of a weight shift in the right foot.

Comment

There is an improvement in the gait symmetry at the ankle in subject 6.

Table 4.55(a): A comparative summary of running gait analysis prior and post intervention: Swing leg advancement – initial swing phase (Knee)

Prior Intervention	***Post Intervention***
Case Study 4 Knees move out of flexion and external rotation into flexion. An irregularity on the left with increased left hip external and posterior pelvic rotation.	The observed irregularity is less.
Case Study 5 Flexion is increased on both sides and both move into internal rotation.	
Case Study 6 Both knees: External rotation and flexion.	

Comment

The symmetry has improved.

Table 4.55(b): A comparative summary of running gait analysis prior and post intervention: Swing leg advancement – initial swing phase (Ankle)

Prior Intervention	***Post Intervention***
Case Study 4 No real push-off. Initiated by a backward rotation of the pelvis, hip extension and external rotation. With push-off the weight is shifted from the 2nd to the 3rd metatarsal head so that foot moves into inversion. It returns to the position of the 2nd metatarsal head as soon as the weight is off. Less subtle on the right.	There is less of a shift from the 2nd to the 3rd metatarsal head in both feet. In other words, the feet move into less inversion.
Case Study 5 Both are in plantar flexion.	With right foot's push-off, only a slight inclination towards the 3rd metatarsal head.
Case Study 6 Plantar flexion: Left and right sides	

Comment

More symmetry and a lesser degree of inversion were noticeable in subjects 4 and 5.

Table 4.56(a): A comparative summary of running gait analysis prior and post intervention: Swing leg advancement – mid swing phase (Hip)

Prior Intervention	***Post Intervention***
Case Study 4 Both hips: Flexion and internal rotation.	
Case Study 5 Both are in flexion and internal rotation. The right hip is in greater internal rotation.	The left and right sides are more equal. There is less medial rotation of the left hip.
Case Study 6 The left hip is lower than the right hip. Both hips move into flexion.	

Comment

The symmetry improved marginally.

Table 4.56(b): A comparative summary of running gait analysis prior and post intervention: Swing leg advancement – mid-swing phase (Knee)

Prior Intervention	***Post Intervention***
Case Study 4 Both sides: Flexion and internal rotation.	Same.
Case Study 5 Both are in flexion and starting to move into external rotation and extension. There is more external rotation on the right than on the left.	The external rotation on the left side is less. Both sides are more equal.
Case Study 6 Both sides: Flexion and internal rotation.	Same.

Comment

The symmetry improved marginally.

Table 4.57(a): A comparative summary of running gait analysis prior and post intervention: Swing leg advancement – terminal swing (Pelvis)

Prior Intervention	***Post Intervention***
Case Study 4 Left side moves into a neutral pelvic position and the right into anterior pelvic rotation.	The left side now also moves into anterior rotation.
Case Study 5 Both in anterior rotation: Right more than left.	The pelvis is more symmetrical.
Case Study 6 Left side of the pelvis moves into anterior rotation. The right side stays in neutral.	The pelvis is more symmetrical.

Comment

The pelvis was more symmetrical in subjects 4, 5 and 6.

Table 4.57(b): A comparative summary of running gait analysis prior and post intervention: Swing leg advancement – terminal swing (Hip)

Prior Intervention	***Post Intervention***
Case Study 4 Both are in flexion.	Both are in flexion.
Case Study 5 Both are in flexion.	Both are in flexion.
Case Study 6 The left hip is lower than the right. Both hips are in flexion.	Both hips are now almost on the same level.

Comment

There is greater symmetry in subject 6.

Table 4.57(c): A comparative summary of running gait analysis prior and post intervention: Swing leg advancement – terminal swing (Ankle)

Prior Intervention	***Post Intervention***
Case Study 4 Left and right sides: slight inversion and plantar flexion.	
Case Study 5 Both are in dorsi flexion.	The amount of dorsi flexion is less.
Case Study 6 Right side: dorsi-flexion. Left side: Slight dorsi-flexion.	

Comment

The symmetry improved marginally.

Table 4.57(d): A comparative summary of running gait analysis prior and post intervention: Swing leg advancement – terminal swing (Toe)

Prior Intervention	***Post Intervention***
Case Study 4 More extension.	
Case Study 5 A great degree of extension on both sides.	Does not go so high on the toes. The amount of MTP extension is less.
Case Study 6 Extension: Left and right sides.	

Comment

As can be noted throughout from the comments in the right column of the preceding tables, the abnormalities in the common running patterns were significantly reduced by the treatment interventions. The soft tissue mobilization of the 'clinically significant' muscles led to an improvement in the running gait of case studies 4 to 6. The running gait became more symmetrical and the abnormal movement patterns normalized to a great extent. Shortening of the myofascial links will lead to asymmetry since the point of gravity will be shifted towards the shortened side. The muscle will follow the path of least resistance and will also add to instability.

4.6.5. Conclusion

The effect of the interventions on the symptoms of CPCS has been very successful. The *intensity of pain and discomfort; distances run before commencement of the symptoms;* as well as *total distances run*, improved to such an extent that all of the subjects were classified as symptom free.

The improvement in these outcome measures was accompanied by a strong correlation between the *tightness of the clinically significant muscles* as determined by the *palpation* *findings* and the symptoms of CPCS. As the restrictions in the myofascial web were removed, the symptoms of CPCS cleared in the subjects.

With regard to the measurement of the tightness in the clinically significant muscles by means of palpation, the validity of the technique could constrain the external validity of the research. The treatment interventions are dependant on the ability of the health professional to assess and identify tightness in the clinically significant muscles. The calibration of this measurement technique will be covered in section 4.8.4.

In spite of a strong correlation between the symptoms of CPCS as reflected by the tightnesses in the clinically significant muscles, and muscle imbalances as reflected by muscle strength and muscle work performance, these results do not provide any conclusions of significance in terms of the research project. Any restriction in a muscle could affect muscle balances, and the results do not reflect on any aspect that is unique to the symptoms of CPCS. The interventions do however have the distinct advantage of rectifying any muscle imbalances that may be present.

During the running gait analysis, the initial observations made during the exploratory research phase, in terms of hind foot pronation as well as the extension at the metatarsophalangeal joint was again observed. During the exploratory phase, one of the objectives set was to assess whether hind foot pronation plays as big a role in the symptoms of CPCS as it does in other running injuries (Hintermann & Nigg, 1998). The experimental research which was conducted with regard to these two aspects will be covered in the next section.

4.7. EXPERIMENTAL RESEARCH

4.7.1. Introduction

This section covers the results of the experimentation with the effects of the interventions on the extension at the first metatarsophalangeal joint as well as on hind foot pronation.

4.7.2. Degree of extension at the metatarsophalangeal joint during terminal stance

4.7.2.1. Results

From Table 4.58 it can be seen that the range of extension at the first metatarsophalangeal joint during terminal stance of all the subjects complaining of CPCS was greater than that of the two controls. They thus rose higher onto their forefeet during the terminal stance than the runners who served as controls.

Table 4.58: Metatarsophalangeal extension at the first toe

Degree of extension at the metatarsophalangeal joint during terminal stance (degrees)								
	Subject 1	***Subject 2***	***Subject 3***	***Subject 4***	***Subject 5***	***Subject 6***	***Control 1***	***Control 2***
Left	48, 33	49, 67	50, 67	58, 67	58, 33	57, 67	41, 00	38, 33
Right	47, 00	49, 00	45, 00	49, 33	45, 33	43, 67	36, 67	20, 86

4.7.2.2. Discussion

As was seen during the literature research the FDL and the FHL muscles are important in preventing extreme plantar to dorsi flexion movement at the metatarsophalangeal joints when the foot is in contact with the ground (Travell & Simons, 1999). Tightness in the calf muscles might effectively lengthen the lever arm against which the FHL and the FDL muscles function and overload them. Therefore an increase in the degree of extension at the first metatarsophalangeal joint may be indicative of a dysfunction of the FHL muscle.

An increase in the flexibility of the calf muscles might theoretically effectively shorten the lever arm against which the FHL and the FDL muscles function and decrease the degree of extension at the first metatarsophalangeal joints.

