General Introduction
Low back pain is a burden of our times and a challenge for medical scientists due to a large variability of complaints, differences in course and prognosis, and the lack of unambiguous diagnostic criteria and successful treatment options. Thousands of investigations could not provide enough knowledge to make low back pain a disorder of the past. According to a worldwide scientific appraisal, low back pain is a leading cause of years lived with disability, with the prevalence of 9.17%, with 9.64% among men, and 8.7% among women.¹ According to a recent survey, 63.5% of interviewed people reported having had low back pain lasting for at least one day in their lifetime.² Only part of the low back complaints can be attributed to specific causes, such as fractures, malignancy, osteoporosis, or rheumatic diseases. In the majority of cases the cause is unclear. In the last three decades, an increasing amount of research has been performed on low back pain, aiming at better subgrouping of the patients with benign low back pain complaints. Still, the diagnostic management of patients with low back pain varies considerably among different healthcare professionals, and usually patients receive a diagnosis of non-specific low back pain. There are different diagnostic tools, which are based on the anatomical localization of pain, patient history, and physical examination findings, in an attempt to make a more specific diagnosis in patients with low back pain. Also, diagnostic blocks are used to make a more specific diagnosis, including facet joint injections, lumbar disc, and sacroiliac joints.³⁻⁵ These blocks are given to the patient to eliminate the pain from a particular anatomical structure that is suspected to be involved in generation of pain. The problem, however is, the selection of the patients for the accurate diagnostic block. In this thesis we will focus on one of the causes of non-specific low back pain, namely the sacroiliac joint (SI joint).

The SI joint connects the sacrum to the iliac bones. The antero-caudal part of the SI joint is synovial, whereby the facies auricularis of sacrum is connected bilaterally to the facies auricularis of the iliac bones. The postero-cranial part is a ligamentous syndesmosis. An articular capsule closes the synovial part of the SI joint, and is reinforced anteriorly by the anterior ligament, and dorsally by interosseal ligament and dorsal ligaments. Three accessory ligaments, the sacrotuberous, sacrospinous and iliolumbar ligament support the SI joint, limiting its movements. The SI joint cannot function independently because the gluteal muscles, together with piriformis muscle are shared with the hip joint, whereas the erector spinae and psoas muscle with the
lumbar spine. Although none of these muscles is capable to act on the SI joint to produce active, physiological movements, the movements may be indirectly encouraged by the muscles action on trunk and lower limbs. However, ranges of motion in the SI joint are very limited. If we stand upright from lying, a tilting movement of the sacrum in relation to the iliac bones occurs. Also bending forward and backwards causes movements in SI joint, but in general the rotations do not exceed mean of 2.5 degrees (0.8 degree-3.9 degrees), or mean, 0.7 mm (0.1-1.6 mm). There is no gender difference in the SI joint movement ability, with the exception of pregnancy, whereby due to hormonal influences the mobility in the female pelvic region increases, enabling the delivery.

According to anatomy textbooks the nerves of lumbo-sacral plexus innervate the SI joint. The posterior innervation is provided mainly by the lateral branches of the posterior rami S1–S2, but also by S3. Contrary to the well-studied dorsal innervation, the anterior nerve supply to the SI joint remains unclear. Older findings suggesting that the ventral aspect of the SI joint is innervated by the nerves of the plexus lumbo-sacral (mainly segments L3–S2) are not confirmed by recent studies. Furthermore, myelinated and unmyelinated nerve fibers were found in dorsal ligaments of the SI joint and in the ventral capsule of the SI joint in human. Although the staining techniques used in these histological studies are suitable to show the morphological characteristics of nerve structures, they are not capable to distinguish between different types of neurotransmitters and neuropeptides, and therefore are not sufficient for functional discrimination of labeled nerve fibers.

