Satakunnan ammattikorkeakoulu
Satakunta University of Applied Sciences

MARTA HEDVIGA OŠE

Risk and prevalence of osteoarthritis of the sound limb in lower limb amputees

Systemized literature review

DEGREE PROGRAMME IN PHYSIOTHERAPY
2024

Author(s)	Type of Publication	Date
Marta Hedviga Oše	Bachelor's thesis	08.01.2025
	Number of pages	Language of publication:
	57	English

Title of publication

Risk and prevalence of osteoarthritis of the sound limb in lower limb amputees

Degree Programme

Bachelor in Physiotherapy

Abstract

The overall amount of lower limb amputations performed in the world has been increasing over the years, the primary cause being diabetes mellitus and peripheral arterial disease. With the increase of the lower limb amputation cases worldwide, more individuals are in need of post-surgical rehabilitation, prosthesis education, gait training and education of the osteoarthritis preventative strategies.

As the lower limb amputation patients undergo rehabilitation, the health care team should be aware of the possible increased risks of osteoarthritis development in the joints of the sound leg. This should be taken into consideration early in the rehabilitation and the patient should be educated about the increased prevalence of developing osteoarthritis and the importance of the preventative strategies put in place.

Developing osteoarthritis in the sound, contralateral limb can add a considerable mental and physical burden for the amputees as their overall functioning and quality of life will be hugely impacted as the condition develops. Since there is no cure for this condition, extra attention should be put on the preventative strategies and management.

This thesis is a systemized literature review and assesses the research done on the topic, creating an overview of the evidence available.

Keywords

A comma separated list of the main keywords describing the content of your thesis.

Rehabilitation, physiotherapy, lower limb amputation, osteoarthritis

CONTENTS

1 INTRODUCTION

The instance of lower limb amputations (LLA) performed yearly in United States has been estimated to be around 150 000, the amount said to be increasing over each year (Molina & Faulk, 2022). Additionally, LLA makes up for around 85% of all amputations performed, making the individuals with LLA a major part of the amputation population (Parvizi & Kim, 2010, p.17). The decision for performing an amputation is made with great care, taking into consideration the patients' overall condition and the state of the tissue of the extremity. The main goal of the amputation is to remove the infected or the non-viable tissue and to determine the best level and coverage of the amputation place (Molina & Faulk, 2022).

A possible correlation between increased prevalence of osteoarthritis (OA) of the sound leg in the lower limb amputation (LLA) population has been studied for many years now. The possible reasonings for the increase is thought to be due to the altered gait, compensatory movements and asymmetry that impacts the limb load division, resulting in putting most of the load on the healthy leg. The possibility of development of OA for these individuals can lead to additive disability, increasing the difficulty of everyday living, functioning and having major consequences on their overall quality of life and independence (Morgenroth et al., 2012) (Doyle et al., 2019). The prevalence of OA of the sound leg in lower limb amputates have been studied for many years. For example, there are reports saying that the instance of developing knee osteoarthritis (KOA) in the sound leg is 10 times more likely in the amputee population than it is in non-amputees (Pouyan Mehryar et al., 2017). Furthermore, there has also been noted a difference of OA prevalence between the types of LLA performed (Davis et al., 2013, p.25).

There are multiple studies supporting the theory of the increased prevalence, pointing out the multitude of data found when examining the increase of osteoarthritis in the amputee population. It is said that around 41–63% of lower limb amputees develop

osteoarthritis on the intact limb (S. Persine et al., 2024). Additionally, Norvell et al. reported that the increase of OA prevalence in people with LLA is 16.1% compared with the OA prevalence in able bodied population of 11.7% (Norvell et al., 2005). Due to the increased risk of developing this disease it is vital to be educated about the possible preventative strategies and rehabilitation plans in order to make the best impact on the patients functioning and quality of life (Morgenroth et al., 2012).

2 AIM AND OBJECTIVE OF THESIS

The main aim of this thesis is to increase the knowledge about the possible prevalence of OA development in the sound limb of lower limb amputees with the use of reliable scientific literature and studies. This thesis will also examine the possible physiotherapy and rehabilitation managements available for this disorder in order to increase functioning and mobility for the individuals with lower limb amputations.

Furthermore, the objective of the thesis is to make a systemized literature review exploring the available scientific and reliable studies relevant to the topic selected. The possible correlation between OA and lower limb amputees will be researched based on the literature. Additionally, the thesis objectives also include identifying the risk factors that might impact the OA development as well as the possible diagnostic methods. A basis for ongoing topic development and research will be established for further education.

3 LOWER LIMB AMPUTATION

The number of lower limb amputations (LLA) performed continues to grow yearly, mostly caused by the increase of diabetes amongst the population. Due to the increased

need for this surgical procedure, more people will be requiring post-amputation rehabilitation. Additionally, educating the patient of the importance of physiotherapy and rehabilitation right after the amputation surgery is extremely important and should be advised. As previously mentioned, many individuals do not undergo the full rehabilitation program after their surgery, not having learned the correct gait or the importance of physical activity (Teater et al., 2023). Furthermore, as mentioned by Teater et al (2023) and supported by Donnelly et al (2022) there are increased probability of the load put on the sound leg only worsening with an incorrect prosthesis alignment, presenting the importance of gait training and physiotherapy after amputation.

3.1 Causes of lower limb amputation

Some of the most well-known causes of LLA are diabetes mellitus, neuropathy, cancer, infections, peripheral vascular disease and trauma. Furthermore, diabetes mellitus and peripheral arterial disease (PAD) are the most common cause of lower limb amputations, being the reason of approximately 75% - 85% of the amputations performed globally (Eidmann et al., 2023; Yuan et al., 2023). For such conditions as diabetes, there are multiple symptoms that usually cannot be resolved by any other means than amputation. For example, poor glycemic control in diabetes patients can lead to issues with foot wound/ulcer healing, posing a greater risk of developing infection. It can then lead to osteomyelitis (infection of the bone) followed by a further developing infection that can lead to septic shock. And, since there is no other way to restore the damaged tissue, the only option left is amputation. Similarly, in PAD the patient develops non-healing wounds resulting of lack of blood flow (Molina & Faulk, 2022).

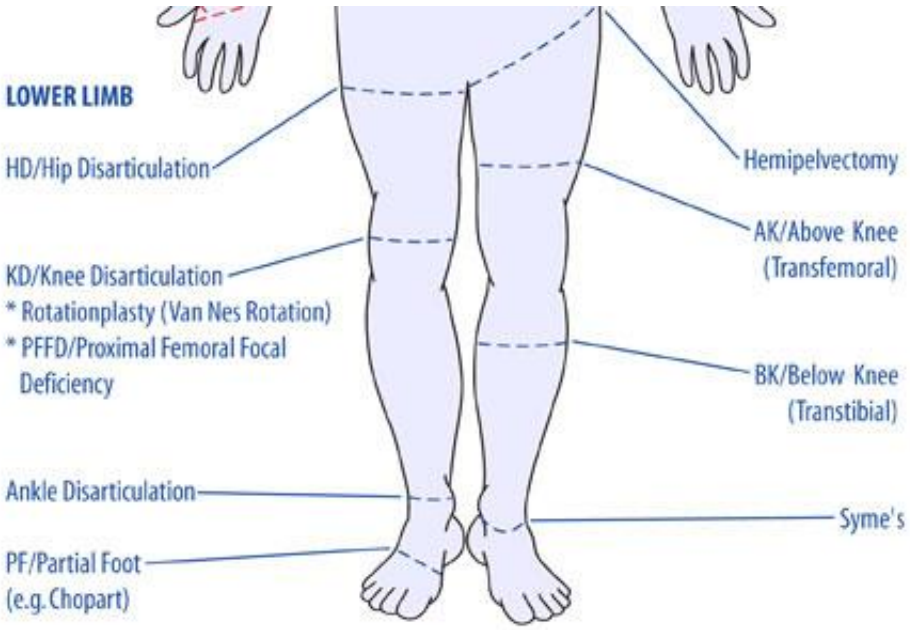
There are two main reasons for considering amputation in patients with PAD: ischemic necrosis or infected necrosis. In the case of ischemic necrosis (dry gangrene) there is a severe lack of blood flow to the tissue, resulting in tissue death and ischemia. Procedures can be done in order to try to renew the blood flow, but if they are unsuccessful, amputation is the only option to remove the affected tissue. Infected

necrosis (wet gangrene) is also caused by blood flow loss, but it further develops into infection as the tissue necrosis sets in. Due to the infection, it can spread quickly, resulting in septic shock and even organ failure. In this case the amputation is needed to be done immediately to prevent further complications of this life-threatening condition (Molina & Faulk, 2022).

In the case of trauma, the amputation can be immediate now of accident or leave the individual with an extremity that is severally damaged. There are multiple protocols used for these occasions to determine if a reconstruction would be possible. In situations of accident the injuries can be life threatening and even though the limb reconstruction is performed, there is still a strong possibility of complications and infection that might lead to amputation later on (Molina & Faulk, 2022).

3.2 Introduction of types of lower limb amputation

There are many different types of LLA (Picture 1), categorized by the level it is performed at. It is important to note that as the level of amputation becomes higher, the rehabilitation process will be harder and the resulting overall functionality of the individual will be lower (Magee, 2021, p.1164). The determining process of the level of amputation is a hard choice between an increased functioning of a lower, more distal level of amputation and a decreased risk of complications of a more proximal one. This discussion calls for a strong clinical judgment and careful assessment of the patient (Parvizi & Kim, 2010, p.17).



Picture 1. Types of lower limb amputations (The War Amps, 2016)

The amputations performed at the hip level are less common and are considered to be very radical and invasive. Hemipelvectomy, also known as trans lumbar amputation, is the partial or full removal of the pelvis on one side of the body, including the removal of the full lower extremity. It is associated with the presence of invasive malignant tumors that were not able to be treated with chemotherapy or other available treatments (Thakur et al., 2018). Furthermore, hip disarticulation is amputation performed through the hip joint and is also considered to be a radical intervention. This type of amputation makes up only approximately 0,5% of all LLA. It is mostly associated with malignant tumors, trauma, infections and limb ischemia (lack of blood flow to the limb) (Moura & Garruço, 2017).

Furthermore, amputations performed at the knee joint area differ at the level of the amputation, each presenting different reasoning and rehabilitation challenges. Transfemoral amputation (TFA) is performed above the knee joint. Since the amputation level is quite high, the overall prosthesis usage success rate is only 25%. Additionally, amputation through the knee (knee disarticulation) is most chosen in cases where there is not enough skin coverage for below knee amputation (BKA). Postsurgical healing is quite fast, and prosthesis fitting can be done early on in the recovery. However, transtibial amputation (TTA) is done around 5-7 cm below the

knee joint and is performed through the tibia and fibula (Murphy Douglas, 2014, p.15-19). For each of these amputation types there are different considerations made beforehand. TFA is usually performed for patients who are not mobile or in cases where the knee couldn't be saved. The individuals with this amputation would use ischium prosthesis (prosthesis that rests on the lower part of pelvis) to walk; however, this type of prosthesis presents difficulty in patient mobility and needs to be removed to be able to do everyday activities. Knee disarticulation is usually considered for younger, more ambulatory patients and presents with more stability and better end bearing limb for prosthesis usage. However, TTA is considered to have the most advantage with the improved mobility and stability due to the natural knee joint being present (Molina & Faulk, 2022).

Furthermore, there are different amputations performed on the lower foot level. Syme amputation is done in between the talus and tibia. Weight bearing is increased by the suturing of heel pad and subcutaneous tissue on the distal end of the stump. For this type of amputation, prosthesis fitting can be complicated due to the low available height (Murphy, 2014, p.15-19)

Boyd amputation is done between ankle mortis (tibiotalar joint) and calcaneus. It is commonly performed to treat osteomyelitis (infection of the bone) and is said to be more difficult to perform than the previously mentioned Syme amputation. However, it is considered to have better advantages and stability (Grady & Winters, 2000). Chopart amputation is done at the level of midtarsal joint, at the talonavicular and calcaneocuboid. Lisfranc amputation is done at the tarsometatarsal junction. Both Chopart and Lisfranc amputations are quite controversial due to the difficult healing and frequent need for re-amputation (van der Wal et al., 2023).

Furthermore, the most common foot joint amputation is the trans metatarsal amputation, performed through metatarsals, proximal to the metatarsal heads. This type of amputation is good for weight bearing and relearning how to walk is much easier than in the previously mentioned amputation types. Additionally, there are also partial toe amputation and toe disarticulation that are considered to be minor amputations (Murphy, 2014, p.15-19).

3.3 Psychosocial factors of lower limb amputation

Amputation causes a permanent disability and impacts the individual for the rest of their life, as the person needs to adjust to their new body structure and function. Amputation is usually performed as a last effort to save the life or the limb of the individual. Or it happens because of a traumatic event. Physical, psychological and social wellbeing is impacted, and it can leave a lasting effect on the individual and perceived their role in society. LLA affects not only the individual's ability to move and participate in everyday activities, but also their overall quality of life. Many individuals with LLA can develop depression and anxiety due to the restriction of movement and the overall feeling of weakness and hopelessness. It also has a huge effect on the person's ability to remain independent or care for their families. Due to all the facts previously mentioned it is advisable to undergo psychological counseling as a part of the amputation recovery as it has been shown to be beneficial to the overall recovery process. The family members of these individuals are also affected by the heavy burden and responsibility to care for someone with LLA and might not have the needed support available or given (Alessa et al., 2022).