It could also be argued that the degree of extension at the metatarsophalangeal joint during terminal stance could be as the result of the decrease in the functional length of the myofascial chain as a result of the effect of stresses that are induced in the fascial web.

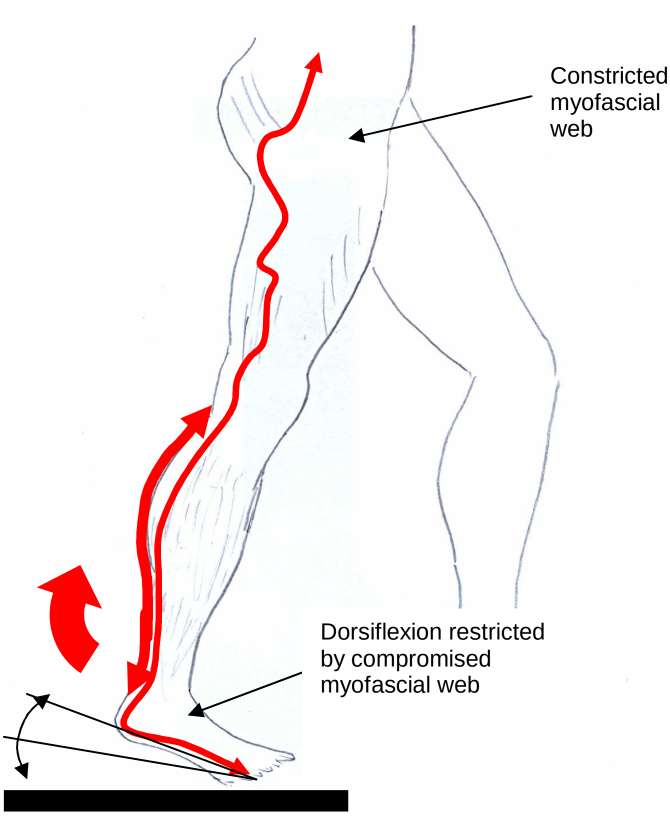

Figure 4.13: Metatarsophalangeal extension

In Figure 4.13 this concept is illustrated graphically. As was argued with the development of the revised model for the pathogenesis of CPCS, the constricted myofascial web proximal to the calf area is reflected by the distorted red line above the knee. It is argued that the length of the myofascial web is constricted through tightness in the clinical significant muscles which compromise the length of fascia available to accommodate the increased demand for range of movements such as the dorsiflexion during running.

During running the normal range of movement is increased, and if these movements are restricted by the constriction of the myofascial web in the clinical significant muscles, it will lead to abnormal stresses in the myofascial web. This in turn will exert abnormal pressure in the posterior compartment. A decrease in the dorsiflexion would also lead to an increase in the degree of extension at the first metatarsophalangeal joint due to the unavailability of sufficient length in the myofascial chain to accommodate the requirements for normal movement, thus forcing the subject to rise higher on his toes.

The revised model for the pathogenesis acknowledges the role that the fascia plays in the stiffness in the calf muscle. Should the interventions thus relieve the stiffness in the clinical significant muscles, and this leads to a greater range of movement in dorsiflexion, it would make a strong case for the restricted fascia being the root cause to the problem and not just a general stiffness of the calf area as the current theoretical perspectives would suggest.

During the three case studies described in Chapter four, a gradual progression in the intervention techniques from soft tissue mobilizing of the posterior part of the lower leg towards the more proximal as well as the anterior soft tissue mobilization have been seen. The flexibility of the soleus calf muscles improved noticeably in case studies one to three after soft tissue mobilization and stretches were included in the interventions. It was therefore interesting to establish whether the intervention led to a decrease in the degree of extension at the first metatarsophalangeal joint.

As a second phase of the experiment it was thus decided to assess the impact of the release of the tight clinical significant muscles on the range of movement of dorsiflexion in the case studies 4 to 6. The results of both the before and after treatment interventions are reflected in Table 4.59.

Table 4.59: Biomechanical measures before and after intervention

Metatarsophalangeal extension (Degrees)						
Side	***Case Study 4***		***Case Study 5***		***Case Study 6***	
	Before *28/01/03*	***After*** *25/10/03*	***Before*** 24/05/03	***After*** 24/05/03	***Before*** 24/05/03	***After*** 24/05/03
Left	50.67	47.00	56.67	52.66	54.00	50.00
Right	48.50	38.00	49.33	40.33	51.00	42.67

There was a noticeable decrease in the degree of extension at the first metatarsophalangeal joint in all the cases. These results are graphically reflected in Figures 4.14 and 4.15

