Pelvis malposition and its effect on knee joint by loading of long duration (presentation in the case of endurance runners)

Dissertation

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Herewith I declare that this Dissertation was developed by myself and that I used only the literature introduced in the list of references.

Jürgen Siegele

Preface

During studying my sporting and professional interests became united. My studies at the Charles- University Prague included a large spectrum. Studying changed my point of view towards job and science. Scientific research made it clear that the connections within therapy always need to bee seen relatively. The declaration of results of the patient always needs to be made unprejudiced and neutrally. As a result the therapists shouldn't commit himself too fast on earlier made typical diagnosis but needs to stay open- minded.

During the treatments the therapists needs to treat the patient individually. You need to be aware of the fact, that not only the symptoms but also the causes need to be treated.

Especially, I want to thank the Charles University in Prague, which gave me the opportunity for studying and to get the doctoral title. Special thanks Prof. Dr. Ing. V. Bunc, Dean of the faculty for Sports and Physical education, PhDr. Petr Shifta, Ph.D. Thanks for supporting Prof. Dr. med. A. Nieß (University of Tübingen, leader of the institute of sports medicine) and Prof. V. Wank (University of Tübingen, leader of the institute of biomechanics) for the supports of my dissertation. Also thanks to all docents which supports me.

Pelvis malposition and its effect on knee joint by loading of long duration (presentation in the case of endurance runners)

Purpose: During endurance run knee problems often appear. This study wants to show the connection between a one- sided malposition of the pelvis and knee joint overloading during an endurance run. We can assume that the sooner the athlete undergoes preventive treatment of a dysfunction, the better is his chance for complete recovery.

Hypothesis: Based on a literature research we expect: that there is a relation between a pelvis malposition and a knee joint overloading.

Method: We tested endurance runners which had pelvis malposition and knee dysfunction. Therefore 100 athletes were tested, 50 with knee pain and 50 without knee problem. Manual examination and clinical instruments (measure tape and goniometer) were used for examination of sacro-iliac joints, for measurement of vertical distance between spinae iliacae anteriores superiores and anatomical leg lenght and for measurement of hip and knee movement ranges. Collected data were analysed by appropriate statistical methods.

Results: The results show that there is a connection between a one- sided pelvic malposition and problem of the knee of endurance athletes. These relations are probably realized by changes in lower extremity kinematics as a result of pathological muscle chains. But we can not say where the primary cause of them is.

Conclusion: On the base of our results we can accept our hypothesis. But the study couldn't work out if the problem was caused by the knee itself and could not clarify whether knee complaints or an os coxae dysfunction or another cause activated the problem in the first place. This is part of further scientific research.

Main importance of our work can be seen in prevention of muscle dysbalances which could cause overload of the knee joint and possibly injuries during running.

Keywords: Pelvic malposition, os coxae, sacroiliac joint, cause- and- effect chain.

Contents

1. Introduction

Long distance runners often have problems with their knees. In my own clinical experience and in my physical therapy practice as a sports physiotherapist of international sports championships I treat a lot of patients who complain about having problems with their knees. Treating the symptoms of the knee often leads to a temporary success, which usually ends with the return of the same symptoms after ashort period of time.

The reasons why endurance runners suffer from knee problems quite frequently is polymerous. They can be subdivided into anatomical, biomechanical and functional reasons. The anatomical factors for example may be connected with different anatomical leg lengths on both sides of the body or with a congenital position of a joint, which is disadvantageous for running. The biomechanical factors may be connected with the kinetics of running and with an overstrain put on the joints and muscles of the lower extremities. The functional factors are connected with the development of pathological muscle chains which pass through the body and even include the lower extremities. The chains cause muscle dysbalances which then cause not the uneven distribution of strain put on joint structures. However, the main cause of the chains may be located in the locomotor apparatus itself but also in internal organs which irritate the muscles, or they can be caused directly by close contact or by means of autonomous nerve reflexes.

In most cases the causes for those problems cannot be found within the knee joint itself.

This is made clear by the fact that after a treatment of the knee problem the patient often does not show painlessness at first. As an active runner, physiotherapist, manual therapist, osteopath, sports physiotherapist of the athletics national team and author of a profession book, I have drawn the conclusion that the cause for a lot of knee problems lies within the dysfunction of the cause and effect chain.

My findings showed that especially endurance athletes often suffer from recurring knee problems. Treating the symptoms of the knee often leads to a temporary treatment success which ends with the same symptoms returning after a short period of time. Therefore, the question arose what might be the cause for the knee problems of the endurance athletes. I found out that almost all of these endurance athletes who had problems with their knees also had a pelvic malposition on the side where the problem occurs. As a result, I examined these connections within the clinical surgery and started to use more and more techniques which not only treat the knee joint but also the pelvis. The main focus lay on the same side where the problem of the knee occurred. After a short period of time it became evident that there is a relation of these two problems. The specialist books show that there is a direct connection of the affections of the knee joint and a one- sided pelvic malposition. I took the techniques from the books and started to use them on my patients. It did not take long to achieve success. As a result, I asked myself if any scientific research exists which especially focuses on endurance athletes. Finally, I decided to carry out an empirically recordable scientific study regarding this topic.

While examining the movement it became evident that they consist of a line up of complex motions. The pelvis is, because of its anatomic position within the body, a central organ (Kapandji, 2001). If there are any blocks or malpositions within the pelvic area, the ongoing movements during running which take place especially in the lower extremities, cause a so called cause- and- effect- chain (Richter and Hebgen, 2006). Especially malpositions of the iliac bone, fixed by hypertone muscles, joint blocks or shortening of fascial structures lead to consequences for the musculoskeletal system (Auerbach and Heyde, 2005). Within the movement chain, especially the knee joint reacts very sensitive to dysfunctions and blocks in the lower extremities (Niemuth, 2005). In the clinical, sports physiotherapists and orthopaedic practice, the work on knee problems normally concentrates on the isolated assessment of findings and treatment of the knee joint, according to the symptoms.

The connection between the affections of the foot and the knee has already been examined scientifically and a study has been published(Kleindienst et al. 2006). Especially if the os calcaneus angle is too large, there is a lot of strain put on the knee joint through the inward rotation of the tibia (Hohmann and Wörther, 2005). The connection between the hip joint and the knee joint within the area of running sports has also been examined (Niemuth, 2005; Walter and Kirschner, 2004). I have not found any literature about descending affections of the pelvis. As the connection of pelvic malpositions and affections of the knee joint is often clearly visible during the examination of endurance athletes in the clinical practice. The following study is meant to show that a one- sided malposition of the iliac bone of endurance athletes which exists over a longer period of time is related to knee problems. Therefore I initiated the following examination in order to analyse the relation between knee problems and a one- sided pelvic malposition. It is important to prevent overloading and injuries of the knee joint. A healthy joint is stable as the surrounding skeletal muscles keep it in balance. If a joint is in dysfunction it is more sensitive to injuries, because its muscles work with different forces in the cause and effect chain and their activity is discoordinated (Richter and Hebgen, 2006).

2. Theories regarding pelvis and knee joint relations

The two iliac bones have an effect on the dynamics of the lower extremity (Deleo et al., 2004). During walking and especially during running kinesiological and biomechanical influences are being transferred to the lower extremity (Hohmann and Wörther, 2005). A lot of muscles originate at the pelvis and connect it directly to the knee joint like the mm. rectus femoris, sartorius, gracilis, biceps femoris, semitendinosus and semimembranosus (Sturesson, 2001).

This means that there is a connection of the physiological movements therefore have a connection between pelvis and knee joint and have an effect on one another. A malposition of the pelvis has a pathological influence on the knee joint and the other way round (Meert, 2003). The reasons for these are direct anatomic and biomechanical connections realized by changes in tonus and power of the above mentioned muscles (Hossain et Nokes, 2005).

2.1 Anatomy of the pelvis

In order to be able to cope with these demands the pelvis has a good ligament locking feature. The pelvis (Figure 1) looks like a bony ring consisting of four bones which are connected to one another through joints – two iliosacral joints and pubic symphysis (Vleeming and Snijders, 1990, Geudvert, 1991). The sacroiliac joints have high stability during compression, but also allow certain mobility (Winkel, 1992). Which is why the pelvis is not rigid, but it can move and change its form (Schünke, 2005).

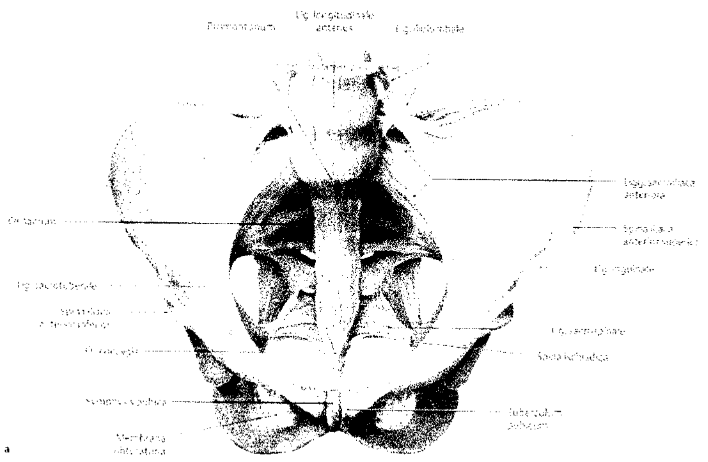

Figure 1: The bony pelvis ossa coxae and os sacrum with ligaments from ventral (Schünke, 2005)

2.1.1 Axes of the pelvis movements

In the frontal plane the horizontal axis of the os coxae is relevant for the anterior and posterior movements of the iliac bones (os coxae). It lies at the height of S3, the amplitude of movement lies between 2° and 5° (Peeters and Lason, 2000). The horizontal axis of the os sacrum lies at the height of S2. Around this axis the nutation and contra nutation movements of the sacral bone of 0,5- 1,5 cm (Meert, 2003) take place. The diagonal axis runs from the upper pole of the basis of the os sacrum and through the lower pole of the hetero- lateral top of the os sacrum (Frisch, 2001).

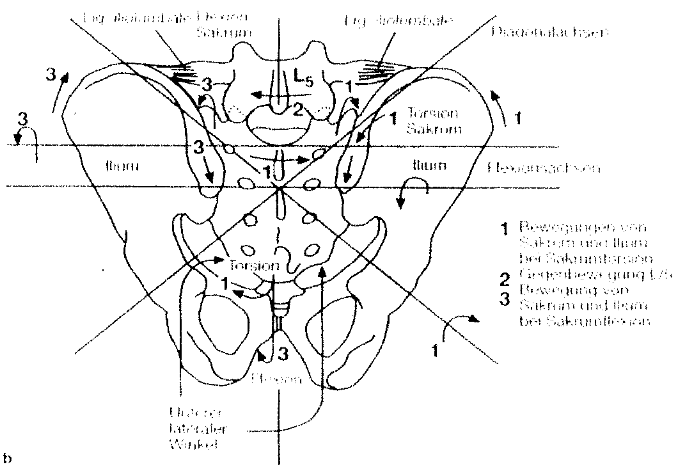

Figure 2: The axes of the pelvis, os coxae axis at the level of S3, os sacrum at the level of S2 and the two diagonal axes os sacrum axes (Frisch, 2001)

In the sagital plane the os coxae move on an axis which, according to Smidt et al. (1995), equals the angle alpha, which lies between the horizontal line and the line between the spina iliaca anterior superior (SIAS) and spina iliaca posterior superior (SIPS). The angle alpha showed 9.2 +/- 2.5° toward anterior right and 8.7 +/- 2.1° left. In bilateral comparison the position is different. We can say that the spina iliaca anterior superior (SIAS) is in a state of anterior rotation, which means that the os coxae stays rotated towards anterior and the one sided pelvic position towards anterior. On the right side we have an anterior rotation of 0.5° more than on the left side (Decupere, 2000).

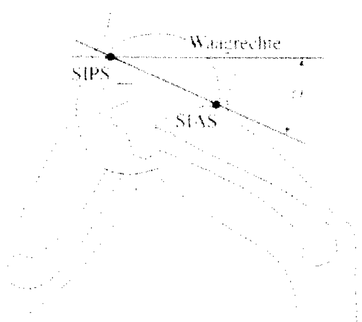

Figure 3: Spina iliaca anterior superior on the right side looks toward anterior (Decupere, 2000)

Conclusion: the movements of the sacroiliac joints are complex. Each of the two bone partners (os coxae and os sacrum) move around their own axis. In the frontal plane the axis of the iliac bone lies at the height of S2 and the one of the sacral bone at the level of S3, in the sagital plane it lies at S1.

2.1.2 Function of the sacoiliac joint

The sacroiliac joint is stable within the frontal section and therefore barely able to move. In the sagital section movements are possible (Brunner, 1991). The range of motion within the sacroiliac joint lies between 2 and 5° in the sagital section (Peeters and Lason, 2000). This value does not depend on the gender. Due to an increasing age, the range of movement may be reduced up to half of it (Decupere, 2000).

Conclusion: Iliac bones can move in different planes. But the greatest range of movement can be expected in the sagital plane (os coxae anterior and posterior rotation). The range of movement in this plane comes to 2 to 5°.

2.1.2.1 Movements os coxae posterior

During the posterior movement of the os coxae the spina iliaca anterior superior (SIAS) turns backwards and upwards. The spina iliaca posterior superior (SIPS) turns to the front and downwards (Kubis, 1969). The following big muscles move the os coxae towards posterior: the m. glutaeus maximus, m. piriformis, mm. obturatorii, mm. gemelli and the m. psoas minor as well as the muscles of the hip- and the knee joint, the m. semitendinosus, m. semimembranosus, m. biceps femoris. (Zalpour, 2002).

2.1.2.2 Movements os coxae anterior

During the movement of the os coxae towards anterior (Figure 4), the spina iliaca anterior superior (SIAS) turns to the front and downwards. The spina iliaca posterior superior (SIPS) turns back and upwards (Meert, 2003).

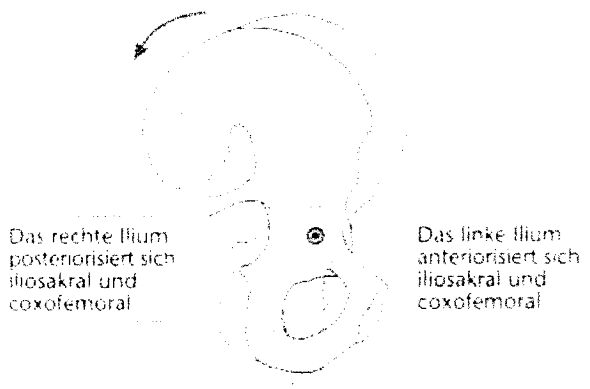

Figure 4: Movements of the left os coxae towards anterior and of the right os coxae towards posterior (Meert, 2003)

The following big muscles move the os coxae towards anterior: the mm. glutaeii medius et minimus (ventral parts) and the m. iliopsoas, as well as the muscles of the hip and the knee joint, the mm. adductores, the m. gracilis, the m. rectus femoris, the m. tensor fasciae latae and the m. sartorius. (Schünke, 2005). The ligg. which help to limit the os coxae movement towards anterior are the ligg. sacrotuberale and sacrospinale.

Conclusion: The iliac bones can move around different axes. The greatest range of movement are to be expected in the sagital plane around the horizontal axis. This movement can be called ventral- and dorsalrotation or ante- and retroflexion or os coxae anterior and os coxae posterior. The positions of the spinae iliacae anteriores (SIAS) and posteriores superiors (SIPS) change during these movements. We believe that these tips can be used for the description of the pelvic position and movement in a healthy state and under a pathological situation. The muscles are involved in these movements, even the muscles interconnecting the pelvis with the knee joint.

2.1.3 Biomechanics of the pelvis

The biomechanics of the pelvis are important for the movements of walking and running (Hohmann and Wörther, 2005). The complex movement of the pelvis is called the intra-pelvic movement (Greenman, 1990). Vectors of force of the lower extremity, the upper extremity and the torso meet at the pelvic ring (Klein and Sommerfeld, 2004). The forces are being strengthened during the performance of movement and by the maximum forces (Walther and Kirschner, 2004). The faster the run, the higher the grade of flexibility and the strain to transfer forces gets (Snijders, 1995).

Conditions for stabilisation are that the friction force F_R has to be either bigger or equal to the vertical force of the hip joint, $F_{ACV} \leq F_R$ (Brinckmann, 2000). In a state of balance this has the consequence that the sum of all torques equals zero. This means that the product of the force of the ligaments and the vertical distance between the ilio-sacral fulcrum minus the product of the vertically working force of the hip joint and the horizontal distance between the ilio-sacral and the hip joint (Burnstein und Wright, 1997). As long as the friction force is either bigger or equal to the vertical force of the hip joint and as long as the torque conditions are being fulfilled, the os sacrum remains stable within the bony pelvic ring (Kummer, 2005).

Conclusion: The forces affecting the pelvis from above and from below meet in the area of the sacroiliac joint. Passive (ligament) and active (muscle) stabilisers are needed to absorb the forces. The forces are transferred to the lower extremities trough the hip joints.

2.1.4 Movement analyses of the pelvis during running

During walking (Figure 5), the left leg (for example) hits the ground and carries the weight. The left os coxae rotate towards dorsal. The counterforce from cranial strengthens the nutation willingness of the os sacrum on the left side. The basis of the os sacrum moves downwards at the side of the supporting leg and rotates towards the other side (Greenman, 1990). Thanks to the tension of the lumbar extensors and the help of the ligaments, as well as the ongoing movement, the right os coxae rotate towards ventral (Dvorák and Dvorák, 1997). The lumbar spinal column is extended and rotated to the right. In the course of the movement the left leg now accepts the full weight. The torso is being inclined to the left side (Bogduk, 1991).

Now, the phase between the *middle position* and the *acceleration phase* is to be examined. Shortly after the middle position the vertical axis of effort moves behind the nutation axis of the os sacrum (Meert, 2003). The left os coxae rotates towards ventral. The centre of gravity of the torso moves to the left, in direction to the supporting area of the supporting leg (Klein- Vogelbach, 2000). As a result, the lumbar spinal column is being inclined to the left during a rotation to the right. The movement is going on inside the iliosacral joint until the joint is fixed (Müller, 2000). Thanks to the support of muscles of the abdomen, the right os coxae is now rotating towards dorsal. After that the right os coxae is rotating towards ventral. The os sacrum rotates around its right diagonal axis (Perry, 2003). During the phase of impression, the right half of the pelvis rotates, together with the lumbar spinal column to the left (Greenman, 1990). When repeating the whole process, the right foot hits the ground. The synergy of the extensors is being activated and the right os coxae rotate out of the end ranged dorsal position towards ventral. The os sacrum moves back into a neutral position, the right leg accepts the body- weight (Snijders, 1995). The biomechanical process starts again.

During the iniciation of the *non supporting phase* the leg is being examined by lifting the left leg from the ground. At the time when the toes are lifted the os coxae stands ventral, the flexors are put under tension (Meert, 2003). When the non- supporting leg outruns the supporting leg, the os coxae rotate towards dorsal. The right os coxae rotate towards ventral around the transversal axis (Greenman, 1990). During a flexion of the hip of approx. 50°, the os coxae starts to rotate towards dorsal until the possibility of motion of the right sacroiliac joint is exhausted (Smidt, 1995). The symphysis pubis is slowing down the distancing, the right os coxae is being moved on a vertical axis towards inflair in correlation to the left one. The ventral part of the ligg. iliolumbalia tightens up and prevents a further rotation (Richardson et al., 2004). The 5th lumbar vertebra now stands in convergence with the right compound pair. The 4th lumbar vertebra compensates the ongoing movement towards cranial so that the 3rd lumbar vertebra stands in an almost steady position (Müller, 2000).

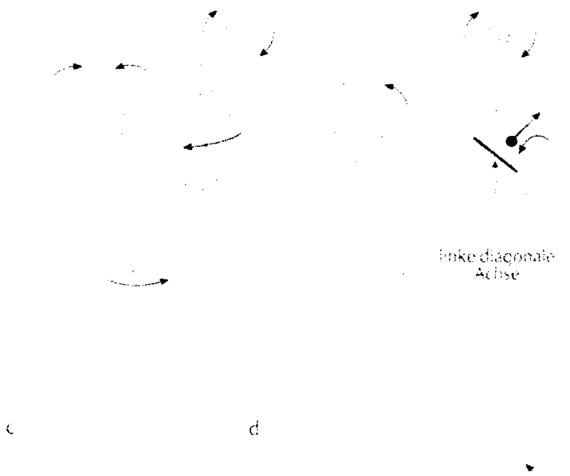

Figure 5: The movements of the pelvis while walking, movement of the os coxae and rotation of the os scrum during the intrapelvic movement (Brokmeier, 2001)

While running the time of reacting to the contact with the ground is shorter in comparison to walking and the maximum of the effort is higher (Kleindienst et al., 2006).

Conclusion: During walking the three- dimensional movements in the sacro-iliac joints are being realised around horizontal and oblique axes. The iliac bones repeat their movements in direction towards ventral and dorsal, the sacral bone moves alternatively around the oblique axes. The ranges of movement in the sacro- iliac joints are limited: passively by the tension of the ligaments and actively by contractions of the muscles.

2.2 Anatomy of the knee joint

The knee joint (Figure 6) consists of different parts from femur and tibia with the menisci between them (Winkel and Hirschfeld, 1985). The menisci balance the incongruent articular surfaces and have a function to absorption and transfer axial forces of pressure (Comford and Mottran, 2001). Its movements are coppeled in the open system with the tibia and in the closed system with the femur (Iwaki, 2001).

The patella serves as a superficial, enlarging sesame bone of the m. quadriceps femoris. The art. tibiofibularis proximalis is in addition to the knee joint (Schünke, 2005).

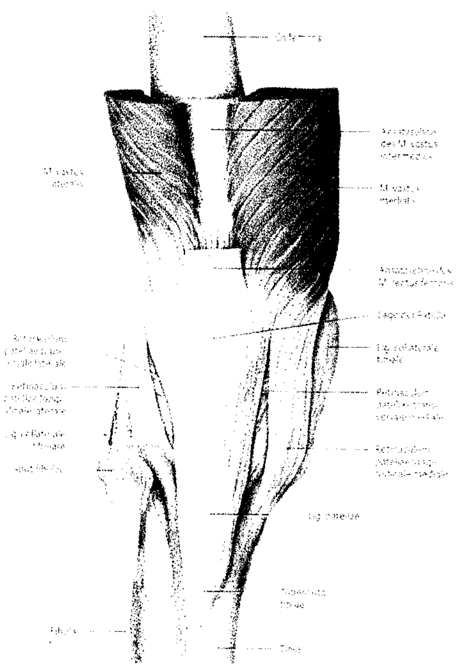

Figure 6: Knee joint from ventral point of view (Schünke, 2005)

The patella glides in the channel between the two femoral condyls as hypomochlion of the m. quadriceps femoris, it moves the position during flexion and extension, cranial and caudal and glides towards lateral during an inward and toward medial by outward rotation (Heimann, 1998).

Conclusion: The knee is a complex joint with a lot of ligaments. Special about the joint are the menisci and the patella.

2.2.1 Axes of knee joint movements

The rotation axis is situated on the condylus medialis tibiae, it runs through the top of the medial cruciate ligament (Frisch, 2001). Lateral there is a stronger movement of rolling and gliding than medial (Kapandji, 2001). This is the consequence of the different condylus femoris and of the position of the rotation axis, which is not situated centrical (Iwaki et al., 2000). The axis runs in full extension from medial to lateral, from cranial to caudal and from anterior to posterior. Which is the reason for a combination of flexion and inward rotation of the tibia. During the extension it leads to an outward rotation (Dvorák and Dvorák, 1997). The amplitude of the associated rotation comes to 15°- 20° and the one of the abduction to 5° (Mink, 2000).

Figure 7: Three-dimensional scheme of position change of the helicoidal axis in the right knee joint (Klein and Sommerfeld, 2005).

Conclusion: The flexion extension axis runs from medial, cranial anterior to lateral, caudal, posterior according to a spiral. The rotation axis is situated on the condylus medialis tibiae, it runs through the top of the medial cruciate ligament.

2.2.2 Function of the knee joint

Within the knee joint movements of flexion and extension, as well as movements of rotation which come to 90° flexion can be actively performed.

2.2.2.1 Movements knee flexion and extension

Description of the kinematics of a **knee flexion**: The m. semimembranosus, the m. semitendinosus, the m. biceps femoris, the m. gracilis, the m. sartorius, the mm.

gastrocnemii and the m. popliteus are responsible for the movement of flexion of the non- supporting leg (open system). During flexion the component of rolling is definitely higher in comparison to the component of gliding (Mink, 2000). The flexion-extension axis runs through the condyls of the femur. During flexion the axis moves towards dorsal. As a result of the smaller getting diameter of the medial femoral condylus the axis lies on a spiral (Frisch, 2001).

The lig. collaterale mediale always has to bear a certain tension, which is why it is able to stabilise the medial articulation (Jerosch and Heisel, 2004). The lig. collaterale laterale is strained during an end ranged flexion and relaxed during a lower grade of flexion. The end ranged flexion is limited by the posterior horns of the menisci, the two cruciate ligaments and the posterior capsule. During the active flexion the menisci are being pulled towards dorsal (Winkel, 1985). The medial meniscus is being pulled towards dorsal by the m. semimembranosus tendon and the lateral fibres of the m. popliteus (Zalpour, 2002). During flexion the pressure of the patella on the femur is getting higher. If the flexion comes to approx. 30° there is more contact between the middle parts of the surface of the patella and the femur, at 90° up to the maximum flexion the cranial part of the patella gets in contact with the femur (Tittel, 2000). The amplitude of the movement comes to 140° during flexion and to up to 160° passive while the hip joint is in flexion (Schomacher, 2001).

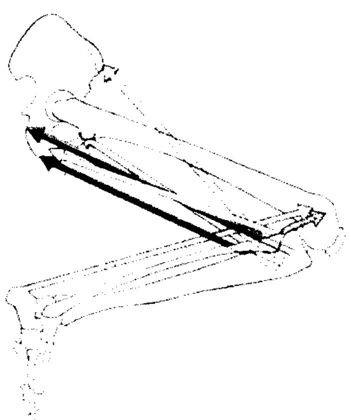

Figure 8: The muscle synergy of the knee flexion on the right Side (Schünke, 2005)

Description of the kinematics of a **knee extension**: The movement of extension is being realized by the m. tensor fascia latae and the m. quadriceps femoris (with its accompanying parts). During this movement the four muscle heads work in different

geometrical positions; the m. vastus medialis develops its maximum force during the final extension (Brokmeier, 2001).
The m. rectus femoris stabilizes the movement and controls it during the whole time (Schünke, 2005). During the last 5°- 10° of the extension it comes to an outward rotation of the tibia within the open system. The responsibility for this lies with the bigger radius of the condylus femoris medialis, the way which has to be overcome is longer. It is also the case that during the extension the lig. collaterale laterale is tightening up and the anterior cruciate ligament is totally tight (Mink, 2000).

2.2.2.2 Movements knee inward and outward rotations

Inward rotation and the outward rotation are possible while the knee joint is flexed (Kapandji, 2001).
The muscles which are responsible for the outward rotation are the m. biceps femoris and the m. tensor fasciae latae. These muscles also stabilize the knee joint. During the outward rotation the anterior cruciate ligament relaxes. The lig. collaterale mediale is put under a weak strain and therefore it is able to stabilize the articulation (Frisch, 2001). It also acts as a brake for the end ranged outward rotation. The end ranged movement is also limited by the dorso- medial joint capsule, the posterior cruciate ligament and the posterior horn of the medial meniscus. During an outward rotation the medial meniscus glides towards dorsal and the lateral one towards ventral on the tibia plateau (Winkel, 1985). During the outward rotation of the femur the lig. patellae pulls towards medial. As a result the patella is being moved towards medial on the femoral condylus. The retro- patellar pressure on the condylus femoris medialis is getting higher (Tibesku and Pässler, 2005). The physiological outer rotation comes to 90° knee flexion to 40°.

The muscles which are responsible for the inward rotation are the m. semimembranosus, the m. popliteus and the pes anserinus superficialis muscle group (Dvorák and Dvorák, 1997). During the inward rotation the posterior cruciate ligament relaxes and allows the movement to happen, the anterior cruciate ligament tightens up and acts as a brake for the end of the inward rotation (Jerosch and Heisel, 2004). The lig. collaterale laterale is always under a weak strain and is therefore able to stabilize the articulation. The end ranged movement is also limited by the lig. collaterale laterale, the dorso-lateral capsule and the tractus iliotibialis

(Mink, 2000). During an inward rotation the medial meniscus glides towards ventral and the lateral one towards dorsal. During an inward rotation of the femur the patella moves towards lateral on the femoral condylus, due to the tensile force of the lig. patellae towards lateral. As a result the retro- patellar pressure on the lateral femoral condylus is getting higher. The inward rotation comes during a 90° knee flexion to 15° (Schomacher, 2001).