Individuals who have undergone LLA have been found to have increased levels of anxiety, depression and posttraumatic stress disorder (PTSD), the latter usually found in amputations resulting from traumatic events such as combat, burns, accidental injuries. Depression is most common in the first two years after amputation, although it can resurface in the adjustment period (Jo et al., 2021). Studies show that around 20.6 - 63% of individuals experience depression after amputation surgery, making it three times more common than in the able-bodied population. Around 83% of these individuals seek psychiatric help in psych clinics at least once after the amputation. If possible, psychological intervention should be started as soon as possible to help the individual with the overwhelming emotions following amputation (Molina & Faulk, 2022).

However, it is important to note that amputation might not always have only negative association for the patients. If an amputation was done as a result of a disease or condition that had resulted with a prolonged period of loss of function, amputation,

although still a major and traumatic operation, would give the individual a new chance of independence and functioning (Gallagher & MacLachlan, 2000).

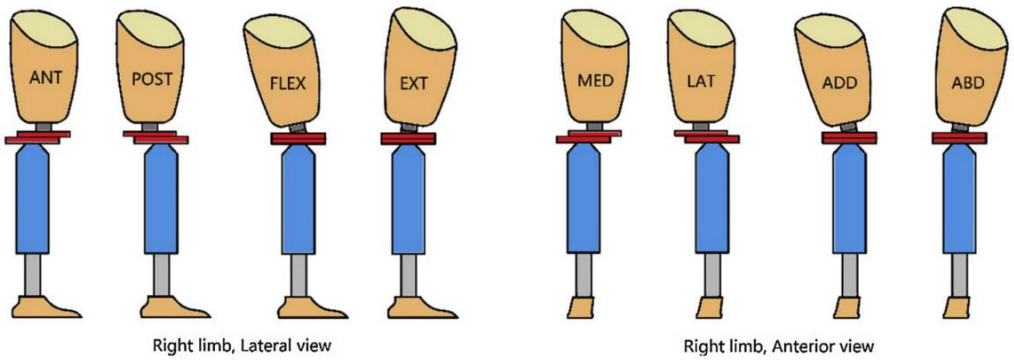
3.4 The importance of individualized prosthesis selection for lower limb amputees

Finding and adjusting a personalized prosthesis for an individual with LLA is a very important part of the rehabilitation process. The residual limb should be assessed first as determining its functioning and condition is an important first step of the prosthesis process. It is important to note that less advanced prostheses are like the more advanced ones in restoring the pattern of gait and the choice of the prosthesis should be made based on the individual and their stump size changes. The individual's ability to control the prosthesis frontal plane is also a very vital part of the process as it is the part of the gait cycle with more possible differences from the norm. In the assessment of the frontal plane many things are noted – participants with LLA can have gait differences such as increased pelvis tilt in the frontal plane (compensatory movement to increase stability), discrepancies in hip abduction and adduction (compensatory movement to increase balance; reduced hip abduction in prosthesis side and increased hip adduction of the sound leg), asymmetric gait, increased trunk lateral flexion towards the affected side (compensatory movement to increase balance, stability and foot clearance) (Kowal et al., 2021).

What is more, in order to examine the improper prosthesis alignment impact on sound leg loading, a study was done by Zhang et al. (2020) with 10 individuals with transfemoral amputations (TFA) and 15 individuals in the control group. The research question was to see how hip and knee joint movements are impacted by the prosthetic alignment for the participants with transfemoral amputations (TFA). As a part of this study, the prosthesis alignments were also tested. This was done in a way of making an initial alignment and 8 different malalignments. Initial alignment was done while assessing the participant and finding the best possible fit for the individual (done by a professional). However, the malalignments were made in order to simulate the most often made mistakes while doing the prosthesis fitting. Four of the malalignments were done in a way where the socket was moved 10 mm forward, backward, medially and

laterally. While the other four were adjusted and left in 6 degrees flexion, extension, abduction and adduction (Picture 2).

Once the adjustments to the prosthesis were made, gait tests were performed for all participants and analysis of the results was done. The results showed that the TFA group had noticeably larger hip joint movement of the sound leg. What is more, both the external rotators and hip abductor moments of the sound leg were decreased for the amputee group when compared to the control group. Difference was also noticed with the peaks of hip extensor, adductor and external rotator of the hip as it was noticed to be a lot larger in the affected, amputation side. And, even though for everyone the effect was different, the hip and knee movement of the sound leg was affected for all of them. This is notable since the lager hip joint movement may be associated with increased risk of hip osteoarthritis further on (Zhang et al., 2020).



Picture 2. The eight malalignments made for the study (Zhang et al., 2020).

It is important to note that starting the rehabilitation process for an individual with LLA can be very difficult both physically and mentally. And developing OA in the joints of their healthy leg only increases the difficulty and heaviness of their condition. This is why it is extremely important to have an optimal prosthesis as most of the LLA individuals put a lot of hope in its effectiveness and the possibility to walk again. It is extremely important to find the right fitting prosthesis for the patient. The prosthesis differentiates based on many different factors - the level/type of amputation, patient's activity level, cause of amputation, stump (condition, scaring and shape), patients overall health, how long ago the amputation was performed, patients' overall goals etc. There are many different types and classifications of prosthesis, each based on the

patient individual needs. Prosthesis can and should be adjusted for different activities by changing the alignment thus increasing stability. However, even though an altered and asymmetrical gait can be caused by an ill-fitting prosthesis, it can also be caused by the individuals musculature weakness, distrust in the prosthetic leg or simply habit. To avoid this, the individuals need to be educated about the correct use of prosthesis and go through full correct gait training rehabilitation (Davis et al., 2013, p.50-57).

Prosthesis that is not correct for the individual or is not adjusted can cause multiple issues in the future as it not only increases the risk of developing osteoarthritis (Kowal et al., 2021). An ill-fitting or uncomfortable prosthesis can cause issues ranging from increased pain, discomfort, skin breakdown, pressure sores, lower back pain, fatigue, flexion contracture and others, resulting in asymmetric walking, putting more load on the sound leg (Turner et al., 2021).

However, it is also important to note that not all lower limb amputees end up using prosthesis. As a part of the rehabilitation process, the patient’s willingness or ability to use the prosthesis is assessed. For some individuals there might be a lack of interest in learning about the topic and they might prefer a different assistive device, such as a wheelchair. For others, the use of a prosthesis might not be recommended due to medical concerns or contraindications like advanced cardiac disease or dementia. It is also important to determine the patient's state of mind about these matters since it will have a huge impact on the rehabilitation process. For example, patients who show a low interest or independence of learning how to use the prosthesis are less likely to be a long-term prosthesis user (Davis et al., 2013, p.35).

3.5 Gait biomechanics and its impact on the lower limb amputees

Gait asymmetry or symmetry index is one of the assessments done on lower limb amputation (LLA) patients as it assesses the difference between both sides of the body during the walking or stance assessment. Gait asymmetry in individuals with LLA can be caused by a variety of reasons, some being muscle imbalance, decrease in force, pain in the stump and decreased confidence in the affected leg (Hafiz Farhan Maqbool

et al., 2024). What is more, gait asymmetry can not only impact the joint but also leave an LLA patient predisposed to developing flexion contracture (flexed joint that cannot be straightened passively or actively) of the tight in the residual limb. As well as predisposing the LLA to developing osteoarthritis in the joints of the sound leg (Kowal et al., 2021).

A study done on the topic involved 7 males in the control group and two individuals with unilateral LLA (one transtibial (TTA) amputee and one transfemoral (TFA) amputee). A device, IMU (MPU 6050, InvenSense Inc.), with motion sensors was used in order to provide data of the gait cycle, including gait phases and asymmetry. It was attached on lateral side of the calf for both legs (on the prosthetic leg for the amputees) (Picture 3). Then they were asked to walk a straight path of 7,2 meters on the ground. Then a walk was also done on a treadmill. The task was asked to be done in three speeds – slow, normal, fast (Hafiz Farhan Maqbool et al., 2024).

What was discovered was that the TFA experienced larger gait asymmetry when compared to both the TTA and the control group. What is more, the TFA also had a larger variation in push off and loading response phases of the gait cycle, concluding that these phases could be more challenging for TFA. The gait cycle duration was longer for both LLA no matter the walking speed. What is more, the stance phase on the sound limb was longer for the LLA, increasing the asymmetry. Treadmill was also used as a part of the assessment as it made a consistent walking speed and controlled conditions. The treadmill part of the study did not seem to impact the gait cycle duration, however it did TFA showed increased gait asymmetry in stance and swing phase than when walking on the ground (Hafiz Farhan Maqbool et al., 2024).

Picture 3. Participants TFA, TTA and a participant form the control group during on ground walking and treadmill walking (Hafiz Farhan Maqbool et al., 2024).

What is more, assessing and identifying the issues with gait asymmetry could be beneficial for the individuals with LLA as an early intervention would decrease the possibility of developing further long-term health concerns, joint degradation, pain and osteoarthritis. Furthermore, although the study had limited participants, the results agreed with the literature on the topic and could provide base knowledge for further studies (Hafiz Farhan Maqbool et al., 2024).

3.6 Limb loading of the sound and prosthetic leg

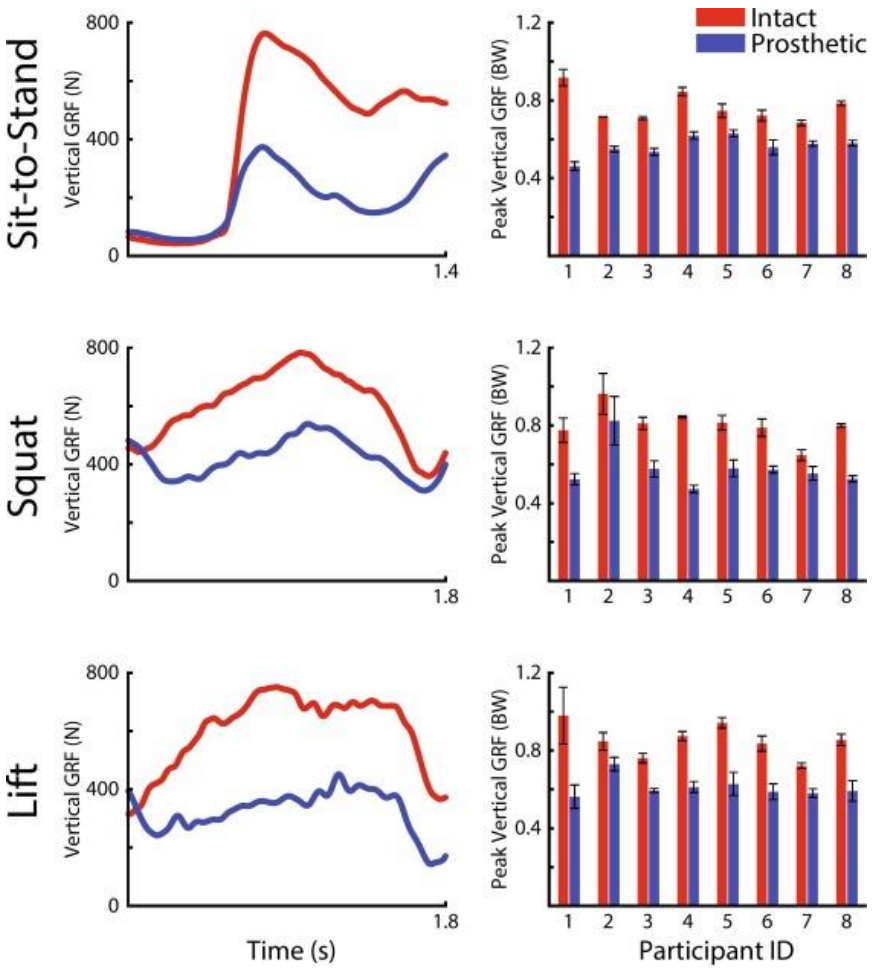
Many studies show that it is common for lower limb amputees to have issues with the overloading of the sound leg due to asymmetric movements and gait. Additionally, improper prosthetic alignment is considered to be one of the contributing factors of increased sound leg loading (Zhang et al., 2020). The force asymmetry for the LLA

individuals can have up to 23% higher between the affected and sound leg (Wasser & Vincent, 2017). This could be caused by multiple of reasons, for example, movement compensation, muscle imbalance, issues with the prosthesis or its limitations etc. Because of this, the risk of developing joint issues and diseases such as osteoarthritis, osteoporosis and joint pain is significantly increased (Teater et al., 2023).