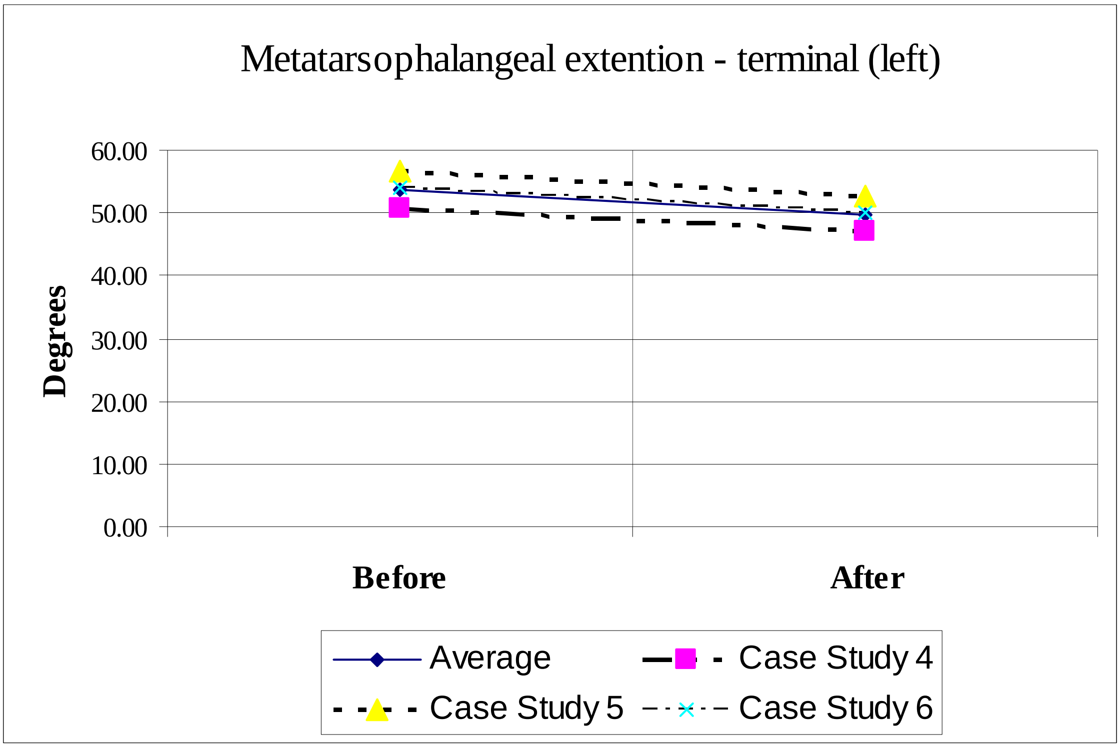

Figure 4.14: Improvement of the metatarsophalangeal extension: Left leg

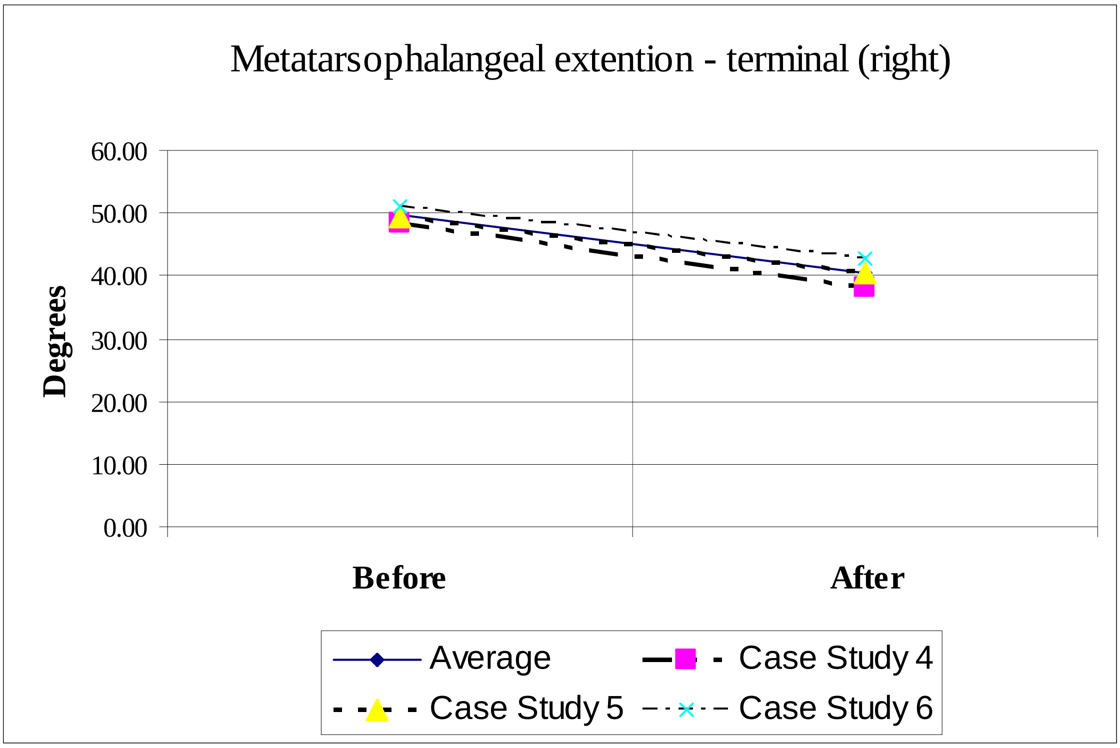

Figure 4.15: Improvement of the metatarsophalangeal extension: Right leg

In both Figures 4.14 and 4.15 the noticeable improvement in the range of movement of both metatarsophalangeal extensions can clearly be seen. This evidence provides a strong support for the new theoretical model which suggests that the restriction of movement is due to fascia that is constricted in the clinical significant muscles. In this process the tightnesses in the posterior compartments were also relieved and one can thus not conclusively argue that the improvement in movement range is solely due to the increased fascia length which resulted from the normalisation of the restrictions in the myofascial web.

In all the cases a distinct improvement in the flexibility at the metatarsophalangeal joint is evident. This effectively rules out the Null Hypothesis which states that the results are purely due to chance. The rival proposition of investigator bias is also ruled out on the basis that the objective evidence is available for scrutiny in the form of the video recordings.

4.7.3. The effect of soft tissue mobilization on subtalar over pronation

4.7.3.1. Results

The results of the interventions are tabled in Tables 4.60 and 4.61.

Table 4.60: Change in left hind foot pronation before and after intervention

Subject	*Left Hind Foot Pronation (Degrees)*											
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
Before	15	13	18	20	18	21	16	14	14	11	16	22
After	11	4	13	10	14	13	5	7	12	9	12	***17***
Difference	4	9	5	10	4	8	11	7	2	2	4	5
% Reduction	27	69	28	50	22	38	69	50	14	18	25	23
*(N)/(A)**	N	N	N	N	N	N	N	N	N	N	N	***A***

Table 4.61: Change in right hind foot pronation before and after intervention

Subject	*Right Hind Foot Pronation (Degrees)*											
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
Before	15	16	17	18	17	22	12	18	17	18	12	22
After	9	10	11	11	14	***15***	8	13	12	12	11	***19***
Difference	6	6	6	7	3	7	4	5	5	6	1	3
% Reduction	40	38	35	39	18	32	33	28	29	33	8	14
*(N)/(A)**	N	N	N	N	N	***A***	N	N	N	N	N	***A***

**N- Normal; A-Abnormal*

In 10 of the 12 cases the extent of improvement was such that the pronation could now be classified as normal. In Table 4.60 subject 12 had a left foot pronation of 17° post intervention. This exceeds the norm of 14° and is accordingly classified as abnormal pronation. In terms of right foot pronation, both subjects six and 12 have pronation which exceeds 14° and both are accordingly classified as abnormal pronation. The extent of improvement in the degree of pronation for these two subjects was between 23% and 32%. These improvements in both the subjects are considered to be significant, although the final measurements are not quite in the normal range. The correlation coefficient between the pre-intervention and post intervention values is a significant 0.86.

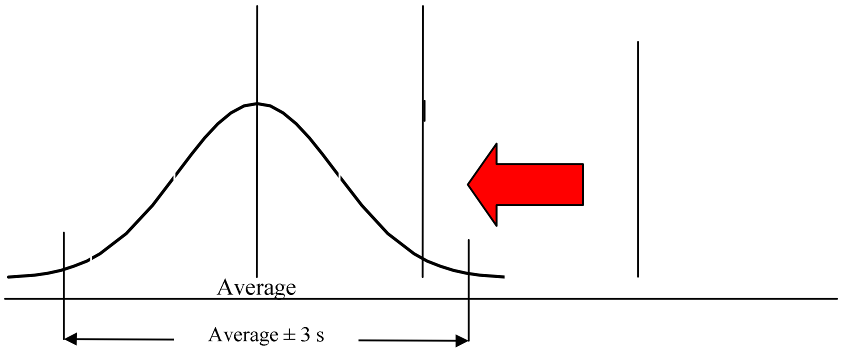

Figure 4.16: Normalisation of hind foot pronation

Figure 4.16 provides a graphical picture of how the abnormal pronation has been reduced in order to fall within ± 3 σ pronation interval that could be considered as normal.

4.7.3.2. Discussion

According to Hintermann & Nigg (1998) over pronation during the later stages of the stance phase of running is a specific biomechanical abnormality that may cause running injuries, not only in the foot and ankle, but also higher up in the lower limbs. The results of this study however indicate the root cause of such injuries may be linked to underlying problems that exist in the myofascial web. Tightness in the clinical significant muscles leads to over pronation which in turn causes secondary effects as discussed above. Over pronation may therefore be a consequence of an already existing compromise in the effective length of the fascial chain.

This study showed that the application of specific soft tissue mobilizing techniques combined with a home stretching programme produced a significant reduction in the degree of hind foot pronation. In addition, all the subjects with fascia related injuries experienced a total relief of symptoms. These included the five subjects who complained of medial shin pain, four subjects with lateral thigh pain and one subject with plantar foot pain, who were respectively diagnosed with medial tibial periostitis, iliotibial band syndrome and plantar fasciitis. The treatment of the symptoms was however not the objective of the study and the participants were thus not followed up in order to assess the longer term effects of these interventions. Releasing the tight 'clinical significant' muscles led to the release of the constrictions of the fascial web which in turn increased the available effective length of the myofascial chain. This reduced the stresses in the chain which led to the normalisation of the biomechanical angles.

4.7.4. Conclusion

The experimental research is in conclusion very supportive of the new theoretical perspectives developed during the case study research. In the following section an additional two case studies will be discussed. These case studies were embarked on as a final step towards the validation of the interventions developed and the supportive theoretical framework.

4.8. RESEARCH VALIDATION

4.8.1. CASE STUDY 7

4.8.1.1. The subject

The subject in Case Study 7 was a 37 year old male athlete who has been complaining of symptoms of CPCS in his left calf for more than a year. He participated in road races of 10 kilometre distances as well as duathlon events (running and cycling). He runs at a pace of slightly slower than six minutes a kilometre.

Inclusion criteria

He experienced pain in his left calf with every run during the previous year. The pain commenced after approximately a kilometre of running. This pain forced him to complete the race by walking. The pain was localized to a small area two thirds down the posterior aspect of the left calf, but whilst running, the pain would spread anteriorly around the lower leg. He rated the intensity of the pain as a 70 on a 100mm VAS.