Conclusion: The knee extension is performed by the m. quadriceps and m. tensor fascia latae and is limited by the strain of the lig. cruciatum anterior and the lig. collaterale laterale. The knee flexion is performed by the hemstrings, mm. gastrocnemii and m. popliteus. It is limited by the strain of the lig. cruciatum posterior and the lig. collaterale mediale.
The muscles which are responsible for the outward rotation are the m. biceps femoris and the m. tensor fasciae latae. It is limited by the strain caused by the lig. collaterale mediale and the dorso medial joint capsulae, the posterior cruciate ligament and the posterior horn of the medial meniscus. The muscles which are responsible for the inward rotation are the m. semimembranosus, the m. popliteus and the pes-anserinus superficialis muscle group. It is limited by the strain caused by the lig. collaterale laterale and the dorso laterale capsulae, the anterior cruciate ligament and the posterior horn of the lateral meniscus.

2.2.3 Biomechanics of the knee joint

As soon as the test person puts his foot to the ground a force which is directed towards caudal and medial comes into being (Jerosch and Heisel, 2004). This force provokes a valgus moment and instability of the joint. The lig. collaterale mediale can absorb this valgus provocation of the knee joint (Burnstein and Wright, 1997).

In order to achieve a balance of the forces and stability of the joint, the resulting force has to be situated at a medial distance of approx. 1.5 cm, seen from the centre of the joint (Brinckmann, 2000).
Therefore, a varus moment comes into being and acts as a counter force. This is only made possible by the tension produced by the lig. patellae. If the valgus force gets stronger, it is compensated by the muscular tension of the m. quadriceps femoris

(Kapandji, 2001). As a result, the extension moment gets stronger and therefore has to be compensated by the tension within the ischiocrural musculature. Due to this increase in force, the joint gains more stability (Kummer, 2005).
In case of an active insufficiency of (e.g.) the m. quadriceps femoris, the body tries to move the point of contact of the joint towards an extreme medial position. The result is that the pulling force which affects the ligg. collaterale gets stronger in order to compensate the stronger varus component (Klein and Sommerfeld, 2004).
On the other hand, if there is for example a stronger valgus component due to a malposition of the leg, the lig. collaterale mediale can compensate the stronger valgus component. In this case the lig. collaterale mediale can produce a force which equals a varisation of approx. 5° (Burnstein and Wright, 1997).

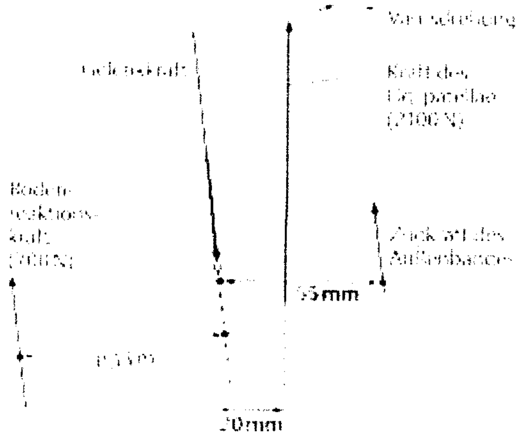

Figure 9: Contact point of knee loading is on the medial side of the knee joint. If it increase and change towards medial, the m. quadriceps have to compensate and the lig. collaterale laterale, too (Burnstein and Wright, 1997)

The knee joint is led by the lig. cruciatum anterius and posterius which have – if you take the optimal case – the possibility to move 2-3mm. Both of the cruciate ligaments *have the possibility to co-ordinate the movements of the knee joint, to lead them.* At a flexion of approx. 20° their tension reaches its minimum (Dürselen et al., 1995).. If the flexion of the knee joint gets stronger the lig. cruciatum posterius tenses up. If the knee joint gets more extended, the lig. cruciatum anterius tightens up. The muscles which support the lig. cruciatum anterius are the ischiocrural muscles. The tension of the m. quadriceps femoris supports the lig. cruciatum posterius (Kapandji, 2001)..

Conclusion: There is a varus- valgus balance if the contact point of the joint is located at a medial distance of approx. 1.5cm seen from the centre of the knee joint.

If the valgus is stronger it gets compensated by an intensification of the tension of the m. quadriceps femoris. If there is an active insufficiency, the lig. collaterale laterale can compensate it up to a certain extent. The lig. collaterale mediale can compensate a stronger valgus up to a certain degree. The tension of the ligg. cruciatum anterius and posterius leads the movement of the knee joint. The tension of the ischiocrural musculature supports the lig. cruciatum anterius and the muscular tension of the m. quadriceps femoris the lig. cruciatum posterius.

2.2.4 Movement analyses of the knee joint during running

The movements of the knee joint differ during different phases in regard to the "actio- and reactio" forces, according to the momentary position of the joint (Kummer, 2005). During running the kinetic and the kinematical data is higher than during walking (Kleindienst, 2006).

If the heel has *contact* with the ground the musculature is working co- synergistic in the so called closed system in order to ward off the centrifugal force of the body. The knee joint is stabilized through cosynergistic activity of the mm. gastrocnemii, the hamstrings, the m. quadriceps and the m. glutaeus maximus works excentric, stabilized the knee joint (Perry, 2003).
The foot touches the ground, the os calcaneum and the os cuboideum form the punctum fixum, the loading response phase starts (Klein- Vogelbach, 1995). While putting the outer edge of the foot onto the ground the muscles contract in order to act against the acting force which is directed towards the ground by a reacting force and therefore to cushion the weight and stabilise the body (Brinckmann, 2003). The knee has a so called absorption function, which means that it absorbs shocks. The m. quadriceps femoris is working excentric, in order to ward off a fall. From dorsal the m. soleus is acting as a brake for the dorsal extension in the upper ankle joint, while the m. gastrocnemius and the ischiocrural muscles are stabilising concentric (Hirschfeld and Winkel, 1985). The m. biceps femoris and the m. tensor fasciae latae are acting as an eccentric brake for the inward rotation of the lower leg from lateral, dorsal and the m. vastus lateralis from ventral, lateral (Brokmeier, 2001).

Figure 10: Cocontractive activity of the muscles stabilising the knee joint (Brokmeier, 2001)

Now, the phase from the *middle* position until the phase of acceleration is being looked at. During the starting phase the knee joint is moved under the centre of gravity of the body or rather the body over the supporting area, the standing foot (Klein-Vogelbach, 2000). The m. rectus femoris starts this movement concentrically by bending the torso at the same time towards ventral in the pelvic area. In this phase the ischiocrural muscles (concentrical) and the m. triceps surae (stabilizing) take on most of the force (Brinckmann, 2000).

If the lower leg rotated inwards the contraction would increase the compression in the knee joint and a luxation tendency might be the consequence (Burnstein and Wright, 1997). The m. rectus femoris stabilizes the bending movement of the hip excentrically. The other three muscular parts of the m. quadriceps femoris stabilise the rolling movement of the femoral condyls towards ventral. The ischiocrural muscles with the pes anserinus superficialis muslces and the mm. gastrocnemii pull the tibia plateau towards dorsal, supported by the m. biceps femoris and the m. tensor fasciae latae (Hohmann and Wörther, 2005).

As the femoral condyls perform mainly a rolling movement during the extension of the knee, the strong tensile force of the m. vastus intermedius on the patella slows down this mechanical process. The m. vastus medialis on the other hand pulls the femur even stronger in the outward rotation and the m. vastus lateralis develops a certain force in direction of the luxation of the patella (Brokmeier, 2001). As the femoral condyls are situated in the posterior part of the tibia plateau and the tibia is being pulled actively towards dorsal this is a simultaneous movement of the two joint partners. The rolling movement is passively being activated by the gliding movement of the tibia plateau. Besides a movement of flexion and extension an inward and outward rotation is now also possible as the forces of compression are limited to a minimum (Kleindienst et al., 2006). The ischiocrural muscles and the m. triceps surae guarantee a synchronously performed active gliding movement of the femoral plateau, whereas the m. quadriceps femoris supports and stabilizes the rolling movement (Winkel, 1985).

In the follows *toe off phase* the knee joint, the hip joint and the pelvis move into extension, muscles are working in order to perform the extension of the knee against the force of its own weight, the m. quadriceps femoris works in extension. The ventral part of the foot has contact with the ground (Klein- Vogelbach, 1995). The extension and the outward rotation of the lower leg stabilize the knee joint, too. During this phase the m. soleus and the m. gastrocnemius work contrarily. The m. soleus works positively dynamic and the m. gastrocnemius negatively dynamic (Klein and Sommerfeld, 2004).

The upper extremities enter the *acceleration phase* in the so called open system. The knee joint moves into flexion, the tibia rolls and glides towards dorsal. In this phase the m. quadriceps works excentrically, the hemstrings and the mm. gastrocnemii move the knee into flexion (Hüter- Becker and Dölken, 2005).

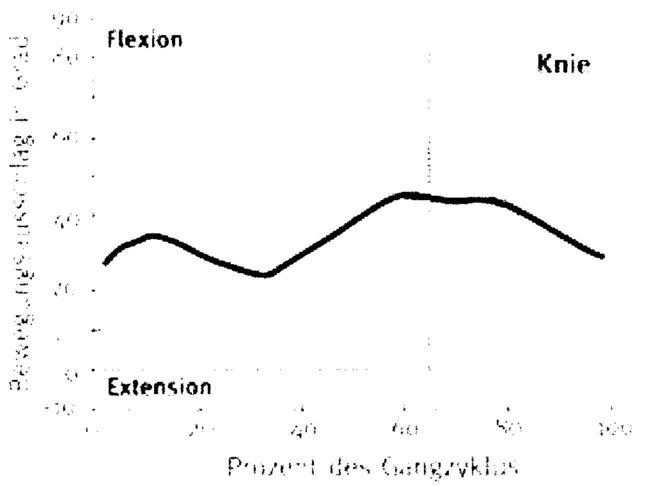

Figure 11: Motion analyses of walking. The dotted vertical line shows the transition from the Supporting to flying phase (Perry, 2003)

During the *middle to the terminal swing phase* the femoral condylus roll arthrokinematically towards ventral while the tibia glides towards ventral at the same time. The movement of gliding and the advantage of path go in the same direction (Brokmeier, 2001). Both joint partners move towards extensoric, activated by concentric activity of the m. quadriceps femoris. The m. triceps surae and the ischiocrural muscles are working excentrically, they slow down the acceleration. Thanks to the bigger femoral condylus the tension of the anterior cruciate ligament and the excentrically located rotation axis the tibia performs an outward rotation during the final extension whereas the femur performs an inward rotation (Dvorák and Dvorák, 1997). Thanks to an increasing activation of the anterior shin bone muscles it comes to a weak extension of the ankle joint towards dorsal (Perry, 2003).

2.3. Pelvic and knee joint relations

The pelvis and the knee joint are related, especially from a functional and anatomical point of view. Long muscles origin at os coxae, cross the knee joint and insert at the tibia and fibula (Saladin, 2004).

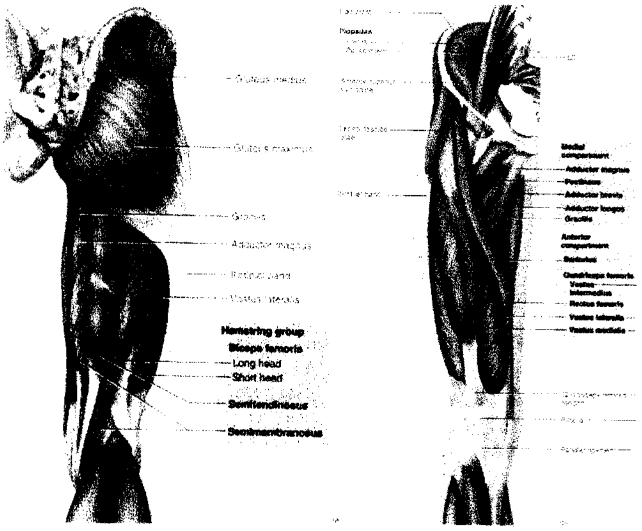

Figure 12: The knee joint is directly connected with the pelvis through the femoral musculature (Saladin, 2004). On the left- the connecting muscles in the back view. On the right- the connecting muscles in the front view

Within the closed system the extensors of the hip move the os coxae towards posterior. Within the open system a hip- extension of more than 10°-15° leads to an ongoing physiological movement of the os coxae towards anterior (Frisch, 2001). Within the closed system the hip- flexors move the os coxae towards anterior. Within the open system a hip- flexion of over approx. 50° results in an ongoing physiological movement of the os coxae towards posterior (Meert, 2003).

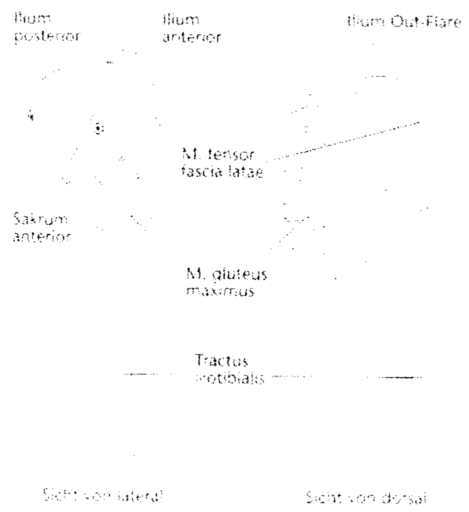

Figure 13: Muscle relation between os coxae and knee joint. The os coxae rotation toward anterior and posterior (Meert, 2003)

In conclusion we can say the long muscle bones influence also the so called cause and effect chain in the lower extremity.

2.3.1 Loading of cause and effect chain

The loading of the cause and effect chain in the lower extremities increases during running (Deleo et al., 2004). The maximum of strain gets higher, the time of the reaction towards the ground gets shorter (Kleindienst et al., 2006). In comparison to a walking state, the phases change from the so-called double stand phase into the supporting phase into one stand and flying phases. The movement in the joints changes, the strain and the forces increase. This depends on how fast the person runs (Hohmann and Wörther, 2005).

If we record ground forces during running, we get two peak curves, the landing peak and the toe off peak during a slow run (Perry, 2003). If the sportsman runs faster these force peaks increase and become maximally 3,5 times higher than the body weight (Lane et al., 1987). While running slowly, the strain put on the foot begins on the calcaneus and continues along the lateral foot margin towards the os metatarsale V and then towards the os metatarsale I (Brokmeier, 2001). If the tempo of running increases, the foot landing changes. The sole meets the floor more ventrally, the landing force peak increases and the contact period of the foot with the floor decreases.

If the sportsman runs faster the activity of the muscles increases (Hohmann et al., 2004). For example, during the so-called heel strike phase the strain increases and the m. glutaues maximus and the m. quadriceps femoris have to work excentrically with more intensity. In the middle stand position the mm. glutaeus medius and minimus work with higher stabilisation activity (Klein- Vogelbach, 2000). During a faster run the pelvis moves more up and down, the whole pelvis rotates around a vertical axis and the so-called intrapelvic movement between individual bones (iliac and sacral bones) increases (Zeller et al., 2005).

If a sportsman runs faster the foot movement changes, too. The centre of body mass follows a straight line in the direction of running so that the body works more economically. The strain put on the foot changes so that the medial margin of the sole is under more stress and the foot gets into a pronation position (Kaltenborn and Evijenth, 1995). As a result of these foot changes, the tibia provides increased inner rotation. As a consequence of this, the knee joint is overstrained (Berg, 2002). The ligaments lead the movement, the propriceptores inside the ligaments, joints and muscles are important to get a high quality of movement (Macefield, 2005). If the strain gets higher and the control decreases at the same time the probability of a dysfunction increases (Brooks, 1986). The most delicate part of the cause and effect chain in the lower extremities is the knee joint, it reacts very sensitively to dysfunctions (Halata et al., 1985).

Conclusion: The strain put on the active and passive structures and neuromuscular system of the body increases during a stressful situation such as during a run. The contact phase decreases and the non supporting phase increases. The runners make longer and faster steps.

2.3.2 Control of cause and effect chain

The ligaments have an important *proprioceptive function*, they influence the sensomotoric control (Johansson et al., 2002). They contain various receptors (Halata et al., 1985). The receptors can be subdivided according to functional aspects into slowly (static) and quickly (dynamic) adapting receptors (Macefield 2005). Even a small tension in the cruciate ligaments leads to changes in the muscle tonus around the joint in order to stabilize it and to coordinate muscle contractions (Sjolander et al., 2002). With electro stimulation the skin influences the modulation of the stretch reflex and the so-called H reflex, both reflexes are connected with the control of the muscle tonus. The stimulation of the skin of the foot sole, at the heel and the metatarsale region shows, that there is a different localisation of electrical stimulation. It changes the muscle tonus of the m. soleus. Heel stimulation led to facilitation of the stretch reflex of the m. soleus but stimulation in the metatarsale region caused inhibition of the reflex in the same muscle (Nakajima et al., 2006).

During a dorsalextension the H-reflex (of the m. soleus) decreases, during a plantarflexion the H- reflex increases, too. A dorsalextension inhibits the activity of the nerve but a plantarflexion increases it (Monita et al., 2001). A movement in the cause and effect chain of the lower extremities shows that if the lower extremities are under stress the activity of the m. soleus is activated during the hip extension. This also occurs in regard to the stimulation of the foot sole (Knikou et al., 2007).

Conclusion: There exists a specific local relation between an irritated skin area and the reflex activation of skeletal muscles. The irritation of the heel skin causes the activation of the m. soleus and knee extensors. A dorsalflexion activates the m. tibialis anterior and inhibits the m. soleus, a plantarflexion has the opposite effect. It seems that nerve reflexes have caused the so-called cause-and-effect chains passing through the lower extremities and that the chains are realised through an increase in the muscle tonus of agonistic muscles which then inhibit antagonistic muscles through reciprocal inhibition.

2.4 Pathokinesiology of pelvic and knee joint relations

If there are any dysfunctions of the os coxae towards their joint partners the result may be pathomechanic consequences (Richter and Hebgen, 2006). How grave those consequences are also depends on the ability of the test person to compensate them (Klein and Sommerfeld, 2004) and which affections are present. The os coxae move three- dimensionally in regard to the femur and the os sacrum. Thanks to these functional connections the joints and muscles have an effect on one another if there is a pelvis malposition and are also able to compensate them up to a certain extent (Kayser et al., 2008). Within the mechanisms which compensate malpositions of the os coxae the whole kinematical sequence of walking and running is affected (Peeters and Lason, 2000). The disruptive elements of the down going cause- and effect- chain are mainly depending on the question of whether there is a one- sided malposition of the os coxae towards anterior or posterior. Dysfunctions and blocks within the pelvic area lead to a malposition of the iliac bone (Greenman, 1990). A one- sided dysfunction of the os coxae changes the functional length of the leg (Thiel and Richter, 2009). Especially for endurance athletes, who always repeat certain kinematical movements, it is difficult to compensate over a longer period of time. This often leads to affections which are described in the following text. The main part of the compensations of dysfunctions in the lower extremities, especially during running, takes place in the knee joint (Hohmann and Wörther, 2005).

Conclusion: A malposition of the pelvis is caused mostly by a dysfunction on one side only. Then only one sacroiliac joint and one hip joint on the same body side do not function normally. Consequently the whole lower extremities on the same side cannot function normally.

2.4.1 Pathokinesiology of os coxae anterior

Due to an os coxae anterior dysfunction the os coxae is standing rotated towards anterior (Thiel and Richter, 2009). The most evident point of reference is the spina iliaca anterior superior (SIAS), which stands from a spatial point of view turned to the front and downwards in the sagital plane (Peeters and Lason, 2000).

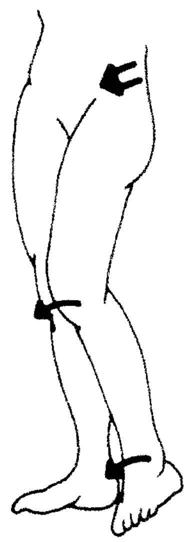

Figure 14: Pathomechanics of the descending cause- and- effect- chain (Peeters and Lason, 2000)

In their physiological field the muscles which pull the os coxae towards anterior work in a converged condition and their trigger points are very often activated (Simon and Travel, 2000), the antagonists are stretched (Richter and Hebgen, 2006).

In case of an os coxae anterior lesion, the ischiocrural musculature is overstretched. The m. semitendinosus and the pes anserinus superficialis muscles can cause pain and an insertion tendopathy (Niemuth, 2005). The m. semimembranosus extends into the capsule of the knee joint and a few fibres insert at the medial meniscus (Zalpour, 2002). The motion of the medial meniscus is limited to the front. In case of fast movements of the leg into an extension of the knee, a mechanical overstress of the medial meniscus can appear. The caput longum of the m. biceps femoris is stretched, too. It inserts at the caput fibulae, which gets pulled to cranial through the traction- effect. (Meert, 2003)

Caused by the movement of the fibula to caudal during an end ranged plantarflexion, this end ranged plantarflexion is no longer possible. Because of the cranial position of the fibula, the m. peronaeus longus is stretched, which leads to an ongoing interior- rotation of the os cuboideum, which leads to an ongoing external rotation and malposition of the os naviculare (Brokmeier, 2000). The m. tibialis posterior is overstreched and can manifest itself in a shint- splint (Winkel, 1992).

As a result of an os coxae anterior position of the thigh, the hip joint stands in an interior rotated position, the leg is functionally longer (Frisch, 2001). The ongoing motion is carrying on to caudal. Due to this static malposition, an os coxae anterior, the knee joint is in a genu valgum, a valgus malalignment (Kapandji, 2001). The pressure on the lateral side of the knee is higher, the lateral meniscus gets compressed. The absorption effect in the knee joint is reduced. The lig. collaterale mediale is stretched (Brokmeier, 2000). The foot stands in a pronation-dorsalextension position, the medial side of the foot is under more stress and shows a tendency to a flat foot. (Schünke, 2001). This can e.g. manifest itself in achilles-tendon pathology (Niethard and Pfeil, 2003). The os calcaneum valgisation increases, which lead then to an interior- rotation of the tibia, which puts stress on the knee joint (Debrunner, 1985).

Figure 15: Valgus (on the left) and varus (of the right) side in the lower extremity. During a valgus the lateral menisci are more under compression and the medial capsulae ligament structures stretched. In varus the medial menisci are more under compression and the lateral capsulae ligament structures stretched (Kapandji, 2001)

During an os coxae anterior lesion on the right side, the os sacrum gets tractioned in an ongoing malposition in L/ L, which has an impact on the spinal column and manifests itself in back pains (Richter and Hebgen, 2006)

Conclusion: During os coxae anterior the muscles providing this movement are hypertonic, the antagonistic muscles (hemstrings) are overstretched. The position and strain bearing in the knee joint are changed. The joint is in valgus position, the lateral side of the joint (meniscus lateralis) is overstrained, the ligaments and the joint capsule of the medial side are overstretched.

2.4.2 Pathokinesiology of os coxae posterior

If there is an os coxae posterior dysfunction, the os coxae is rotated towards posterior. The most prominent point of reference is the spina iliaca anterior superior. In the sagital plane it stands from a spatial point of view rotated towards dorsal and cranial and is linked to an inflair (Peeters and Lason, 2000).

In their physiological field the muscles do not work anymore. Muscles, that draw the os coxae to posterior, work in an approximated condition and their trigger points are frequently activated (Simon and Travel, 2000), the antagonists are stretched.

The m. sartorius and the m. gracilis are being stretched, which may lead to overstrain and an insertions tendopathy (Richter and Hebgen, 2006). The m. tensor fasciae latae is being stretched. As it tightens the fascia latae, it may be under a permanent tensile force which may lead to overload in the lateral area of the knee joint (Auerbach and Heyde, 2005). Especially for endurance athletes as well as for cyclists, this problem can be expanded to a so- called long- distance knee or runner`s knee. In this case there isn't only the insertions tendopathy of the tendon but also an inflammation of the bursa taking place (Niethard and Pfeil, 2003). The m. rectus femoris, which inserts at the tuberositas tibiae, is also being stretched. The pressure on the patella is getting higher. Thanks to the permanent tensile force, athletes who are jumpers may get a so- called jumper's knee (Tibescu and Pässler, 2005).

As a result of the posterior- position of the os coxae, the thigh stands rotated outwards within the hip joint, the leg is functionally shorter (Frisch, 2001). The ongoing movement is prolonged towards caudal. Caused by this static malposition, the knee joint stands in a genu varum and a bandy leg position during the one-sided posterior position of the os coxae while standing (Niethard and Pfeil, 2003). The pressure put on the medial side of the knee is higher, the medial meniscus gets compressed. Therefore the absorption effect within the knee joint is reduced. The lig. collaterale laterale is being overstretched. The foot is standing in a supination plantarflexion position, the lateral side of the foot is under more strain (Brokmeier, 2001). The os cuboideum is rotated outwards, the os naviculare inwards and has the tendency towards a pes cavus (Debrunner, 1985). This may lead to an apponeuritis of the sole of the foot or if the patient is a runner with high intensities of strain to a fatigue fracture of the os metatarsale II (Hohmann and Wörther, 2005).
Going up, during a posterior lesion of the os coxae on the right side, the os sacrum is being pulled into a malposition towards L/ R, which has an effect on the spinal column and may result in back pain (Peeters and Lason, 2000).

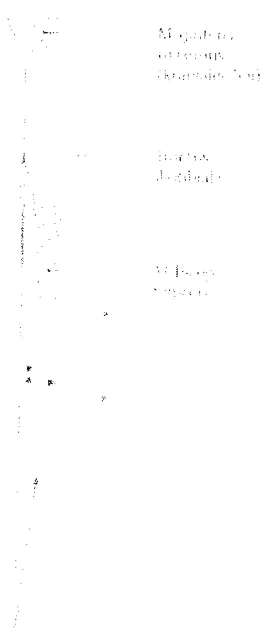

Figure 16: Pelvis malposition results in knee joint varus, the m. biceps caput longum rotates the os coxae toward posterior (Schünke 2005)

Conclusion: During os coxae posterior the muscles performing this movement are hypertonic, the antagonistic muscles (mm. rectus femoris, gracilis, tensor fasciae latae) are overstretched. Position and strain of the knee joint change. The joint is in valgus position, lateral side of the joint (meniscus medialis) is overstrained, the ligaments and the joint capsule on lateral side are stretched.

2.4.3 Overloading and pain during running

If the os coxae is malpositioned we can also speak about malfunction (Zeller et al., 2005). The dysfunction of the sacroiliacal joint goes hand in hand with a weaker absorption effect and a fixed rotated os coxae toward anterior or posterior (Deleo, 2004). This malfunction influences the lower extremities as a whole and especially the knee joint (Jerosch and Heisel, 2005). The knee joint is the most sensitive joint in the lower extremities and is very sensible to overstrain and dysfunction if there is a cause and effect chain in the whole lower extremity (Deleo, 2004). If the pelvis experiences a malfunction, the knee joint also experiences an overstrain and dysfunction (Richter and Hebgen, 2006). We can detect overloading of the knee according to the cause and effect chain theory, which includes a change in the muscle chain and activated trigger points (Licht et al., 2009). During loading which happens over a longer period of time, the active and passive structures of the joints in the lower extremities are overloaded (Brokmeier, 2001). If the loading happens over a longer period of time, it is safe to assume that the knee joint will be overloaded, in dysfunction and start to hurt (Hohmann and Wörther, 2005).

Pain in the knee joint itself is caused by many primary reasons which can be localized in the knee joint itself or in a distant place (Niethard and Pfeil, 2003). The pain transferred from distant points can originate in the lumbar region, such as radicular syndrom caused by mechanical irritation of nerve roots, or pseudoradicular syndrom caused by joint or muscle dysfunctions (Homann and Wörther, 2005). The pain, of deep and diffuse character, can be referred from visceral organs, which are supplied by sympathetic nervous system from those spinal cord segments (Brokmeier, 2001) they simultaneously supply the lower extremity with the sympathetic nerves. It regards predominantly, for example, intestines and the organs of urinary and sexual systems (Butler and Moseley, 2007).

In the knee joint itself, a structural problem can be present which regards and bones (degenerations) and passive or active structures (Jerosch and Heisel, 2004). In order to determine the cause of the knee pain, the therapeut needs a lot of experience and even then, there could still be other reasons for the overstrain (Brokmeier, 2001). In our study we wanted to create a homogenous sample of runners in which the knee joint pain is caused exclusively by functional changes in locomotor apparatus, by the so-called cause and effect chains (Richter and Hebgen, 2006). That is why we created several exclusion criteria. We excluded people with serious problems with their knee joints, for example, probands with acute stabbing knee pain or those who have recently had operations and injuries. We excluded also the persons with problems of the organs in the small pelvis, having those symptoms which can indicate problems with the inner organs refering pain into the knee joint itself (Brokmeier, 2001).