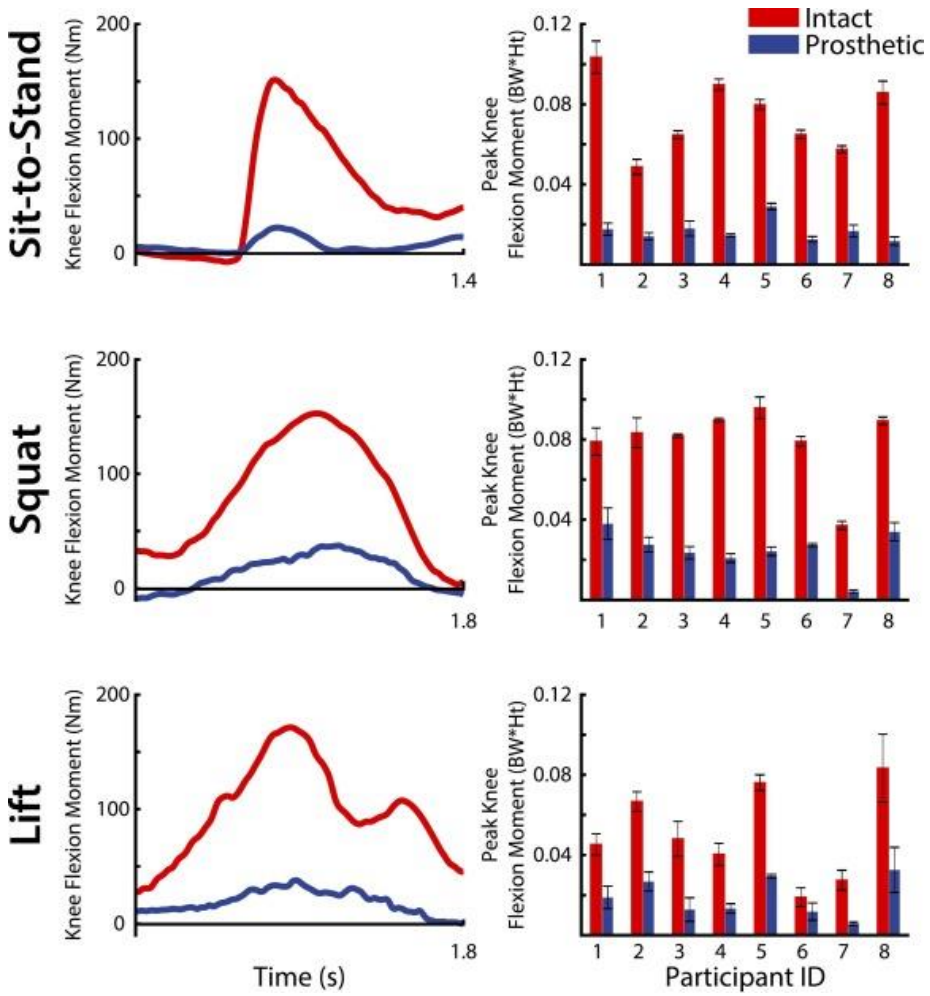
Furthermore, a study was done by Teater et al. in order to assess how unilateral transtibial amputees (TTA) with prosthesis are loading their sound leg and if they are putting less load on the limb with the prosthesis. Biomechanics of limb loading have been studied extensively with the use of gait analysis, however this study focused on movements associated with the activities of daily living, including three main movements - sit to stand, squatting and lifting. These movements can be challenging for some lower limb prosthesis users (LLPUs) and while others are able to do it independently, there can be noticeable asymmetrical movements present as the load is placed on the sound leg. Due to the increased complexity of the tasks, they are commonly avoided or perceived as difficult by LLPUs. There were eight TTA participants and eight control group participants. Each of them was asked to perform the previously mentioned movements in a way that felt the most comfortable to them. Sit to stand was performed with three chair heights (48 cm, 38 cm, 28 cm) and the participants were asked not to use the arms for assistance when standing up. As for squatting, the participants were asked to stand with legs shoulder width apart and squat down to a comfortable level. Then they did the lifting part of the study, where the participants were asked to lean down, pick up a 10 kg box from the floor and stand back up. During the study, the peak vertical ground reaction force (GAF) (the primary direction of the force noted under the participants feet while the tasks were performed), peak knee flexion moment and the ankle range of motion (ROM) was measured (Teater et al., 2023).

The results of the study showed an increased load being put on the sound leg, resulting in greater peak GRF (Picture 4) for every TTA participant and bigger knee flexion moment (Picture 5). On average the peak GRF for the control group was around 5% (difference between the dominant and non-dominant leg) while for the TFA the sound leg GRF was bigger in the prosthesis leg by 36% in sit to stand, 39% in squatting and

39% in lifting. As for the peak knee flexion, the control group difference was 3 % while for the TFA the sound leg peak knee flexion was bigger than the prosthesis leg by 343% during sit to stand, 218% in squatting and 168% in lifting. What is more, ROM of the prosthetic ankle was significantly decreased when compared with the sound ankle as most prosthesis lack ankle ROM (Teater et al., 2023).



Picture 4. Left: Vertical ground reaction force (GRF) during sit to stand (48 cm), squatting and lifting. Right: Participant GRF averages during sit to stand, squatting and lifting. The values are normalized to bodyweight. * Red – the intact leg, blue – the prosthetic leg. (Teater et al., 2023).



Picture 5. Left: Knee flexion moment during sit to stand (48 cm), squatting and lifting. Right: Participant averages during sit to stand, squatting and lifting. The values are normalized to bodyweight and height. * Red – the intact leg, blue – the prosthetic leg. (Teater et al., 2023).

Furthermore, due to the increase of load being put on the sound leg, patient education about the correct gait, prosthesis use, and an equal weight distribution is vital. This is important because when done incorrectly, it can only increase the risk of damage and the possibility of developing OA in the sound leg. This is especially important for those who have had amputations for a long time (Gailey, 2008).

4 OSTEOARTHRITIS

The name "*osteoarthritis*" (OA) was first said to be mentioned in the mid-nineteenth century where it was named by one of the fathers of orthopedic surgery, surgeon Richard von Volkmann who differentiated it from rheumatoid arthritis. The name given already holds clues of the condition - "*osteo*" meaning bone, "*arthro*" meaning joint and "*itis*" meaning inflammation, making the name "*osteoarthritis*" hold the literal meaning of the condition - "inflammation of the bones in the joint". Some years later Hermann Senator and Garrods presented the idea that OA might be affecting the whole joint and that the inflammation was one of the main reasons of its development. This contrasted with the common belief that this condition was caused simply by the cartilage breakdown process over time and should not be a disease at all. Pathologist Rudolf Virchow argued that OA, just like rheumatoid arthritis, was a stage of arthritis deformans, creating confusion in the field that lasted for more than 50 years. However, the name "*osteoarthritis*" was only recognized in the mid-20th century. Today, more than 130 years later, OA is described to be a complex degenerative joint disorder considered to be the most common arthritis form in the world. However, there is still no cure and no way to reverse the damage done to the joint. It affects the lives of many people, resulting in moderate to severe disability. This disability affects around 250 million people worldwide, resulting in being considered the 11th most debilitating disease in the world (Dobson et al., 2018).

Osteoarthritis is classified into two main categories - Primary OA and Secondary OA. The classification is based on their characteristics and causes. Primary OA, also known as Idiopathic OA, is considered to have no viable cause, developing due to aging and possible genetic influence. However, Secondary OA results due to a specific cause, for example, injury, inflammatory arthritis and others (Sen & Hurley, 2023).

The symptoms of OA vary based on everyone. For some the symptoms can be mild and non-disruptive to their everyday life. For others it can cause serious levels of pain and disability. The symptoms may include joint pain while in movement (can improve with rest at first) and with pain in rest and during the night at the later stages of OA

development. Stiffness during a period of time after rest or inactivity (for example, in the mornings) is also a very common symptom of OA. Limited movement, swelling and feeling of instability of the joint can also be present. The joints that are most affected by OA are hands, lower back, neck, hips and knees. What is more, symptoms specific for knee OA include scraping and grinding while walking and instability. However, for OA in the hip joint the symptoms include pain in the hip joint and around the joint area (inner thigh, buttocks, groin) and stiffness. Loss of range of motion may also be present. As the condition develops, the symptoms increase and worsen. This can put a strain on the individuals daily living and quality of life as such activities as walking or getting up from the chair are progressively increasing in difficulty (Garrick, 2017).

4.1 Pathophysiology

The main reasoning of osteoarthritis development is still unknow. However, once it starts to progress, it impacts all structures of the joint including joint cartilages, tendons, ligaments, synovium, bone and meniscus in the joint (Garrick, 2017). The cartilage of the joint starts to break down, causing the joint space to become smaller and decreasing the distance between the bones. Osteophytes (also known as bone spurs) start to form in the joint space, increasing the pain and limiting movement. As these changes are happening in the joint, the synovium (joint lining) is also affected and inflammation develops, leading to swelling of the joint (Maqbool et al., 2021). As the disease progresses, the symptoms worsen with an increase in pain, swelling and joint movement limitations. Furthermore, due to the increase of these symptoms, the individual might be less active, leading to muscle weakness that in turn causes even more stress for the joint and decreasing its stability. As the condition develops, the joint and the bone may also start to lose their natural shape (Garrick, 2017).

4.2 Risk factors

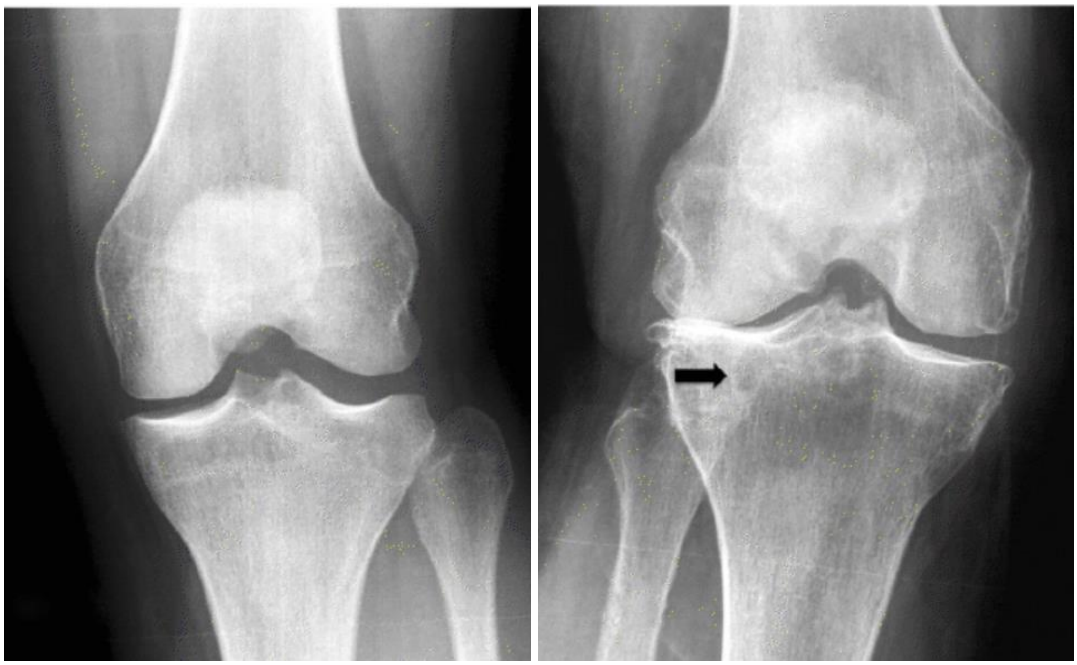
Increased predisposition of OA involves many different factors. Some non-modifiable factors that cannot be impacted or changed are aging, gender (female), genetic

predisposition and individual's joint alignment and basic anatomy. The modifiable factors are obesity (additional stress on the weight bearing joints a hips and knees), trauma, muscle weakness, repetitive motion stress on the joints and inactivity (Jang et al., 2021).

4.3 Diagnosis

Osteoarthritis is a condition that despite how common it is, is not easily diagnosed. One of the most important things in the overall diagnostic process is to differentiate osteoarthritis from other possible forms of arthritis, for example, ankylosing spondylitis (Jang et al., 2021). However, there is not one test to determine OA. The diagnostic process may include the patient's full medical history and family health history, physical exams, imaging (X-ray to assess the joint space, bone, bone spurs and MRI to assess soft tissue damage) and blood tests. Blood tests are taken in order to make sure to rule out any other conditions and possible infection. A fluid sample from the joint might be taken to roll out possible infection and crystals (Garrick, 2017).

X-ray is the most commonly done test for osteoarthritis diagnosis and assessment. For radiographic assessment of osteoarthritis development, a Kallgren – Lawrence grading system was developed and later on adopted by the World Health Organization (WHO). It consists of five grades. 0 – no OA signs, 1 – doubtful, 2 – minimal, 3 – moderate and 4 – severe OA presence in the joint. These grades were given based on various aspects of the joint – joint space, osteophytes (small yellow dots seen in radiographic imaging), cartilage narrowing, bone shape changes and presence of cysts (Picture 6). However, even though radiography is considered to be the best tool for following the overall progression of osteoarthritis, it is lacking in sensitivity to detect early osteoarthritis changes (Sharmila Majumdar, 2010, p. 78).