Exclusion criteria

He had a sonar scan of the lower left leg done on the 11th of May 2007. The results of the showed no abnormalities (tears) of the gastrocnemius- or soleus muscle or the achilles tendon. There was an area of local thickening of the fascia between the medial gastrocnemius- and the soleus muscle, but it was not pressure sensitive in this area.

4.8.1.2. Research procedure

Subjective assessment – Interview

Running history

This subject had been competing in running events since he can remember. He participated in road races varying in distance between 5 kilometres and 21 kilometres and started taking part in duathlon events during the last couple of years. He recently joined a cross training group of athletes, alternating running and mountain bike training as part of their weekly training programme. At the time of his inclusion into the study, he couldn't run at all and he was wearing a neutral running shoe (Assics TN 635 Nimbus). He used different shoes (clip-on) for cycling.

Previous running injuries

He had no previous running injuries.

Current symptoms

He felt the pain in his left calf for the first time a year ago during the Kentron 10 km race. He had to walk the last kilometre. Since 2007, he experienced pain in his calf with every run. The pain started after a one kilometre and he had an intensity rating of 70 on a 100mm VAS. The last race he competed in was during the March 2007 where he participated in a duathlon event at the Cradle of Humankind. This duathlon entailed a 5 km run, a 20 km cycle and another 5 km run. He experienced calf pain the whole time.

History of symptoms and previous treatment received

He received two physiotherapy sessions for the pain in his left calf, but these two treatments had no effect on his symptoms. He received cross-frictions, massage, needling, ultrasound therapy, interferential therapy, stretches and heat; all applied to the area of the painful left calf. Thereafter, he was referred for a sonar scan of the left lower leg. Apart from a small, localized area of adhesions between the medial gastrocnemius and soleus muscles, the results of the scan were normal. It was thought that the local adhesions in the fascia around the calf muscles might be a cause for the symptoms of CPCS.

In summary, the subjective outcome measurements as measured before the intervention:

- The intensity of pain / discomfort at rest was 70 on the 100mm VAS.
- He did not run at all, i.e. 0 km per week.

Objective assessment – Physical examination

Muscle strength tests

Muscle strength was assessed on 23/05/2007 by a biokineticist on a calibrated Isokinetic dynamometer, using a standardized testing protocol. Significant differences in muscle strength between the left and right sides were established as reflected in Table 4.62

Table 4.62: Isokinetic dynamometer test results[*] prior to intervention: Case Study 7

Movement tested*	***Peak torque (Nm)***			***Work per repetition (Nm/s)***		
	Right	***Left***	***Deficit***	***Right***	***Left***	***Deficit***
Hip extensors	164	126	*-23*	187	149	*-20*
Hip flexors	107	125	*14*	118	138	*15*
Hip internal rotators	49	24	*-50*	31	27	*-13*
Hip external rotators	34	22	*-36*	39	26	*-34*
Hip abduction	121	141	*14*	75	110	*-32*
Hip adduction	42	35	*-16*	12	3	*-78*
Knee extensors	134	130	-3	153	160	4
Knee flexors	94	77	*-17*	115	103	*-11*
Knee internal rotation	28	24	*-14*	22	15	*-31*
Knee external rotation	30	24	*-18*	24	16	*-33*
Ankle inversion	38	57	***	43	35	***
Ankle eversion	43	46	***	43	39	***
Ankle plantar flexors	62	83	*25*	35	31	*-12*
Ankle dorsi flexors	30	37	*19*	18	16	-8

[*]Statistically significant differences in italic;

[**] Tested at a speed of 30/30 and with five repetitions

**** Not determined*

***Analysis of running gait, including movement patterns* (23/05/2007).**

The abnormal movement patterns are reflected in Table 4.63.

Note: The gait analysis assessment was verified by 17 post graduate physiotherapists and 5 post graduate biokineticist during a two day course on fascia presented by the researcher.

Table 4.63 (a): Running gait analysis: Case Study 7 prior to intervention (Upper body)

Running gait analysis: Case Study 7 (23/05/07)							
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***	
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre- swing***	***Initial swing***	***Terminal swing***
Shoulders	Left leg: right shoulder in more extension and retraction than the left shoulder with right leg in this phase.						
Thoracic Region	No thorax rotation was observed towards the right side.		A thoraco-lumbar curve, convex towards the right side, was evident with weight-bearing on the left as well as on the right leg.				
Pelvis	The pelvis on the right side, stayed in a position of posterior rotation throughout the gait.	Due to the posteriorly rotated position of the right pelvis during the loading phase of the right leg, there is a lot of jarring on the right SI-joint area.			Pelvis is still posteriorly rotated on the right side.		Pelvis on the right side does not move into anterior rotation as is seen on the left side.
Hip	The left hip remained in adduction throughout the different phase of the gait, as a result the left leg, took more weight than the right leg (which explains the thoraco-lumbar convex curve towards the right). This also cause more strain on the left calf muscles, especially on the medial side of the lower leg.	The right hip was constantly in more lateral rotation than the left hip.		The push-off of the right hip also took place from out of a position of lateral hip rotation on the right.	More lateral rotation on the right side.	From this position to mid swing, there is an increased amount of medial rotation on the right side in order to counter act for the initial increased lateral rotation on the right side.	

Table 4.63 (b): Running gait analysis: Case Study 7 prior to intervention (Lower body)

Running gait analysis: Case Study 7 (23/05/07)								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre- swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Knee	Almost full knee extension on both sides.	The degree of knee extension decreases a little on both sides.	The degree of extension in both knees increase again.	The tibias move into more external rotation with the knees in extension.	Both knees are extended with a degree of external rotation of the tibias.	The right knee in a position of more flexion in comparison to the left knee shortly after the push-off phase. This is most probably necessary because of the increased posterior rotation of the pelvis on the right side and the increased degree of lateral flexion of the right leg in order to swing the leg forwards.	Both knees: flexion and internal rotation.	Both knees: extension and external rotation.
Ankle	The subject runs very flat footed. There is hardly any heel-toe action.	Both sides: shift the weight to the medial side of the foot (move into hind foot pronation).	The right foot is also in a position of more abduction because of the increased degree of lateral rotation at the right hip.	Both feet move into a position of hind foot pronation.	Both feet are in a neutral position with plantar flexion.	The right foot has a weaker push-off in comparison to the left, most probably also because of the position of the right foot (more abduction). The left calf muscles are therefore definitely working harder. The problem is: looking at the results of the Cybex tests: the left calf muscles that seem to work harder have tested the weakest! (Although its work per repetition is more in the left leg than in the right leg).	Both sides: slight inversion and plantar flexion.	Both sides: slight inversion and plantar flexion.

Thorax Area

No thorax rotation was observed towards the right side. A thoraco-lumbar curve, convex towards the right side, was evident with weight-bearing on the left as well as on the right leg.

Pelvis

The pelvis on the right side, stayed throughout the gait in a position of posterior rotation. Because of the posteriorly rotated position of the right pelvis during the weight acceptance phase on the right hip, it seems as though there is a lot of jarring on the right SI-joint area during this phase.

Hips

The left hip remained in a position of adduction throughout the different phase of the gait, which means that the left leg, took more weight than the right leg. This partly explains the thoraco-lumbar convex curve towards the right. This can also cause more strain on the left calf muscles, especially those on the medial side of the lower leg. The right hip was constantly in more lateral rotation than the left hip. The push-off of the right hip also took place from out of a position of lateral hip rotation on the right.

Knees

The right knee is in a position of more flexion in comparison to the left knee shortly after the push-off phase. This is most probably necessary because of the increased posterior rotation of the pelvis on the right side and the increased degree of lateral flexion of the right leg in order to swing the leg forwards.

Ankles

The subject runs very flat footed. There is hardly any heel-toe action. The right foot is also in a position of more abduction because of the increased degree of lateral rotation at the right hip. The right foot has a weaker push-off in comparison to the left, probably due to the position of the right foot, i.e. more abduction. The left calf muscles are therefore definitely working harder. The problem is: looking at the results of the Isokinetic dynamometer tests: the left calf muscles that seem to work harder have tested the weakest! (Although its work per repetition is more in the left leg than in the right leg)

A wobble is also occasionally observed in the right foot shortly after push off. This wobble is caused by a relative increased amount of medial rotation in the right hip to counteract the increased lateral rotation in the right hip. At this point in time, the right foot is in a position of midair, and therefore illustrates the wobble.