We wanted to examine runners with knee overloading and pain during running or those who had problems if they had to cope with a lot of strain during a longer period of time (Hohmann and Wörther, 2005).The pain should get better after 5-10 minutes.

According to the gate control theory (Melzack and Wall, 1965), the pain will get less intense during movement. Amongst runners, more endorphins will be released into the body after approximately 20 minutes (Berg, 2007). If the pain does not get better after that time, we can assume that there is a serious problem with the knee joint itself, for example structural problems (Brokmeier, 2001) or an inflammation of the knee joint (Schomacher, 2001), or greater problems in the human body with refered pain into the knee (Brokmeier, Berg, 2002). We have competitive runners who run 10 km or half marathons on streets and who run at least 40 km a week. This means that we can assume that the problems in the knee are not serious enough to keep them from running, but enough to cause them pain (Homann and Wörther, 2005).

One possible interpretation of the pain during running is that pain during loading could be caused by a mechanical problem because the knee is overstrained (Niethard and Pfeil, 2003). Pain during loading over a long period of time could be a result of a cause and effect chain in the lower extremity (Richter and Hebgen, 2006). It is clear that other problems throughout the body could also cause problems with the knee joint (Jerosch and Heisel, 2005). The pain is then transferred to the knee joint, for example, like a referred pain by means of muscle chains (Licht et al., 2008).

Runners who experience problems during long distance running may have so-called pseudoradiculare pain, which can be caused by joint blocks or muscle dysfunctions (Brokmeier, 2001). For example, joint blocks of the lumbar spine or of the sacroiliacal joints can provoke pain in the knee joint (Thiel and Richter, 2009). Muscles that hurt during running are mostly overloaded because of the presence of activated trigger points (Simon and Travel, 2000). The activated trigger points result mostly from overloading or trauma (Simon and Travel, 2000). One theory exists that this is a result of local hypoxia in the muscle, which causes a so-called rigor complex. It means that the actin and myosin filaments are not able to relax. The muscle becomes hypertonic and causes a typical pattern of referred pain (Licht et al., 2008). Trigger points are often signs of so-called referred pain patterns. This means that the pain manifests itself in a different part of the body. For example, if there is an activated trigger point in the m. glutaeus minimus, the pain is referred to the lateral part of the thight reaching the knee joint. The trigger points are especially activated during sports (Richter and Hebgen, 2006).

According to their characteristics, the pain can be divided into two groups. The so-called somatic pain is transmitted by sensory A delta fibres (Berg, 2003). It character is sharp, the pain is located on the body surface and the patient is able to locate it exactly (Berg, 2007). It originates in the somatic area of the human body which contains skin, subcutis and organs of the locomotor apparatus (Pape and Silbernagel, 2008). On the basis of previous tests, we can draw the conclusion that most members of our sample experienced somatic pain (Zalpour, 2002). Pain during resting is mostly caused by so-called visceral pain (mediated by sensory C- fibres), which, for example, can occur during inflammation (Berg, 2003). It is felt like a slow, deep pain and it is difficult to localize it. Therefore, the probands are not able to locate the pain exactly. Visceral pain is a typical sign for illnesses of the inner organs (Berg, 2003). It is referred to the spinal column and soft tissues of the dorsum (Head hyperalgetic zones) and from the spine it goes on to the periphery which also includes the extremities. It is mediated by the sympathetic nervous system which accompanies arteries and influences blood perfusion in the skeletal muscles. The sympathetic nerve fibres from spinal cord segments from Th 10 up to L2 provide the lower extremities with what they need. During running the probands often experienced knee pain caused by loading (Homann and Wörther, 2005). The cartilage of the joints has no pain nerve fibres, so that we can assume that the pain originates in the cartilage capsule (perichondrium) or from refered pain (Berg, 2003).

It is also possible that the pain occurs because of changes of metabolism in the tissues which include the skeletal muscles, for example, after so-called overtraining. This overtraining may be caused by acidity which can result from anaerobic production of energy as a result of blood hypoperfusion. In this case the muscles have not enough oxygen for aerobic energy production (Zalpour, 2002). They use the anaerobic way for energy production. In this case the final product is lactate acid which irritates free nerve endings (that are) present in tissues (Hüter- Becker and Dölken, 2005). Normally, the arteries are enlarged after starting of muscle work, so that the working muscles get more oxygen and nutrients. Irritation of sympathetic motor nerves by spine blocks at the level between Th 10 and L2 will keep the arteries in the muscles of lower extremities from enlarging (Hüter- Becker and Dölken, 2005). This leads to an increase in the production of acides and to visceral pain development (Berg, 2007).

We asked the probands in our study to define the intensity of the pain they experienced on a scale from 0 to 100. Zero means no pain, 100 maximal pain. The pain threshold is subjective and differes interindividually from person to person (Butler and Moseley, 2007). We wanted to clarify how strong the pain was and if it is possible to relate it to the type of os coxae malposition (anterior or posterior).
The dysfunction of a joint has different signs; a joint dysfunction with changes of movement ranges, and the bad coordination of the surrounding skeletal muscles (Bizzini, 2000). The result is a cause and effect chain which is realised by a chain of hypertonic muscles which pass through the whole body (Richter and Hebgen, 2006). Changes of the position of the joints cause a functional and mechanical overloading of the active and passive structures that surround the joint. The pain experienced is one of the signs of a joint dysfunction. Pain can also be transferred to the joints of the lower extremities by other means than a cause and effect chain. For example, problems with the lumbar spine and illnesses of internal organs could cause problems in the lower extremities (Brokmeier, 2001), especially in the most sensitive joint of the lower extremities, the knee joint (Deleo, 2004). Therefore, we created disqualifying criteria in order to exclude those persons from our sample who suffered from referred pain. The presence of the pain shows overloading during running (Hohmann and Wörther, 2005). If the sacroiliacal joint is blocked and the pelvic bone is malpositioned, the whole functionality of the lower extremities is affected. The result is a so-called cause and effect chain (Richter and Hebgen, 2006). Especially if the runners has problems during running and also show several qualifying and disqualifying criteria, it prooves that there is an existing dysfunction of the knee joint. Problems with the lumbar spine, the hip joint and ankle, for example, a flat foot, could also provoke knee problems (Niethard and Pfeil, 2003). Pain in the joint itself during loading which happens over a longer period of time could be a sign for such problems. Concerning runners, up to 10% have problems with their knee joint during running (Niemuth, 2005). There are several causes of the knee pain. For our study it is not necessary to know exactly what are the causes of the knee pain. We only want to find out, what happens with the os coxae and the sacroiliac joint during running if the runner has knee problems. To get the results we needed, to ask the runners if they experienced pain in the knee joint with ordinal scaled, yes or no (Zöfel, 2003). In order to find out whether there is a different experience of pain of a os coxae malpositioned toward anterior and one toward posterior we asked the probands, only

out of interest, if they experienced the pain differently. We also asked them to descride intensity of the pain on a scale from 0 to 100. Hence, we were able to calculate the pain in comparison to an os coxae malposition, because we had an interval scaled value (Thomas and Nelson, 2001). We have to be careful as the pain is subjective, the individual's threshold is different (Butler and Mosesley, 2007). We are aware of this fact and for the study. We were still interested in a bilateral comparison as additional information.

3. Summary of literature overview

In this chapter we point out the main informations we introduced in previous chapters and which could serve like important backgrounds for targets and hypothesis for this study.

A dysfunction of the pelvis may be diagnosed according to two main signs, the position of the anterior and posterior superior iliac spines and a dysfunction of the sacroiliac joints (Thiel and Richter, 2009). Changes in the spine position can be measured with a scale. We can measure the vertical distance between them. A dysfunction of the sacroiliac joint may be diagnosed through different manual methods (Frisch, 2001). We prefer the leaning-forward test.

The two most important pathologies inside the pelvis are os coxae anterior and posterior (Meert, 2003). Each of them can be present only on one body side, the other side can be healthy, without a dysfunction (Vleeming and Snijders, 1990) or can suffer from the same or opposite dysfunction. As a result of a one-sided dysfunction, a cause-and-effect chain appears in the lower extremities (Deleo et al., 2004).

The long muscles which interconnect the pelvis and the knee joint, such as the m. biceps femoris (caput longum) and the m. rectus femoris have a direct influence on the knee joint (Hossain and Nokes, 2005). The m. iliopsoas and the m. piriformis influence the position of the os coxae on the same side (Auerbach and Heyde, 2005). If there is a blockade of the iliosacral joint or a malposition within the pelvic area, a so-called cause-and-effect-chain could arises in the lower extremities as a result of these pelvic pathologies (Richter and Hebgen, 2006). In this case, the knee joint is especially sensitive to these dysfunctions (Niemuth, 2005). A malposition of the iliac bone which has developed as a result of muscle hypertonus, joint blocks or shortening of fascial structures leads to dysfunctions in the musculoskeletal system and activates the myofascial trigger points (Licht et al., 2008). Anatomically shorter lower extremities cause a lateral tilt of the pelvis. This pelvis position could overstrains the knee joints, too.

A shorter leg gets compensated by genu varum through overstrain put on the medial meniscus and an stretching of the ligaments on the lateral joint side (Lanz and Wachsmuth, 2004), a longer leg gets compensated by genu valgus through overstrain put on the lateral meniscus and an stretching of the medial ligaments (Frisch, 2001). We aim to measure the anatomical length of the lower extremities, because if there is a big difference in a bilateral comparison we can draw conclusions about its influence on the position of the pelvis (Kayser et al., 2008).

The ranges of movement in the knee joints in direction to flexion and extension depend on the tonus and power of the muscles which move the knee joints (Lane et al., 1987). If any cause-and-effect chain is present in the lower extremities, the agonistic muscles causing the chain will be hypertonic, the antagonistic muscles will be stretched and hypotonic as a result of reciprocal inhibition (Simon and Travel, 2000). This results in a muscle dysbalance and bad muscle coordination which then cause the knee problem. Degenerative (structural) changes in a joint cause the reduction of the full range of a movement and negatively influence the cause-and-effect chains (Deleo et al., 2004). That is why we want to measure the full range of movements of the knee joints (Brosseau et al., 2001) and the hip joints (Auerbach and Heyde, 2005). There are two reasons for this measurement. First: (as an exclusion criterion) persons with structural changes in these two joints cannot be members of our experimental group. Second: we expect changes in the knee joint movement ranges (in comparison to the knee joint of the other side) when a cause-and- effect chain is present during long distance running (Niemuth, 2005).
The results of the literature overview show that there are some difficulties in the understanding of the interrelation of a pelvis malposition and knee complains of long

distance runners. We would like to fill this gap through a study of the relation between a pelvis dysfunction.

4. Purpose of the study

The aim of the study is to test whether there is a relationship between a one-sided malposition of the pelvis and knee dysfunction and if there is an influence of sportive activities because of the stress caused by a long duration of the activity. Therefore, we want to measure the position of the pelvis through the measurement of the vertical distance between the anterior superior iliac spines in order to diagnose a pelvis dysfunction, to examine sacro- iliac joints through the leaning-forward test and to state which side of the pelvis does not function normally. We want to examine the ranges of movement in the hip and the knee joints in order to exclude structural damage and to say if there is a relation between a pelvis malposition and a knee joint dysfunction. We want to measure the anatomical leg length, as big differences get compensated through a change in the knee joint position resulting in an overstrained joint. The persons get a paper in which they describe if they feel pain during running. We describe qualifying and disqualifying criteria to get a homogeneous group of probands and to prevent the affection of the results through unexpected factors like knee joint injuries, operations, degeneartions and illnesses of internal organs which could cause visceral pain in lower extremities and neurological affections in lumbar region. After selection of theses problems from our sample we can expect that all problems in the knee region during running should follow only functional problems between pelvis and the joints of lower extremities.

Scientific results which we receive through this study could help clinicians to improve the examination of patients and invent further treatment, especially in sports physiotherapy to prevent knee joint injuries.

5. Hypothesis

In our study we search for relations between a pelvis malposition and knee problem. This is a common problem which can affect any person regardless of gender, age, job or sport. Endurance running was selected for our work because of the multiple repetition of the same cyclic movement and the increased stress put on the lower extremities and their joints which include the knee joints. Than the forces caused by the lower extremities are high enough. By doing so we were able to work out that it is not possible to compensate this strin with other joints of the lower extremities.

The hypothesis was set up as a consequence of the literature research:

Pelvis malposition is related to the knee joint overloading

6. Methodology

A group of long endurance runners got examined with the help of manual and instrumental methods which measure distances in cm (Berg, 2007) and angles in degrees ° (Leighton, 1994). In the following chapters we will describe the study plan, the sample, the strategy of analysation, the anamnesis data, the methods of examination, the collection of data and the statistics.

6.1 Study plan

We want to test endurance runners which have a pelvis malposition and a knee dysfunction. The running is a specific movement of permanently repeating stereotype movements without the quick changing of the direction of the movement and without direct contact with other sportsmen (Hohmann and Wörther, 2005). During the running events between Stuttgart and Heilbronn, every participant gets a handout in addition to his starting documents. On this handout, there is a note that runners who have problems with their knees without any pain in the knee and who are interested can take part in the study and may in return participate in a raffle. Runners who are interested give the filled handout to me personally (in the final area), or they send it to the given post address of my therapy and rehabilitation centre. The first selection of the probands will be made depending on their age. Those persons receive a phone call concerning the date of their examination. The patients who show one or more of the disqualifying criteria will be excluded and cannot participate in the examination. The disqualifying criteria are described above in the following chapter. Subsequently, the selected probands come to the rehabilitation centre and fill out a document in which they give some information about their knee pain. Then they get examined manually and with simple instruments. These tests and measurements should show whether there is a block of the iliosacral joint and if the ossa coxae are in a malposition (Zeller et al., 2005). We will use 100 persons for the study, 50 with and 50 without knee problems . They get selected according to the disqualifying criteria. Both groups will get examined as described in the following chapters. Therefore, examination methods will be used. In addition, we will analyse the collected data statistically.

6.2 The sample

The participants of the examination are female and male persons. We plan to test 100 probands. They will be subdivided into two groups: one group (50 persons) with knee problems, second group (50 persons) without knee problems. We will compare the measurement results of both groups and they will be selected according to the same criteria.

Qualifying and disqualifying criteria for probands selection:

1) The age of the runners should not be higher than 50 years, as over 50, secondary influences like arthrosis, injuries, problems with inner organs are more frequent (Lane et al., 1987). Persons who are younger than 20 years are also excluded, as the growth of their bones has not yet been finished completely (Niethard and Pfeil, 2003).

2) We test persons who have been running a minimal average of 40 km per week during the last 6 months. Than the forces caused by the lower extremities are high enough for us to assume that it is not possible to compensate them with other joints of the lower extremities (Deleo et al., 2004) if there is a malposition of the pelvis (Hohmann and Wörther, 2005).

3) Runners with acute stabbing knee pain who have had a knee operation or who have had an accident where the knee was involved. Such knees are not qualified for the study because their structural dysfunction or problem (pain) can originate from other health problems and not from running (Niethard and Pfeil, 2003).

4) If the difference of the whole range of movement is greater than 15% in the hip and in the knee joint if we compare the left and the right side, the test person cannot participate either. If there is an even greater difference we can assume that there is a structural (damage) problem (Shellock and Mink, 1999).

5) Runners who have huge problems with the internal organs of the small pelvis cannot participate as we can assume that these illnesses will have an effect on the position to the os coxae (Meert, 2003).

6) Probands with a dysplasia of the hip joint will not be tested because the kinesiology and function of movements will differ on both body sides (Bachmann et al., 1999).

7) People with a neurological affection in the lumbosacral area will not be tested because the control they have over their body and especially over their muscles is different (Berg, 2007).

6.3 Strategy of analysis

The 100 probands (50 with, 50 without knee problem) will be measured in the lower extremities and will be asked for general data, running strain and pain (feeling and localization) while running. The relevant data will be measured again 4 weeks later. This retest will show if anything changed. In the statistic evaluation we describe the results and introduce tables and graphics there (diagrams, boxplotts).
The normal deviation of the date will be checked with the Kolomogorov- Smirnov-test, to see if the groups are normally deviated. The F- test (Levene- test) is used to check the homogenity of variance (Thomas and Nelson, 2001

6.4 Anamnesis data

In this chapter the anamnesis data are described. We asked members of our sample for the gender, age, body high and body weight and for intensity of running load (how many km they run weekly). The results are shown and described in the following chapter. Totally 100 persons took part in our study. They were subdivided into 2 groups, into the proband group with knee problem and into the control group without knee problem. Each group contained 50 persons.

Distribution of men and women

In the following Figure 17 the deviation of male and female probands is described

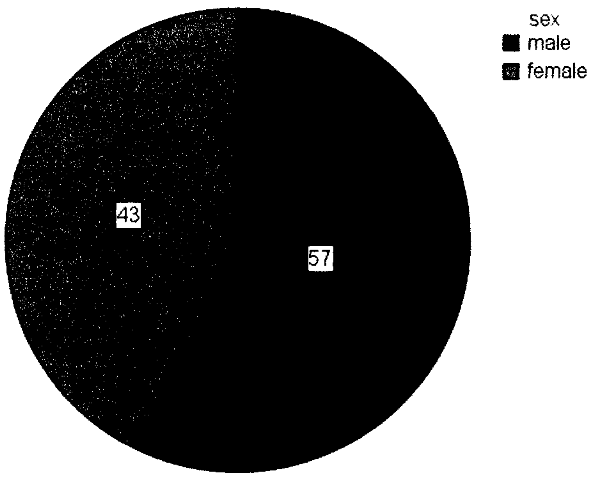

Figure 17: Distribution of men and women in our sample, 57 men and 43 women

Persons of both sexes were present in our sample of 100 persons, 57 men and 43 women (Figure 17), the average age was 34 +/- 10 years, ranging from 20 - 50 years.

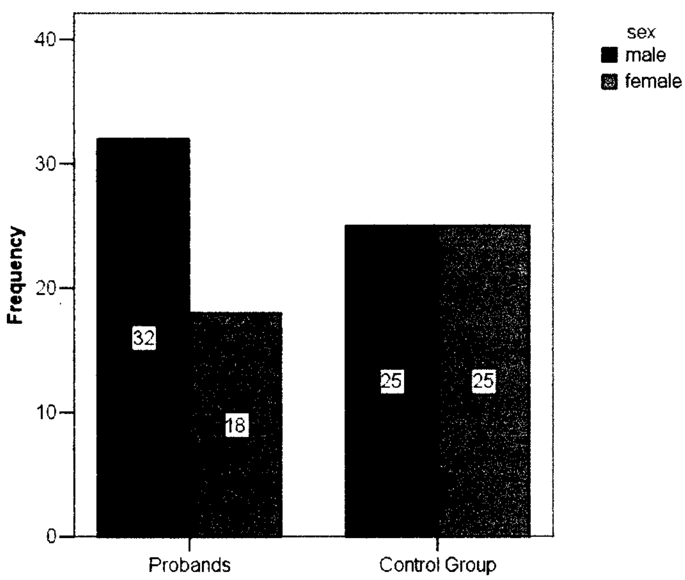

Figure 18: Distribution of men and women in the proband group (32 men, 18 women) and in the control group (25 men and 25 women)

In the proband group there were 32 men and 18 women, in the control group there were 25 men and 25 women (Figure 18).

Age distribution in proband and control group

The average age was different in the two groups (Figure 19). In the proband group, the persons were between 21 and 50 years old, in average 39 +/- 8 years. In the control group the persons were between 20 and 50 years, in average 29 +/- 8 years old.

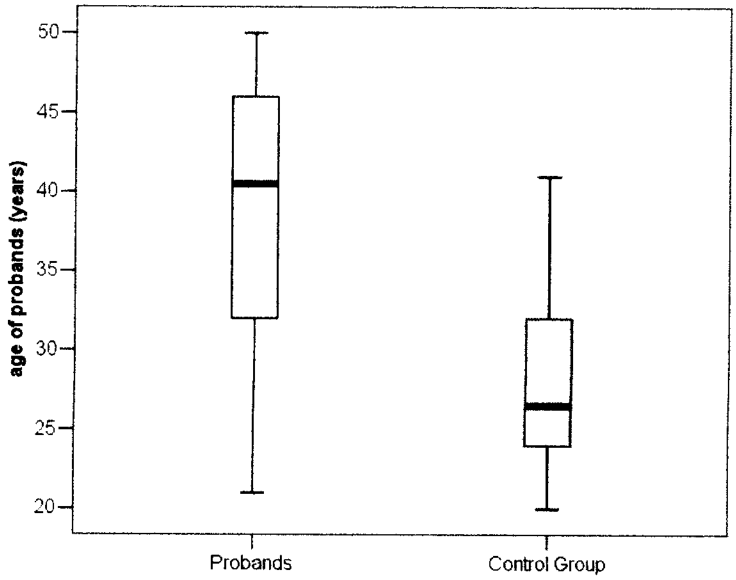

Figure 19: Distribution of age in the proband group (39 +/- 8 years old) and in the control group (29 +/- 8 years old)

As a conclusion we can say that the mean age of the proband group was approximately 10 years higher than the mean age in the control group.

Body height distribution in proband and control group

The body height (Figure 20) in the proband group ranged from 163 to 189 cm, in average 176 +/- 7 cm. The body height in the control group ranged from 156 to 191cm, in average 174 +/- 8 cm.

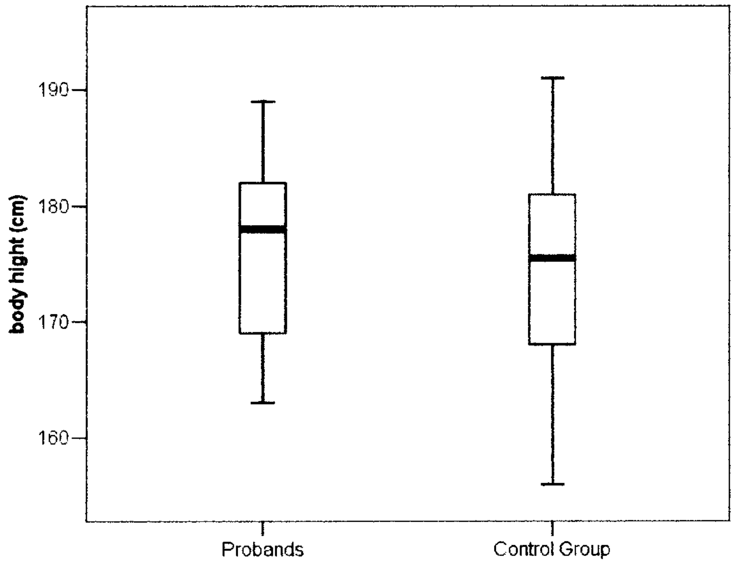

Figure 20: Distribution of body height in the proband group (176 +/- 7 cm) and the control group (174 +/- 8 cm)

In conclusion we can say that the mean body high was nearly the same in both groups. The difference was only 2 cm.

Body weight distribution in proband and control group

The body weight (Figure 21) in the proband group ranged from 49 kg to 81 kg, in average 68 +/- 8 kg. The body weight in the control group ranged from 44 to 79 kg, in average 65 +/- 8 kg. The body weight in the proband group was approximately 3 kg higher than in the control group.

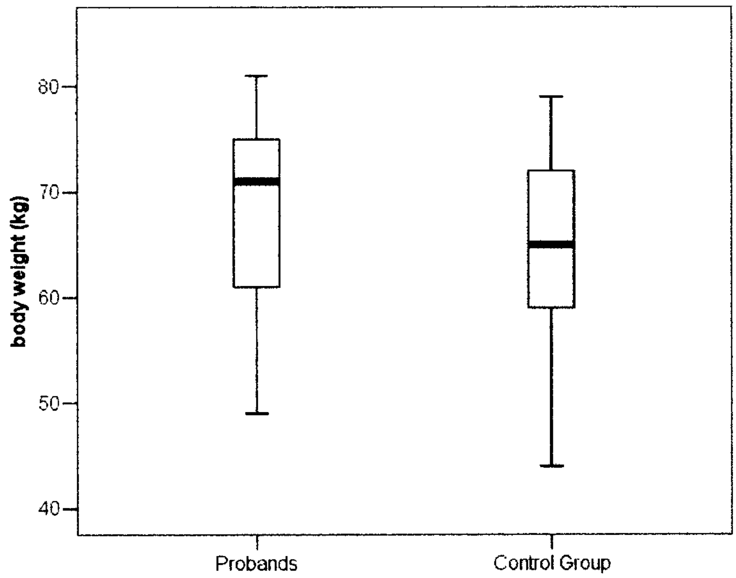

Figure 21: Distribution of body weight in the proband group (68 +/- 8 kg) and the control group (65 +/- 8 kg)

We can conclude that body weight in the proband group was approximately 3 kg higher than in the control group.

Strain during running in proband and control group

One of the qualifying criteria for the sample was running at least 40 km weekly. Our athletes ran between 40 and 90 km per week during the last 6 months, the average value came to 55.8 +/- 11.5 km. The distribution is shown in the following diagram (Figure 22).

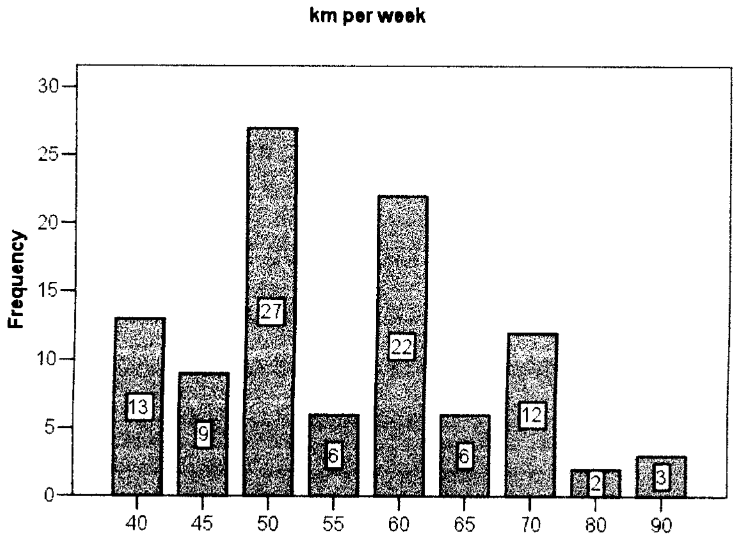

Figure 22: Distribution of running distances per week in both groups (55.8 +/- 11.5 km)

Figure 22 shows the distribution of the running distances in our sample (both groups together). It is shows that 27 people ran 50 km weekly, 22 persons ran 60 km, 13 persons ran 40 km and 12 persons 70 km per week.

Now we can see how many km per week the proband group (Figure 23) and the control group (Figure 24) ran.

The 50 persons of the proband group (Figure 23) ran between 40 and 90 km weekly, in average 55.8 +/- 11.5 km. 15 people ran 50 km and 13 people ran 60 km per week. 9 athletes ran over 60 km. 10 probands ran less than 50 km.

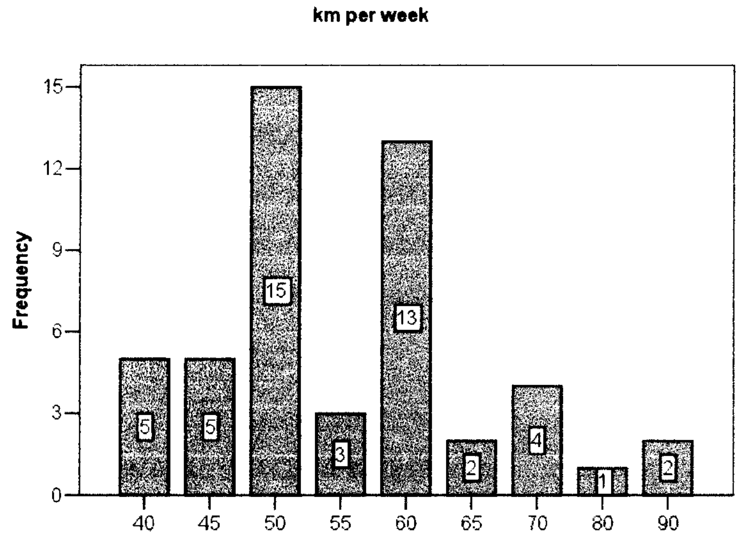

Figure 23: Distribution of running distance per week in the proband group (55.8 +/- 11.5 km)

The 50 persons of the control group ran between 40 and 90 km weekly, in average 55.9 +/- 11.7 km during last 6 months. 47 persons ran between 40 and 70 km weekly, 2 persons ran more than 75 km per week (Figure 24).