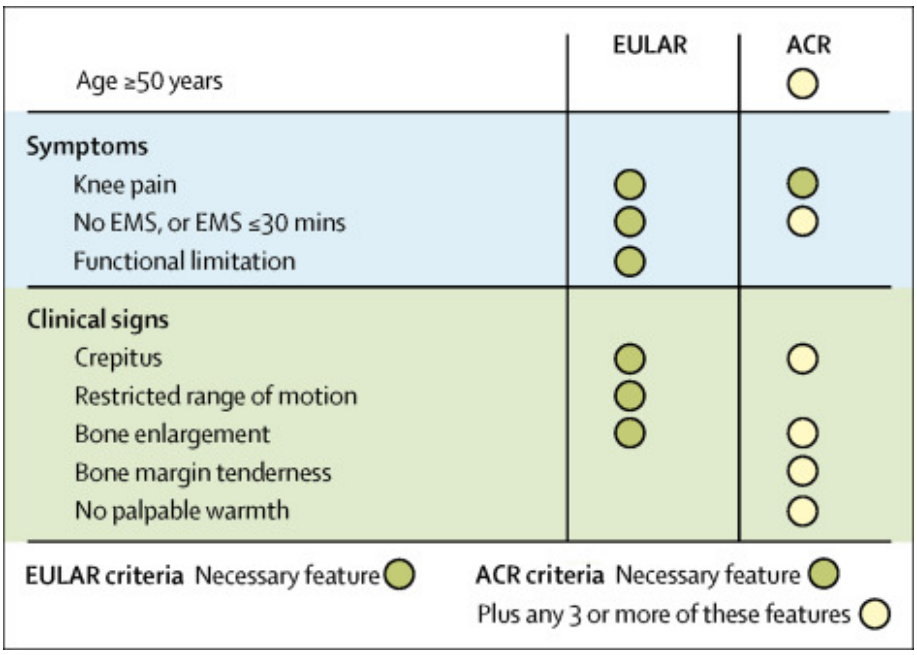


Picture 6. Radiological imaging of a healthy knee (left) with a KL score of 0 and a knee with a KL score of 4 (right). A subchondral cyst is also present (arrow) (Sharmila Majumdar, 2010, p. 79, 82).

MRI scans can detect a lot more than in radiological imaging as it evaluates the joint as a whole, not just the joint cartilage. It provides a view of ligaments, meniscus and soft tissue that is not well seen on x-ray imaging. Due to this, the beginning stages of OA can be seen a lot earlier. Additionally, MRI is safer than x-ray as it does not have radiation exposure (Moskowitz et al., 2015, p. 180-190)

However, the overall diagnosis is based on the patient's symptoms (may include pain, pain after exertion, stiffness in the mornings etc.) and physical examination, where the attention is focused on possible crepitus of the joint, tenderness, restricted, painful or limited movement etc. Patients' history needs to be attained as well as information about their quality of life, sleep, occupation, and overall function through the day and night as this will provide beneficial information on the patients functioning and any possible comorbidities. Furthermore, there are many classifications and diagnostic criteria in place that could help in the diagnosis. For example, American College of Rheumatology or European League Against Rheumatism for knee OA (Picture 7) as they can be beneficial in the early diagnostic process and each includes specific parts,

such as clinical, laboratory and radiographic findings (Hunter & Bierma-Zeinstra, 2019).



Picture 7. American College of Rheumatology (ACR) and European League Against Rheumatism (EULAR) criteria for knee osteoarthritis diagnosis (Hunter & Bierma-Zeinstra, 2019). *EMS – early morning stiffness

4.4 Psychosocial factors of osteoarthritis

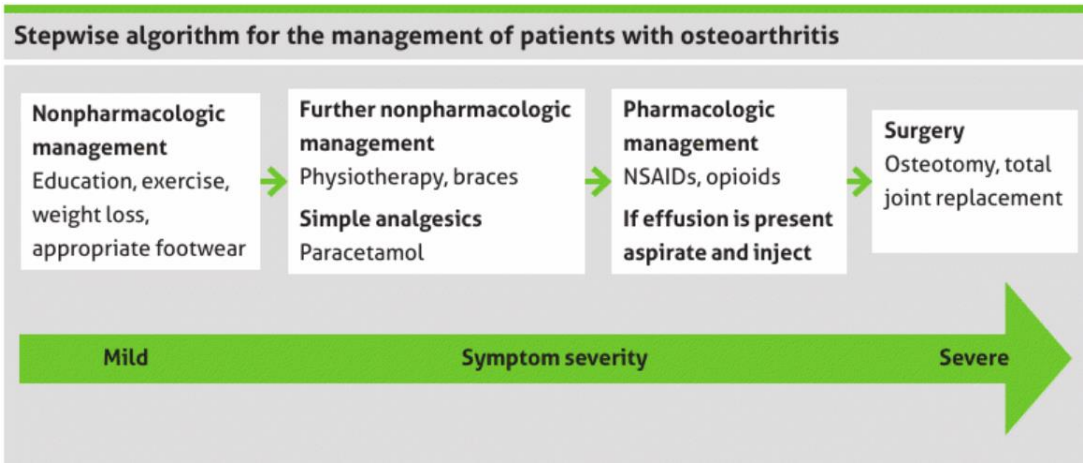
There are multitude of pathologies and complications that have an increased risk of developing in the amputee population, affecting their life and functioning. For example, they are more prone to back pain, more predisposed to developing osteopenia and osteoporosis as they put less load on their affected limb. Furthermore, due to multiple reasons, they are also more prone to developing osteoarthritis. For individuals who have already experienced limitations in their daily functioning and mobility, developing osteoarthritis in their sound leg can be extremely difficult to deal with both physically and emotionally (Gailey, 2008).

Around 20% of the individuals with OA suffer from depression and it is the one of the most common comorbidities of this disease. OA, like many other chronic conditions without a cure, can feel isolated and terrifying. If the feelings are not addressed, they

develop further, only increasing the symptoms by locking the individual in a cycle of depression. It can start with the feelings of helplessness and further develop into fatigue. This in turn only further aggravates OA symptoms as the individual becomes less active, increasing pain levels, stiffness and further developing the feeling of isolation (Wang & Ni, 2022). The increase in pain levels, common in symptomatic OA, has a strong impact on the individual as it is also accompanied by increased disability and limitations with functioning. Pain is one of the first symptoms of symptomatic OA and it only increases with time. The pain first occurs with increased joint use and the individual can get some relief with rest, but, as the condition progresses, pain eventually starts to occur in rest. In individuals with hip and knee OA a connection between joint pain and psychological wellbeing has been reported and the results included depression, anxiety and poor mental well-being (Moskowitz, 2007, p. 19).

5 MANAGEMENT AND TREATMENT

There is no cure for OA and there is no way to reverse the damage done, however there are many treatment options and strategies relating to the symptom severity of the patient that could be beneficial for the amputation patient and could increase their overall quality of life while also slowing down the joint degradation process (Picture 8) (Grässel & Muschter, 2020).



Picture 8. Stepwise algorithm for the management of patients with osteoarthritis. An example of a basis of OA treatment that can be adjusted based on the individual.
*NSAIDs – nonsteroidal anti-inflammatory drugs (Arden et al., 2014, p.83)

5.1 Patient education

Patient education about the condition is one of the first steps for not only the OA treatment and management plan, but also to make sure that the individual in knowledgeable of the preventative strategies of the condition. This is extremely important as many individuals with the condition avoid physical activity and basic movements due to fear of pain while not knowing that inactivity can result in more issues in the future. Furthermore, there is a lot of misinformation about how individuals with OA should rest or use medications as a sole solution. Based on multiple studies and literature, this should be strongly discouraged. Once the patient has the knowledge about the condition, there is further understanding about how the symptoms come to be and what kind of actions will worsen or lessen them. This knowledge can feel empowering for the patient and gives them confidence to explore other possible management strategies (Arden et al., 2014, p.3-5).

Additionally, educating the patient about the importance of maintaining a healthy weight is vital for any patient with OA, especially amputees, as being overweight increases, the stress put on the joints of the sound leg. It can also limit mobility and increase the risk of injury. This is especially important for weight bearing joints such as knees and hips as these are the joints that are most at risk of developing OA (Garrick, 2017).

5.2 Post-amputation rehabilitation

Physiotherapy is a very important part of increasing the individual's overall functioning in life after amputation. The LLA individuals who have undergone the full physiotherapy treatment are more likely to have better gait, walking speed and experience with their prosthesis than those who have not done physiotherapy.

Additionally, studies show that the individuals that undergo a full physiotherapy program have a survival rate increase of one year. However, a huge number of amputees do not receive rehabilitation in the post-surgical period – a statistic done of 12 599 veterans with lower limb amputations discovered that only 55% of them had received rehabilitation after surgery. And even though some amputees might receive the post amputation physiotherapy, they do not go through a more comprehensive rehabilitation process, resulting in patients still being at fall risk now of their discharge from hospital. If this is the case, the patient could develop gait impairments and functional limitations as they are not educated in the correct movements and prosthesis use while performing their everyday activities. This could then lead to compensatory movements and asymmetric gait that, as mentioned before, increases the risk of secondary health issues, such as OA (Gailey et al., 2020).

One way to assess lower limb amputees' functioning and mobility while using prosthesis and without it is to use the Amputee Mobility Predictor (AMP). This assessment is quick to do (10-15 minutes) and uses little to no equipment. The score given for the individual ranges from 0 to 42 points, however in the non-prosthesis testing the maximal score is 38 points. There are mostly 3 scores available for each task (0 – not able to perform the task, 1 – minimal achievement, 2 – able to do the task independently and with success) and the tasks are made to be progressive in their difficulty. The tasks are divided in sections – ability to maintain a sitting position/balance, ability to do a simple transfer while maintaining balance, ability to maintain standing balance while performing various activities, gait assessment and assistive device usage. This test battery is considered to be a great way to determine amputees' abilities and limitations of their body movements and functioning. It is also a way to assess any progress made in the rehabilitation process (Gailey et al., 2020).

Once the individual has gone through the AMP, the results can be used as a tool to create an exercise program as it shows movement and functioning limitations the individual has for specific tasks, making it easier to understand what to focus on. The idea of Evidence – Based Amputee Rehabilitation (EBAR) consists of physiotherapy assessment, treatment prescription and later reassessment. And, as the scores of the AMP are evaluated, the exercises given to the patient are made to target the limitations

found. A study done to assess the benefits of this type of rehabilitation plan was done with unilateral TTA individuals who had undergone the surgery for at least one year and had been using the current prosthesis for a minimum of 6 months. The individuals had also undergone a post-operative rehabilitation and had prosthesis training (Gailey et al., 2020).

The study was small, including 18 participants with the average age of 63,2 and the average 8 years since the amputation was performed. 81,2 % of the participants were male and 75% of the amputation cause was diabetes or peripheral vascular disease. The study time was set to be 8 weeks and was started with an AMP testing with prosthesis (AMPPro) and without it (AMPnoPro), followed by a 6 minutes' walking test (6MWT). Then the individuals were randomly given either the EBAR based on their results or put in a wait list control group. After this was done the EBAR program was implemented for the individuals and lasted for an hour 3 times per week for the full 8 weeks of the study. During the study time the AMP and 6MWT were performed at week 2, 4 and 6 to determine any functional or mobility changes (Gailey et al., 2020).

The EBAR program consisted of 5 focus groups. It started with cardiopulmonary endurance and flexibility training. This part of the session consisted of around 15 minutes warmup and stump check to avoid any possible issues with the residual limb. The activities increased in difficulty as the weeks passed, starting with non-weight bearing, then partial weight bearing followed by full weight bearing. For example, during week 1 and 2 the focus was sitting to stand training while in week 7 to 8 the participants did treadmill walking. They were also given a lower limb and trunk stretching exercise plan. The next part of the session was about lower limb and trunk muscle strengthening. Here the assessment from the AMP was used in order to determine the individual exercises, starting with the ones the client scored less in. The same was done in coordination and balance, weight bearing, stance control and gait training. During the weeks the exercises progressed in difficulty. As the mid study assessment was done, the lower scored tasks were assessed again. If the participant gained the maximum score for the task they previously struggled with, the exercise used to train for it was stopped, swapped by a different one, focusing on the next low

scoring task. This was done in order to make sure that the individuals would not be too overwhelmed by a large number of exercises (Gailey et al., 2020).

The conclusion of the study showed noticeable changes in test scores. The participants who completed the 8-week training had noticeable improvement. The AMPPro average scores increased from 36,4 to 41,7. AMPnoPro testing the increase was from 23,2 to 27,1. Additionally, the 6MWT distance increased from 262,6 meters to 268,8 meters in the 8 weeks (increased by 16%). The biggest difference was seen in the prosthesis use AMP part of the testing as the effect and increase concluded was twice as big as that for the non-prosthesis AMP testing. This showed a massive improvement in prosthesis mobility and the ability to function. The wait list participants did not have any significant changes (Gailey et al., 2020).