If one compares the gait analysis to the tightness found in the clinically significant muscles and the muscle strengths as tested with the Isokinetic dynamometer, the whole picture tends to blend in beautifully. The Quadratus lumborum and Gluteus medius muscles were most probably tight on the right hand side because of the position of relative adduction of the left leg. It is clear that the left calf muscles are working harder, since it tested respectively as a two and a one on the tightness scale. The adductors on the left side have also tested tighter than on the right side.

Gait analysis post intervention

Thorax Area

Good symmetry between the left and the right sides with regard to rotation.

Pelvis

The right side of the pelvis is in much less posterior rotation. A better symmetry is seen between the two sides. There is a lot less evident jarring in the vicinity of the right SI-joint during the weight bearing acceptance phase on the right side.

Hips

The right hip is in less lateral rotation. The line of extension during the push-off phase in the right leg also looks better. There is less sideway movement and a more energy is spent directing the subject in a more forward line (forward drive). The movement patterns in the hips are a lot smoother and more symmetrical.

Knees

There is now an equal degree of knee flexion.

Ankles

The subject still runs very flat footed, but the push off with the right leg is a lot better and the placing of both feet is now very similar.

Toes

The muscle imbalances according to the Isokinetic dynamometer tests have definitely improved in terms of the hip rotations, hip flexors and extensors as well as the plantar flexors.

Biomechanical angles (23/05/2007)

The biomechanical angle measurements of 23/05/2007 are provided in Table 4.64.

Table 4.64: Biomechanical angles: Case Study 7 before intervention.

Movement	***Joint Range of Movement (degrees)****
Hind foot pronation left	15,67
Hind foot pronation right	14,17

**Averages of six measurements*

Soft tissue palpation (clinically significant muscles)

All the clinically significant muscles were palpated for tightness and spasm and rated on a scale from 0 to 2. These outcomes are reflected in Table 4.65.

Table 4.65: Tightness of clinically significant muscles: Case Study 7 prior to intervention (Date: 23/05/2007)

Muscle	***Left Side***			***Right Side***			***Muscle***	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula			2		1		*Sternocleidomastoid*			2		1	
Trapezius			2		1		*Scalenii*			2		1	
Latissimus dorsi		1		0			*Pectoralis major*			2	0		
Erector spinae			2		1		*Pectoralis minor*			2	0		
Quadratus lumborum		1			1		*Serratus anterior*	0			0		
Gluteus medius		1		0			*Subscapularis*			2		1	
Gluteus maximus		1		0			*External oblique*		1		0		
Piriformis			2		1		*Rectus abdominus*	0			0		
Semimembranosus	0					2	*Psoas- umbilicus head*	0			0		
Semitendinosus			2		1		*Psoas- iliac head*		1		0		
Biceps femoris	0				1		*Psoas- groin*		1		0		
Gastrocnemius			2	0			*Iliotibial band*	0			0		
Soleus		1		0			*Vastus lateralis*		1		0		
Plantar fascia	0			0			*Vastus medialis*	0			0		
							Adductor longus	0			0		
							Adductor magnus		1		0		
							Pes anserinius	0			0		

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

4.8.1.3. Interventions

All the clinically significant muscles with a relative tightness rating of one or two were mobilized. Myofascial release techniques were applied according to the approach of Barnes (1990) and Mannheim (1994) and trigger point release techniques were applied according to the approach of Travell & Simons (1999) and specific soft tissue mobilization was applied according to Hunter's approach (1998). The subject was seen once a week for eight weeks and was instructed to stretch on a daily basis. Stretches were provided for the following muscles (30 seconds and repeated twice):

- the trapezius
- the levator scapula
- the pectoralis
- the abdominal muscles
- the iliopsoas
- the piriformis
- the hamstrings
- the gastrocnemius and
- the soleus muscles

Clinical observations during the intervention period

Treatment period

23rd May 2007 – 17th July 2007

Interview

- The intensity of pain/discomfort at rest, and at the end of every training session was plotted on a 100 mm VAS: He had no discomfort for both.
- He ran a weekly distance of 25 kilometres.
- He ran at a pace of less than six minutes per kilometre.

Physical examination

Muscle strength tests

The strength of the hip extensors, the hip flexors, the hip abductors, the hip adductors, the medial- and lateral rotators of the hip, the knee extensors, the knee flexors, the medial- and lateral rotators of the knee, the invertors and evertors of the ankle as well as the dorsi- and plantar flexors of the ankle were assessed on a calibrated Isokinetic dynamometer, using a standardized testing protocol. The results are provided in Table 4.66.

Table 4.66: Isokinetic dynamometer test results* after intervention: Case Study 7

Movement tested**	**Peak Torque (Nm)**			**Work per repetition (Nm/s)**		
	Right	**Left**	**Deficit**	**Right**	**Left**	**Deficit**
Hip extensors	180	145	-20	191	126	-34
Hip flexors	126	117	-8	152	122	*-20*
Hip internal rotators	24	19	*-22*	22	20	-6
Hip external rotators	30	20	*-32*	28	20	*-29*
Hip abduction	106	141	*25*	79	103	*24*
Hip adduction	56	66	*16*	27	23	*-15*
Knee extensors	163	149	-8	205	276	*-14*
Knee flexors	94	92	-1	123	121	-2
Knee internal rotation	23	28	*19*	20	24	*17*
Knee external rotation	37	26	*-30*	34	23	*-32*
Ankle inversion	37	30	*-19*	19	14	*-29*
Ankle eversion	26	28	*10*	16	18	8
Ankle plantar flexors	69	72	4	38	31	*-18*
Ankle dorsi flexors	28	39	*28*	15	16	8

**Statistically significant differences between right and left are given in italics*

***Tested at a speed of 30/30 and with 5 repetitions; *** Not measured*

Table 4.67: Running gait analysis: Case Study 7 after intervention (Date: 17/07/2007)

Running gait analysis: Case Study 7 *(17/07/2007)*								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
	Initial contact	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre--swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Shoulders	A much better rhythm. Shoulder movements more symmetrical.							
Thoracic region	Equal thoracic rotation towards both sides.							
Pelvis	The pelvis on the right side is much less in posterior rotation.	Lesser degree of posterior rotation of right pelvis during loading phase of the right leg - less jarring of the right SI-joint during this phase.					Pelvis on the right side, move into neutral.	
Hip	Right hip is in less lateral rotation.			Extension is done from a better position; definitely less lateral rotation.				
Knee						The degree of knee flexion is now equal in both knees.		
Ankle	Still very flat footed.	Both sides: shift the weight to the medial side of the foot (hind foot pronation).	Foot placing on the right is better: less in abduction.	Both feet move into a position of hind foot pronation.	Both feet are in a neutral position with plantar flexion.	Better push-off with the right leg.	Both sides: slight inversion and plantar flexion.	Both sides: slight inversion and plantar flexion.

Reassessment of running gait and movement patterns

Running gait and movement patterns were also reassessed and the differences/ improvements in comparison to the previously assessed gait are given in Table 4.67.

Biomechanical measurements

The biomechanical measurements made on 17/07/2007 are reflected in Table 4.68.

Table 4.68: Biomechanical angles: Case Study 7 after intervention

Movement	***Joint Range of Movement (degrees)****
Hind foot pronation left	10,67
Hind foot pronation right	11,33

** Averages of six measurements*

Soft tissue palpation (clinically significant muscles)

All the clinically significant muscles were palpated for tightness and spasm and rated on a scale from 0 to 2. These results appear in Table 4.69.

Management

The week after the first intervention the subject ran a distance of 15.5 km. The first session was a 6 km run and he felt good on completion of the run. The second run was a 4 km run. He felt his left calf after 3 km but could complete the run. The intensity of the pain was rated as a 65 on a 100mm VAS. During the third run, two days later he felt uncomfortable from the start and managed a 3 km run (intensity was 75 on a 100mmVAS). After his third run, the treatments focussed on the tight left sided cervical muscles, subscapularis and external oblique muscles. His rotation towards the right side improved and he had no more discomfort during further runs.