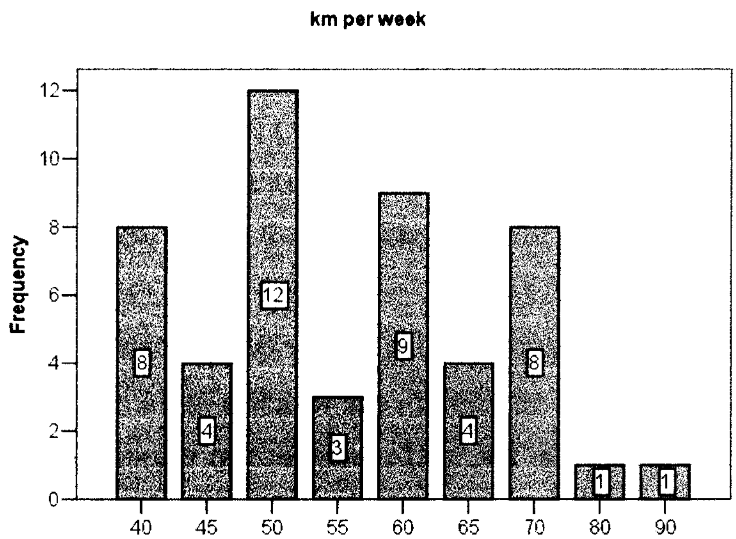

Figure 24: Distribution of running distance per week in the control group (55.9 +/- 11.2 km)

Finally, we can say that both groups ran nearly the same distance per week. We can only see, that the distribution in the control group is more steady than in the proband group.

6.5 The methods of examination

In this chapter we describe the methods of examination and the measuring instruments. For my examinations I use instruments which are obviously used in clinical practice and which are used to measure the distances and the angle grades. The literature data (Brosseau et al., 2001; Kool and Bie, 2001; Berg, 2001) and logical validity attest the validity of the instruments used for the measurement of distances and angles.

Parameters for measurement

a. Testing of sacroiliac joint function. I use the lean- forward test while sitting as it has been described by Frisch (2001). In the starting position the patient is sitting upright on the treatment couch without any contact of the proband´s feet with the ground. The therapist's thumbs palpate the skin depressions in the area of the spina iliaca posterior superior while the patient moves his upper part of the torso forwards and downwards. It has to be tested which side of the spina iliaca posterior superior moves earlier towards cranial ventral, which which means that an ongoing movement that starts too early is initiated. This is an accepted qualitative test, to see if there is a difference between movement of the iliosacral joint on both body sides. If the test is positive there is a blocked iliosacral joint (Brokmeier, 2001). Joint blockage is present on that side where the spine movement starts earlier.

b. The anatomic leg length is to be measured. The patient lays in back position. The most prominent point of the trochanter major is measured in relation to the foot sole (lateral margin of the heel). The unit is measured with the help of a tape measure. The units of measurement are centimetres (cm). The measurement takes place in bilateral comparison. We need the data in order to find out if there is an anatomical length difference, as a difference of over 1.5 cm in bilateral comparison influences the position of the pelvis (Kayser et al., 2008).

c. The position of the two anterior superior iliac spines in relation to one another within the frontal section is to be measured. It is also called one sided pelvic or os coxae malposition, these 3 definitions mean the same. The proband lays in back position. The two spines are being marked with a pen. The distance from the right to the left spina iliaca anterior superior in direction towards cranio- caudal of the frontal section is being measured. The units of measurement are centimetres (cm). The instrument used for the measurement is a pelvimeter with tape measure inside. It was built by professionals for our study. We have tested the validity of the measurement in the biomechanic institute in Tübingen, which is described in chapter 6.5 and 12.5 (Thomas and Nelson, 2001).

d. The movement amplitude of the knee joints in relation to the active flexion and extension is being measured. The proband lays in back position. The goniometer is placed with its axis in the middle of the knee seen from the lateral side. One arm of the goniometer is situated as a lengthening towards the middle of the malleolus lateralis, the other towards the trochanter major. They have already been marked before. The patient is asked to bend his leg in the knee joint as far as possible. After that he lies down his leg on the mat and is now asked to move the knee into extension. This is to be measured in angle grades (Brosseau et al., 2007). If there is a difference greater than 15% in comparison to the other side, we can assume that there is a structure problem in the knee joint (Hohmann et al., 2004).

e. The movement amplitude of the hip joints in relation to the active rotation is being measured. The probands lies in stomach position. The knee joint is 90° flexed. The axis of the goniometer is placed in the middle between the patella apex and the tuberositas tibiae. One arm of the goniometer is vertical, the second one lies on the middle of the lower leg. The proband is being asked to move his leg in the hip joint actively in the endorotation and after that in the exorotation. The end of the movement is reached if the os coxae of the same side start to move as well (Meert, 2003). The angle between these two lines is being measured. The unit of measurement are angle grades (°). The measurement compares the two sides. The measurement of the movement is supposed to exclude that there are any structural damages. If there is a structural damage the amplitude of the movement gets smaller. If there is a difference of more than 15% in comparison to the other side, we can assume there is a structure problem in the hip joint (Brokmeier, 2001).

f. The probands will be asked to describe the subjective intensity of their knee pain during running and to put it into a scale between 0 and 100 mm. 0 means the probands have no pain, 100 means the probands have so much pain that they would not be able to run. The persons make a point in the protocol scale.

Table 1: Overview of parameters measured in our work

No	Parameter	Target of test
a.	Leaning- forward test	Sacroiliacal dysfunction
b.	Anatomic leg length	Exclusion of anatomic differences
c.	Position of the two SIAS towards one another in the frontal section	Find out about one- sided os coxae malposition
d.	Movement amplitude of the knee joints (flexion/ extension)	Exclusion of structural damages
e.	Movement amplitude of the hip joints (endo/ exorotation)	Exclusion of structural damages
f.	Pain scale	Intensity of pain

(The protocols are in the supplement.)

6.6 Collecting the data

We prepared some protocols and tables for each test person. In which we fill in the results of the measurements, which means all the measured distances and angles. During the measurement of the distances (unit are cm) the athletes' anatomical leg length and the cranio- caudal distance of the spinae iliacae anteriores superiores get measured. The athletes' range of movement (units in angle degrees) from maximal knee flexion to maximal extension and the endrorotation and exorotations of the hip joint get tested. The documentation will provide information about the subjective feeling of the knee pain (pain scale). The following table shows the results of the collected data regarding the measurement parameters introduced beforehand. We received the figures in the table from the measurements of individual persons who are introduced in the appendix 12.7.

6.7 Statistics

We use descriptive and interference statistics to show and describe correlations and differences. With the help of dependent and independent t- tests (middle value, t-value, df) we are able to decide if mean differences between two groups are statistically significant or not. The Pearson correlation coefficient will be calculated to quantify the correlation between two variables. These results will be described (t- test and correlations). In addition we will show the result of a t- test with a 95% interval of confidence (Cuming and Finch, 2005).

The measurement method has to be valid and reliable (Thomas and Nelson, 2001). The validity of our measurements has been proven – see literature data (Brosseau et al., 2001; Kool and Bie, 2001). The validity and the coefficient of reliability was provided for devices we used for the measurement (chapter 12.3 to 12.6).

The validity and reliability of the pelvimeter got tested. We had to do this because the device is not used in every day clinical practice. To show the validity of the pelvimeter method, we compared it with the optic system, simi motion 3- D. We carried out this test in the biomechanical institute in the department of biomechanic in the Rubrecht Charles University, Tübingen with Prof. Dr. V. Wank. We made a test with 5 persons with the pelvimeter and the same test was carried out with the optic measurement system by Prof. Dr. Wank (criteria and concurrent validity). Then we calculated a reliability coefficient r, which is shown in the following table (the values are shown in the appendix, chapter 12.5).

Table 2: Correlation coefficient of pelvimeter. Our tests compared to the optic mess system simi motion 3 D shows a high- level (0.987, p = 0.02)

Correlations

		optic	pelvimeter
optic	Pearson Correlation	1	,987**
	Sig. (2-tailed)		,002
	N	5	5
pelvimeter	Pearson Correlation	,987**	1
	Sig. (2-tailed)	,002	
	N	5	5

**. Correlation is significant at the 0.01 level (2-tailed).

The result shows a high level of correlation so that we can accept the pelvimeter for measurement of SIAS vertical distances.

We have proven the pelvimetertest, goinmetertest and tape measure are proved with the test- retest method (Thomas and Nelson, 2001). The results are shown in a table in the chapter 12.4 The correlation coefficients show a significant level between p< 0. 01 and p< 0. 05. So we can accept it for our work.

We have proven the objectivity, it's also called intertester reliability. This means how independent is our test from the individual tester. Different therapists measured the same joint in the same person with the same method on the same therapy table at the same day. It was measured by 3 persons, by myself (therapist 1) and by two other therapists (therapist 2 and 3) with a long- time experiences of making measurements with these instruments. 10 persons were measured in the test- retest with a goniometer for measuring the angles in degrees by knee flexion/ extension (Brosseau et al., 2001). We also measured also the anatomical leg length (cm) with a tape measure (Zöfel, 2003). With the pelvimeter we measured the distances of the two spinae iliacae anteriores superiors (SIAS) in bilateral comparison (cm scale). The results are shown in a table in the chapter 12.3. The correlations coefficients show a significant level between p< 0. 01 and p< 0. 05. So we can accept it for our work.

7. Results

In this chapter the results of the manual examination and the instrumental measurements are shown. In the following tables the data was processed according to descriptive statistics and the important data was calculated with the t- test and correlation.

The following 2 tables (Table 3 and 4) shows the summary of the collecting data.

a. The leaning- forward test shows which side is positive in regard to a forward- turned bending of the torso. This side has a dysfunction within the sacroiliac joint (L= left side, R= right side).

b. Anatomic leg length (cm), the side which is anatomically longer is put on the record (the side which is longer is described).

c. Distance- measurement of the SIAS reveals (cm). It gets disclosed which side stands toward cranial or rather caudal (La= left anterior, Lp= left posterior, Ra= right anterior and Rp= right posterior).

d. Range of movement of the knee joint in flexion (°).

e. Range of movement of the knee joint in extension (°).
The values of knee joint flexion and extension denote which side shows which difference (the side which have more range of movement in bilateral comparison is described).

f. Range of movement of the hip joint in endorotation (°).

g. Range of movement of hip joint in exorotation (°).
The values denote which side shows which difference (the side which have more range of movement in bilateral comparison is described).

h. Intensity of subjective knee pain. The probands were asked to make a point on the pain scale which ranges from 0 (no pain) and 100 (so much pain that is not able to run).

This data are described in the following tables (Table 3 and Table 4). The data about intensity of pain (h) are only described in table 3 because in Table 4 are shown the control group, which have no problem.

In the following tables the points which are listed in the examination protocol are shown:

Table 3: Measured data in the proband group

Name	a. side of sacro-iliacal dysfunction	b. difference anatomic leg length bilateral comparison	c. SIAS malposition bilateral comparison	d. Difference knee flexion bilateral comparison	e. Difference knee extension bilateral comparison	f. Difference hip endorotation bilateral comparison	g. Difference hip exorotation bilateral comparison	h. subjective pain scale knee
T.B.	L	0,3 L	La 0,4	1° R	2° L	3° L	2° R	67
K.K.	L	0,4 L	La 0,6	1° R	0	5° R	3° L	42
I.R.	L	0,1 R	Lp 0,5	4° L	3° L	6°L	4° L	74
S.K.	R	0,4 L	Ra 0,4	9° L	4° L	3°R	1°L	40
U.H.	R	0,3 L	Ra 0,4	2° L	1° R	4° R	3° L	43
R.B.	R	0,5 L	Ra 0,4	5° R	2° L	3° L	3° R	47
G.J.	R	1,3 R	Ra 0,9	5° R	3° R	1° R	1° L	75
D.H.	R	0,2 L	Rp 0,3	5° R	0	3	0°	69
S.Z.	L	0,2 R	Lp 0,5	0	1° L	3° R	3° L	64
R.W.	L	0,1 L	Lp 0,8	4° R	7° R	1° L	3° L	77
G.S.	L	1,2 L	Lp 0,9	2° R	0	1° L	2° R	83
E.A.	R	0,3 R	Rp 0,4	6° L	2° L	2° R	4° R	43
M.T.	R	0,3 R	Ra 0,5	1° L	2° L	1° L	1° R	47
J.M.	R	0,5 L	Ra 1,1	1° L	1° R	2° L	1° L	48
R.H.	R	0,5 R	Rp 0,6	2° R	2° L	4°L	1° R	64
A.S.	R	0,2 L	Ra 1,4	1° R	3° L	2° R	1° R	65
P.M.	R	0,6 L	Ra 0,4	5° L	2° R	1° R	1° R	46
Z.K.	R	0,3L	Ra 0,5	1° L	1° L	0° R	1°R	46
R.K.	R	1,3 L	Ra 0,8	3° R	2°L	0° L	3°R	57
G.K.	L	0,8 R	Lp 0,5	4° L	1°R	2°R	0° L	65
E.B.	R	0,2 R	Rp 0,4	2° L	2° L	1° R	2° L	63
M.B.	R	1,1 R	Ra 1,1	3° R	4° L	3° L	2° R	57
F.L.	L	0,5 R	Lp 0,9	3° R	4° L	4° R	1° R	67
S.M.	L	1,1 R	Lp 0,9	5° R	0	5° L	3° R	79
B.W	L	0,5 R	La 1,6	3° R	2° L	3° R	3° R	43
H.W.	L	0,4 R	Lp 0,4	2° R	0	2° R	3° L	79
B.S.	L	0,5 L	Lp 0,2	3° R	2° L	2° R	3° L	68
P.R.	R	0,3 R	Ra 1,5	4° L	3° L	7° R	4° L	65
F.T.	L	0,4L	Lp 1,3	4°R	2°R	3°R	3°R	71
S.M.	R	0,6L	Ra 1,6	3°L	4°L	4°L	6°R	61
H.R.	L	0,8R	Lp 0,9	6°R	4°L	6°R	2°L	72
S.M.	L	0,1R	Lp 1,8	2°L	3°R	2°L	2°L	79
B.M.	L	0,5R	Lp 1,5	3°L	3°R	5°R	2°L	87
J.E.	R	0,2R	Ra 1,1	2°L	3°R	4°R	3°R	58
R.S.	L	0,5R	La 0,9	2°L	3°L	6°L	3°R	53
D.G.	L	0,3L	La 1,5	2°R	2°L	4°R	3°L	63
G.N.	R	0,4R	Rp 1,0	1°L	3°L	3°L	1°R	77
A.B.	R	0,3L	Rp 0,9	1°R	2°L	3°L	3°L	72
L.G.	L	0,2R	La 1,2	4°R	3°R	3°L	2°L	56
S.S.	L	0,1L	Lp 1,1	4°R	3°L	2°R	3°L	73
D.G.	R	0,4L	Ra 0,8	5°R	3°R	5°R	3°L	38
G.S.	R	0,8R	Ra 0,8	4°L	3°R	5°L	4°R	46
R.B.	L	0,4L	Lp 0,8	2°L	3°R	1°R	1°L	75
T.Z.	L	0,7L	Lp 1,5	1°R	4°L	2°L	3°R	82
A.S.	L	0,5L	Lp 0,4	5°R	4°L	3°L	2°L	67
H.H.	L	0,7R	Lp 0,8	2°L	2°R	2°R	2°L	74
B.B.	R	0,4R	Ra 0,8	10°R	5°L	5°R	3°L	49
K.M.	R	0,7R	Rp 1,3	3°R	2°L	2°L	4°R	75
C.T.	L	0,5R	Lp 0,8	2°R	1°L	3°L	2°R	74
U.B.	R	0,7R	Ra 0,9	4°R	2°L	5°L	4°R	63

Table 4: Measured data in the control group

Name	a. side of sacro-iliacal dysfunction	b. difference anatomic leg length bilateral comparison	c. SIAS malposition bilateral comparison	d. Difference knee flexion bilateral comparison	e. Difference knee extension bilateral comparison	f. Endo Difference hip endorotation bilateral comparison	g. Difference hip exorotation bilateral comparison
B.R.	0	0,5R	(Ra) 0,2	1°R	0°	2°L	2°R
R.L.	0	0,3R	(Ra) 0,1	2°R	2°L	2°R	2°L
F.H.	0	1,0L	(Ra) 0,2	2°R	0°	1°L	2°R
H.H.	0	0,4L	(Lp) 0,4	4°R	2°L	3°R	2°R
D.S.	0	0,3R	(Ra) 0,2	4°R	5°L	5°L	1°R
C.B.	0	0,3R	0	5°R	0°L	2°R	1°L
D.H.	0	0,5R	(Ra) 0,2	3°L	0°	2°L	7°L
R.B.	0	0,2L	(Rp) 0,5	4°L	5°L	3°R	5°L
O.B.	0	0,1L	(Ra) 0,4	3°L	1°R	3°L	1°R
S.L.	0	0,2L	(La) 0,3	4°R	3°L	5°R	2°L
J.R.	0	0,3L	(Ra) 0,4	2°L	3°R	3°R	1°R
T.M.	0	0,3R	(Ra) 0,4	4°L	3°R	5°L	0°
L.D.	0	0,4R	(Ra) 0,2	1°L	2°R	3°R	2°L
S.S.	0	0,6L	(Rp) 0,4	3°L	4°R	3°R	3°L
A.T.	0	0,3R	(Ra) 0,1	3°L	2°L	3°L	2°R
C.S.	0	0,6L	(Ra) 0,2	2°R	2°L	3°R	1°R
M.Z.	L	0,5L	(Lp) 0,5	3°L	1°L	3°R	2°R
E.B.	0	0,4L	(Ra) 0,2	4°R	1°L	3°R	3°L
F.B.	0	0,3L	(Ra) 0,3	2°R	1°R	3°R	2°L
L.H.	0	0,3R	(Ra) 0,1	4°R	4°L	1°L	2°R
M.T.	0	0,7R	(Ra) 0,4	3°L	1°R	5°R	6°L
M.P.	0	1,1L	0	1°R	1°L	3°L	1°R
T.Z.	0	0,1L	Ra 0,1	2°L	1°L	2°L	3°R
D.H.	0	0,4L	(Rp) 0,5	5°R	3°R	2°R	0°
J.D.	0	1,3L	(Rp) 0,2	4°L	3°L	2°R	4°L
K.W.	0	0,4R	(Ra) 0,3	2°R	3°R	3°R	3°R
M.K.	0	0,3L	(Ra) 0,2	1°L	1°R	1°L	0°
M.H.	R	0,3L	(Rp) 0,5	1°R	3°L	3°L	6°R
N.W.	0	0,3R	(Rp) 0,2	1°R	2°L	6°R	5°L
C.F.	0	0,3R	(Ra) 0,5	3°L	3°R	1°L	2°R
P.R.	0	0,5R	(La) 0,3	5°R	5°L	1°L	1°R
T.D.	0	0,5R	(Ra) 0,3	2°L	2°R	5°R	5°L
B.M.	0	0,4L	(Lp) 0,3	2°R	2°L	3°R	2°R
K.S.	0	0,7L	(Ra) 0,4	2°L	2°L	3°R	2°L
St.S	0	0,4R	(La) 0,3	3°L	0°	3°L	5°R
L.M.	0	0,4R	(Ra) 0,3	3°R	5°L	3°L	5°R
D.K.	0	0,4L	(Ra) 0,3	2°R	3°L	3°R	2°L
M.M.	L	0,6R	(Lp) 0,2	5°R	2°L	7°R	3°L
C.S.	0	0,4R	(Ra) 0,3	4°L	2°R	3°L	4°L
F.M.	0	0,2L	(Ra) 0,2	3°R	2°L	5°L	3°R
E.A.	0	0,4L	(Ra) 0,3	1°L	2°R	3°L	1°R
W.K.	R	1,1L	(La) 0,5	0°	5°R	0°	5°L
B.U.	0	0,4L	(Rp) 0,4	4°R	1°L	4°R	3°L
I.K.	0	0,9R	(Lp) 0,6	5°R	3°L	2°R	2°L
K.W.	0	0,4L	(Rp) 0,4	1°R	4°L	2°L	1°R
D.S.	L	0,6L	(La) 0,4	2°L	2°R	1°R	3°R
S.Z.	0	0,5L	(Ra) 0,2	5°L	3°L	3°R	2°L
J.S.	0	0,8L	(La) 0,4	2°R	3°R	2°R	1°L
H.F.	0	0,9R	(Ra) 0,2	2°L	1°R	3°R	2°L
A.M.	0	0,6L	(La) 0,4	4°L	2°R	3°L	2°R

7.1 Results of manual examination and measurements

First, we tested the function of iliosacral joints using the leaning forward test. Then we describe the results of the anatomic leg length measurements and the measurements of the range of movement of a knee joint flexion and extension and a hip joint endorotation and exorotation.

7.1.1 Leaning forward test

The leaning forward test is a qualitative test which was used to show if there is a ilio-sacral dysfunction in one of the body sides. The presence of the dysfunction is necessary in order to diagnose a pelvis malposition and consequently for the evaluation of our hypothesis.

In the proband group all 50 persons had an iliosacral joint dysfunction. This means that all runners in the proband group showed a positive result. 24 sacro-iliac dysfunctions were localised on the left side, 26 on the right side. In the control group only 5 persons had a sacro-iliac dysfunction. 3 of them had dysfunctions on the left side, 2 of them on the right side.

In conclusion we can say that a positive leaning forward test was much more common in the proband group with knee problem (50) than in the control group (5).

7.1.2 Anatomic leg length measurement

A difference in leg lengths could influence the result of our work. It changes the position of the pelvis and the shorter leg is more loaded.

The anatomical leg length on the right side in the **proband group** (Figure 25) amounts to 80.2 to 98.2 cm, in average 89.2 +/- 3.9 cm. There were 29 persons with a longer leg. The leg was 0.1 cm to 1.3 cm longer, in average of 0.5 +/- 0.2 cm. On the left side the anatomic leg length amounts to 79.8 cm to 98.0 cm, in average 89.1 +/- 3.9 cm. There were 21 persons with a longer leg. The leg was 0.1 cm to 1.3 cm longer, in average 0.5 +/- 0.3 cm.

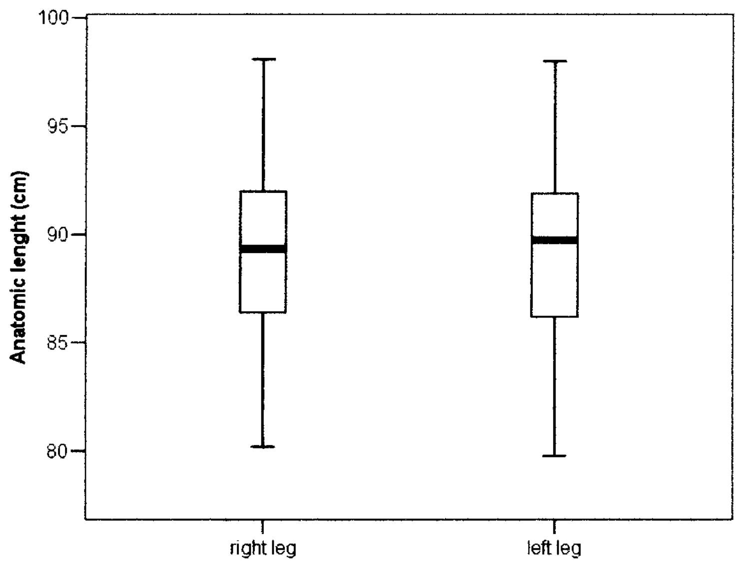

Figure 25: Anatomic leg length in bilateral comparison in the proband group amounted to 89 +/- 4 cm on both sides

The anatomic leg length in the **control group** (Figure 26) on the right side amounts to 74.4 cm and 98.3 cm, in average 88.3 +/- 5.0 cm. There were 22 persons with a longer leg, it was 0.2 cm to 1.1 cm longer, in average of 0.4 +/- 0.2 cm. On the left side the anatomic leg length amounts to 74.9 cm and 98.0 cm, in average 88.4 +/- 5.0 cm. There were 28 persons with a longer leg, it was from 0.1 cm to 1.3 cm longer, with a average of 0.5 +/- 0.3 cm.

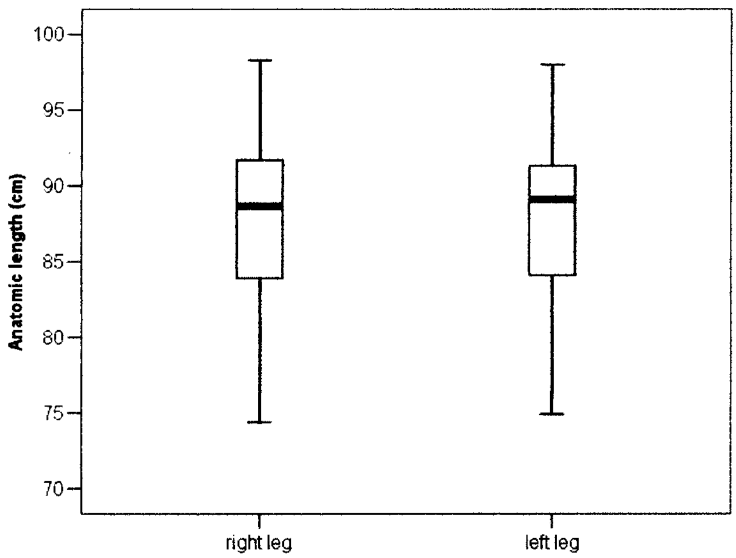

Figure 26: Anatomic leg length in bilateral comparison in control group amounted to 88 +/- 5 cm on both sides

In conclusion we can say that the mean leg length in both groups is nearly the same. There is no person with a big difference (over 1.5 cm) in the anatomical leg length in bilateral comparison.

7.1.3 Knee joint movement ranges towards flexion and extension

In our study the active range of movement of the knee joint towards flexion and extension was tested in the proband and control groups on both body sides. The reason for this examination is that we want to diagnose a structural problem in the knee joints which belongs to the exclusion criteria.

In regard to the **proband group** (Figure 27 and 28), the flexion on the right knee side amounted to 128- 145°, in average 138 +/- 4°. There were 28 persons with a higher range of movement of 1- 7°, in average 3 +/- 1°. The extension on the right side was between 0° and 9°, in average 6 +/- 2°. There were 24 persons with a higher range of movement of 1- 7°, in average 2 +/- 1°.
The flexion on the left side amounted to126° and 148°, in average 137 +/- 4°. There were 22 persons with a higher range of movement of 1°- 9°, in average 3 +/- 1°. The extension on the left side amounted to 0° and 11°, in average 6 +/- 3°. There were 26 persons with a higher range of movement of 1- 8°, in average 3 +/- 1°.

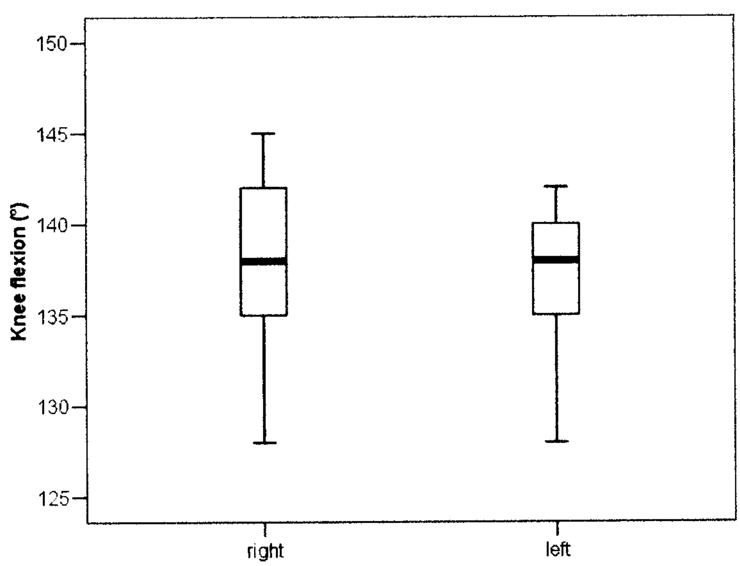

Figure 27: Range of movement in knee joint flexion in proband group amounted to 138 +/- 4 ° on the right and 137 +/- 4° on the left side

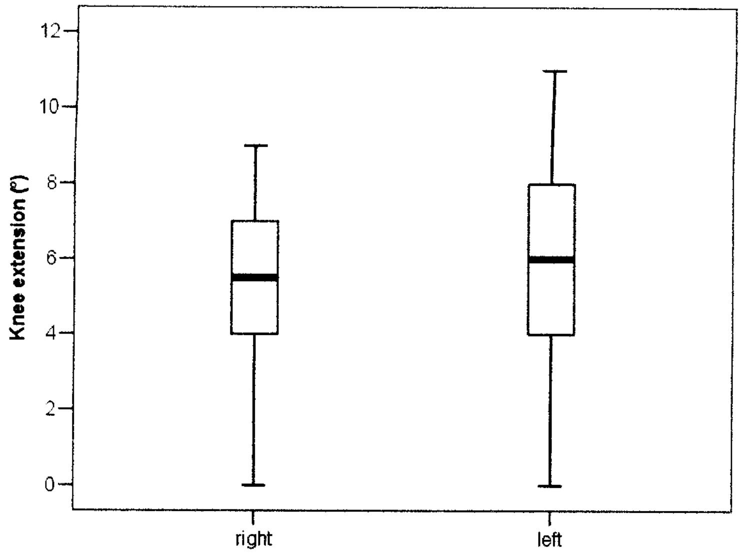

Figure 28: Range of movement in knee joint extension in proband group amounted to 6 +/- 2° on the right side and 6 +/- 3° on the left side

In the **control group** (Figure 29 and 30) the flexion on the right knee side amounted to 130- 148°, in average 140 +/- 4°. There were 24 persons with a higher range of movement of 1- 5°, in average 3 +/- 1°. The extension on the right side amounted to 0° and 11°, in average 7 +/- 3°. There were 24 persons with a higher range of movement of 1°- 6°, in average 2 +/- 1°. The flexion on the left side amounted to 130° and 150°, in average 140 +/- 5°. There were 26 persons with a higher range of movement of 1- 5°, in average 3 +/- 1°. The extension on the left side amounted to 2° and 14°, in average 7 +/- 2°. There were 26 persons with a higher range of movement of 1- 5°, in average 2 +/- 1°.