Taking into consideration the small number of participants (study was finished by 16 participants, 9 finished the training while 7 did the wait list period) the effect gained still suggests that the individuals with LLA could benefit from a program focusing on improving the individual movement and functioning issues. Furthermore, it increases the ability to adapt to prosthesis use and avoids the development of poor gait that could result in increased risk of secondary condition development (including osteoarthritis). Additionally, this type of exercise program showed a great improvement in muscle strength, endurance and aerobic abilities, having a major impact on LLA individual's quality of life (Gailey et al., 2020).

5.3 Physical activity

The average guidelines for amputee exercise recommendation are similar to able-bodied individuals. The recommendations include focusing on improving cardiovascular fitness (30-60 min, 3-5 times per week), neuromotor ability (2-3 times per week, including training in coordination, balance and proprioception), muscle strength (2-3 times per week). The exercises should adjust based on the individual, taking into consideration their well-being and pain levels of the day. If the pain worsens, the exercise sessions can be split into smaller portions throughout the day.

Or the overall intensity and speed of exercising can be decreased. Additionally, it is important to remember that the higher the level of amputation for the individual, the more energy they will spend for an exercise (Wasser & Vincent, 2017).

Physical activity has proven to be very beneficial in reducing OA pain and stiffness for individuals with LLA. A study found that exercising presented a similar effect of limiting pain as pain relieving anti-inflammatory medication, while also presenting less side effects (Maqbool et al., 2021). It is also beneficial for flexibility, muscle strength and building endurance. It is vital to maintain physical activity as an amputee and it shouldn't be excluded due to the presence of OA. While exercising can be more painful for these individuals, the exercise plan should be adjusted while taking their pain levels into consideration but maintaining to be physically active (Wasser & Vincent, 2017). The optimal introduction into physical activity for amputees should be done with educating the individual about the benefits of exercise and adjusting the plan accordingly (Arden et al., 2014, p.86).

5.3.1 Aerobic exercise

Aerobic exercises are important for cardiovascular health and should be incorporated in LLA individuals exercise program. This type of exercise is also beneficial for non-active amputees with obesity or those who are at risk of developing secondary health issues like heart disease or hypertension. There are many different aerobic activities the individual can do depending on their ability or interest. Such activities include walking, running, cycling and others. Furthermore, if the individual is not able to do an activity due to residual limb pain, the activity needs to be adjusted or switched for an alternative exercise, such as swimming (Wasser & Vincent, 2017). Exercises in water is also beneficial for lowering joint stress, while the warm water can aid in alleviating pain (Garrick, 2017). As repetitive motions might cause pain or discomfort in the residual limb, the aerobic activities can be changed during the week. Additionally, for individuals who struggle with increased pain in the residual limb, such activities as antigravity treadmill walking is a possibility. During the activity the load on the lower limb joints are lessened, decreasing the pain and discomfort while

maintaining the cardiovascular training for longer periods of time. This is also beneficial for optimal gait learning (Wasser & Vincent, 2017).

5.3.2 Coordination, balance and flexibility training

LLA leaves an impact on the individual's ability to perform daily living activities as the balance and coordination is affected due to limb loss. Due to this change an abnormal pelvic and the lower back develop to compensate the postural imbalance, theorized to increase the risk of knee OA development (Wasser & Vincent, 2017). To lessen the impact on the individuals functioning, balance and agility exercises can be beneficial (Garrick, 2017). Additionally, focusing on postural and core muscles could increase the walking stability, balance and be beneficial for fall risk prevention. Yoga and tai chi have been theorized to be beneficial for amputees with knee OA as it focuses on increasing core strength and stability while promoting controlled movements. Standing balance training with the use of uneven surfaces and movement should also be included as it targets the core, glute and hip muscles (Wasser & Vincent, 2017).

Due to the use of prosthesis, it was found that the hip, pelvis and trunk ROM was limited. Daily flexibility training should be considered to restore the motion of the joints, helping with lessening of knee OA pain and different musculoskeletal pain typical for amputees. The focus of the stretch should be the knee and hip extensors and flexors as well as hip adductors and abductors. The stretching position should be helped up to 60 seconds focusing on maintaining the position. Such activities as yoga can be beneficial for muscle engagement and stretching while also providing mind and body relaxation (Wasser & Vincent, 2017).

5.3.3 Strength training

Strength training has been shown to have a substantial effect on pain, quality of life and overall function in the amputee population. Strength training can be very beneficial for OA management as it strengthens the muscles that are supporting the

affected joints and reduces the load on them. It can be performed with the use of resistance bands, weights or just body weight exercises (Garrick, 2017). Decreased muscle strength can be one of the factors that increases the OA risk. This is the reason strength training is an important factor is OA management and symptom reduction. For the individuals with LLA the focus should be put on strengthening quadriceps, hamstrings and hip adductors (Arden et al., 2014, p.85).

Furthermore, resistance strength training is one of the strength training methods that are recommended for amputees. It should be started gradually as the correct technique should be developed before the exercises progress with weights. The starting recommendations are 2 times per week with a possibility to increase the training to 3 times per week (Wasser & Vincent, 2017). This type of training increases the overall muscle strength by using an external force or weight that the muscles work against. It, alongside other strength training types, has shown benefits in strengthening the muscles of the legs, core, hips and lower back region. The benefits of strengthening these muscle groups are noticeable in better posture control, confidence and stability, increased balance, increased walking speed, improved gait and was even beneficial for the ability to relearn how to run. Due to these reasons, strength training combined with other exercise types seems to be beneficial for prevention or management of the sound limb OA. Additionally, it would also be beneficial for the overall health and quality of life of the lower limb amputee population who is known to struggle with decreased muscle strength, gait and posture control, chronic back pains, balance issues and other deficits. The weekly recommendation of resistance strength training is 2-3 times (for each muscle group) with 1-3 sets and 10-15 repetitions based on the individual. To determine the individual's capabilities, it is suggested that the 10 RM test (the maximum amount of weight the individual is able to lift for 10 repetitions) is done to understand 1 RM (the maximal amount of weight the individual is able to lift for 1 repetition) as the suggested starting point of the lower limb amputee training should be 40-50% of their 1 RM. It is recommended that the resistance strength training is done with weight machines as a closed chain exercises (limbs are fixed an remain in contact with the weight machine or the ground while performing the exercise) and be supported by other training types (Rosario et al., 2023).

5.4 Biomechanical support

The evidence available about knee bracing, foot orthosis and foot insoles use in OA symptoms management is inclusive and mixed (Mohit Kapoor & Mahomed, 2015, p.158). However, there is literature supporting the use of knee braces for the sound leg of amputees to increase mobility, stabilize the joint and help with the weight retribution as it limits the stress being put on the selected compartment of the joint. Poor knee frontal alignment is a possible sign of unequal load distribution, and it could lead to more stress being put on one side of the knee, increasing the risk of developing damage. Because of this, the use of knee brace is theorized to help in correcting the frontal alignment of the knee. For example, medial OA develops in the inner part of the joint and calls for a valgus inducing brace that pushes the knee outwards (reduces stress in the medial joint part, shifts the load to the lateral part). Or if a client experiences lateral knee compartment OA, varus inducing brace is needed - pushing the knee inwards reduces the stress in the lateral joint part, shifts the load to the medal part (Arden et al., 2014, p.86).

However, having OA in one side of the knee is different from OA that has affected the entire knee. Additionally, a review done of five different randomized control trials discussing the knee varus brace usage impact in an able-bodied papulation with OA compared to no treatment or a different treatment concluded that the evidence of knee brace usage was of low quality and there was little or no impact on individuals pain levels or function. There are no clear international guidelines supporting the same viewpoint and more detailed studies to determine the possible benefits are needed. Additionally, a lot of individuals with knee instability try to compensate for it with increased activations of the muscles around the knee joint. While this might increase the feeling of stability, it also results in increased pressure placed on the knee joint, having a potentially progressing effect on the osteoarthritis process. The usage of a knee brace can result in decreased muscle contractions and provide some pain relief (Mohit Kapoor & Mahomed, 2015, p.159).

A study was done with 1003 able boded individuals who suffered from OA in the knee to determine if a semi-rigid knee brace would have any effect on their mobility, pain

and daily functioning within a time period of 3 weeks. There were two types of braces provided, each having the same effect on knee joint medial side pressure reduction (Picture 9). The main reasoning of the brace usage is a possibility to delay joint replacement surgery for foreseeable future, especially important for active and younger individuals (Dries et al., 2022).

Picture 9. The two types of semi rigid knee brace used in the study (Dries et al., 2022).

The questioner was completed by 381 individuals at the end of the 3 weeks and the conclusion of the study showed that the individuals experienced pain relief, increased joint support and increased mobility in their everyday life. 62% of the individuals noticed improvement in daily functioning. 52% of the participants noted reduction of pain and 30% of them categorized the pain reduction as “significant to vary significant”. It is also important to note that 9% of the individuals did not experience any changes at all, presenting a reason for more research to understand this outcome. However, research is lacking on the impact of knee brace usage on the tissue and cartilage in the long therm. Additional research is also needed to find out if the individuals used any pain relief medication as this can have an impact on the presented conclusion of the reduction of pain (Dries et al., 2022).

5.5 Surgical treatment

If other treatments have not been successful or if the damage to the joint is too extensive, surgery may be considered. This decision can be impacted by the age, level of disability, pain levels, impact on daily life and occupation of the individual. There are many different types of surgical treatment available, each of them presenting with different complications and benefits, the most common being arthroscopy, osteotomy and joint replacement surgery/arthroplasty (Garrick, 2017).

Arthroscopy is a procedure done to diagnose or clean the joint space, get rid of loose fragments and repair bone and cartilage. This procedure is minimally invasive and can give the patient temporary relief. The procedure is done by making small incisions and inserting surgical instruments within the joint, guiding the operation with the help of a camera. However, the improvement of the symptoms only last about 1-2 years, with most patients presenting with no change in symptoms after the procedure. The procedure should be considered if the individual suffers an acute trauma or is presenting with a symptomatic meniscus injury or tear. This procedure should not be presented as an effective treatment for chronic osteoarthritis (Moseley et al., 2002).

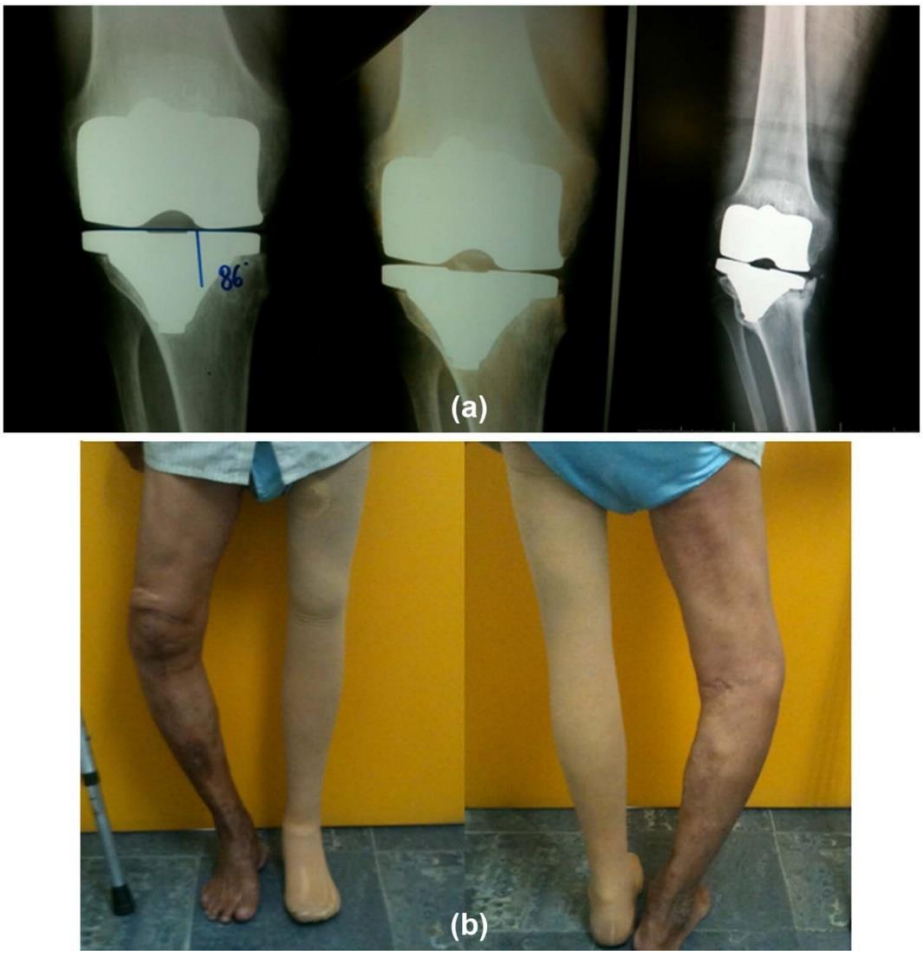
Osteotomy is a surgical procedure where there is a cut done through the bone as a way to relieve some of the stress being put on the joint and realign it. This procedure could result in reduced pain and have benefits on the patients' overall functioning. It also has shown to decrease the need for a full joint replacement by years. However, more research needs to be done as there is no evidence of osteotomy being more effective than other surgical methods (Arden et al., 2014, p.95-96).