Table 4.69: Tightness of clinically significant muscles: Case Study 7 after intervention (Date: 17/07/2007)

Muscle	***Left Side***			***Right Side***			***Muscle***	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula		1		0			*Sternocleidomastoid*	0			0		
Trapezius		1		0			*Scalenii*	0			0		
Latissimus dorsi		1		0			*Pectoralis major*		1		0		
Erector spinae	0			0			*Pectoralis minor*	0			0		
Quadratus lumborum	0			0			*Serratus anterior*	0			0		
Gluteus medius	0			0			*Subscapularis*	0			0		
Gluteus maximus	0			0			*External oblique*	0			0		
Piriformis	0			0			*Rectus abdominus*			2		1	
Semimembranosus	0			0			*Psoas- umbilicus head*	0			0		
Semitendinosus	0			0			*Psoas- iliac head*		1		0		
Biceps femoris	0			0			*Psoas- groin*		1		0		
Gastrocnemius		1		0			*Iliotibial band*	0			0		
Soleus	0			0			*Vastus lateralis*	0			0		
Plantar fascia	0			0			*Vastus medialis*	0			0		
							Adductor longus	0			0		
							Adductor magnus	0			0		
							Pes anserinius	0			0		

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

4.8.1.4. Synthesis/discussion

The symptoms of CPCS were accompanied by tightness in the clinical significant muscles as postulated by the revised theoretical model for the pathogenesis of CPCS. The release of the tightness in these muscles by means of soft tissue mobilization techniques did lead to the disappearance of the symptoms. After the interventions the subject was symptom free, although a thickening of the fascia between the medial gastrocnemius- and the soleus muscle was revealed by the sonar scan of the lower left leg.

In terms of the biomechanical measures the subject had abnormal hind foot pronation prior to the interventions. After the interventions the degree of hind foot pronation decreased to below 14° and could thus be classified as normal.

4.8.2. CASE STUDY 8

4.8.2.1. The subject

The subject in Case Study 8 was a 38 year old female athlete who participated competitively in road running races. She has been complaining of symptoms of CPCS in her right lower leg since June 2006.

Inclusion criteria

She complained of a pain over the anterior-medial (shin) part of her right calf that increased with exercise and decreased with rest.

Exclusion criteria

All the other causes of lower leg pain were differentially excluded based on the exclusion criteria described in Chapter 2.

4.8.2.2. Research procedure

Subjective assessment – Interview

o ***Running history***

The subject had been running for a period of 10 years. Her first 42 kilometre race was done two years prior to the interview and her first ultra marathon during April 2006. This was the Loskop Marathon which covered a distance of 50 kilometres. At the time of inclusion into the study, she was running with Assics (TN 661) shoes which were a slight anti-pronation shoe. She ran at a pace of six and a half minutes per kilometre.

o ***Previous running injuries***

Previous injuries that he had encountered included:

- Right hamstring during October/ November 2005.
- Right sided ITB syndrome during March 2006.

o ***Current symptoms***

She complained of a pain over the “shin” of her right leg. It burned like fire and a definite swelling could be seen over the shin of the right lower leg. She described the intensity of the pain as a 75 on a 100mm VAS. She has only managed a 4 km run during the whole of 2007 and this was during April 2007. It was just too painful to run.

o ***History of symptoms and previous treatment received***

She ran the Loskop Marathon during April 2006, after which she rested for a period of 2 months. When she resumed her running, she became aware of the pain in her right shin. During September 2006, she received two physiotherapy treatments for this condition, consisting of massage, ultrasound therapy, interferential therapy and stretches. The degree of pain was no better after the two sessions. During October 2006, she received a further 2 sessions of needling. The pain was again not reduced by these two treatment sessions. She then decided to rest the injury for a longer period of time. With regular intervals she tried to run around the block to test the calf. The first time it always felt good, but the second time round she was aware of her calf and when she tried the third time, the calf would burn, swell up. The level of pain she rated as a 75 on a 100mm VAS. She finally decided to rest the calf until 2007. She tried to run around the block once, but it was sore immediately. The only other run she did during 2007 was a four kilometre run during April and again, the calf was very sore. She then went to a podiatrist who said that her right leg was shorter than her left and she needed an insert to raise her right foot. She ran once with the shoes with the insert in and the pain in her right calf was even worse.

In summary, the subjective outcome measures before the intervention were as follows:

- She had no pain/discomfort at rest
- The amount of pain/discomfort whilst running was 75 on a 100mm VAS.
- She averaged a weekly distance of 0 kilometres per week.

Objective assessment – Physical examination

o ***Muscle strength tests***

Muscle strength was measured by a biokineticist on 04/07/2007 on a calibrated Isokinetic dynamometer, using a standardized testing protocol. The results are reflected in Table 4.70.

Table 4.70: Isokinetic dynamometer test results* prior to intervention: Case Study 8

*Movement tested***	*Peak torque (Newton-meter)*			*Work per repetition(Nm/s)*		
	Right	***Left***	***Deficit***	***Right***	***Left***	***Deficit***
Hip extensors	38	165	*77*	-5	174	*103*
Hip flexors	165	95	*-43*	264	155	*-42*
Hip internal rotators	66	22	*-67*	14	27	*50*
Hip external rotators	71	19	*-73*	27	22	*-20*
Hip abduction	100	83	-18	75	52	*-31*
Hip adduction	20	35	*42*	0	9	0
Knee extensors	188	178	-6	199	216	8
Knee flexors	71	71	0	76	102	*25*
Knee internal rotation	16	18	8	15	16	8
Knee external rotation	20	20	0	18	22	*19*
Ankle inversion	61	35	*-42*	65	37	*-44*
Ankle eversion	58	38	*-35*	68	47	*-30*
Ankle plantar flexors	28	49	*42*	11	26	*58*
Ankle dorsi flexors	18	28	*38*	8	15	*45*

**Significant differences are given in italic; **Tested at a speed of 30/30 with 5 repetitions*

Significant muscle imbalances existed between the left and the right sides of his body.

o ***Analysis of running gait, including movement patterns***

The following movement patterns listed in Table 4.71 deviated from the normal/ideal running patterns:

- She in general, had a very irregular and uneven running rhythm.
- She had abnormal stress on the link in her right side. The right hip which was in a position of medial rotation and extension with the push-off (twisting the right gluteus maximus muscle), but at the same time, the pelvis on the left side dipped inferiorly with the weight-bearing on the right leg.

Table 4.71(a): Running gait analysis: Case Study 8 prior to intervention (Upper body)

Running gait analysis: Case Study 8:06/07/07								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
Phase	***Initial contact***	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre-swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Shoulders	Right leg: left shoulder, moves into more abduction with extension in comparison to the right. Left leg: the left shoulder is in more protraction and medial rotation than the right shoulder (caused by tightness in pectoralis major and minor).							
Thoracic region	Very little thoracic rotation with rotation to the right more than to the left.							
Pelvis			With weight-bearing on the right side, the left pelvis sinks through.					
Hip			The left hip is in more adduction that the right hip.	Right hip push off: in extension and medial rotation.				

Table 4.71(b): Running gait analysis: Case Study 8 prior to intervention (Lower body)

Running gait analysis: Case Study 8:06/07/07								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
Phase	***Initial contact***	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre- swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Knee	Almost full knee extension on both sides.	The degree of knee extension decreases a little on both sides.	The degree of extension in both knees increase again.	The tibias move into more external rotation with the knees in extension.	Both knees are extended with a degree of external rotation of the tibias.		Both knees: flexion and internal rotation.	Both knees: extension and external rotation.
Ankle	Hardly any heel toe action.		Right foot is in a position of more abduction than the left.		Weak push-off on both sides.			

Biomechanical angles 06/07/2007

The outcomes of the measured biomechanical angles are reflected in Table 4.72.