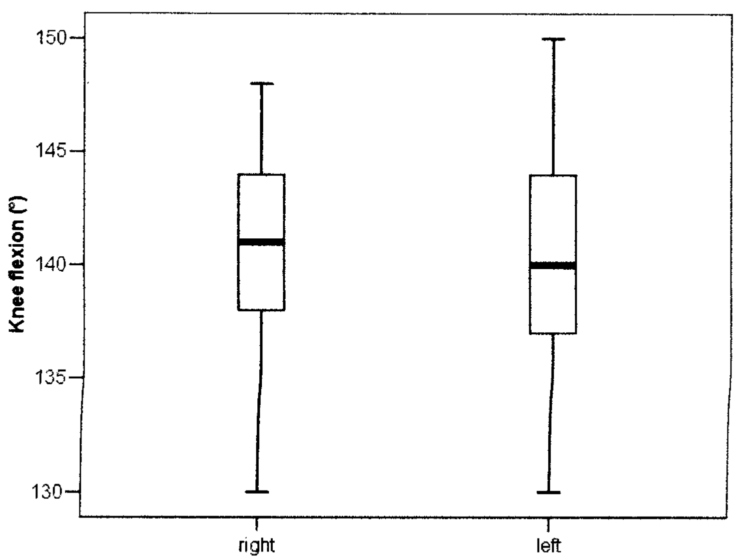

Figure 29: Range of movement in knee joint flexion in control group amounted to 140 +/- 4° on the right side and 140 +/- 5° on the left side

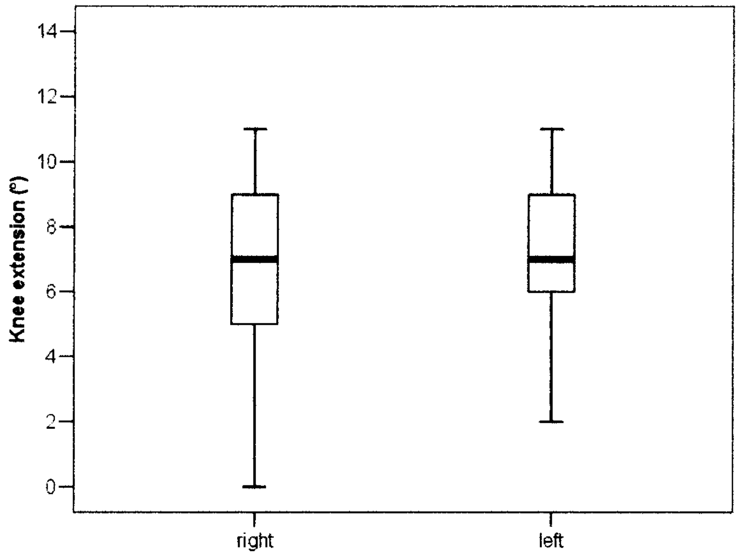

Figure 30: Range of movement in the knee joint extension in control group amounted to 7 +/- 3° on the right side and 7 +/- 4° on the left side

We can conclude that no person in the both groups we measured showed greater difference in the full range of movement of both knees than 15 %. It means that no person was excluded from the measurements.

7.1.4 Hip joint movement ranges towards endorotation and exorotation

In the study the range of movement of the hips towards endorotation and exorotation was tested in the proband and in the control group. As in regard to the knee joints, the reason for this examination is the fact that we want to diagnose structural problems in the hip joints which is one of the exclusion criteria.

By the **proband group** (Figure 31 and 32) the endorotation of the hip joint on the right side amounted to 32° and 49°, in average 40 +/- 5°. There were 29 persons with a higher range of movement of 1- 7°, in average 3 +/- 1°.The exorotation on the right side amounted to 30° and 48°, in average 37 +/- 3°. There were 23 persons with a higher range of movement of 1- 4°, in average 2 +/- 1°.The endorotation on the left side amounted to 29° and 50°, in average 40 +/- 3°. There were 21 persons with a higher range of movement of 1- 8°, in average 3 +/- 1°.The exorotation on the left side amounted to 28- 48°, in average 38 +/- 4°. There were 27 persons with a higher range of movement of 1- 4°, in average 3 +/- 1°.

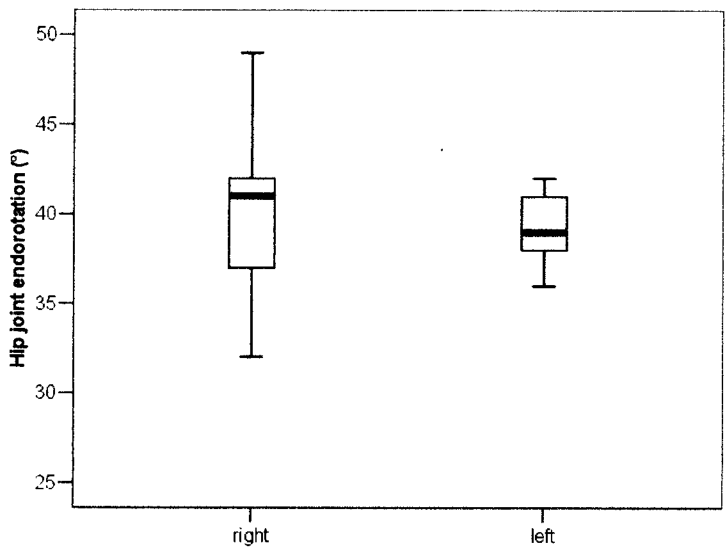

Figure 31: Range of movement in hip joint endorotation in proband group amounted to 40 +/- 5° on the right side and 40 +/- 3° on the left side

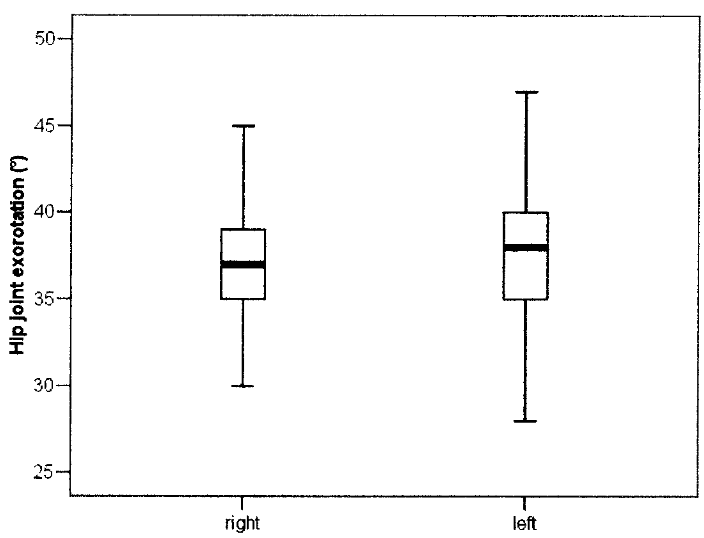

Figure 32: Range of movement in hip joint exorotation in proband group amounted to 37 +/- 3° on the right side and 38 +/- 4° on the left side

In the **control group** (Figure 33 and 34) the endorotation on the right side amounted to 32° and 52°, in average 41 +/- 3°. There were 27 persons with a higher range of movement of 1- 7°, in average 3 +/- 1°.The exorotation on the right side amounted to 22° and 50°, in average 36 +/- 3°. There were 22 persons with a higher range of movement of 1- 5°, in average 2 +/- 1°.The endorotation on the left side amounted to 3° and 52°, in average 41 +/- 5 °. There were 23 persons with a higher range of movement of 1- 5°, in average 3 +/- 1°. The exorotation on the left side amounted to

28° and 49°, in average 37 +/- 4°. There were 28 persons with a higher range of movement of 1- 9°, in average 4 +/- 2°.

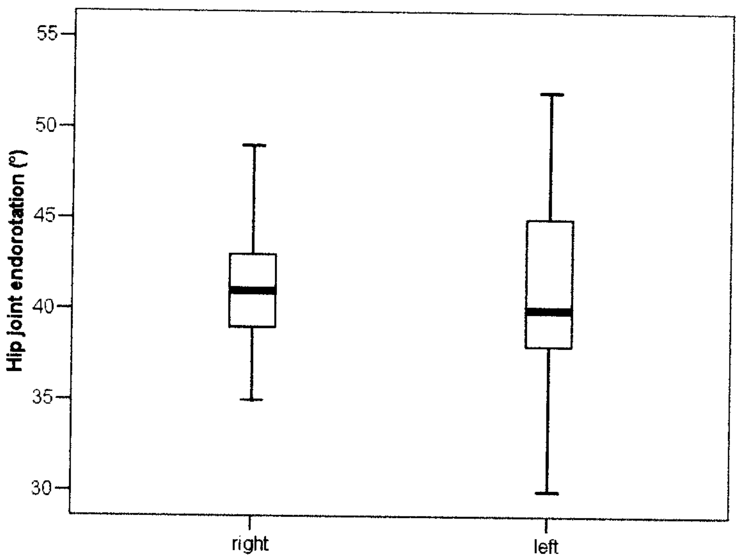

Figure 33: Range of movement in hip joint endorotation in control group amounted to 41 +/- 3° on the right side and 41 +/- 5° on the left side

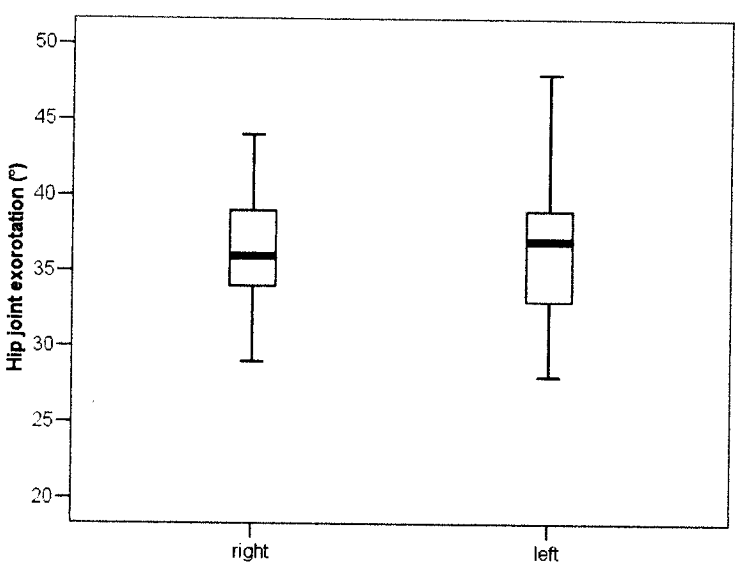

Figure 34: Range of movements in hip joint exorotation in control group amounted to 37 +/- 3° on the right side and 37 +/- 4° on the left side

We can conclude that no person in the two groups showed greater differences in the full range of movement of hip endorotation and exorotation according to the disqualifying criteria. It means that no person was excluded from the measurements.

7.2 Results of pelvic bone deviations

In this chapter we present a comparison of the pelvic bone deviation of the proband and the control group. It also shows the pelvic bone malposition in bilateral comparison in the pretest and in the retest. Especially the malpositions of the pelvic bones towards anterior and posterior in the proband and the control group are shown.

This examination together with the ilio-sacral joint examination (see chapter 7.1.1 leaning forward test) is necessary in order to diagnose a pelvis malposition and thus for evaluation of our hypothesis. In the following diagrams we show the one- sided pelvic deviation which is also described in the diagrams with the spina iliaca anterior superior (SIAS), they describe the same.

7.2.1 Comparing pelvic bone deviation of proband and control groups

We measured the position of the pelvic bones in bilateral comparison by the proband and control group in the first (pretest) and second examinations (retest).

7.2.1.1 Deviation pelvic bones pretest

We wanted to compare the results of both groups to ascertain if there is a difference in magnitude of the vertical SIAS distance. If the difference is statistically bigger in the proband group, it will support our hypothesis.

During the first measurement, the pretest (Figure 35) we recorded in the **proband group** a vertical difference between the spina ilaca anteriores superiors (SIAS) in bilateral comparison of minimally 02 cm and maximally 1.8 cm, in average 0.9 +/- 0.4 cm.

In the **control group** we recorded a difference between the spina ilaca anteriores superiors in bilateral comparison of minimally 0 cm and maximal 0.6 cm, in average 0.3 +/- 0.1 cm.

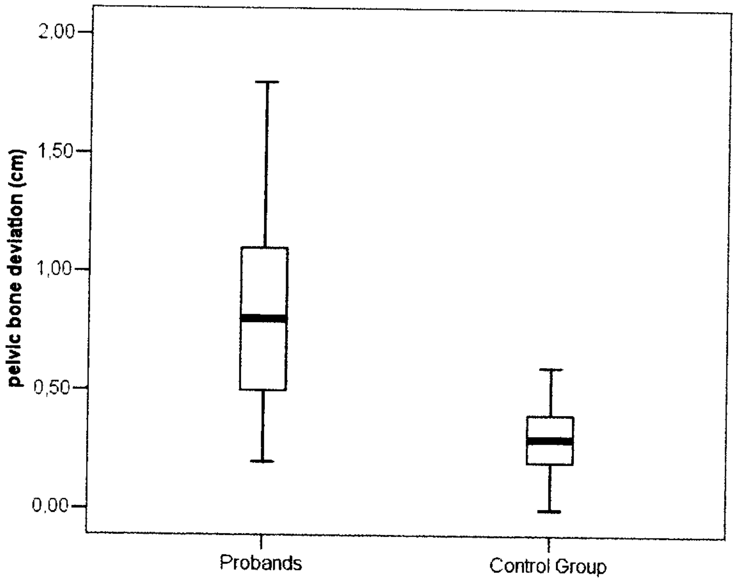

Figure 35: Pelvic bone deviation in proband group amounted to 0.9 +/- 0.4 cm and in control group 0.3 +/- 0.1 cm in the pretest

The following measurements are necessary in order to answer our first hypothesis. Therefore we will go more into detail and make a calculation with the t- test. The result of the t- test shows the deviation in the proband group and that there is a difference in bilateral comparison of the two pelvic bones, in average the difference amounts to 0.9 +/- 0.4 cm in the proband group and to 0.3 +/- 0.1 cm in the control group.

The independent t- test ($t = 0.9434$, $df = 98$, $p < 0.001$) shows a significance in the differences of the middle values of the proband and control group. That means that there is a significant difference between the position of the pelvic bones in bilateral comparison in the proband and the control group.

The following 95% confidence interval shows these results graphically.

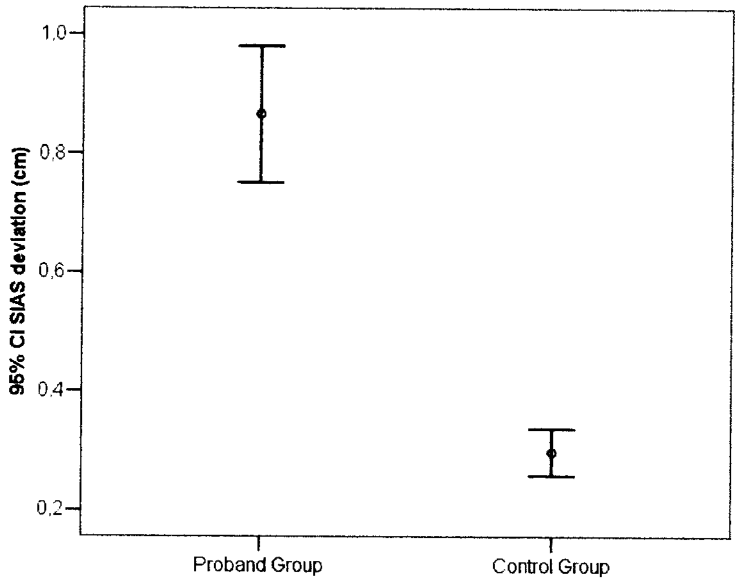

Figure 36: 95% confidence interval shows differences of pelvic deviations (cm) in bilateral comparison in the proband group 0.9 +/- 0.4 cm and in control group 0.3 +/- 0.1 cm

So we can conclude that there is a difference with a high significance level between the pelvis malposition in bilateral comparison of the proband and control group.

7.2.1.2 Deviation of pelvic bones retest

We made the same measurements 4 weeks later. We were interested if whether dysfunctions found in the first examinations were still present four weeks later. If yes it says something about their stability.

In the **proband group** we found a difference of SIAS vertical distance in bilateral comparison of minimally 0,2 cm and maximally 2.5 cm, in average 0.9 +/- 0.5 cm.

It is interesting for our measurements what has happened to the deviation after 4 weeks. Do we get a significant correlation if we compare the data of the pre- and the retest? So we calculated a correlation coefficient in regard to one-sided pelvic malposition.

Table 5: Correlation of SIAS deviation between pretest and retest (4 weeks later), correlation coefficient r = 0.87 shows a high significance (p < 0.001)

Correlations

		SIAS deviation four weeks later	SIAS deviation
SIAS deviation four weeks later	Pearson Correlation	1	,872**
	Sig. (2-tailed)		,000
	N	48	48
SIAS deviation	Pearson Correlation	,872**	1
	Sig. (2-tailed)	,000	
	N	48	50

**. Correlation is significant at the 0.01 level (2-tailed).

If we look at the correlation coefficient we can see that the value of the pelvic deviations (on both sides) amount to a coefficient of 0.87, in correlation with the pelvic deviation four weeks later. This person correlation coefficience is on a highly significant level. It means there is a correlation between the SIAS deviation (one sided pelvic deviation) of the test and the retest in the proband group. We can also say that the pelvic deviation regarding the persons with knee problem was stable according to their pelvic deviation in several tests (here 4 weeks later).

In the retest of the **control group** we found a difference between the 2 pelvic bones in bilateral comparison of minimally 0.1 cm and maximally 1.9 cm, in average 0.4 +/- 0.2 cm.

The one sided pelvic bone deviations in bilateral comparison in vertical direction of the retest are shown in the following diagram.

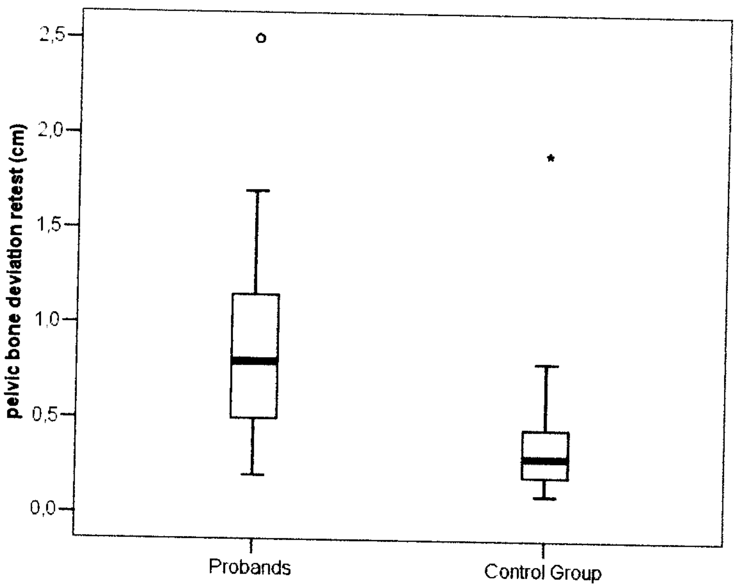

Figure 37: Pelvic bone deviation in proband group amounted to 0.9 +/- 0.5 cm and in control group 0.4 +/- 0.2 cm in the retest 4 weeks later

In the diagram we can see 2 deviations which are in the upper part. This is why we have to look at it in detail.

7.2.2 Pelvic bone malposition in bilateral comparison during the pretest

Now, it will be described which pelvic bone stands in an anterior and which a posterior malposition. We repeat the comparison of the proband and the control group. We were interested in whether anterior and posterior os coxae malpositions occur with the same frequency on both body sides as you may expect due to the similar anatomical structure.

7.2.2.1 Malposition pelvic bone toward anterior and posterior proband group

In the proband group (50 persons) 24 persons had a one-sided malposition of the pelvic bone towards anterior. 26 persons had a malposition towards posterior.

Of the 24 persons with an anterior malposition (Figure 38), 6 persons had the dysfunction on the left side and 18 persons on the right side. Of the 26 persons with a posterior malposition, 19 persons had a malposition towards posterior on the left side and 7 persons on the right side.

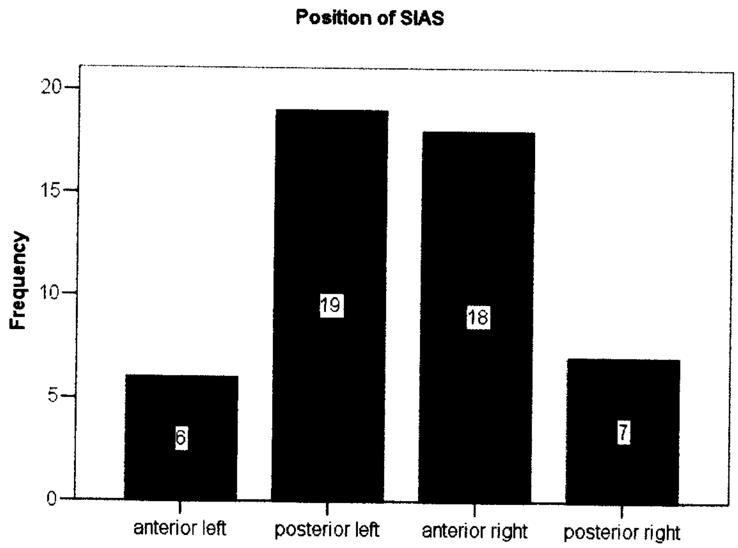

Figure 38: Distribution of os coxae malposition in the proband group: malposition towards posterior left: 19 persons, anterior left: 6 persons, anterior right: 18 persons and posterior right: 7 persons

We can conclude that the left iliac bone has the tendencany to stand in a posterior malposition whereas the right one tends to move towards anterior.

In the proband group, 24 persons had an **anterior malposition** of the pelvic bone. The minimal vertical difference between the two pelvic bones (SIAS deviation) in bilateral comparison was 0.4 cm and the maximal difference was 1.6 cm, the average difference was 0.9 +/- 0.4 cm (Figure 39).

In the proband group, 26 persons had a **posterior malposition** of the pelvic bone. The minimal vertical difference between the pelvic bones (SIAS deviation) in bilateral comparison was 0.2 cm, the maximal difference was 1.8 cm, the average difference was 0.8 +/- 0.4 cm (Figure 39).

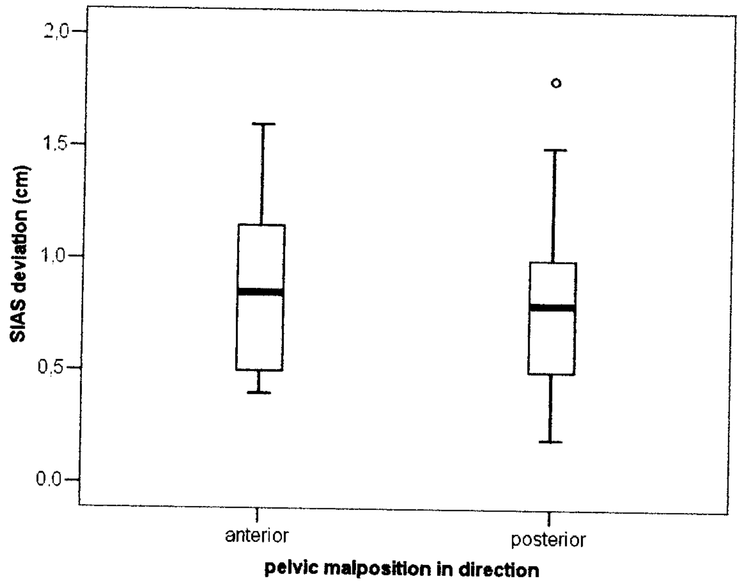

Figure 39: Malposition of SIAS in vertical direction, os coxae malposition towards anterior 0.9 +/- 0.4 cm and toward posterior 0.8 +- 0.4 cm in the proband group

We can conclude that in average the SIAS deviation towards anterior and posterior is almost identical.

7.2.2.2 Malposition pelvic bone toward anterior and posterior control group

In the control group 45 persons had no iliosacral dysfunction. Only 5 persons had a dysfunction of the iliosacral joint.

2 persons had an **anterior malposition** of the pelvic bone. The minimal vertical difference between the pelvic bones (SIAS) in bilateral comparison was 0.40 cm and the maximal difference was 0.5 cm, the average difference was 0.45 +/- 0.1 cm.

3 persons had a **posterior malposition** of the pelvic bone. The minimal vertical difference between the pelvic bones in bilateral comparison was 0.20 cm, the maximal difference was 0.5 cm, the average difference was 0.4 +/- 0.2 cm.

In conclusion we can say that only 5 persons of the control group have shown an iliosacral blocked side. This number is too small to say anything about the malposition. In regard to the other 45 persons, we can only say whether there is a difference between the pelvic bones but we cannot find out which side stands moved towards which direction.

7.2.3 Pelvic bones malposition in bilateral comparison during retest

After 4 weeks we measured the vertical distance between the spina iliacae anteriores superiors on both body sides one more time. We were not able to collect data from 3 persons, 1 of the control group and 2 of the proband group. Two persons had had a knee operation in the meantime, 1 person was not measured because she had moved to another country.

7.2.3.1 Malposition pelvic bone toward anterior and posterior proband group

In the proband group, 2 persons suffered a supination trauma during the four weeks between both measurements. The measurement results of these persons four weeks later show bigger differences in the vertical distance of SIAS. The first proband had had a SIAS deviation right anterior of 0.4 cm in the first session (pretest). After 4 weeks (and a supination trauma) we found an os coxae posterior malposition on the right side and a 1.9 cm difference between the SIAS.

The second proband with a supination trauma (on the right side) had had a difference of 0.2 cm between the SIAS and a left posterior malposition during the first test. During the retest 4 weeks later, we found a posterior coxae malposition on the right side and the difference between the SIAS amounted to 1.7 cm.

One person of the proband group complained about a local pain in the lumbar spine before the retest measurement took place. During the first test we measured a SIAS difference of 1.8 cm and found a left posterior coxae malposition. During the retest (4 weeks later) the malposition was found on the same side, but the SIAS vertical distance was greater (2.5 cm).

7.2.3.2 Malposition pelvic bone toward anterior and posterior control group

One person of the control group suffered a supination trauma in the time between the first and the second examination. In the first examination (pretest) the vertical difference between the SIAS was 0.2 cm and we found a right anterior malposition of the iliac bone. 4 weeks later (retest), a right posterior os coxae malposition was diagnosed and the difference between the SIAS amounted to 1.5 cm. Another person of the control group got an intervertebral disc herniation L5/ S1. During the pretest examination we found a left posterior os coxae malposition and a 0.4 cm difference between the SIAS. During the retest examination the left os posterior coxae malposition was found again but the SIAS difference was a lot bigger (1.9 cm).

We can conclude that all 3 persons who suffered a supination trauma in the time between test/retest had experienced a posterior movement of the os coxae.

7.3 Pelvic bone deviation and intensity of knee pain

In this chapter we would like to find out if there is a difference or a correlation between the os coxae malposition and the intensity of pain in the knee joint.

First, we checked if there is a deviation of the pelvic bone in bilateral comparison towards anterior and posterior. Now we want to know if there is a correlation between those deviations and the probands' intensity of pain. Then, we receive a correlation between the intensity of pain and the deviation of a one-sided malposition of the pelvic bone.

In regard to an os coxae malposition towards **anterior,** 24 persons showed a difference between the SIAS of 0.4 cm to 1.6 cm, with an average of 0.8 +/- 0.4 cm. The intensity of pain according to the pain scale, which ranges from 0 to 100 mm, was between 38 and 67, in average 53 +/- 10.