Joint replacement is the most commonly performed surgery for severe OA management in the hip and knee joints. Surgery can increase joint functioning while also providing the individual with pain relief. Although this surgery is considered to be an effective treatment for osteoarthritis of the sound leg for lower limb amputees, there is still a notable increased difficulty of the post-operative rehabilitation process. This is mainly due to the limited functioning of the prosthetic leg and its lowered ability to compensate in gait while the contralateral leg is healing. Issues with the

prosthetic leg and stump might also cause an intervalence of the rehabilitation process, delaying it. Furthermore, the procedure is more difficult due to the lack of contralateral limb. For example, for a above knee amputee, contralateral knee joint replacement is more challenging as the surgeon is unable to compare the knees and legs, leading to difficulty to adjust the implant length, movement and the optimal alignment. However, more information and high evidence studies are needed on the topic as the increased risk of complications in relation to benefits needs to be determined. Furthermore, total hip replacement is regarded to be a very successful operation, providing the amputees with a noticeable improvement in function. However, there is a possibility for a need for reoperation around 25 years after the original one. The reasoning for this is unknown, it is yet to be discovered if it is linked to the altered biomechanics of the contralateral limb (Walton et al., 2024).

Furthermore, for a lower limb amputee due to the additional load being put on the implant and increased possibility of implant failure, the need for a revision surgery is quite common. The contralateral leg joint replacement surgery differs from that done on an able-bodied individual as more planning and detailed research is needed. There are many things that need to be taken into consideration – leg length, implant stability, obligatory post-operative rehabilitation to regain the ROM and muscle strength etc. A case study was done by Helito et al of 60 years old transfemoral lower limb amputee in need of a complete knee replacement surgery. The amputation of the left leg had resulted from a traffic accident 20 years prior. The individual had used his prosthesis very often, up to 10 hours per day, and did not use any assistive aids as he felt like he did not need them. But 15 years after the amputation he started to experience knee pain and began using a cane. He did not have any other health-related issues, and his mobility remained mostly nonaffected as he was able to walk with no issues or distance limitations. However, the patient developed osteoarthrosis in the knee of his contralateral leg that resulted in increased varus and flexion contracture. Due to this, he had to undergo total knee replacement surgery. After the surgery the patient had a full post-surgical rehabilitation that consisted of passive, active assisted, active therapeutic exercise with progressive, muscle strengthening exercises to regain the ROM of the joint (full extension, 90 degrees flexion in first day’s post operation) and the muscle strength. The individual was also provided with gait training in the days

following the operation, progressing from a walking frame to a cane and then without any assistive aids in the time of around six weeks post-surgery. However, a year after the surgery, the patient presented with a varus instability and a significant right knee bone deformity (Picture 10) (Helito et al., 2014).



Picture 10. a)The knee joint implant; b)Varus deformity of the right knee resulting from the failed total knee replacement surgery (Helito et al., 2014).

The patient was still mobile and did not use any assistive aids to help with walking. The ROM was 115 degrees even with the deformity of the joint. Due to the presenting issue, a revision surgery was done in order to fix the bone defect. This time added attention was put on increasing the stability of the joint with the use of a new implant and a graft from the tissue bank. The leg length increased by 4 cm and the prosthetic leg was adjusted in order for both legs to be the same length. The surgery was deemed to a success (Picture 11) and the patients ROM of the knee joint was returned to the

115 degrees within a period of 6 weeks after operation and the patients was able to walk without the use of any assistive aids in total of 4 months after surgery (Helito et al., 2014).

Picture 11. a) The revision knee replacement surgery; b) The patient postural results and the new knee joint implant (Helito et al., 2014).

Even though total knee replacement surgery is considered to be the most affective surgical treatment for osteoarthritis in LLA, it should still be noted that the new joint will remain to be under more load and stress than the contralateral, prosthetic leg. Due to this, the possible need for a second operation remains high. The rehabilitation process should be made slow in its progression as the increased load on the newly operated knee implant is present. Around 70% of the prosthetic limbs have been found to be shorter than the healthy leg, the discrepancies in limb length leading to an

increased load. It should be assessed with great attention as it leaves a huge impact on the individual's gait and posture, putting the healthy leg at an increased risk. Furthermore, it is important to note that the individuals who have had a lower limb amputation while they were younger are in increased risk of developing arthrosis younger than the rest of the population. Due to this, patient education and prevention strategies need to be put in place and should be obligatory for these individuals (Helito et al., 2014).

6 THESIS PROCESS AND METHODS

6.1 Systemized literature review

The literature review type used for this thesis was systemized literature review. As such, it is a tool to assess the current state of knowledge of the topic selected, providing a comprehensive summary of the findings. Additionally, the evidence quality, knowledge gaps and possible connections are discovered and included in the summary made. As a part of systematized literature review, research questions are made with great attention as this will be the basis of the entire thesis process. It is made with the use of PICOS tool. Then inclusion and exclusion criteria are made to manage the evidence gathered, setting boundaries and specifications. After this is completed, reliable information sources are found and selected in order to make sure that the studies found are trustworthy. The sources used for this thesis were Pubmed, ScienceDirect, Google scholar and SAMK Finna. SAMK library was also used to find additional information and books about the topic. Furthermore, the evidence is analyzed for possible biases and conclusions are made based of the information gathered.

The beginning stages of research and deliberation of the topic started on March 2024 when the thesis topic discussion took place. The authors choice of the topic was based on interest and previous reading, leading to a decision to write a systematic literature

review of the prevalence of osteoarthritis in lower limb amputees. Through April and May of 2024, the author begun collecting information on the topic, looking at multiple scientific sources and gathering relevant literature. Once the theoretical base of the thesis was gathered, the writing process was started at the end of May 2024 and continued through the summer months. The thesis writing process, started in May 2024, was concluded in October 2024 and a PowerPoint presentation was made. The overall thesis writing process was completed by December as the presentation will be done on the 8th of January 2025.

6.2 Research Question

The aim of the thesis was to present and comprehensive overview of the current evidence of the risk and prevalence of osteoarthritis of the sound limb of lower limb amputees by the method of systematized literature review.

The research question made for the thesis was “What is the prevalence of osteoarthritis in the sound limb in lower limb amputees?” and “What are the treatments of osteoarthritis of the sound limb of lower limb amputees?”.

6.3 Inclusion and Exclusion Criteria

As a part of the information gathering process, inclusion and exclusion criteria were developed (Table 1). This was made in order to specify the evidence found for the selected topic, making sure that the information was relevant.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
18+ of age individuals (male and female) with lower limb amputations and osteoarthritis of the sound limb	>18 of age individuals (male and female) with lower limb amputations and osteoarthritis of the sound limb

Treatment options for osteoarthritis of the sound limb of lower limb amputees	Treatment options for different conditions of the sound limb of lower limb amputees
Randomized control trials, meta-narrative analysis, systematic review	Randomized control trials, meta-narrative analysis, systematic review not used
Studies in English	Studies not in English
Published 2010 and forward	Published before 2010

6.4 Search Strategy and Study Selection

PICO framework was used to develop search strategies. It is a very commonly used search tool to form a research question. The concept consists of five main parts, including population, intervention, comparison, outcome and study type (Eriksen & Frandsen, 2019).

The PICO strategy used for this thesis was:

- Population: 18 + (male and female) individuals with leg amputations (type now specified) with osteoarthritis in the sound limb
- Intervention: assessment of treatment options available
- Control: control group with no lower limb amputations or control group with lower limb amputation but no osteoarthritis development in the sound leg
- Outcome: benefits of the treatment available

Study selection was made mainly by using reliable and scientific databases such as Pubmed and ScienceDirect. A manual search was also performed. When performing the search, such search terms as “physiotherapy for osteoarthritis” and “leg amputee osteoarthritis treatment” were used. The studies found fallowed a criterion of RCT, Meta-analysis that had been performed in the last 10 years and written in English. In total 63 studies were found and PRISMA flowchart (Figure 1) was used as a part of the assessment process. After the removal of nonrelevant or duplicate studies as the initial stage of the assessment, 10 articles were assessed further. Of these, 5 were

excluded based on not meeting inclusion criteria and 5 were included in this thesis (Table 2).

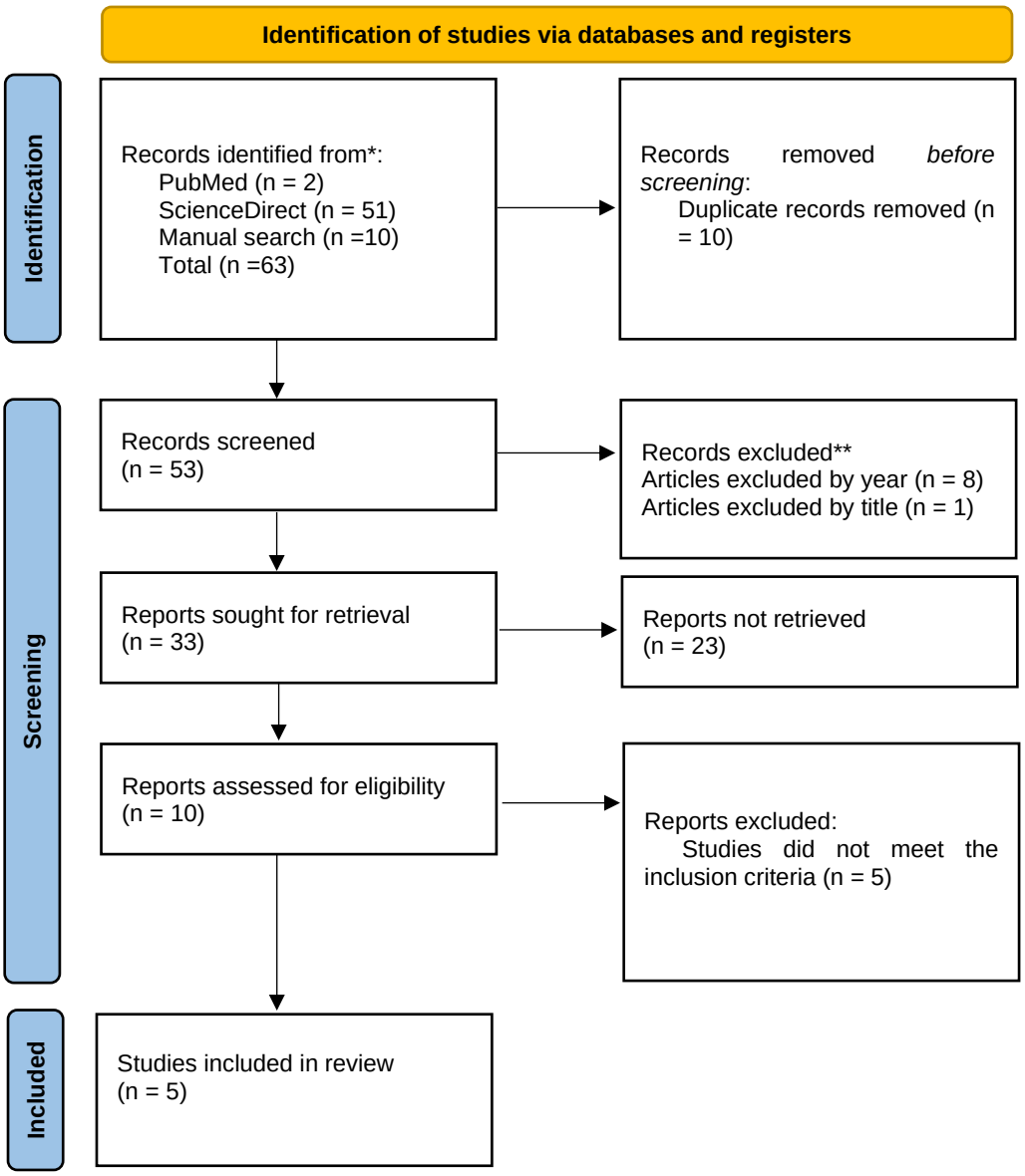


Figure 1. Study selection on Prisma flowchart

Table 2. Summaries of studies selected for this systemized literature review

Author	Title	Outcome
Struyf et al. (2009)	"The Prevalence of Osteoarthritis of the Intact Hip and Knee Among Traumatic Leg Amputees"	78 participants; 27% of the participants had hip OA, 14% of the individuals had knee OA. General population prevalence of knee OA - 1,58% in men and 1,33% in woman and hip OA - 1,13% in men and 0,98% in woman
Gailey (2008)	“Review of secondary physical conditions associated with lower-limb amputation and long-term prosthesis use”	44 studies; Increased risk of sound leg OA being in TFA (around 63%) when compared with TTA (around 41%). Increase of OA when compared with the general population is 3-5 times higher in LLA population. Prevention - prosthetic alignment correction, gait training and full rehabilitation course after amputation.
Donnelly et al. (2022)	“Assessing Ground Reaction Forces and Degenerative Changes of Sound Limb in Unilateral Lower Extremity Amputees: A Systematic Review”	21 studies; Increase of OA prevalence in the sound leg of amputees. The joint loading of the sound leg and ground reaction forces were increased in the sound leg due to compensation of the gait. Prevention - correct prosthesis alignment and full rehabilitation course after amputation.
Teater et al. (2023)	“Unilateral transtibial prosthesis users load their intact limb more than their prosthetic limb during sit-to-stand, squatting, and lifting”	8 participants; Assessment of the load on the legs while performing sit to stand, squat and lift. The evidence gathered showed a major increase of load put on the healthy leg for all the tasks ($p < 0,02$)
Welke et al. (2019)	“The prevalence of osteoarthritis: Higher risk after transfemoral	9 414 participants; Assessment of the prevalence of OA is decreased in the amputee group, however the age of

	amputation? - A database analysis with 1,569 amputees and matched controls”	development of OA in amputee group is noticeably younger

6.5 Study Quality Assessment

When assessing the research articles for this thesis additional attention was brought to the quality of the studies. As the topic is not widely researched, there was a strong lack of methodological studies present. However, two systematic review studies were found, increasing the reliability of the data presented. Additionally, the risk of biases was assessed in each of them and included in the study. The content of each study was assessed based on the inclusion and exclusion criteria, so the selected studies followed the same screening process.