Table 4.72: Biomechanical angles: Case Study 8 before intervention

Movement	***Joint Range of Movement (degrees)****
Hind foot pronation left	18,5
Hind foot pronation right	19

**Averages of six measurements*

o ***The tightness of the clinically significant muscles***

All clinically significant muscles were palpated for tightness and rated on a scale of 0 – 2. The outcomes are provided in Table 4.73.

4.8.2.3. Intervention

All the tight clinically significant muscles were released. Different release techniques were used, depending on the muscle involved. Myofascial release techniques were used according to Barnes (1990) and Manheim (1994). Trigger point release techniques were done according to Travell & Simons (1999) and specific soft tissue mobilization were done according to Hunter (1998). The subject was seen once a week during eight weeks and instructed to stretch the following muscles on a daily basis. Each stretch had to be held for 30 seconds and repeated twice:

- the trapezius
- the levator scapula
- the pectoralis
- the abdominal muscles

Table 4.73: Tightness of clinically significant muscles: Case Study 8 prior to intervention (Date: 06/07/2007)

Muscle	***Left Side***			***Right Side***			***Muscle***	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula			2		1		*Sternocleidomastoid*	0			0		
Trapezius		1			1		*Scalenii*	0			0		
Latissimus dorsi	0			0			*Pectoralis major*		1		0		
Erector spinae	0			0			*Pectoralis minor*	0			0		
Quadratus lumborum		1		0			*Serratus anterior*	0			0		
Gluteus medius			2		1		*Subscapularis*		1		0		
Gluteus maximus	0				1		*External oblique*	0			0		
Piriformis		1				2	*Rectus abdominus*	0			0		
Semimembranosus	0			0			*Psoas- umbilicus head*					1	
Semitendinosus	0			0			*Psoas- iliac head*	0			0		
Biceps femoris	0			0			*Psoas- groin*	0			0		
Gastrocnemius	0				1		*Iliotibial band*		1			1	
Soleus	0			0			*Vastus lateralis*		1		0		
Plantar fascia	0			0			*Vastus medialis*	0			0		
							Adductor longus	0			0		
							Adductor magnus	0			0		
							Pes anserinius	0			0		

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

- the iliopsoas
- the piriformis
- the hamstrings
- the gastrocnemius and
- the soleus muscles

The following clinical observations were made during the intervention period:

o ***Treatment Period (6 July 2007 to 23 August 2007)***

Her running gait was assessed running barefoot, with running shoes on and with the running shoes and the added insert in the right running shoe. The running gait patterns of the right leg deviated more from the norm with the insert than without on the video-clip. It was decided not to tamper with the insert immediately but to continue with the interventions and to reassess the symptoms the week thereafter.

During the first week after her first intervention, she managed to run three times. During the first run, she became aware of a sensation (3 on a 100mm VAS) after a distance of two kilometres but it disappeared again whilst running and she completed her four kilometre run with no symptoms. She ran for the second time that week (three days later). She ran a distance of three kilometres on a treadmill and became aware of a lumbar left sided discomfort. Take note: no calf discomfort. Still in the same week (two days later), she ran three kilometres on the treadmill, but then complained again of a left lumbar discomfort and the right shin pain (an intensity of 28 on a 100mm VAS). With palpation it was found that the area over her right posterior-lateral calf as well as the quadratus lumborum muscle on the left was very tight. She was instructed to remove the insert from her right running shoe.

After she removed the insert from her right shoe and replaced it with the normal insert with which the shoe was bought, she had no more discomfort of her right calf during any of her other runs during the intervention period of eight weeks. The discomfort in her left lower back also disappeared during the following week.

Two weeks later she ran two days in succession without any pain. During the middle of the intervention period, the subject developed a bad bronchitis and could not run for that week; but she ran again the weeks thereafter and remained symptom free.

Final Assessment Results (23/08/2007)

- ***Interview***

- She had no discomfort/ pain at rest or during or after a run anymore.
- She ran a weekly distance of 17 kilometres.
- She is enjoying her running again for the first time since the Loskop Marathon.

Physical examination

- ***Re-assessment of running gait and movement patterns***

The following movement patterns deviated from the normal/ ideal running patterns (see Table 12.2.5 for more detail):

- ***The tightness of the clinically significant muscles***

The tightness of the clinically significant muscles was again rated on a scale of 0 – 2.

Table 4.74: Running gait analysis: Case Study 8 after intervention (Date: 23/08/2007)

Running gait analysis: Case Study 8:06/07/07								
Joint	***Weight acceptance***		***Single leg support***			***Swing leg advancement***		
Phase	***Initial contact***	***Loading response***	***Mid-stance***	***Terminal stance***	***Pre--swing***	***Initial swing***	***Mid-swing***	***Terminal swing***
Shoulders	Better rhythm; equal shoulder movements.							
Thoracic region	Equal rotation to both sides. Rotation has increased to both sides.							
Pelvis			The left pelvis dips much less with the weight on the right leg.					
Hips			Right leg in less adduction.	Right hip in less medial rotation.				
Knees								
Ankles	Still hardly any heel-toe action.		Right foot in much less abduction.					

Table 4.75: Tightness of clinically significant muscles: Case Study 8 after intervention (Date: 23/08/2007)

Muscle	***Left Side***			***Right Side***			***Muscle***	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***		***0***	***1***	***2***	***0***	***1***	***2***
Posterior fascia links							***Anterior fascia links***						
Levator scapula		1		0			*Sternocleidomastoid*	0			0		
Trapezius	0			0			*Scalenii*	0			0		
Latissimus dorsi	0			0			*Pectoralis major*	0			0		
Erector spinae	0			0			*Pectoralis minor*	0			0		
Quadratus lumborum		1		0			*Serratus anterior*	0			0		
Gluteus medius		1		0			*Subscapularis*	0			0		
Gluteus maximus	0			0			*External oblique*	0			0		
Piriformis	0				1		*Rectus abdominus*	0			0		
Semimembranosus	0			0			*Psoas- umbilicus head*	0			0		
Semitendinosus	0			0			*Psoas- iliac head*	0			0		
Biceps femoris	0			0			*Psoas- groin*	0			0		
Gastrocnemius	0			0			*Iliotibial band*	0			0		
Soleus	0			0			*Vastus lateralis*	0			0		
Plantar fascia	0			0			*Vastus medialis*	0			0		
							Adductor longus	0			0		
							Adductor magnus	0			0		
							Pes anserinius	0			0		

Key: 0= normal fascia 1= tight fascia 2=very tight fascia

o *Biomechanical angles (Date: 23/08/2007)*

The measurements of the biomechanical angles made on 23/08/2007 are reflected in Table 4.76.

Table 4.76: **Summary of biomechanical angles: Case Study 8**

Movement	*Joint Range of Movement (degrees)**
Hind foot pronation left	9,2
Hind foot pronation right	9,8

* *Averages of six measurements*

4.8.2.4. Synthesis/discussion

The symptoms of CPCS were accompanied by tightness in the clinical significant muscles as postulated by the revised theoretical model for the pathogenesis of CPCS. The release of the tightness in these muscles by means of soft tissue mobilization techniques did lead to the disappearance of the symptoms. After the interventions the subject was symptom free.

In terms of the biomechanical measures the subject had abnormal hind foot pronation prior to the interventions. After the interventions the degree of hind foot pronation decreased to below 14° and could thus be classified as normal.

4.8.3. Reflection

The penultimate section of this chapter deals with reflection on the knowledge gained from both the literature and practical experimentation and the implications that this have on the new or revised theoretical model that has been developed for the pathogenesis of CPCS. These reflections will be cryptic as these issues had been covered in detail in the preceding parts of the thesis.

4.8.3.1. Knowledge from the literature study

The most revealing part of the literature research in terms of successful interventions, was the fact that the only interventions that had some degree of success, was the surgical release of the fascia. This led to a reduction in the posterior compartment and the normalisation of the blood flow to the area resulted in the disappearance of the symptoms. These interventions were however not always successful in the longer term as the symptoms often reoccurred once the subject started running again. This fact provides an indication of:

- The fact that the root cause of the problem had not been resolved;
- That the solution to the problem is fascia related in the sense that the surgical release of the fascia leads to the clearance of the symptoms;
- That by implication the solution to the problem lies in the release of the pressure in the posterior compartment; and
- The fact that the symptoms reappear once the subject starts running again provides an indication that the fascia plays a role in the pathogenesis of the condition.