Regarding an os coxae malposition towards **posterior,** 26 persons showed a difference between the SIAS of 0.2 cm to 1.8 cm, with an average of 0.9 +/- 0.4 cm. The pain intensity in this group was in average 72 +/- 9.

We can conclude that an os coxae malposition towards posterior is linked to a higher subjective intensity of the knee pain.

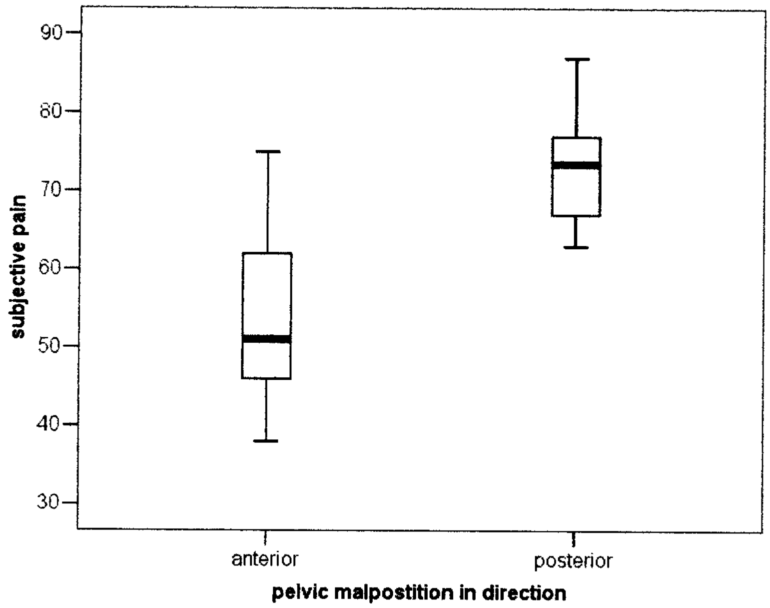

Figure 40: Intensity of knee pain in regard to os coxae malposition towards antrior amounted to 53 +/- 10 and towards posterior to 72 +/- 9

In conclusion we can say that the intensity of pain in regard to a one-sided pelvic malposition towards anterior is less intensive than in regard to a malposition towards posterior.

In addition, we carried out a t- test to see if there is a difference between a one-sided pelvic malposition (in cm) and the intensity of pain (Table 6). We would like to know if there is a significant difference between the group with an anterior os coxae malposition and the one with a posterior os coxae malposition.

Table 6: Results of t- test for the variables of SIAS deviation and intensity pain scale of the proband group between anterior and posterior position. The upper row of the t- test shows the SIAS deviation with t- value = 0.596, df= 48, p= 0.572 (not significant). The lower row shows the values of the pain scale, t- value = -7.152, df= 48, p< 0.001 (significant).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
SIAS deviation	Equal variances assumed	,155	,696	,569	48	,572	,06538	,11483	-,16550	,29627
	Equal variances not assumed			,569	47,518	,572	,06538	,11492	-,16574	,29651
pain scale	Equal variances assumed	2,564	,116	-7,152	48	,000	-18,833	2,633	-24,128	-13,539
	Equal variances not assumed			-7,110	45,627	,000	-18,833	2,649	-24,167	-13,500

Based on the t- test we can conclude that there is a highly significant difference between the intensity of pain and an os coxae malposition towards anterior and posterior (t = -7.152, df = 48, p < 0.001).

The 95% confidence interval of this t- test is shown in Figure 41.

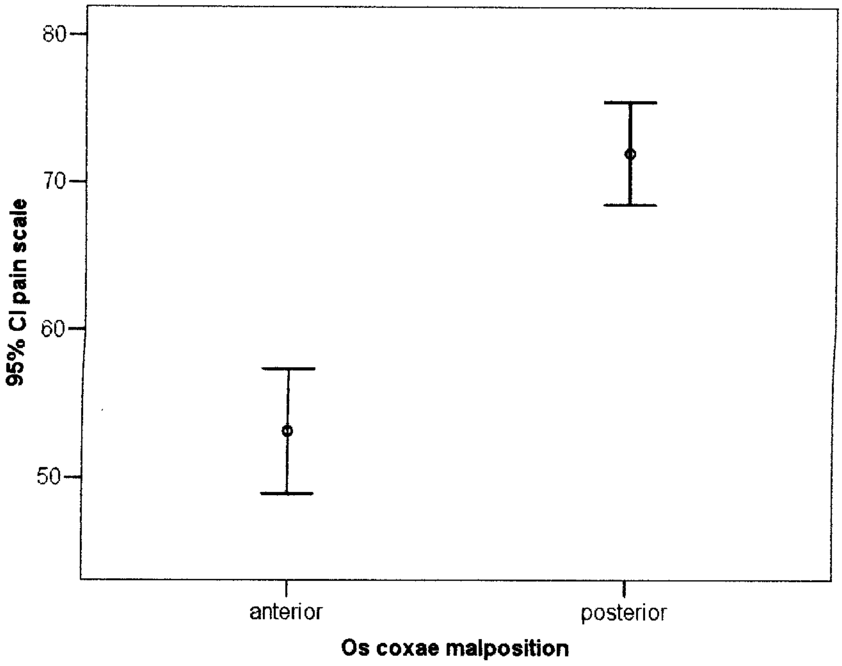

Figure 41: 95 % confidence interval of middle value of intensity pain scale of the knee joint and os coxae malposition toward anterior (53 +/- 10) and posterior (72 +/- 9)

We can conclude that there is a difference of a one-sided os coxae malposition towards anterior and posterior in regard to the subjective feeling of knee pain.

7.3.1 Pelvic bone malposition posterior and intensity of knee pain

We would like to know if there is a correlation between the one side os coxae malposition (SIAS deviation) toward posterior and the subjective intensity of knee pain (Table 7).

Table 7: Correlation coefficient r= 0.588 between os coxae posterior deviation and subjective intensity of knee pain is significant for p= 0.002

Correlations

		SIAS deviation	pain scale
SIAS deviation	Pearson Correlation	1	,588**
	Sig. (2-tailed)		,002
	N	26	26
pain scale	Pearson Correlation	,588**	1
	Sig. (2-tailed)	,002	
	N	26	26

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation coefficient r = 0.59 is highly significant. It means that there is correlation between a one sided os coxae malposition (SIAS deviation) toward posterior and the subjective intensity of knee pain.

7.3.2 Pelvic bone malposition anterior and intensity of knee pain

We would like to know if there is a correlation between the one sided os coxae malposition towards anterior and the subjective intensity of knee pain (Table 8).

Table 8: The correlation coefficient r= 0.444 between os coxae anterior deviation and subjective intensity of knee pain shows no significance for p= 0.030

Correlations

		SIAS deviation	pain scale
SIAS deviation	Pearson Correlation	1	,444*
	Sig. (2-tailed)		,030
	N	24	24
pain scale	Pearson Correlation	,444*	1
	Sig. (2-tailed)	,030	
	N	24	24

*. Correlation is significant at the 0.05 level (2-tailed).

The result shows that there is a correlation coefficient r = 0.44 which means that there is only a significant correlation between the one sided SIAS deviation (pelvic malposition) toward anterior and the subjective intensity of knee pain.

7.4 Summary of the results

The rresult of the **anamnesis data** showed that, in the proband group, there were more men (32) than women (18), in relation approximately 3/5 to 2/5. In the control group we had the same number of men and women (25 men and 25 women). We can assume that the gender distribution has no influence on our results. In regard to the age distribution we can see that, in the proband group, the average age is higher (39 +/- 8 years) than in the control group (29 +/- 8 years). We can assume that the higher age of the proband group had an influence on our results. The average body height was almost the same in the two groups, 176 +/- 7 cm in the proband group and 174 +/- 8 cm in the control group. The average body weight differed. The body weight in the proband group is in average 68 +/- 3 kg, in the control group 65 +/- 8 kg. There is a tendency to higher weight in the proband group. It may be due to the higher number of men in the proband group. But maybe we can also say that a higher body weight could be a risk factor for pelvic malpositions and for the related knee problem of long distance runners. All persons showed a difference of the anatomic leg length in bilateral comparison, from minimally 0.1 cm to maximally 1.3 cm. We had no person in our sample with a big difference in leg length so that we can assume that in bilateral comparison the difference was too small to influence our study.

In both groups the loading/strain during running was the same, they run in average 56 +/- 12 km weekly, so we can assume that the intensity of running did not influence our results.

In regard to the **results** of examinations I started with the *leaning forward test* to see if there is a dysfunction of the iliosacral joint. In the proband group all 50 persons had positive result, which means that the test was positive for all persons in the proband group on the same side where the knee problem occurred. The distribution of dysfunctions on the left and right body sides was almost identical. In the control group only 5 persons had an iliosacral dysfunction.

We compared the range of movement in the *knee joint* of the two body sides. We found no one whose difference was greater than 15% of the full range of movement, which is why nobody was excluded from our sample. If we go into detail we can see there that is a similar tendency in both groups. In both groups the knee joint flexion in both groups is in average slightly stronger on the right body side, whereas the extension is slightly stronger on the left side.

A similar tendency could be seen in regard to the hip joints. If we compared the full range of movement between the hips on both body sides we found nobody who exceeded 15% of difference. In a similarly way as the knee joints, the hips showed a tendency to a stronger endorotation on the right side and a stronger exorotation on the left one. In regard to the knee and hip joint we only speak about tendencies as the differences were to small.

All members of our proband group had a pelvis malposition with knee problem and most members of the control group had one without knee problem But in the proband group the differences shown in the bilateral comparison of the os coxae position were way bigger (in average 0.9 +/- 0.4 cm) than in the control group (in average 0.3 +/- 0.1 cm). In the *retest* 4 weeks later we found minimal differences of the middle values. We can assume that the differences of the pelvic position and malposition are stable over a period of time of 4 weeks. If we go into detail we can see that during the second examination persons who had had an injury in the 4 weeks showed bigger differences (supination injury or problems with lumbar spine). These persons had a relatively high deviation of the spinae iliacae anteriores superiors in bilateral comparison towards vertical. As for the persons who suffered a supination trauma, their malposition of the os coxae of the same side changed towards posterior, in one case 1.7 cm in the other case 1.9 cm. We could say that there is a tendency of the os coxae towards posterior, after a supination trauma. Regarding the persons who had problems with the lumbar spine we found one whose os coxae had moved towards anterior (2.3 cm) and one towards posterior (1.7 cm). We were not able to measure 3 persons of our sample the second time. One left the town and his new address was unknown. 2 had had a knee operation in the meantime and were not measured.

In the proband group (50 persons) a one-sided malposition of the os coxae of the right side was found more often (18: 6), on the left side posterior os coxae malposition was more frequent (19: 7). In conclusion we could say that the left os coxae show a stronger tendency to a posterior malposition, whereas the right os coxae could have a tendency to an anterior malposition.

During the examination of the pelvic deviation and the intensity of knee **pain** we found differences within the proband group in bilateral comparison. In regard to a malposition towards posterior the intensity of knee pain was stronger, in average (72 +/- 9) than in regard to a malposition towards anterior (53 +/- 10). So we could assume that the malposition towards posterior provokes a stronger intensity of pain than the malposition towards anterior.

8. Discussion

The discussion of our work will be subdivided into several chapters. First, we want to dispute the methodological part of our study, predominantly the fact if the examination methods we used could influence the results. Then the results of our work will be compared with results of other authors to incorporate them into present scientific knowledge in this field. We would like to emphasize the clinical usage of our study which could help physiotherapists and sports physiotherapists to improve their examination, therapeutic abilities, to prevent knee joint overloading followed by knee joint injuries.

The study was carried out in order to verify the relation between a pelvis malposition and the knee problem of endurance athletes. Based on our literature research (Richter and Hebgen, 2006; Peeters and Lason, 2000; Frisch, 2001; Meert, 2003; Snijders, 1995), we hypothetically expected that there is a correlation. All these authors believe this relation to be a result of so-called cause-and-effect-chains, seen from a functional, anatomical point of view.

100 persons in total took part in our study. They were subdivided into 2 groups: proband group (with knee problem) and control group (without knee problem). Each group contained 50 persons. They were examined twice, the second examination took place four weeks after the first one. We chose endurance runners because of the repetition of stereotype cyclic movements without quick changes of the movement direction and without direct contact with other sportsmen (Hohmann and Wörther 2005).

If possible, we wanted to create a homogenous collection of probands in order to exclude factors which could negatively influence the results. Hence, we created qualifying criteria regarding the age between 20 and 50 years (Lane et al. 1987; Kool and Bie, 2001) and a sufficient loading of the locomotor apparatus during running (minimally 40 km per week) (Deleo et al. 2004; Hohmann and Wörther 2005), and disqualifying criteria like former knee operations and structural problems in the region of the pelvis and the lower extremities (Niethard and Pfeil 2003), differences in the movement ranges of the hip and knee joints when comparing the left and the right leg (bigger than 15%) (Shellock and Mink 1999; Brokmeier 2001), illnesses of internal organs which could influence the position of the iliac bones (Meert 2003), a hip joint dysplasia which could influence the kinesiology of the lower extremities (Bachmann et al. 1999) and neurological affections in the lumbosacral area which could negatively influence the muscle function (Richardson and Hodges, 2004).

8.1 Discussion about methodology

Manual and instrumental methods were used for the examinations of the iliosacral function, the position of the iliac bones os coxae in regard to the position of the spina iliaca anterior superior (SIAS), the measurements of the movement ranges of the hip and knee joints and for the measurement of the anatomical leg length.

Many scientists have doubts in regard to manual examinations as they fear possible subjective mistakes and do not believe that the results – as they are provided by different persons – are comparable. For a long time, manual skills have been used for highly exact bone tip palpation and for the efficient providing of different manual tests to evaluate joint and muscle function. We do not touch the bone directly, but take it between our fingers and the bone is a layer of soft tissues, like skin, subcutaneous tissue and so on. Therefore we calculate with small mistakes in our study. In order to prevent or to minimize the mistake risk resulting of the above mentioned subjective factors, all examination tests were carried out by one person who is a physiotherapist with a 15-year-long practical experience. There are many other factors which influence the results of our measurements, for example the health state of the patient, the temperature of the room, the softness of the therapy table, sunshine, air pressure and so one.

Hence, we all examinations took place in the same environment. It means we measured all persons in the same room between 15.00 h and 18.00 h, with a constant temperature of 22° and on the same therapy table.
Another problematic issue is the validity of manual tests in regard to the purpose of our study. Only one manual test was used for the evaluation of an iliosacral joint dysfunction. It was the leaning forward test as described in detail in textbooks about manual therapy (Frisch 2001). This test is commonly used in clinical practice and in clinically oriented scientific works to describe the function of the iliosacral joint. Therefore, we can accept it even from a point of view concerning its validity. The test is simple to provide it and is not specific. It means that we can conclude that the joint does not function normally but we are not able to say in which direction it is blocked (Kayser et al., 2008). The direction of the iliocsacral joint dysfunction was examined during the measurement of the vertical distance between the SIAS on both body sides.
Simple instruments were used for the measurement of the distances (vertical distance between SIAS of both body sides and anatomical leg length). We used a cm scale (tape) for the anatomical leg length measurement (Kool and Bie, 2001) and a pelvimeter (cm scale) which had been especially constructed for our study to measure the differences in the vertical distance of the SIAS. The pelvimeter had also been tested by Prof. Dr. V. Wank (biomechanic department, Ruprecht Charles University of Tübingen) using an optic system, simi motion 3- D calculation. The results were very good. The points on the body surface, the distance which we wanted to measure, were painted beforehand with a skin pen. These points were painted by the same skilled person who provided the manual examinations to ensure a maximum exactness of the bone palpation. The coefficient of reliability of the measurements gets compared in chapter 6.5 and the data can be found in the appendix.

Other instruments were used for the measurement of the joint angles in the hip and knee joints. A goniometer was used for this examination. The goniometer is also a generally accepted measurement device and the manner of measurement is described in textbooks (Brosseau et al., 2007). The validity of the instruments used for the measurement of distances and angles has been empirically proven (Brosseau et al., 2001; Kool and Bie 2001; Berg, 2007). Furthermore, we tested the validity and reliability of the goniometer by repeating the same measurements with the same persons (see chapter 6.5, 12.3.1 and 12.4.1) and we calculated the reliability coefficient (Thomas and Nelson 2001). Three therapists carried out the measurements with 10 different persons (see appendix 12.4).

At the beginning of our study, we also wanted to measure the lateral tilt of the pelvis to have more information about the position and function of the pelvis. The instrument (inclimeter) had been constructed especially for our study. It measures the angle between a horizontal line and a line interconnecting the SIAS and SIPS of both body sides in an upright standing position. It is described that differences of more than 2 angle degrees or more can be measured. This is not exact enough for our study. We tested the instrument in a similar way as we had tested the previous ones but the reliability coefficient does not allow the usage of the instrument in our study in regard to the exactness of the measurement.

8.2 Discussion of the results

According to our results we can state that higher age and higher body weight *(Kleindienst et al., 2006) could be risk factors for endurance runners for the* development of knee problem. The higher the age, the higher the risk for structural problems of the locomotor apparatus and the knee joint (Lane et al. 1987). Higher body weight influences the joints of the lower extremities biomechanically as it provokes changes of the movement kinetics (Shellock and Mink, 1999). We can expect stronger forces which affect the bones, cartilages and muscles during a multiple repetition of the same cyclic movement. Predominantly the knee joint menisci have to absorb these forces (Illguth and Jäger, 1996).
All members of the proband group had an iliosacral joint dysfunction and an os coxae malposition on the same side. It was diagnosed through the examination of the iliosacral joint function and through the measurement of the vertical distance between the SIAS of the two body sides. It corresponds with findings of other authors (Thiel and Richter 2009) who believe these two signs to be typical and characteristic symptoms for a pelvis dysfunction (Zeller et al., 2005; Vleeming and Snijders, 1990). According to them, an os coxae dysfunction occurs on both body sides or ventrally (os coxae anterior) or dorsally (os coxae posterior). One of the most interesting

findings in our work is that the right os coxae has the tendency to stand in an anterior malposition but the left one tends to show a posterior malposition. How to explain this difference? One could expect that because of the symmetry of the anatomical structure of both body halves, the symptoms of different dysfunctions of the locomotor apparatus should be equal for both body sides. Probably, nerve control mechanisms play a role in this difference. The Kabat method of proprioceptive neuromuscular facilitation (Reichel, 2005; Lewit, 1981) could help to understand this phenomenon. According to the method, diagonals occur due to the activation of skeletal muscles during natural movements. These diagonals pass obliquely through the body and could be one of the causes of these differences.

Another possibility is that the above mentioned tide could be caused by hand dominancy. According to statistics, the occurrence of left-handed people in the population amounts to approximately 15%. We did not follow this laterality factor in our proband group but 24 of the 50 persons had an os coxae malposition on the left body side. In regard to right-handed persons we expected the right shoulder to be more ventrally during walking and running and that this would be compensated by a ventral deviation of the left part of the pelvis. That it is connected with an os coxae posterior of the left os coxae. This corresponds with our findings which say that the left os coxae show a stronger tendency towards os coxae posterior. This corresponds with authors which state that the right os coxae of the majority of all healthy people is deviated towards anterior (0.5°) in comparison to the left side (Decupere, 2000).

We measured the anatomical leg length because we expected that it had an influence on the position of the iliac bones. Literature data (Richter and Hebgen, 2006) states that a shorter leg can influence the position of the pelvis, but only when the differences of both legs are bigger than 1.5 cm (Thiel and Richter, 2009). We did not find any correlation between these two signs. In our sample none of the persons showed such a big difference in the leg length in bilateral comparison.

We measured the ranges of movement of the hip and knee joints. There were two reasons for this. First, we used this measurement as one of the exclusion criteria because the literature data claims that if the difference is bigger than 15% between both body sides, it means that there is a structural problem of the joint (Brokmeier, 2001). No person from our sample was excluded because of such an extreme difference. Hence, we only expected functional problems in the knee joints. Structural joint problems cause the pain in the joint itself. But it is known that joint dysfunctions are very often transferred to a joint from distant points of the locomotor apparatuses.

As a result of our measurements we could conclude that the left leg has a stronger tendency for an increased exorotation of the hip and extension of the knee joint. The opposite situation was found in the right leg. If we compare these findings with an os coxae malposition we could say that different patterns exist in the left and in the right leg. The os coxae anterior on the right side have the tendency to be connected with the endorotation of the hip and flexion of the knee joint. The os coxae posterior on the left side has the tendency to be related to the exorotation of the hip and extension of the knee joint. This finding differs from the literature data (Richter and Hebgen, 2006) which describes the endorotation of the hip to be a part of extension muscle chains. But we got these results through the measurement of healthy persons.

We measured the vertical distances between the SIAS of both body sides. In our study, this pathological sign was present in both groups (proband and control) we examined. Interesting for the discussion is the fact that the vertical distance between the SIAS on both body sides was much bigger in the proband group with the knee problem than in the control group without the knee problem Decupere (2000) measured the rotation position of both iliac bones in bilateral comparison in angle degrees. He measured the angle between a horizontal line and the line pathing through the SIAS and SIPS. He concluded that the right os coxae of healthy persons show a stronger anterior rotation (0.5°). In our sample the anterior rotation of the os coxae was present on both body sides.

Four weeks later we carried out the second examination of the sacroiliac joints and the measurements of the SIAS vertical distances. We received nearly the same results as during the first test. In the meantime, several persons had suffered a supination trauma, which changed the position of their os coxae towards posterior. We can assume that these changes were the result of pathological muscle chains originating from the injury place. In regard to biomechanical aspects we can speak about a so-called ascending cause-and-effect-chain (Peeters and Lason, 2000).

Some authors (Richter and Hebgen, 2006) describe pathomechanics which influence the locomotor apparatus. For example, during a supination trauma the fibula is being pulled towards caudal, ventral and moves the os cuboideum into an outward rotation and the os naviculare into an inward rotation. In combination with a plantarflexion position of the foot, this causes a pes cavus (Lewit, 1997). The tibia is moved into an outward rotation. This has an effect on the femur and turns it into an outward rotation. In the knee joint a genu varum occurs, the medial meniscus gets compressed and the *lateral collateral ligament experiences a stretch stress* (Jerosch and Heisel, 2004). As the fibula changes its position towards caudal there is a tensile force on the m. biceps femoris (caput longum), which rotates the os coxae of the affected side towards posterior (Peeters and Lason, 2000).

We could ***conclude*** that the so-called cause-and-effect-chains pass through the whole length of the lower extremities, all joints and muscles are involved. However, the examination result does not show where the primary cause of the chain is located. Therefore, it is important to find out the primary cause of the chain (Richter and Hebgen, 2006). According to our own opinion, only treatment of the primary cause and the symptoms can re-establish the integration state of the body.
One could expect a similar distribution of anterior and posterior os coxae malpositions on the left and right side. But we conclude on the base of our results that the right os coxae have a stronger tendency for an anterior malposition and the left os coxae for a posterior malposition. This cannot be explained by hand dominancy as discussed above. We have to conclude that the right and the left body half behave differently. The reason for these differences remains unclear.

In the proband group the knee overstrains of all persons was connected with deviations of the iliac bones. The mean difference between the SIAS position in vertical direction was more than one half of a centimetre. Most of the persons of the control group showed these differences, too. But the distance between the SIAS was way smaller than in regard to the control group. The conclusion could be that a bigger os coxae deviation is necessary to cause knee overstrain. In the proband group, the os coxae deviations of all persons were connected with an iliosacral dysfunction on the same body side. It means that a dysfunction of these joints causes a stronger os coxae malposition than in the control group where only 5 persons had an iliosacral

dysfunction. One could expect that the SIAS vertical distance of these 5 persons was similar to the distances in the proband group, but that was not the case. The difference in this group was between 0.4 and 0.5 cm. It was slightly bigger than the difference of other persons of the control group, but smaller than in the proband group. We assume that the knee pain could play an important role.
If we think about these 3 values of the SIAS vertical distances we can assume that a combination of several factors could play a role here. In regard to members of the control group without an iliosacral dysfunction (0.3 cm of SIAS difference) muscle dysbalances could (probably) be the reason (Janda, 1994). In regard to the 5 persons of the control group with an iliosacral dysfunction (0.45 cm of SIAS difference) a combination of a muscle dysbalance and an iliosacral dysfunction or only the latter could cause the difference (Kayser, 2008). In the proband group (0.9 +/- 0.3 cm of SIAS difference) the pain is another factor which could increase the SIAS vertical difference through nerve reflexes (Richter and Hebgen, 2006).

All members of the proband group showed a connection between the pelvic malposition and the pain in the knee joint on the same body side. This result supports our first hypothesis about a relation between a pelvis malposition and knee problem. This relation is probably realised by cause-and-effect chains which have been described by many authors on the base of muscle interconnection between the pelvis and the knee (Richter and Hebgen, 2006; Peeters and Lason, 2000; Frisch, 2001; Meert, 2003; Snijders, 1995). Especially in regard to runners all the aspects of the whole chain of movement have to be taken into account (Hohmann and Wörther 2005). We got the same result in regard to athletes of our sample who took part in running events in Stuttgart and Heilbronn.

An os coxae anterior dysfunction is obviously connected with an increased extension of the knee joint and with an increase in the inward rotation of the hip joint (Niethard and Pfeil 2003) which leads to a functional lengthening of the lower extremities. An os coxae dysfunction towards posterior is connected with a tendency for an increased flexion of the knee joint and for an increase outward rotation of the hip joint (Niethard and Pfeil, 2003; Richter and Hebgen, 2006; Peeters and Lason, 2000; Frisch, 2001; Meert, 2003; Klein and Sommerfeld, 2004).

The intensity of pain may be a result of an overloading of the bones and the menisci or an hyperextension of other soft tissues – muscles, joint capsule and ligaments. For example, with regard to endurance runners, an overloading of the ventral part of the knee joint is caused by an increased tension of the m. rectus femoris as a result of an os coxae anterior malposition (Hohmann and Wörther 2005).

It is described that the muscles and fascial structures of inner organs have an influence on the position of the pelvis. For example, the gliding of the kidney on the fascia of the m. psoas influences the position of the os coxae (Peeters and Lason, 2000). The ligaments of some other organs insert directly at the pelvis, such as the ligg. pubovesicalia (Meert, 2003).
Another factor in this process are the relative shortening or elongation of the leg. This length difference is compensated by the foot position. A shorter leg is compensated by a foot supination with a lateral deviation of the knee (genu varum). A longer leg is compensated by the flattening of the foot arches, the pronation of the foot and by a medial deviation of the knee joint (genu valgum). The genu varum or valgum cause an overloading of the medial or lateral part of the knee joint and a hyperextension of the joint capsule, ligaments and muscle insertions on the other side (Lanz and Wachsmuth, 2004).

Pain is a very subjective feeling. Every person has another pain threshold. A feeling of pain is influenced by different factors such as the psychological state, fatigue, parameters of weather and so one.
Pain in the knee region can be caused by a problem in the knee joint itself, such as a structural change in the bone, cartilage, ligaments or joint capsule (Schomacher, 2001). But very often, the pain is transferred to the knee joint by means of cause and effect chains, which are realized by a chain of hypertonic muscles originating in a distant point of the locomotor apparatus (Richter and Hebgen, 2006) or refered pai with other causes (Jerosch and Heisel, 2005). Our results show that the primary cause of such a chain is very often situated in the pelvic region. A primary dysfunction of the sacroilical joint changes the position of the os coxae. According to our results, we can assume that an extensor muscle chain causes more intensive subjective pain in the knee region (Brokmeier, 2001). Another possibility is that the

pain is referred to the knee joint from a dysfunction of the lumbar spine, the hip joint, the ankle, activated triggerpoints or from internal organs (Licht et al., 2008).

Our results show that knee pain which is linked to an os coxae posterior malposition are more intense than pain which is linked to an os coxae anterior malposition. The os coxae posterior belongs to the extension muscle chain. This chain is realised by postural muscles which are stronger than phasic muscles which are part of the flexion muscle chain (Chaitow, 2002). Especially the postural muscles of runners are overloaded (Kleindienst et al., 2006).

The so-called cause-and-effect chains are realised by hypertonic muscles which contain triggerpoints (Simon and Travel, 2000). The triggerpoints are very often situated in the m. biceps femoris. The muscle is inserted into the fibular head and the pain gets transferred to the dorsal side of the knee joint (Licht et al., 2008).

There is also another possibility how the problem may be transferred to the knee joint region. This transfer if for obvious reasons called pseudradiculare pain (Berg, 2007). The basis of this pain transfer is the irritation of a peripheral nerve orginating from the lumbo- sacral plexus by blocked lumbar vertebrae (Cholewicki and McGill, 1996).
By the radicular pain the pain is superficial and exactly located. The so-called dermatoms are involved. Dermatome L3 runs on the medial surface of the thigh and knee joint. Dermatome L4 passes along the ventral surface of the thigh and knee joint and continues towards the big toe of the foot. Dermatome L5 is situated on the lateral side of the knee, dermatom S1 on the dorsal side (Panjabi, 1992).