7 SYSTEMIZED LITERATURE REVIEW

A total of 5 studies were selected for this part of the thesis. The study selection followed the inclusion and exclusion criteria to promote the relevance to the topic selected. Additionally, the studies that were selected provide an overall state of the research of the topic available now about the possible correlation between increased osteoarthritis risk in the sound leg in lower limb amputees.

Struyf et al (2009) performed a study to assess the prevalence of osteoarthritis in the contralateral leg (hip and knee) for traumatic lower limb amputees. 78 individuals were selected for the study, including individuals with different level amputations (transtibial, knee, transfemoral) that had happened no later than 5 years before. The individuals were also required to be able to use a prosthetic and be at least 18 years of

age. What was discovered was that knee osteoarthritis was present in 27% of the participants while hip osteoarthritis was present for 14% of the individuals. When comparing to the general population prevalence (knee osteoarthritis 1,58% in men and 1,33% in woman, hip osteoarthritis 1,13% in men and 0,98% in woman) showed the increase of osteoarthritis prevalence in amputee population. What is more, no connection was found between the level of amputation and the prevalence of osteoarthritis. However, the small size of the study needs to be taken into consideration. Furthermore, a systematic review by Gailey (2008) provided the same results, noting the increased prevalence of osteoarthritis in the sound leg, suggesting that it is due the increased load of the healthy leg, poor prosthetic alignment and prosthetic duration use. The review consisted of 44 articles of various themes as it assessed osteoarthritis, bone health, prosthesis use and back pain. A comparison of amputation level was researched, the greater risk of sound leg osteoarthritis being in transfemoral amputees (around 63%) when compared with transtibial amputees (around 41%). What is more, the overall increase of osteoarthritis of the hip and knee when compared with the general population is around 3-5 times higher in the lower limb amputee population. The prevention of osteoarthritis development was suggested to be prosthetic alignment correction, gait training and full rehabilitation course after amputation.

A systematic review done by Donnelly et al (2022) assessed the ground reaction force and degenerative changes of the amputee contralateral sound leg. 21 studies were included in the systematic review. What was discovered was that there is an major increase of osteoarthritis prevalence in the sound leg of amputees. The predictors of joint degeneration are factors like time duration since amputation, amputation level (higher instance in transfemoral amputees when compared with transtibial amputees), prosthetic type and weight bearing. Additionally, the joint loading of the sound leg and ground reaction forces were both increased in the sound leg due to compensation of the gait and can increase the prevalence of osteoarthritis. The possible solution or prevention strategy was said to be correct prosthesis alignment and full rehabilitation course after amputation.

To assess if the prevalence of contralateral leg osteoarthritis in connected with the increased load of the sound leg of lower limb amputees, Teater et al (2023) performed a study involving a series of tests that assessed the load of the legs while patients performed sit to stand, squat and lifting. Additionally, the ankle ROM of the prosthetic leg was also assessed. Eight individuals with transtibial amputations were asked to perform the motions. The evidence gathered showed a major increase of load put on the healthy leg for all the tasks ($p < 0,02$). The sound limb had around 36-48% grater peak ground reaction force. Additionally, the peak knee flexion movement was 168-343% greater than that of the prosthetic leg. As for the prosthetic leg ankle, it provided almost less than half of ROM when compared with the healthy ankle. The results showed that the prosthesis users put more load on the healthy leg that might be a contributing factor for osteoarthritis development. However, the small size of the study should be noted.

A study done in 2019 in Germany explored the possible connection between the increased instances of OA in transfemoral amputees. The total number of participants was 9,414, consisting of 1569 patients with transfemoral amputees and five groups of 1569 control group patients. The mean age of the study was 63,3 years. The age groups consisted of similar numbers of participants both from the control group and the amputee group. In the study it was concluded that the prevalence of OA decreased in the amputee group, contradicting many other research done on the topic. The writers of the study speculate that many sources show how amputees are less active than the non-amputee population, reducing the risk of OA even though the load on the amputee patient joints is known to be increased. Additionally, the information about the participants was limited, so there is no mention of other health factors, such as obesity that is known to have an impact on OA development or the patient's prosthetic treatment. But, due to the large number of participants the authors of the study regard the study limitations as acceptable (Welke et al., 2019).

However, while further evaluating the patients it was noticed that while the overall OA instance in amputation patients seemed to be lowered, the transfemoral amputees who did have a bigger instance of OA of the knee and hip were significantly younger than those in the control group. This could show the possible acceleration of the condition

in this population. This was seen in the age distribution of patients diagnosed with polyarthritis (joint disease affecting five or more joints at the same time), coxarthrosis (hip OA) and gonarthrosis (knee OA). The prevalence of all the previously mentioned conditions was seen as increased and surpassed the control group from the ages 40-69 in polyarthritis, ages 30-69 in coxarthrosis and ages 20-59 and 70-79 in gonarthrosis (Welke et al., 2019).

8 CONCLUSION

The results of this systemized literature review suggest that there could be an increased prevalence of osteoarthritis in the sound leg of lower limb amputees, however due to the limited studies available on the topic, more research is needed. The studies available, except one, had evidence of the increased prevalence when comparing the lower limb amputee population with the abled bodied population. The causes of it are guessed to be the increased load and ground force of the sound leg, poor prosthesis alignment and decreased physiotherapy time after amputation that would include gait and prosthesis training.

Additionally, the treatment of osteoarthritis in the sound limb of lower limb amputees depends on the conditions of the disease. As there is no cure for this condition, it is vital to provide education about the prevention before the development of the disease. What is more, full physiotherapy course, gait training and prosthesis training should be undergone by these patients as this has strong evidence of secondary complication prevention for these individuals. If it is not done, the patient is at more risk of complications in the future due to movement compensation, prosthesis misalignment and learned incorrect gait. If osteoarthritis has developed in the joint, the treatment strategy is symptom management and slowing down the degeneration process. Strength training and mobility training has had positive evidence, available studies suggesting them to be beneficial in pain and stiffness reduction. Knee brace use for the sound leg has had some positive evidence, however more studies are needed to verify

the effect. If the disease has had a drastic impact on the joint, surgical intervention is considered. From those a full joint replacement surgery has had the best research results in patients functioning and quality of life.

9 DISCUSSION

This thesis aim was to provide an overall summary of the evidence available on the topic presented. Five studies were included, two of them being systematic literature reviews. Due to the limitation of literature present, the inclusion criteria were changed to include studies from 2008, providing additional research material available. The rest of the inclusion and exclusion criteria remained unchanged. However, that still provided a problem of study sizes – most of the studies consisted of small participant groups, reducing their statistical reliability of the topic.

The first authors to describe the possibility of increased OA prevalence in the sound limb of lower limb amputees were D. S. Hungerford and J. Cockin. They found that there is increased prevalence of patellofemoral OA of the sound limb between British and American World War I amputee veterans than those without amputations. 22% of the veterans with no amputations had patellofemoral OA, while 41% of the veterans with TTA and 63% of the veterans with TFA had developed patellofemoral OA of the sound limb (Gailey, 2008).

Similar conclusions were reached in other studies, suggesting that the prevalence of OA noted between military amputees was 16,1% while non amputee prevalence was noticeably lower – 11,7%. The cause of this was theorized to be due to the gait abnormalities and the overall increased load for the contralateral leg (Norvell et al., 2005). The same conclusion was made in a different study that further examined 78 traumatic amputee OA prevalence and discovered an increase when compared to the public (Struyf et al., 2009). However, there are studies contradicting the theory of increased amputee OA prevalence, not noting any increase while comparing the

amputees with the general population. However, it was noted that the individuals with LLA were developing OA a lot earlier than able-bodied population, showing an increased rate of joint damage development (Welke et al., 2019).

Rehabilitation for individuals with lover limb amputation is difficult both physically and mentally. They face a lot of challenges with adjusting to their new body and relearning how to function again. It can be extremely hard to face these new issues and the support and guidance from a physiotherapist can be an extremely important part of their recovery. The rehabilitation process should involve many different types of training, focusing on aerobics, strength, flexibility, balance and coordination training. The patients need to understand the importance of maintaining their physical health and abilities, while also protecting the joints of the sound leg. An important aspect of the recovery process should also be put on the patient's mental health and their feelings through the process. Amputation is a serious and life-changing procedure and can leave a lasting effect on the individual's mental health. Due to this, psychological help and support for the patients would be extremely beneficial.

Cases where lower limb amputees develop osteoarthritis in their sound leg are very serious as it further limits the individual's functionality and their ability to rely on their sound leg. Developing osteoarthritis can be frightening for these individuals as they are already experiencing limited mobility and additional issues with their sound leg can feel debilitating. Due to this, physiotherapist need to be able to inform the individuals about the importance of correct prosthesis alignment, exercising and gait training early in their recovery to prevent the possible development of osteoarthritis and other conditions in their future. However, in the case where the individual has developed osteoarthritis in the sound leg joints, treatment methods should be applied, and the patient needs to be educated of the condition and its symptoms. During the thesis writing process, the author had physiotherapy practice in trauma and orthopedic hospital and was able to work with individuals with osteoarthritis in different stages of development. The author was also able to observe hip and knee replacement surgeries done for individuals with severe stages of osteoarthritis, seeing the impact and damage this condition has left on the joints. The experience provided additional

insight of the condition and impact left on the individuals as well as increased the authors knowledge of the practical side of osteoarthritis treatment.

As for the ethical considerations of the studies included in the thesis, there were several concerns mentioned that should be considered before working with this population. Firstly, the privacy and data protection is vital in order to maintain patient confidentiality and anonymity. Secondly, all types of lower limb amputees, unless specifically previously selected types, should be considered to avoid selection bias and increase fair representation. What is more, this patient group is a vulnerable population and due to this, there must be clear guidelines set in place. For example, protecting the patients emotional and physical health from harm and maintaining a safe research environment. Some questions might bring up difficult emotions and cause emotional distress, especially related to the reason of amputation as it can be a traumatic experience and could have left an lasting impact on the patients mental health.

In conclusion, more research on the topic is needed to fully understand the impact and reasoning of the increased osteoarthritis prevalence for these individuals. Additionally, the studies need to include more information about the individual daily activity levels, prosthetic leg use duration, time duration after amputation and the individual weights as these are all factors that could impact the load being put on the sound leg. Additionally, it would be beneficial to have information about the individual's rehabilitation process after amputation – did they undergo the full physiotherapy treatment, gait training and prosthesis training after the amputation as incorrect learned behavior could be the reason of the increased prevalence. The importance of physiotherapy and rehabilitation for individuals with lower limb amputation is vital and should be provided early in the recovery process. Physiotherapists should be able to provide support and knowledge for these individuals to help them remain independent and active, leaving a positive, lasting impact on their quality of life and functioning.

REFERENCES

Alessa, M., Alkhalaf, H. A., Alwabari, S. S., Alwabari, N. J., Alkhalaf, H., Alwayel, Z., & Almoaibed, F. (2022). The Psychosocial Impact of Lower Limb Amputation on Patients and Caregivers. Cureus, 14(11). https://doi.org/10.7759/cureus.31248

Arden, N., Blanco, F., C Cooper, Guermazi, A., Daichi Hayashi, Hunter, D., M Kassim Javaid, Francois Rannou, Roemer, F., & Jean-Yves Reginster. (2014). Atlas of Osteoarthritis. Springer Healthcare Ltd.

Davis, A. J., Kelly, B. M., & Catherine, M. (2013). Prosthetic Restoration and Rehabilitation of the Upper and Lower Extremity. Demos Medical Publishing.