The subject in Case Study 4 had a similar experience as the latter. After surgical intervention his symptoms cleared only to return when he started running again.

The literature also revealed that conventional physiotherapy interventions were limited to the calf area. None of the interventions or the supporting theoretical models took into account the continuous and non-elastic nature of the involved fascia. These findings from the literature were supported by the findings of the exploratory research phase where the traditional conventional physiotherapy interventions did not lead to any noticeable improvements.

The investigation into the nature of the fascia revealed aspects which had a profound implication on the theoretical perspectives of the condition. Although the role of non-compliant fascial boundaries in the perpetuation of the condition is widely recognised, the nature of fascia as such had not been previously explored in this context. The continuous nature of fascia and its relatively inelastic has major implications in terms of the pathogenesis as well as the perpetuation of the condition. The most important being that the root causes of the initiation of CPCS is the stress in the myofascial web and that the source of the stress could indeed lie external to the calf area. If these stresses are not relieved it would appear logical that the symptoms could re-occur during running when stresses in the fascia are accentuated as a result of the greater ranges of motion required.

The clinical significant muscles were identified by the researcher based on the myofascia which links these muscles to that of the calf area. These linkages were established through the second phase of the literature research dealing with the myofascial web. This also enabled the researcher to hypothesise that constrictions in the myofascial web should manifest in tightness in these muscles. Similarly it also enabled the hypothesis that constrictions in the myofascial web would compromise the length of the fascia which in turn should have an effect on biomechanical measures, especially during activities such as running where the accentuated movement patterns will demand a greater availability of the fascia to execute the running motions. In addition to the restrictions on biomechanical movements it will also places abnormal stresses on the fascia web during such exercises which in turn would increase the pressure in the posterior compartment, restrict blood flow, leading to the pathogenesis of CPCS.

4.8.3.2. Knowledge gained from experimentation

In all the case studies the symptoms of CPCS were accompanied by tightness in the clinical significant muscles. The release of the tightness in these muscles in all the cases led to the alleviation of the condition and all the subjects could resume their running careers, even those who have had surgical interventions in the past. In contrast to the limited success with the surgical interventions none of the subjects had any problems with the reoccurrence of the symptoms. This implies that the root cause of the problems with all of the subjects had been resolved.

In one instance one of the subjects had a problem with the reoccurrence of symptoms. This was during the treatment process when all the tightnesses were not released effectively yet and the subject was running in loose sand and in a strong head wind which required additional forces from the muscles. Such accentuated force is accompanied by increased stresses in the myofascial chain which would tend to increase the pressure in the posterior compartment which in turn could trigger the initiation of the condition.

All the subjects had biomechanical abnormalities which are consistent with the causal relationships propagated by the new theoretical model. The fact that these abnormalities showed significant improvement once the tightness in the clinical significant muscles had been released further enhances the credibility of the new theoretical framework. The hind foot pronation of all the subjects returned to normal after the release of the tightness in the clinical significant muscles. With the experiment on hind foot pronation all the subjects showed significant improvement in the extent of pronation with the release of the tightness in these muscle.

The one aspect which in conclusion provides the greatest credibility for the new theoretical model for the pathogenesis of CPCS is the astonishing degree of replication that has been achieved with the interventions, and the systematic elimination of rival theories. According to Yin (1994) even as little as three replications of results is adequate as validation of a theoretical concept supported by a strong theoretical model.

4.8.4. Validation of tightness assessment technique

In an attempt to validate the assessment technique used for determining the tightness in the clinically significant muscles, a subject with symptoms of CPCS was recruited for the exercise. Two physiotherapists, who regularly utilize soft tissue mobilization techniques, were recruited to assess the tightness of the clinically significant muscles in the subject. Forty three of these muscles were selected on a random basis and each of the physiotherapists assessed the tightness of these muscles independently from each other. The assessments by the researcher was taken as the “correct” assessment and used as a benchmark for the other results. In tables 4.77(a) and 4.77(b), these values are reflected by the blocks with the shading. In spite of the inherent subjectivity of palpation assessments, the extent of correlation between the individual assessments was encouraging.

Table 4.77 (a): Validation of soft tissue rating process (Posterior fascia links)

Date	10 February 2007	**Legend**
Physiotherapist	1;2;3	• - single opinion •• - agreement by two
Subject:	1	••• - consensus opinion [green box] Correct assessment

Muscle	*Left Side*			*Right Side*		
	0	*1*	*2*	*0*	*1*	*2*
Posterior fascia links						
Levator scapula (1)		••	•		•	••
Levator scapula (2)		•••			••	•
Trapezius (1)		••	•		••	•
Trapezius (2)		••	•		•••	
Latissimus dorsi		••	•	•	•	•
Erector spinae						
Quadratus lumborum (1)			•••		•••	
Quadratus lumborum (2)	•	••			••	•
Quadratus lumborum(3)		•••			•	••
Quadratus lumborum (4)		••	•		••	•
Gluteus medius						
Gluteus maximus						
Piriformis (1)	••	•		••	•	
Piriformis (2)			•••		•••	
Semimembranosus			•••		•••	
Semitendinosus						
Biceps femoris						
Gastrocnemius						
Soleus(1)		••	•			•••
Soleus (2)		•	••		•	••
Quadratus plantae		••	•		••	•

Table 4.77 (b): Validation of soft tissue rating process (Anterior fascia links)

Date	10 February 2007	**Legend**
Physiotherapist	1;2;3	• - single opinion •• - agreement by two ••• - consensus opinion ▭ Correct assessment
Subject:	1	

Muscle	***Left Side***			***Right Side***		
	0	***1***	***2***	***0***	***1***	***2***
Sternocleidomastoid (1)		•••			••	•
Sternocleidomastoid (2)		•	••	•	••	
Scalenii						
Pectoralis major (1)		••	•			•••
Pectoralis major (2)		••	•			•••
Pectoralis major (3)		••	•			•••
Pectoralis minor		••	•			•••
Serratus anterior						
Subscapularis			•••		••	•
External oblique (1)			•••		••	•
External oblique (2)		•	••		••	•
Rectus abdominus						
Psoas (1)			•••		•••	
Psoas (2)			•••		•••	
Psoas (3)			•••		•••	
Iliotibial band						
Vastus lateralis						
Vastus medialis (1)			•••		•••	
Vastus medialis (2)		•	••		••	•
Adductor longus		•	••		••	•
Adductor magnus						
Pes anserinius			•••		•••	

The number of links that were assessed in the subject totalled 43 links. This provides a total of a 129 links that were assessed between the three physiotherapists. Out of these 2 links were classified as being tight, while the researcher was of the opinion that they were not. Similarly 2 links were classified as not tight, while the researcher was of the opinion that they were.

The analysis of the data that appears in table 4.77(a) and 4.77(b) is reflected in Table 4.78. As can be seen from the table, in 96.8% of the possible outcomes the three physiotherapists were in agreement on whether a muscle was tight or not. The application of the intervention techniques developed is not so much dependant on the degree of tightness, as on the fact whether the muscle involved is correctly identified as tight or not.

The three physiotherapists were in general in consensus on the majority of the assessments, i.e. 60.5% of the assessments. The conclusion is thus that a general physiotherapist who is familiar with soft tissue techniques should be able to apply the interventions with success. Specific training, which the two physiotherapists were not exposed to, should greatly enhance the ability of the therapist to accurately and with confidence, identify the tight muscles and the extent of tightness in them.

Table 4.78: Analysis of validation data on tightness

Description	**number**	**%**
Total number of links per subject	43	
Grand total of links (43x3)	129	100%
Total number of tight links correctly identified	125	96.8%
Tight links classified as not tight	2	1.6%
Links not tight but classified as tight	2	1.6%
Number of “wrong” classifications	4	3.2%
Consensus on the degree of tightness	78	60.5%