A deviation of the knee joint around a rotational axis overloads the soft tissues, too. The axis of the knee rotations is located approximately in the middle of the medial tibia condylus (Klein and Sommerfeld, 2005). If any cause-and-effect chain is present in the lower extremities, the agonistic muscles, causing the chain, are hypertonic, the antagonistic muscles are overstretched and hypotonic as a result of the reciprocal inhibition (Reichel 2005; Simon and Travel, 2000). This results in a muscle dysbalance and bad muscle coordination which finally cause the knee problem. The chaining hypertonic muscles also influence the coordination of the locomotor apparatuses. Especially the knee joint with its greate number of receptors which are important for the coordination of movements, can influence the cause-and-effect chain of the lower extremities if there are any disturbances in this joint (Richter and Hebgen, 2006).

Disturbances in the joints also weaken the absorption effect in the lower extremities during running (Hohmann and Wörther, 2005). For example, if the sacroiliac joint is blocked, the runner's absorption function in the pelvis and in the hip joint becomes less effective (Auerbach and Heyde, 2005). As a result of the malposition of the os coxae, the functional leg length will change (Vleeming and Snijders, 1990), which means that the os coxae anterior malposition will increase the functional leg length, an os coxae posterior malposition will shorten it (Lanz and Wachsmuth, 2004). As a consequence, the strain in the lower extremities and especially in the knee joint changes. If the leg length is functionally shorter, the lateral part of the knee is under more load and the medial structures of the soft tissue are overstretched (Kleindienst et al., 2006). If the functional leg length increases, the opposite effect occurs. In both situations the absorption effect in the lower extremities is less effective (Kayser et al., 2008). This means we have two important joints in the cause and effect chain in the lower extremities with a less effective absorption effect (Brokmeier, 2001). This could be one reason for runners' problems, due to inadequate loading during long distance running. As a result of these changes within the joint, the muscle chain will be also changed and the trigger points will be activated (Simon and Travel, 2000).

Existence of muscle chains is supported by scientific studies which follow up the changes in the muscle activation during movements of the joints or after an electro stimulation of the skin or of sensitive nerves innervating the skin. (Knikou et al., 2007) The results prove the existence of typical reflex muscle patterns. For example, a dorsal flexion of the ankle activates the m. tibialis anterior and flexor muscles of the knee joint, a plantar flexion of the same joint activates the m. soleus and the knee joint extensors. Likewise, there is a specific connection between the localisation of the skin irritation (for example on the foot sole skin) and the pattern of activated muscles in the lower extremities. (Morita, Crone, Christenhuis et al. 2001) These reflex muscle patterns exist not only in individual extremities but also between upper and lower extremities (Zehr et al., 2001).

During our work we measured the anatomical length of the lower extremities, because if there is a big difference in bilateral comparison, it influences the position of the pelvis (Kayser et al., 2008). The anatomically shorter leg bears a bigger part of the body weight.

In our work, we tried to compare the location of an os coxae malposition and the intensity of knee pain (according to pain scale). One possibility is that a one-sided os coxae posterior malposition leads to the development of an extension muscle chain of the extensor muscles. The muscles belong to the postural (anti gravitation) muscles. These muscles have some special and characteristic abilities (Pedersen, 1997). They are stronger and contain a greater amount of fibrous connective tissue (Bader- Johannson, 2000). We can consider these factors to be a reason for the differences.

We carried out the same examination of the pelvis (iliosacral joint function and vertical distance between SIAS on both body sides) in both groups four weeks later. If we compare the examination results gained during both sessions we can conclude that we got almost the same results. One could expect that the time interval had change the situation in the control group significantly, 4 weeks is a long period of time for the development of some pathological changes due to injuries or illnesses. In summary 5 probands showed a difference, 3 had suffered a supination trauma, 2 have had a knee operation, 1 pain in the lumbar spine and 1 patient had a discus herniation in the lumbar columna. The muscles and ligaments that interconnect the lumbar spine with the pelvis can change the biomechanics of the lumbar spine and also change the position and function of the pelvis (Müller, 2000).

Between the first and second examination (4 weeks later) are not enough time for the development of degenerative changes. We did not expect changes in regard to the members of the proband group, because their activities were not limited during the break time. It means that pelvis position and malposition are relatively stable and a result of intensive endurance running.

8.3 Prevention

After having analysed the examination results of the pelvis in our sample and consequences of pathologies for the cause and effect chain in the lower extremities, it becomes evident that injury prevention is very important. If the pelvis position changes, this change directly influences neighbouring joints like the lumbar spine and joints of the whole lower extremities (Deleo, 2004). Cause and effect chains consist of hypertonic muscle chains (Richter and Hebgen, 2006). Muscle imbalances develop around each joint. Hypertonic muscles of the chain inhibit via spinal cord nerve reflexes (reciprocal inhibition) their antagonistic muscles. The muscle coordination around each joint change and the joints are more susceptible to overloading and injuries (Bizzini, 2000). For example, young long- distance runners whose pelvises do not function correctly could experience a lot of problems, not only in the knee joints but also in the lumbar spine (Hohmann and Wörther, 2005). If this dysfunction is not treated, it could cause further problems for the athlete. Especially a runner who competes on a high level might experience serious problems if an existing malfunction is not examined and treated. It might be the end of his career as an athlete. For example, competitive cross- country runners need a healthy pelvis which interacts correctly with the neighbouring joints, the hip and lumbar spine (Niemuth, 2005). Coaches also have to observe the runner´s movements and make sure that the athlete undergoes treatment as soon as possible.

An early diagnosis of a pelvic malposition and a cause and effect chain, which leads from the pelvis to the lower extremities, makes it possible to treat the runner as soon as possible. Such a treatment is very important from a preventative point of view because a joint in dysfunction is more susceptible to functional and mechanical overload (Brokmeier, 2001). The results of our work show that an examination of the pelvic function is necessary if the athlete suffers from a problem with the joints of the lower extremities. A pelvic malposition initiates a pathological cause and effect chain which runs to the lower extremities and has a negative effect on the function of the whole leg. Using diagnostic devices is very useful for this purpose. Hence, we developed the pelvimeter which can help with the diagnosis of a pelvic malposition.

Problems with the lumbar spine, the hip joint and the ankle could influence the sacroilical joint and the knee joint and cause dysfunctions (Deleo, 2004). Therefore, it is necessary to find out (as soon as possible) if a runner is experiencing problems. If the sports physiotherapist diagnoses the pelvis malposition early, it is relatively easy to treat it successfully. If the primary cause of the sacroiliacal joint block and the malposition of the os coxae are found too late, it is not as easy to treat it successfully. Especially if the runners have knee problems that are caused by a pelvic dysfunction and the sports physiotherapist does not find it in an examination, it could mean the end of the runners' career. Therefore, long distance runners have to undergo a standardized examination which takes place during a clearly defined period of time. In order to prevent further problems, the sacroiliacal joint and the os coxae have to be examined and treated if necessary. Our pelvimeter helps inexperienced, young therapists to examine the pelvic bones in bilateral comparisons.

Similarly, they can have problems with the manual treatment of joints and muscles, as it takes long time to build up manual skills which are necessary for successful treatment. During treatment, not only the symptoms have to be treated, but also the complete lower extremities (Richter and Hebgen, 2006). Very often the pelvic bone is not treated, although it functionally belongs to the lower extremities. Manual and technical methods may be used for examination and treatment (Frisch, 2003). Different methods of physical therapy are beneficial in order to relax the muscles, to reduce muscle and joint problems.

In regard to long distance runners, it is necessary to find out their primary problem and to treat it as soon as possible. If the sports physiotherapist, the trainer and the athlete work all together as a team, this can be realized. The athlete has to undergo a preventative examination and treatment. Beforehand, he has to check the dates with the sports physiotherapist and the trainer. This is a very important result of our study.

8.4 Clinical usage of the results

People who do other sorts of sports or people who do not do any sports at all can also suffer from pain of the knee joint as the result of a so-called cause-and-effect chain; you do not have to be an endurance runner (Kleindienst et al., 2006; Hohmann und Wörther, 2005). Problems within the knee joint itself are not necessarily the main cause for the pain during running. If this state lasts for a longer period of time, it can cause structural damage (Zalpour, 2002). Therefore, it is important to notice such a problem in time. We are sure that those factors influence one another, especially in regard to a constant loading of the joint for a longer period of time (e.g. arthrosis). Therefore it is important to check the iliosacral function as well, if one examines and treats the knee joint (Frisch, 2003). If there is an affection, one should examine and if necessary treat the pelvis, all the joints, the corresponding soft tissue and the lower extremities as well (the hip joint and the foot, too, if there is a so-called ascending cause-and-effect chain, s. below).

We believe also that a reason for the problems of the cause and effect chain is also the existence of physiological and pathological muscle chains. Walking is a natural human movement. Typical physiological muscle chains are realized during this movement. Similar muscle chains are used for running or for other sportive activities. But the muscle work is more intense and the muscle loading differs as well (Shumway- Cook and Woollacott, 1995). This can result in a joint block or muscle hypertonus somewhere in the locomotor apparatus (Steck et al., 2007).

Another important clinical outcome is the fact that the primary cause of a knee joint problem may be situated in another part of the human body. The reason for this is that each primary joint or muscle dysfunction subsequently develops a chain of joint blocks transmitted through the by the increase in the muscle tonus (muscle hypertonus) (Hodges, 2004). Unfortunately do most physiotherapists and sports physiotherapists only treat the painful area of their patients' bodies without taking the chaining into consideration (Werner et al., 2000).

For example, a supination trauma which is typical for endurance runners results in a muscle chain (mm. peronaeii, m. biceps caput longum) and a biomechanical chain (art. tibiofibularis and ilisocaral joint blocked) causing an os coxae posterior malposition. This was true for 3 members of our sample which suffered this trauma in the time between the first and second examination. Another example would be a so-called runners knee. We worked out that there is a correlation between the type of one -sided os coxae malpositions (os coxae anterior or os coxae posterior). An important message for physiotherapists is that clinical experience alone is not enough to improve their knowledge about relations inside the locomotor apparatus. Our work shows that the usage of even simple instruments is beneficial in order to achieve a better understanding of internal relations between joints and muscles. Further studies are needed in order to understand physiological and pathological muscle chaining which is very often the basis of pathological syndroms.

9. Conclusion

The study, which displays the relation of a pelvic malposition and knee problems as a *result of long distance running, has shown that a one- sided malposition of the iliac* bone can probably lead to functional changes in the lower extremities. This result is important to prevent further injury. It makes the examination and treatment of the runner possible, according to the chain in the whole lower extremities (including os coxae and sacroiliac joint). Early treatment is the best way to prevent injuries occurring due to loading which exists over a longer period of time.

We can accept the hypothesis because:

- the knee problem of all the members of the proband group was linked to an os coxae malposition on the same body side,
- sacroiliacal dysfunction in the proband group was present on the same body side where os coxae malposition and knee overloading were present, whereas most members of the control group did not suffer from an sacroliliacal dysfunction.
- os coxae deviation was much bigger in the proband group in comparison with the control group. This difference was statistically signíficant.

Further scientific research could clarify where the pain occurs and its causes. It could also clarify which stage of the treatment is the most successful one in regard to the cause and effect chain in the lower extremities.

10. Literature

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11. Lists

In this chapter the list of figures and the list of tables are described.

11.1 List of Figures

Figures in Appendix

11.2 List of Tables

Tables in Appendix

12. Appendix

12.1 Protocol

1. *Anamnese*

Date:

Name: Age:

Body height: Weight:

km/ week:

2. *Parameter of examination*

	Right	Left	Difference
1. Sitting forward test (side of dysfunction)			
2. Anatomic leg length (cm)			
3. Knee joint flexion/ extension (°)			
4. SIAS distance bilateral comparison (cm)			
5. Hip joint endorotation/ exorotation (°)			

Pain scale (subjective knee pain)

0 ________________________________ **100**

Comment

12.2 Handout

Therapie Reha-Zentrum Bottwartal

Jürgen Siegele & Team

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Melden Sie sich in unserem Zelt.
Wir führen eine Studie über Kniebeschwerden bei Ausdauerläufern durch.

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Figure 42: Flyer which was given to all long distance runners by the running events

12.3 Intertester correlation coefficients measurement methods

In this chapter the objectivity of gonimeter, tape measure and pelvimeter are described

12.3.1 Objectivity goniometer

Table 9: Test – retest correlation coefficients of goniometer measurement knee joint flexion on the right side of 3 different therapists

Correlations

		Rechts Test Goniometermessung knee flexion Therapeut 1	Rechts Retest Goniometermessung knee flexion Therapeut 1	Rechts Test Goniometermessung knee flexion Therapeut 2	Rechts Retest Goniometer messung knee flexion Therapeut 2	Rechts Test Goniometermessung knee flexion Therapeut 3	Rechts Retest Goniometermessung knee flexion Therapeut 3
Rechts Test Goniometermessung knee flexion Therapeut 1	Pearson Correlation	1	,957**	,955**	,954**	,945**	,914**
	Sig. (2-tailed)		,000	,000	,000	,000	,000
	N	10	10	10	10	10	10
Rechts Retest Goniometermessung knee flexion Therapeut 1	Pearson Correlation	,957**	1	,916**	,953**	,894**	,924**
	Sig. (2-tailed)	,000		,000	,000	,000	,000
	N	10	10	10	10	10	10
Rechts Test Goniometermessung knee flexion Therapeut 2	Pearson Correlation	,955**	,916**	1	,968**	,878**	,897**
	Sig. (2-tailed)	,000	,000		,000	,001	,000
	N	10	10	10	10	10	10
Rechts Retest Goniometermessung knee flexion Therapeut 2	Pearson Correlation	,954**	,953**	,968**	1	,907**	,903**
	Sig. (2-tailed)	,000	,000	,000		,000	,000
	N	10	10	10	10	10	10
Rechts Test Goniometermessung knee flexion Therapeut 3	Pearson Correlation	,945**	,894**	,878**	,907**	1	,878**
	Sig. (2-tailed)	,000	,000	,001	,000		,001
	N	10	10	10	10	10	10
Rechts Retest Goniometermessung knee flexion Therapeut 3	Pearson Correlation	,914**	,924**	,897**	,903**	,878**	1
	Sig. (2-tailed)	,000	,000	,000	,000	,001	
	N	10	10	10	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

Table 10: Test – retest correlation coefficients of goniometer measurement knee joint extension on the right side of 3 different therapists

Correlations

		Rechts Test Goniometermessung knee extension Therapeut 1	Rechts Retest Goniometermessung knee extension Therapeut 1	Rechts Test Goniometermessung knee extension Therapeut 2	Rechts Retest Goniometermessung knee extension Therapeut 2	Rechts Test Goniometermessung knee extension Therapeut 3	Rechts Retest Goniometermessung knee extension Therapeut 3
Rechts Test Goniometermessung knee extension Therapeut 1	Pearson Correlation	1	,927**	,835**	,902**	,878**	,820**
	Sig. (2-tailed)		,000	,003	,000	,001	,004
	N	10	10	10	10	10	10
Rechts Retest Goniometermessung knee extension Therapeut 1	Pearson Correlation	,927**	1	,850**	,958**	,811**	,856**
	Sig. (2-tailed)	,000		,002	,000	,004	,002
	N	10	10	10	10	10	10
Rechts Test Goniometermessung knee extension Therapeut 2	Pearson Correlation	,835**	,850**	1	,889**	,737*	,927**
	Sig. (2-tailed)	,003	,002		,001	,015	,000
	N	10	10	10	10	10	10
Rechts Retest Goniometermessung knee extension Therapeut 2	Pearson Correlation	,902**	,958**	,889**	1	,783**	,890**
	Sig. (2-tailed)	,000	,000	,001		,007	,001
	N	10	10	10	10	10	10
Rechts Test Goniometermessung knee extension Therapeut 3	Pearson Correlation	,878**	,811**	,737*	,783**	1	,791**
	Sig. (2-tailed)	,001	,004	,015	,007		,006
	N	10	10	10	10	10	10
Rechts Retest Goniometermessung knee extension Therapeut 3	Pearson Correlation	,820**	,856**	,927**	,890**	,791**	1
	Sig. (2-tailed)	,004	,002	,000	,001	,006	
	N	10	10	10	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 11: Test – retest correlation coefficients of goniometer measurement knee joint flexion on the left side of 3 different therapists

Correlations

		Links Test Goniometermessung knee flexion Therapeut 1	Links Retest Goniometermessung knee flexion Therapeut 1	Links Test Goniometermessung knee flexion Therapeut 2	Links Retest Goniometermessung knee flexion Therapeut 2	Links Test Goniometermessung knee flexion Therapeut 3	Links Retest Goniometermessung knee flexion Therapeut 3
Links Test Goniometermessung knee flexion Therapeut 1	Pearson Correlation	1	,929**	,849**	,917**	,911**	,788**
	Sig. (2-tailed)		,000	,002	,000	,000	,007
	N	10	10	10	10	10	10
Links Retest Goniometermessung knee flexion Therapeut 1	Pearson Correlation	,929**	1	,867**	,891**	,894**	,787**
	Sig. (2-tailed)	,000		,001	,001	,000	,007
	N	10	10	10	10	10	10
Links Test Goniometermessung knee flexion Therapeut 2	Pearson Correlation	,849**	,867**	1	,829**	,864**	,742*
	Sig. (2-tailed)	,002	,001		,003	,001	,014
	N	10	10	10	10	10	10
Links Retest Goniometermessung knee flexion Therapeut 2	Pearson Correlation	,917**	,891**	,829**	1	,786**	,778**
	Sig. (2-tailed)	,000	,001	,003		,007	,008
	N	10	10	10	10	10	10
Links Test Goniometermessung knee flexion Therapeut 3	Pearson Correlation	,911**	,894**	,864**	,786**	1	,875**
	Sig. (2-tailed)	,000	,000	,001	,007		,001
	N	10	10	10	10	10	10
Links Retest Goniometermessung knee flexion Therapeut 3	Pearson Correlation	,788**	,787**	,742*	,778**	,875**	1
	Sig. (2-tailed)	,007	,007	,014	,008	,001	
	N	10	10	10	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 12: Test – retest correlation coefficients of goniometer measurement knee joint extension on the left side of 3 different therapists

Correlations

		Links Test Goniometermessung knee extension Therapeut 1	Links Retest Goniometermessung knee extension Therapeut 1	links Test Goniometermessung knee extension Therapeut 2	Links Retest Goniometermessung knee extension Therapeut 2	Links Test Goniometermessung knee extension Therapeut 3	Links Retest Goniometermessung knee extension Therapeut 3
Links Test Goniometermessung knee extension Therapeut 1	Pearson Correlation	1	,927**	,875**	,891**	,863**	,868**
	Sig. (2-tailed)		,000	,001	,001	,001	,001
	N	10	10	10	10	10	10
Links Retest Goniometermessung knee extension Therapeut 1	Pearson Correlation	,927**	1	,805**	,849**	,748*	,823**
	Sig. (2-tailed)	,000		,005	,002	,013	,003
	N	10	10	10	10	10	10
links Test Goniometermessung knee extension Therapeut 2	Pearson Correlation	,875**	,805**	1	,828**	,917**	,828**
	Sig. (2-tailed)	,001	,005		,003	,000	,003
	N	10	10	10	10	10	10
Links Retest Goniometermessung knee extension Therapeut 2	Pearson Correlation	,891**	,849**	,828**	1	,775**	,889**
	Sig. (2-tailed)	,001	,002	,003		,008	,001
	N	10	10	10	10	10	10
Links Test Goniometermessung knee extension Therapeut 3	Pearson Correlation	,863**	,748*	,917**	,775**	1	,855**
	Sig. (2-tailed)	,001	,013	,000	,008		,002
	N	10	10	10	10	10	10
Links Retest Goniometermessung knee extension Therapeut 3	Pearson Correlation	,868**	,823**	,828**	,889**	,855**	1
	Sig. (2-tailed)	,001	,003	,003	,001	,002	
	N	10	10	10	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

12.3.2 Objectivity tape measure

Table 13: Test – retest correlation coefficients of tape measurement from 3 therapists of anatomic leg length on the right side

Correlations

		Rechts Test Tape meassure anat. leg length Therapeut 1	Rechts Retest Tape meassure anat. leg length Therapeut 1	Rechts Test Tape meassure anat. leg length Therapeut 2	Rechts Retest Tape meassure anat. leg length Therapeut 2	Rechts Test Tape meassure anat. leg length Therapeut 3	Rechts Retest Tape meassure anat. leg length Therapeut 3
Rechts Test Tape meassure anat. leg length Therapeut 1	Pearson Correlation	1	,995**	,987**	,987**	,991**	,996**
	Sig. (2-tailed)		,000	,000	,000	,000	,000
	N	10	10	10	10	10	10
Rechts Retest Tape meassure anat. leg length Therapeut 1	Pearson Correlation	,995**	1	,985**	,984**	,983**	,995**
	Sig. (2-tailed)	,000		,000	,000	,000	,000
	N	10	10	10	10	10	10
Rechts Test Tape meassure anat. leg length Therapeut 2	Pearson Correlation	,987**	,985**	1	,996**	,982**	,994**
	Sig. (2-tailed)	,000	,000		,000	,000	,000
	N	10	10	10	10	10	10
Rechts Retest Tape meassure anat. leg length Therapeut 2	Pearson Correlation	,987**	,984**	,996**	1	,986**	,993**
	Sig. (2-tailed)	,000	,000	,000		,000	,000
	N	10	10	10	10	10	10
Rechts Test Tape meassure anat. leg length Therapeut 3	Pearson Correlation	,991**	,983**	,982**	,986**	1	,989**
	Sig. (2-tailed)	,000	,000	,000	,000		,000
	N	10	10	10	10	10	10
Rechts Retest Tape meassure anat. leg length Therapeut 3	Pearson Correlation	,996**	,995**	,994**	,993**	,989**	1
	Sig. (2-tailed)	,000	,000	,000	,000	,000	
	N	10	10	10	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

Table 14: Test – retest correlation coefficients of tape measurement from 3 therapists of anatomic leg length on the left side

Correlations

		Links Test Tape meassure anat. leg length Therapeut 1	Links Retest Tape meassure anat. leg length Therapeut 1	Links Test Tape meassure anat. leg length Therapeut 2	Links Retest Tape meassure anat. leg length Therapeut 2	Links Test Tape meassure anat. leg length Therapeut 3	Links Retest Tape meassure anat. leg length Therapeut 3
Links Test Tape meassure anat. leg length Therapeut 1	Pearson Correlation	1	,994**	,984**	,990**	,994**	,989**
	Sig. (2-tailed)		,000	,000	,000	,000	,000
	N	10	10	10	10	10	10
Links Retest Tape meassure anat. leg length Therapeut 1	Pearson Correlation	,994**	1	,989**	,994**	,990**	,993**
	Sig. (2-tailed)	,000		,000	,000	,000	,000
	N	10	10	10	10	10	10
Links Test Tape meassure anat. leg length Therapeut 2	Pearson Correlation	,984**	,989**	1	,990**	,982**	,984**
	Sig. (2-tailed)	,000	,000		,000	,000	,000
	N	10	10	10	10	10	10
Links Retest Tape meassure anat. leg length Therapeut 2	Pearson Correlation	,990**	,994**	,990**	1	,991**	,996**
	Sig. (2-tailed)	,000	,000	,000		,000	,000
	N	10	10	10	10	10	10
Links Test Tape meassure anat. leg length Therapeut 3	Pearson Correlation	,994**	,990**	,982**	,991**	1	,995**
	Sig. (2-tailed)	,000	,000	,000	,000		,000
	N	10	10	10	10	10	10
Links Retest Tape meassure anat. leg length Therapeut 3	Pearson Correlation	,989**	,993**	,984**	,996**	,995**	1
	Sig. (2-tailed)	,000	,000	,000	,000	,000	
	N	10	10	10	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

12.3.3 Objectivity pelvimeter

Table 15: Test – retest correlation coefficients of pelvimeter measurement vertical differences of spinae iliacae anteriores superiores in bilateral comparison from 3 therapists

Correlations

		Test Differences spinae iliacae anteriores superiores Therapeut 1	Retest Differences spinae iliacae anteriores superiores Therapeut 1	Test Differences spinae iliacae anteriores superiores Therapeut 2	Retest Differences spinae iliacae anteriores superiores Therapeut 2	Test Differences spinae iliacae anteriores superiores Therapeut 3	Retest Differences spinae iliacae anteriores superiores Therapeut 3
Test Differences spinae iliacae anteriores superiores Therapeut 1	Pearson Correlation	1	,944**	,949**	,966**	,938**	,982**
	Sig. (2-tailed)		,000	,000	,000	,000	,000
	N	10	10	10	10	10	10
Retest Differences spinae iliacae anteriores superiores Therapeut 1	Pearson Correlation	,944**	1	,919**	,940**	,947**	,934**
	Sig. (2-tailed)	,000		,000	,000	,000	,000
	N	10	10	10	10	10	10
Test Differences spinae iliacae anteriores superiores Therapeut 2	Pearson Correlation	,949**	,919**	1	,966**	,908**	,970**
	Sig. (2-tailed)	,000	,000		,000	,000	,000
	N	10	10	10	10	10	10
Retest Differences spinae iliacae anteriores superiores Therapeut 2	Pearson Correlation	,966**	,940**	,966**	1	,953**	,961**
	Sig. (2-tailed)	,000	,000	,000		,000	,000
	N	10	10	10	10	10	10
Test Differences spinae iliacae anteriores superiores Therapeut 3	Pearson Correlation	,938**	,947**	,908**	,953**	1	,940**
	Sig. (2-tailed)	,000	,000	,000	,000		,000
	N	10	10	10	10	10	10
Retest Differences spinae iliacae anteriores superiores Therapeut 3	Pearson Correlation	,982**	,934**	,970**	,961**	,940**	1
	Sig. (2-tailed)	,000	,000	,000	,000	,000	
	N	10	10	10	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

12.4. Measurement values of reliability coefficients

12.4.1 Measurement values goniometer

Table 16: Test and retest values of Goniometer (°) measurement of knee joint flexion and extension of both sides by first therapists

Right test goniometer-measure knee flexion therapist 1	Right retest goniometer-measure knee flexion therapist 1	Left test goniometer-measure knee flexion therapist 1	Left retest goniometer-measure knee flexion therapist 1	Right test oniometer-measure knee extension therapist 1	Right retest goniometer-measure knee extension therapist 1	Left test goniometer-measure knee extension therapist 1	Left retest goniometer-measure knee extension therapist 1
138	137	134	136	8	7	7	6
141	140	144	143	5	4	6	7
142	141	137	135	12	10	11	9
135	137	132	131	4	3	6	7
149	148	144	145	11	14	13	15
137	135	140	143	7	5	4	6
145	143	138	140	10	12	13	15
137	138	133	131	8	7	5	3
149	151	148	146	14	16	12	13
139	139	141	144	9	7	6	7

Table 17: Test and retest values of goniometer (°) measurement of knee joint flexion and extension of both sides by second therapists

Right test goniometer-measure knee flexion therapist 2	Right retest goniometer-measure knee flexion therapist 2	Left test goniometer-measure knee flexion therapist 2	Left retest goniometer-measure knee flexion therapist 2	Right test goniometer-measure knee extension therapist 2	Right retest goniometer-measure knee extension therapist 2	Left test goniometer-measure knee extension therapist 2	Left retest goniometer-measure knee extension therapist 2
137	138	135	136	8	7	6	8
139	140	144	143	6	5	8	5
140	141	138	137	9	10	12	14
136	137	135	134	2	4	3	4
148	150	141	143	14	13	12	14
138	136	142	138	5	4	3	8
146	145	135	139	8	11	12	14
139	140	131	135	8	6	3	2
147	148	143	147	12	13	9	12
140	141	144	146	10	9	8	5

12.4.2 Measurement values tape measure

Table 18: Test and retest values (cm) on both sides with tape measure to test the anatomic leg length (therapist 1)

Right test tape measure anat. leg length therapist 1	Right retest tape measure anat. leg length therapist 1	Left test tape measure Anat. leg length therapist 1	Left retest tape measure anat. leg lenght therapist 1
89,4	89,6	88,9	89,1
86,7	86,9	87,5	87,3
92,5	92,2	91,6	91,8
87	86,7	88,6	88,4
85,8	85,5	87,1	86,8
93,4	93,1	94,1	93,8
90,2	90,4	91,5	91,6
88,1	87,7	86,5	86,8
87,9	87,6	88,5	88,9
89,6	89,4	88,3	88,1

Table 19: Test and retest values (cm) on both sides with tape measure to test the anatomic leg length (therapist 2)

Right test tape measure anat. leg length therapist 2	Right retest tape measure anat. leg length therapist 2	Left test tape measure anat. leg length therapist 2	Left retest tape measure anat. leg lenght therapist 1
89,4	89,2	89,7	89,6
86,5	86,9	87,4	87,7
92,1	92,4	91,8	91,6
86,7	86,9	88,3	88,4
85,9	85,5	87,3	86,9
93,0	93,4	94,4	93,8
90,5	90,7	91,3	91,8
88,6	88,7	86,9	86,8
87,3	87,4	88,9	88,6
90,1	90,4	87,6	87,9

Table 20: Test and retest values (cm) on both sides with tape measure to test the anatomic leg length (therapist 3)

Right test tape measure anat. leg length therapist 3	Right retest tape measure anat. leg length therapist 3	Left test tape measure anat. leg length therapist 3	Left retest tape measure anat. leg lenght therapist
89,1	89,3	89,6	89,8
86,7	86,4	87,3	87,6
92,4	92,1	91,9	91,6
87,3	86,7	88,4	88,6
85,7	85,4	87,0	86,7
93,5	92,9	94,3	93,8
89,8	90,3	91,8	91,7
87,8	87,9	86,3	86,8
87,4	87,6	88,3	88,6
90,2	89,8	88,6	88,4

12.4.3 Measurement values pelvimeter

Table 21: Test and retest values of SIAS deviation (cm) in bilateral comparison from all 3 therapists

Test differences spinae iliacae anteriores superiores therapist 1	Retest differences spinae iliacae anteriores superiores therapist 1	Test differences spinae iliacae anteriores superiores therapist 2	Retest differences spinae iliacae anteriores superiores therapist 2	Test differences spinae iliacae anteriores superiores therapist 3	Retest differences spinae iliacae anteriores superiores therapist 3
0,4	0,4	0,5	0,4	0,4	0,5
0,7	0,6	1	0,9	0,6	0,9
0,2	0,3	0,1	0,4	0,3	0,2
0,5	0,6	0,3	0,5	0,7	0,6
1,2	1,3	1,5	1,6	1,3	1,5
0,8	0,9	0,7	0,8	0,6	0,9
0,5	0,5	0,6	0,7	0,5	0,7
1,5	1,7	1,8	1,9	1,4	1,6
0,7	0,4	0,5	0,8	0,6	0,7
0,4	0,6	0,5	0,7	0,6	0,5

12.5 Validity

In this chapter the values from the optic system simi 3-D and pelvimeter in comparison are shown for the calculation of validity. Than the measurement instrument simi 3-D is described (Biomechanic institute, University of Tübingen).