Considering the anatomy, one can divide the SI joint pathology into intra-articular (infection, arthritis, spondyloarthopathies, malignancies) and peri-articular, or extra-articular causes (enthesopathy, fractures, ligamentous injuries and myofascia). However, as in most low back pain complaints, often no specific explanation for the SI related complaints can be found. Unidirectional pelvic shear stress, repetitive torsional forces, and inflammation, can all give rise to SI joint pain. Risk factors for pelvic pain include leg length difference, abnormal gait pattern, trauma, scoliosis, lumbar fusion surgery with fixation of the sacrum, heavy physical exertion, and pregnancy.
The prevalence of the SI joint pain in patients suffering from low back pain, is estimated on 13-30\%\textsuperscript{19}, and depends highly on applied diagnostic criteria. According to the International Association for the Study of Pain, the SI joint pain should 1) originate from the anatomical region of the SI joint, and 2) be reproduced by specific pain provocation tests, or 3) completely relieved by the selective infiltration of local anesthetics into this joint. However, the diagnostic accuracy of these criteria is not well studied. Regarding the first IASP criterion, the literature suggests that SI joint-related pain, though originating from the SI joint, can have a diffuse character and can refer to the buttock, groin and/or lower extremity.\textsuperscript{20-22} However, the typical location of SI joint pain overlies the dorsal aspect of the SI joint, adjacent to the posterior superior iliac spine (PSIS), also called the "Fortin area", which is consistent with findings by Van der Wurff et al., who showed that in patients with SI joint pain, pain is most intense in this area.\textsuperscript{20,22} Dreyfuss et al. used palpation tenderness in this area to diagnose SI joint pain, but it appeared to have poor diagnostic accuracy, as it has very low specificity.\textsuperscript{23} This may be the result of the fact that standardization of the manner in which pressure is applied with the palpation test is difficult, and may lead to different outcomes between different experts.

With respect to the second IASP criterion, there are several pain-provocation tests described, which intend to stretch or compress tissue structures related to the SI joint. However, the reliability (except for the Gaenslen test and thigh thrust test) as well as validity of these tests in clinical practice is a point of discussion.\textsuperscript{24} The third IASP criterion addresses the selective infiltration of the SI joint, whereby a local anesthetic is injected in the joint cavity (synovial part of the SI joint). This criterion is often used as a reference standard in diagnosing SI joint pain.\textsuperscript{19,23,25,26} However, the sensitivity and specificity of this technique are questionable.\textsuperscript{27} A precondition for the effectiveness of this infiltration is blocking pain-signaling structures. Based on the general anatomical knowledge, one could assume, that pain-signaling structures, i.e. nociceptors can be found in articular structures such as the ventral capsule, as well as in peri-articular structures such as the anterior, posterior and interosseous ligaments, subchondral bone of the ilium and sacrum. Therefore, not only synovial part of the joint, but also peri-synovial structures, like ligaments and muscles should be considered in the diagnosis.\textsuperscript{28}
Furthermore, according to reviews published in the last decade, utilization of multiple diagnostic tests in physical examination should be applied, instead of relying on the result of a single test. As there are many unanswered questions regarding SI joint pain; this thesis will focus on assessment of the diagnostic accuracy of the IASP criteria in their ability to discriminate among the individuals with and without SI joint pain.

*Aim and outline of this thesis*

The main aim of this thesis is to contribute to the assessment of SI joint pain. We intend to conduct two lines of investigation. First one will be focused on improvement of anatomical knowledge of the SI joint, particularly on the distribution of nociceptors in SI joint. The second one will focus on the validity of the diagnostic criteria for SI joint pain. In chapter 2 and 3 we describe the anatomical structures involved in the SI joint, which are capable to produce pain, and attempt to provide new insights into the pathogenesis of SI joint pain. As mentioned previously, the IASP proposed three criteria for diagnosing SI joint pain. To assess the validity of IASP criteria diagnostic algorithm commonly used in clinical practice, we perform a systematic review of the literature, of which the results are described in chapter 4. The main purpose of this review was to determine whether the diagnostic criteria, as proposed by the IASP are capable to discriminate between individuals with and without SI joint pain. The evaluation comprised the methodological assessment of the studies and the summary of the diagnostic validity by sensitivity, specificity and diagnostic odds ratio of diagnostic tests. In chapter 5 we will assess whether pressure pain originating for the anatomical region of SI joint can be measured reliably. For this purpose we evaluate the inter-examiner reliability of pressure algometry using a manual dynamometer, and establish normal values for the pain pressure thresholds in the SI joint region in healthy volunteers, and patients with SI joint pain. In chapter 6 we describe the distribution of the injected medications in the SIJ. In this study we inject a contrast medium in SI joint region of 7 human cadavers, using different approaches, and visualize its spread with a CT scan. According to the third IASP criterion, SI joint pain should be completely relieved by infiltration of local anesthetics into the joint. However, there is no consensus about the medications that should be used for this purpose. Therefore, in chapter 7 we describe de results of a study whereby we compare the effectiveness of standard used
medications with the placebo. Our goal was to determine the effect and the duration of the effect of the infiltration of the SI joint in patients with benign chronic low back pain. General information about SI joint and diagnostic and treatment options for SI joint pain are discussed in chapter 8.
Reference List


16. Schoenberger M, Hellmich K. [Sacroiliac dislocation and scoliosis]. Hippokrates