12.5.1 Values calculation of validity

Table 22: Measurement values (cm) of SIAS position from optic system simi 3- D In comparison with pelvimeter

SIAS position	Optic system	Pelvimeter
right anterior	0,3	0,3
right posterior	0,5	0,4
left posterior	0,4	0,3
right anterior	1,1	1,2
left anterior	0,4	0,4

12.5.2 Measurement instrument simi 3 D

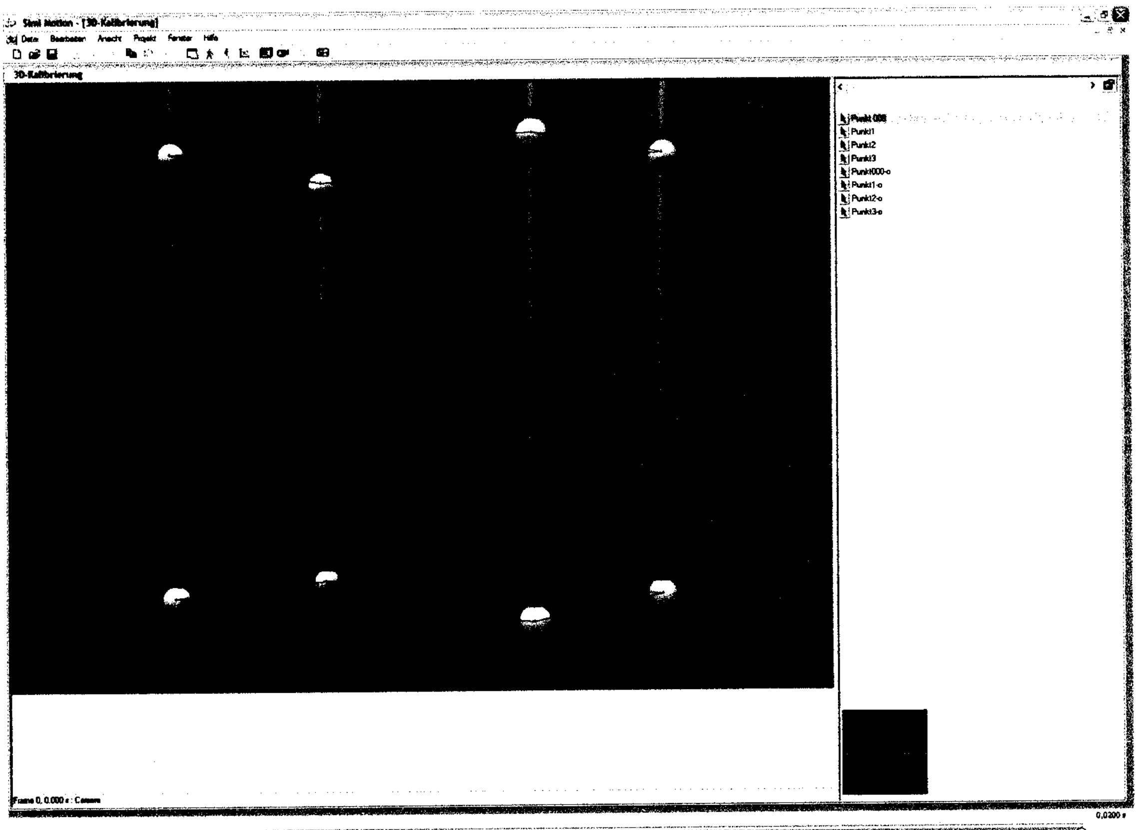

Figure 43: Calibration of simi 3- D measurement in biomechanical institute

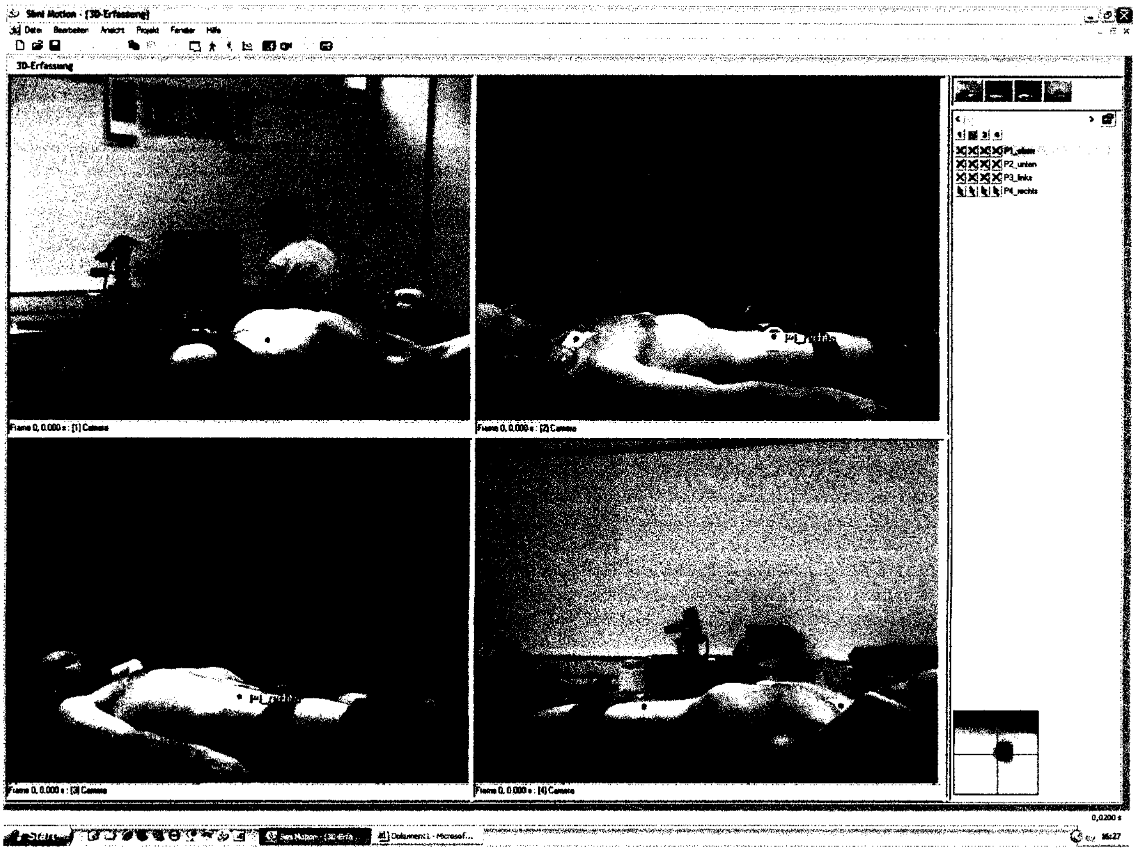

Figure 44: Simi 3- D measurement process of SIAS deviation (cm) in biomechanical institute

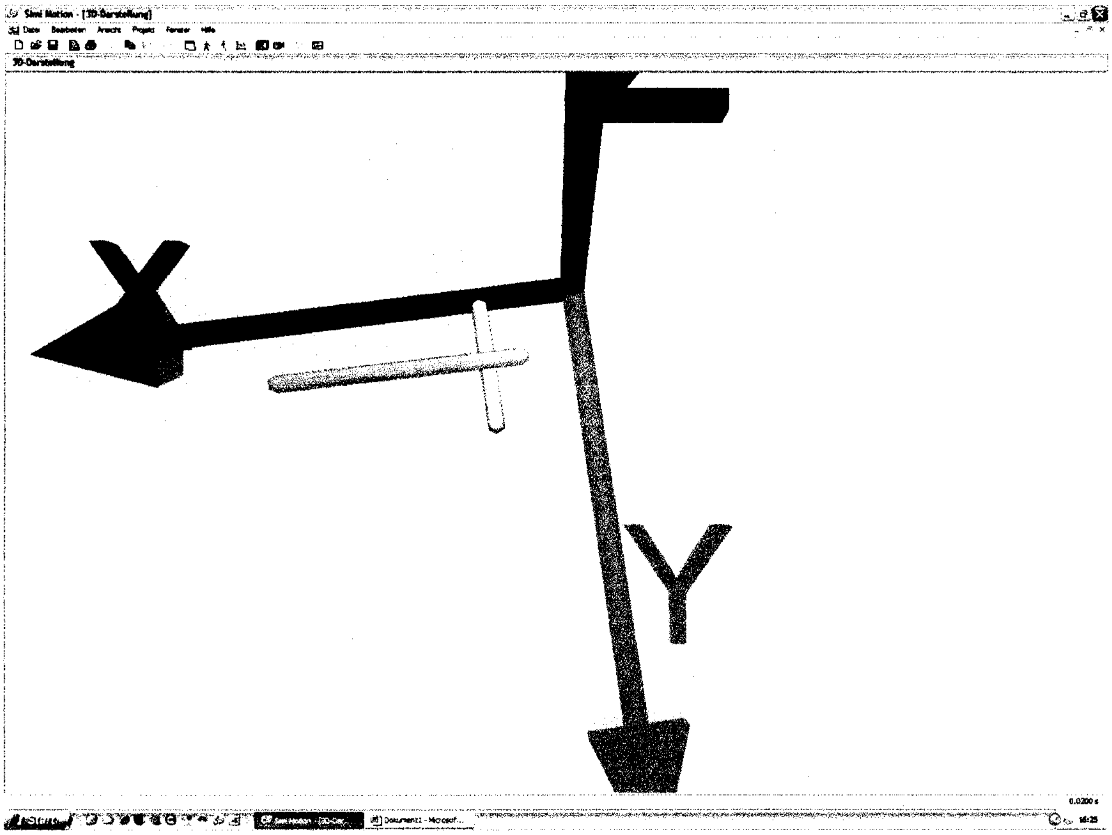

Figure 45: Bilateral comparison of SIAS correlation is drawn in direction of x- axis – by simi 3-D Instrument

12.5.3 Measurement instrument pelvimeter

We developed the pelvis measuring instrument in order to carry out this study.

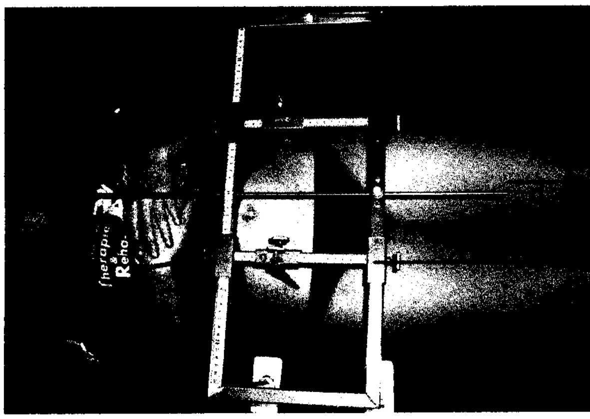

Figure 46: Pelvimeter in front view

The pelvis measuring instrument stands on four height adjustable support pillars (1). The instrument is being placed over the patient's pelvis (Figure 50). Two libellas (2) are used for the horizontal adjustment of the measuring instrument. The measure pens (3) are placed on the spina ilica anteriores superiors (SIAS). The position may be achieved by opening and then moving the pens through the knurled nut (5). The patient's axial position is realized by aligning the tubular steel with the patient's tip of the nose, his incissura jugularis, his navel and his symphysis. The cranio- caudal distance of the SIAS may be read on the scale (7).

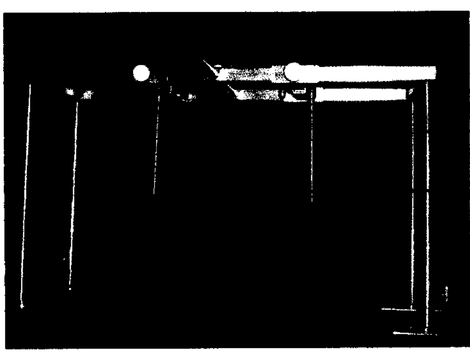

Figure 47: Pelvimeter in side view

12.6 Supplement tests and statistic values of the results

In this chapter are the values of the Kolomogorov- Smirnov- test, the t-tests and correlations are shown.

12.6.1 Normal deviation

Table 23: Results of Kolomogorov- Smirnov- test for the variables SIAS deviation and subjective pain scale in proband group. There is no significance in both cases and therefore we can assume normal distribution of the data

One-Sample Kolmogorov-Smirnov Test

		SIAS deviation	pain scale
N		50	50
Normal Parameters[a,b]	Mean	,8660	62,24
	Std. Deviation	,40285	13,263
Most Extreme Differences	Absolute	,146	,103
	Positive	,146	,101
	Negative	-,084	-,103
Kolmogorov-Smirnov Z		1,035	,727
Asymp. Sig. (2-tailed)		,234	,666

a. Test distribution is Normal.

b. Calculated from data.

Table 24: Results for Kolomogorov Smirnov- test for the variables SIAS deviation in control group. The test is not significant and therefore we can assume normal distribution of the data

One-Sample Kolmogorov-Smirnov Test

		SIAS deviation
N		50
Normal Parameters[a,b]	Mean	,2980
	Std. Deviation	,13775
Most Extreme Differences	Absolute	,162
	Positive	,162
	Negative	-,150
Kolmogorov-Smirnov Z		1,143
Asymp. Sig. (2-tailed)		,147

a. Test distribution is Normal.

b. Calculated from data.

12.6.2 Average and t-tests

Table 25: Mean, standard deviation and standard error of mean values of SIAS deviation in proband and control group

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
SIAS deviation	Probands	50	,8660	,40285	,05697
	Control Group	50	,2980	,13775	,01948

Table 26: Mean, standard deviation and standard error of mean values of SIAS deviation and SIAS deviation 4 weeks later (proband group)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SIAS deviation	,8521	48	,40053	,05781
	SIAS deviation four weeks later	,8625	48	,45271	,06534

Table 27: Results of t- test from test and retest of SIAS deviation. The test is not significant t= -0.326, df = 47, p=0.476. It means that there is no statistic significance difference between the both measurements

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	SIAS deviation - SIAS deviation four weeks later	-,01042	,22145	,03196	-,07472	,05388	-,326	47	,746

Table 28: Correlation coefficient between SIAS deviation and subjective pain scale r= 0.296 is statistically significant (p= 0.037).

Correlations

		SIAS deviation	pain scale
SIAS deviation	Pearson Correlation	1	,296*
	Sig. (2-tailed)		,037
	N	50	50
pain scale	Pearson Correlation	,296*	1
	Sig. (2-tailed)	,037	
	N	50	50

*. Correlation is significant at the 0.05 level (2-tailed).

12.7 Measurement data

Values of measurements from the 100 sample: group Nr. (1= proband group, 2 = control group), SIAS localisation *pretest* (La 1= left anterior, Lp 2= left posterior, Ra 3 = right anterior, Rp 4 = right posterior), subjective pain in a scale between 0 (no pain) and 100 (not able to run), gender in man (0) and women (1), age of probands in years, body high in cm, body weight in kg, loading per week (km), SIAS localisation *retest* (La 1= left anterior, Lp 2= left posterior, Ra 3 = right anterior, Rp 4 = right posterior), anatomic leg length (cm, right0 1, left= 2),knee flexion (°) on the right and left side, Hip joint (°) in endorotation and exorotation on the right and left side. 999 means missing values (no data in control group by knee pain because they had no pain). The other measurement data are described in chapter 7 (Results).

Table 29: Measure values of the sample

Group Nr.	Nr.	SIAS Local. La=1 Lp=2 Ra=3 Rp=4	Pain scale	Gender m=0 w=1	Age years	Body high (cm)	Body weight (Kg)	Km weekly	SIAS local. pretest La=1 Lp=2 Ra=3 Rp=4	Anatom. leg length (cm) r=1	Anatom. leg length (cm) l=2	Knee flex (°) right	Knee ext (°) right	Knee flex (°) left	Knee ext (°) left	Hip endo (°) right	Hip exo (°) right	Hip endo (°) left	Hip exo (°) left
1	1	1	67	1	37	169	61	45	1	83,9	84,2	139	8	138	6	36	42	39	40
1	2	1	42	0	49	178	73	50	1	89,3	89,7	143	6	142	6	46	36	41	39
1	3	2	74	1	39	167	55	60	2	84,1	84	136	4	140	7	35	43	41	47
1	4	3	40	1	45	170	64	40	3	85,7	86,1	132	4	141	8	40	36	37	37
1	5	3	43	0	49	184	75	60	3	90,8	92,1	137	3	139	2	42	37	38	40
1	6	3	47	0	50	170	65	90	3	86,7	86,2	143	8	138	5	41	37	38	34
1	7	3	75	0	47	181	76	45	3	89,3	88	142	6	137	3	41	36	40	37
1	8	4	68	0	34	179	74	45	4	91,7	91,9	135	7	130	7	45	46	42	46
1	9	2	64	1	29	178	65	50	2	90,1	90,9	134	8	135	7	42	35	39	38
1	10	2	77	0	35	183	76	55	2	94,6	94,7	143	9	136	2	38	35	39	38
1	11	2	83	1	47	168	59	50	2	85,3	86,5	136	4	134	4	36	40	37	42
1	12	4	43	1	46	167	58	45	4	86,9	86,6	136	5	142	7	41	39	39	35
1	13	3	47	0	34	183	77	50	3	92,7	92,4	139	6	140	8	39	36	38	35
1	14	3	48	0	46	179	71	60	3	89,4	89,8	139	5	140	4	37	39	39	40
1	15	4	64	0	44	179	73	50	4	90,8	90,3	139	3	137	5	37	37	41	36
1	16	3	65	0	37	185	76	60	3	92,6	92,8	137	2	136	5	41	37	39	36
1	17	3	46	0	34	177	72	50	4	88,7	89,3	135	5	139	3	39	35	38	34
1	18	3	46	0	48	182	75	70	3	92,5	92,5	137	3	138	2	38	35	38	34
1	19	3	57	1	46	168	57	50	3	85,3	86,6	138	3	135	5	37	38	37	35
1	20	2	65	1	47	166	54	60	2	83,9	83,1	128	6	132	5	41	36	39	36
1	21	4	63	1	30	171	64	60	4	86,4	86,2	138	7	140	9	42	37	41	39
1	22	3	57	0	40	180	71	60	3	91,3	90,2	141	5	138	8	36	38	39	36

1	23	2	67	1	25	169	64	50	0	87	86,5	143	4	140	8	43	37	39	36
1	24	2	79	0	43	187	78	40	2	94,7	93,6	139	4	134	4	37	38	42	35
1	25	1	43	0	42	184	73	60	1	92,4	91,9	142	4	139	6	41	36	38	39
1	26	2	79	0	45	182	77	65	2	92,5	92,1	143	5	141	5	38	36	39	39
1	27	2	68	1	39	169	64	50	4	85,2	85,7	142	7	139	4	42	35	39	38
1	28	3	65	1	49	168	62	60	3	88,5	88,2	134	5	138	2	36	34	31	38
1	29	2	71	0	41	171	68	50	2	87,9	88,3	132	2	128	0	32	31	29	28
1	30	3	61	0	39	179	73	50	3	90	90,6	129	0	132	4	41	38	37	38
1	31	2	72	0	51	179	81	45	2	92	91,2	132	6	126	10	35	36	36	38
1	32	2	79	0	43	186	72	40	2	98,1	98	138	8	140	5	40	30	48	32
1	33	2	87	0	32	173	68	50	2	88,4	87,9	145	7	148	4	45	43	40	41
1	34	3	58	0	37	165	59	70	3	85,5	85,3	138	9	140	6	45	37	41	40
1	35	1	53	0	48	184	65	60	1	94,2	93,7	138	4	140	7	42	44	48	41
1	36	1	63	1	23	180	75	50	1	90,1	89,8	137	7	135	9	41	33	37	36
1	37	4	77	1	27	163	49	55	4	80,2	79,8	132	5	133	8	46	48	49	47
1	38	4	72	0	42	175	60	70	4	85,1	85,4	129	6	128	8	38	43	41	46
1	39	1	56	1	29	166	52	50	1	80,9	80,7	145	9	140	6	46	36	47	38
1	40	2	73	1	31	171	55	60	2	87,5	87,6	145	8	141	11	48	36	46	39
1	41	3	38	1	26	165	52	90	3	84,4	84,8	138	7	133	8	48	45	47	48
1	42	3	46	1	24	169	60	40	3	86,8	86	136	8	140	5	49	38	50	34
1	43	2	75	0	25	177	72	60	2	90,8	91,2	133	8	135	5	34	32	33	35
1	44	2	82	0	21	188	76	55	0	91,5	92,2	143	6	142	10	38	35	40	32
1	45	2	67	0	47	189	78	65	2	96	96,5	142	4	137	8	45	34	42	36
1	46	2	74	0	50	174	65	40	2	86,9	86,2	131	2	133	0	41	36	39	38
1	47	3	49	0	41	185	73	70	3	95,5	95,1	138	5	134	10	35	31	40	34
1	48	4	75	0	37	181	76	60	4	92,5	91,8	142	5	139	7	39	41	37	37
1	49	2	74	0	32	182	74	50	2	91,8	91,3	143	7	141	8	42	38	39	40
1	50	3	63	0	43	179	71	80	3	90,5	91,2	137	7	141	5	41	43	46	39
2	51	3	999	1	45	176	70	45	3	86,4	86,2	138	7	140	9	42	37	41	39
2	52	3	999	1	21	164	58	60	4	83,5	83,2	142	10	140	10	40	30	42	28

2	53	3	999	0	47	178	67	55	3	88,2	89,2	141	8	139	8	39	22	40	31
2	54	2	999	1	27	169	55	40	1	86	86,6	136	6	132	8	35	39	32	37
2	55	3	999	0	27	180	66	45	3	91,7	91,3	145	0	141	5	40	29	45	30
2	56	0	999	0	29	178	69	50	2	90,7	90,4	140	9	145	9	32	37	30	38
2	57	3	999	1	30	174	58	40	3	98,3	98	141	10	144	10	46	34	48	41
2	58	4	999	0	24	183	72	80	4	91,1	91,3	142	0	146	5	40	30	37	35
2	59	3	999	0	31	178	72	50	3	90,4	90,5	131	8	134	7	46	48	49	47
2	60	1	999	1	25	156	44	60	1	74,4	74,9	145	11	140	14	49	38	47	36
2	61	3	999	1	26	167	58	50	3	83,8	84,1	146	8	148	5	41	50	38	49
2	62	3	999	1	32	163	55	40	3	82,2	81,9	143	10	147	7	46	48	51	48
2	63	3	999	1	20	165	53	60	3	82,3	81,9	148	10	149	8	50	38	47	40
2	64	4	999	1	24	168	62	70	4	80,8	81,4	133	9	136	5	45	39	42	36
2	65	3	999	0	21	167	62	40	4	85,1	84,8	145	8	148	10	47	44	50	42
2	66	3	999	1	22	171	64	50	3	87,6	88,2	148	8	146	6	52	39	49	38
2	67	2	999	0	26	184	67	70	2	92,5	93	135	4	138	5	38	30	35	28
2	68	3	999	1	28	175	69	40	3	89,7	90,1	134	5	130	6	43	31	39	34
2	69	3	999	1	24	170	65	60	3	85,2	85,5	142	10	140	9	43	36	40	38
2	70	3	999	1	24	179	65	50	4	91,1	90,8	139	6	135	10	41	39	40	41
2	71	3	999	0	22	180	74	70	0	92	91,3	132	7	135	6	47	38	52	44
2	72	0	999	0	32	171	65	70	1	87,8	88,9	145	6	144	7	39	35	42	34
2	73	3	999	0	24	181	72	65	3	88,4	88,5	143	10	145	11	40	42	42	39
2	74	4	999	0	41	185	74	60	4	93,4	94,2	140	10	135	7	40	35	38	37
2	75	4	999	0	28	179	73	60	4	89,1	90,4	137	5	141	8	40	32	38	36
2	76	3	999	1	23	160	49	65	3	81,7	81,3	148	10	146	7	48	35	45	32
2	77	3	999	0	21	181	67	40	3	87,9	88,2	140	7	141	6	39	39	40	39
2	78	4	999	0	20	178	69	50	4	90,7	91	138	8	137	11	48	38	51	32
2	79	4	999	1	24	174	59	45	4	89,8	89,5	145	8	144	10	41	42	35	47
2	80	3	999	1	28	172	65	50	3	88,7	88,4	142	10	145	7	40	32	41	30
2	81	1	999	0	25	181	65	90	1	94,5	94	142	5	137	10	40	29	41	28
2	82	3	999	1	22	173	64	55	3	87,5	87	148	10	150	8	50	41	49	36

2	83	2	999	1	24	165	59	40	2	81,9	82,3	144	3	142	5	42	33	39	31
2	84	3	999	1	29	165	48	70	3	82,4	82	140	4	143	4	37	35	40	30
2	85	1	999	0	27	183	76	50	1	93,2	92,8	138	5	135	10	35	38	38	33
2	86	3	999	0	23	191	77	60	3	96,5	96,9	140	5	138	8	36	31	33	33
2	87	3	999	0	50	183	74	70	3	92	91,4	145	0	140	2	42	34	35	37
2	88	2	999	1	25	168	53	45	2	83,3	82,9	138	8	142	6	37	38	40	42
2	89	3	999	1	26	165	57	50	3	83,9	84,1	145	9	142	11	42	35	47	32
2	90	3	999	1	24	165	53	70	4	83,2	83,9	130	5	132	7	41	35	38	37
2	91	3	999	0	36	188	79	55	3	95,9	96,3	135	8	136	6	35	36	38	35
2	92	1	999	0	34	178	71	50	1	90,1	91,2	142	9	142	4	41	22	41	38
2	93	4	999	0	46	178	70	65	0	88,6	89	142	5	138	6	41	35	37	38
2	94	2	999	1	45	175	68	60	2	90,5	89,6	141	5	136	8	38	36	36	38
2	95	4	999	1	26	160	59	50	4	78,5	78,9	141	6	140	10	38	41	40	40
2	96	1	999	0	49	188	75	65	2	94,9	95,5	141	7	143	5	35	37	34	32
2	97	3	999	0	32	178	65	60	3	91,2	91,7	132	5	137	8	42	35	39	37
2	98	1	999	1	31	172	63	40	1	86,7	87,5	141	5	139	8	41	36	43	37
2	99	3	999	0	49	184	73	50	3	94,9	93,8	139	6	141	5	39	35	36	37
2	10	1	999	0	29	186	75	70	1	92,9	93,5	131	5	135	3	40	37	43	35