Dobson, G. P., Letson, H. L., Grant, A., McEwen, P., Hazratwala, K., Wilkinson, M., & Morris, J. L. (2018). Defining the osteoarthritis patient: back to the future. Osteoarthritis and Cartilage, 26(8), 1003–1007. https://doi.org/10.1016/j.joca.2018.04.018

Donnelly, K. N., Davis, C., Liotta, N., Perkins, A., Agrawal, V., Highsmith, J., & Love, S. (2022). Assessing Ground Reaction Forces and Degenerative Changes of Sound Limb in Unilateral Lower Extremity Amputees: A Systematic Review. Acta Scientific Orthopaedics, 03-19. https://doi.org/10.31080/asor.2022.05.0542

Doyle, S. S., Lemaire, E. D., Nantel, J., & Sinitski, E. H. (2019). The effect of surface inclination and limb on knee loading measures in transtibial prosthesis users. Journal of NeuroEngineering and Rehabilitation, 16(1). https://doi.org/10.1186/s12984-019-0509-9

Dries, T., Van der Windt, J. W., Akkerman, W., Kluijtmans, M., & Janssen, R. P. A. (2022). Effects of a Semi-rigid Knee Brace on Mobility and Pain in People with Knee Osteoarthritis. Journal of Rehabilitation Medicine - Clinical Communications, 5, jrmcc00085. https://doi.org/10.2340/jrmcc.v5.2483

Eidmann, A., Kamawal, Y., Luedemann, M., Raab, P., Rudert, M., & Stratos, I. (2023). Demographics and Etiology for Lower Extremity Amputations—Experiences of an University Orthopaedic Center in Germany. Medicina, 59(2), 200. https://doi.org/10.3390/medicina59020200

Eriksen, M. B., & Frandsen, T. F. (2019). The Impact of Patient, Intervention, Comparison, Outcome (PICO) as a Search Strategy Tool on Literature Search Quality: a Systematic Review. Journal of the Medical Library Association, 106(4), 420–431. NCBI. https://doi.org/10.5195/jmla.2018.345

Gailey, R. (2008). Review of secondary physical conditions associated with lower-limb amputation and long-term prosthesis use. The Journal of Rehabilitation Research and Development, 45(1), 15–30. https://doi.org/10.1682/jrrd.2006.11.0147

Gailey, R. S., Roach, K. E., Applegate, E. Brooks., Cho, B., Cunniffe, B., Licht, S., Maguire, M., & Nash, M. S. (2002). The Amputee Mobility Predictor: An instrument to assess determinants of the lower-limb amputee's ability to ambulate. Archives of Physical Medicine and Rehabilitation, 83(5), 613–627. https://doi.org/10.1053/apmr.2002.32309

Gailey, R., Gaunaurd, I., Raya, M., Kirk-Sanchez, N., Prieto-Sanchez, L. M., & Roach, K. (2020). Effectiveness of an Evidence-Based Amputee Rehabilitation (EBAR) Program: A Pilot Randomized Controlled Trial. Physical Therapy, 100(5). https://doi.org/10.1093/ptj/pzaa008

Gallagher, P., & MacLachlan, M. (2000). Positive meaning in amputation and thoughts about the amputated limb. Prosthetics and Orthotics International, 24(3), 196–204. https://doi.org/10.1080/03093640008726548

Garrick, N. (2017). Osteoarthritis. National Institute of Arthritis and Musculoskeletal and Skin Diseases. https://www.niams.nih.gov/health-topics/osteoarthritis#:~:text=Osteoarthritis%20is%20a%20degenerative%20joint

Grady, J., & Winters, C. (2000). The Boyd amputation as a treatment for osteomyelitis of the foot. Journal of the American Podiatric Medical Association, 90(5), 234–239. https://doi.org/10.7547/87507315-90-5-234

Grässel, S., & Muschter, D. (2020). Recent advances in the treatment of osteoarthritis. F1000Research, 9(1). https://doi.org/10.12688/f1000research.22115.1

Hafiz Farhan Maqbool, Mahmood, I., Ali, A., Iqbal, N., Seong, J.-T., Abbas Ali Dehghani-Sanij, Sundas Naji Alaziz, & Mohammed Ibrahim Awad. (2024). Gait Asymmetrical Evaluation of Lower Limb Amputees using Wearable Inertial Sensors. Heliyon, 10(12), e32207–e32207. https://doi.org/10.1016/j.heliyon.2024.e32207

Hunter, D. J., & Bierma-Zeinstra, S. (2019). Osteoarthritis. The Lancet, 393(10182), 1745–1759. https://doi.org/10.1016/s0140-6736(19)30417-9

Jang, S., Lee, K., & Ju, J. H. (2021). Recent Updates of Diagnosis, Pathophysiology, and Treatment on Osteoarthritis of the Knee. International Journal of Molecular Sciences, 22(5), 2619. https://doi.org/10.3390/ijms22052619

Jo, S.-H., Kang, S.-H., Seo, W.-S., Koo, B.-H., Kim, H.-G., & Yun, S.-H. (2021). Psychiatric understanding and treatment of patients with amputations. Yeungnam University Journal of Medicine, 38(3), 194–201. https://doi.org/10.12701/yujm.2021.00990

Kesikburun, S., Köroğlu, Ö., Yaşar, E., Güzelküçük, Ü., Yazcoğlu, K., & Tan, A. K. (2015). Comparison of Intact Knee Cartilage Thickness in Patients with Traumatic Lower Extremity Amputation and Nonimpaired Individuals. American Journal of Physical Medicine & Rehabilitation, 94(8), 602–608. https://doi.org/10.1097/phm.0000000000000216

Kowal, M., Winiarski, S., Gieysztor, E., Kołcz, A., Walewicz, K., Borowicz, W., Rutkowska-Kucharska, A., & Paprocka-Borowicz, M. (2021). Symmetry function in gait pattern analysis in patients after unilateral transfemoral amputation using a

mechanical or microprocessor prosthetic knee. Journal of NeuroEngineering and Rehabilitation, 18(1). https://doi.org/10.1186/s12984-021-00810-w

Magee, D. J. (2021). Orthopedic Physical Assessment (6th ed.). Elsevier Saunders.

Maqbool, M., Fekadu, G., Jiang, X., Bekele, F., Tolossa, T., Turi, E., Fetensa, G., & Fanta, K. (2021). An up to date on clinical prospects and management of osteoarthritis. Annals of Medicine and Surgery, 72(72), 103077. https://doi.org/10.1016/j.amsu.2021.103077

Mohit Kapoor, & Mahomed, N. N. (2015). Osteoarthritis[Recurs electrònic] : Pathogenesis, Diagnosis, Available Treatments, Drug Safety, Regenerative and Precision Medicine. Springer International Publishing.

Morgenroth, D. C., Gellhorn, A. C., & Suri, P. (2012). Osteoarthritis in the Disabled Population: A Mechanical Perspective. PM&R, 4, S20–S27. https://doi.org/10.1016/j.pmrj.2012.01.003

Moseley, J. B., O'Malley, K., Petersen, N. J., Menke, T. J., Brody, B. A., Kuykendall, D. H., Hollingsworth, J. C., Ashton, C. M., & Wray, N. P. (2002). A Controlled Trial of Arthroscopic Surgery for Osteoarthritis of the Knee. New England Journal of Medicine, 347(2), 81–88. https://doi.org/10.1056/nejmoa013259

Moskowitz, R. W., Altman, R. D., & Buckwalter, J. A. (2015). Osteoarthritis Diagnosis and Medical/Surgical Management. Philadelphia Wolters Kluwer Health [Ann Arbor, Michigan]

Moura, D. L., & Garruço, A. (2017). Hip disarticulation – case series analysis and literature review. Revista Brasileira de Ortopedia (English Edition), 52(2), 154–158. https://doi.org/10.1016/j.rboe.2016.09.008

Murphy, D. P. (2014). Fundamentals of amputation care and prosthetics. Demos Medical.

Norvell, D. C., Czerniecki, J. M., Reiber, G. E., Maynard, C., Pecoraro, J. A., & Weiss, N. S. (2005). The prevalence of knee pain and symptomatic knee osteoarthritis among veteran traumatic amputees and nonamputees. Archives of Physical Medicine and Rehabilitation, 86(3), 487–493. https://doi.org/10.1016/j.apmr.2004.04.034

Osteoarthritis: In Depth. (n.d.). NCCIH. https://www.nccih.nih.gov/health/osteoarthritis-in-depth

Parvizi, J., & Kim, G. K. (2010). Amputation of the Lower Limb. Elsevier EBooks, 17–19. https://doi.org/10.1016/b978-1-4160-0236-9.00018-3

Physiopedia. (2014). Amputations. Physiopedia. https://www.physio-pedia.com/Amputations

Pouyan Mehryar, Tahmineh Rezaeian, Mohammad Sharif Shourijeh, Vishal Raveendranathan, Messenger, N., O'Connor, R., & Abbas Dehghani-Sanij. (2017). Changes in knee joint kinetics of transfemoral amputee's intact leg: An osteoarthritis indication? Gait & Posture, 57, 151–152. https://doi.org/10.1016/j.gaitpost.2017.06.340

Prieto-Alhambra, D., Arden, N., & Hunter, D. J. (2014). Osteoarthritis : The facts. Oxford University Press, Incorporated.

Rosario, M. L. V. V., Costa, P. B., da Silveira, A. L. B., Florentino, K. R. C., Casimiro-Lopes, G., Pimenta, R. A., Dias, I., & Bentes, C. M. (2023). Effects of Resistance Training in Individuals with Lower Limb Amputation: A Systematic Review. Journal of Functional Morphology and Kinesiology, 8(1), 23. https://doi.org/10.3390/jfmk8010023

S. Persine, S. Leteneur, Gillet, C., J. Bassement, F. Charlaté, & E. Simoneau-Buessinger. (2024). Kinetic adaptations of the intact limb in transfemoral amputees using a microprocessor prosthetic knee. Gait & Posture, 108, 170–176. https://doi.org/10.1016/j.gaitpost.2023.11.022

Sen, R., & Hurley, J. A. (2023). Osteoarthritis. National Library of Medicine; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK482326/

SEVENTH EDITION (7th ed.). Elsevier Ltd

Sharmila Majumdar. (2010). Advances in MRI of the knee for osteoarthritis. World Scientific.

Struyf, P. A., van Heugten, C. M., Hitters, M. W., & Smeets, R. J. (2009). The Prevalence of Osteoarthritis of the Intact Hip and Knee Among Traumatic Leg Amputees. Archives of Physical Medicine and Rehabilitation, 90(3), 440–446. https://doi.org/10.1016/j.apmr.2008.08.220

Struyf, P. A., van Heugten, C. M., Hitters, M. W., & Smeets, R. J. (2009). The Prevalence of Osteoarthritis of the Intact Hip and Knee Among Traumatic Leg Amputees. Archives of Physical Medicine and Rehabilitation, 90(3), 440–446. https://doi.org/10.1016/j.apmr.2008.08.220

Teater, R. H., Wolf, D. N., McDonald, K. A., & Zelik, K. E. (2023). Unilateral transtibial prosthesis users load their intact limb more than their prosthetic limb during sit-to-stand, squatting, and lifting. Clinical Biomechanics (Bristol, Avon), 108, 106041. https://doi.org/10.1016/j.clinbiomech.2023.106041

Thakur, A., Elliott, B., Naik, R., Khan, N., McQuaid, S., & Arsene, C. (2018). Recurrent hospitalisations in a rare case of hemicorporectomy: a challenging case for medical management. BMJ Case Reports, bcr-2017-222375. https://doi.org/10.1136/bcr-2017-222375

The War Amps. (2016). The War Amps. Waramps.ca. https://www.waramps.ca/home/

Turner, S., Belsi, A., & McGregor, A. H. (2021). Issues faced by people with amputation(s) during lower limb prosthetic rehabilitation. Prosthetics & Orthotics

International, Publish Ahead of Print(1). https://doi.org/10.1097/pxr.0000000000000070

van der Wal, G. E., Dijkstra, P. U., & Geertzen, J. H. B. (2023). Lisfranc and Chopart amputation: A systematic review. Medicine, 102(10), e33188. https://doi.org/10.1097/md.0000000000033188

Walton, T. J., Abigail, & Goodwin, V. A. (2024). Hip and knee replacement in lower limb amputees: a scoping review. BMC Musculoskeletal Disorders, 25(1). https://doi.org/10.1186/s12891-024-07342-z

Wang, S.-T., & Ni, G.-X. (2022). Depression in Osteoarthritis: Current Understanding. Neuropsychiatric Disease and Treatment, Volume 18(1), 375–389. https://doi.org/10.2147/ndt.s346183

Wasser, J. G., & Vincent, H. K. (2017). Exercise for Amputees With Osteoarthritis. ACSM's Health & Fitness Journal, 21(5), 55–57. https://doi.org/10.1249/fit.0000000000000322

Welke, B., Jakubowitz, E., Seehaus, F., Daniilidis, K., Timpner, M., Tremer, N., Hurschler, C., & Schwarze, M. (2019). The prevalence of osteoarthritis: Higher risk after transfemoral amputation?—A database analysis with 1,569 amputees and matched controls. PLOS ONE, 14(1), e0210868. https://doi.org/10.1371/journal.pone.0210868

Yuan, B., Dong, H., Gu, S., Xiao, S., & Song, F. (2023). The global burden of traumatic amputation in 204 countries and territories. Frontiers in Public Health, 11. https://doi.org/10.3389/fpubh.2023.1258853

Zhang, T., Bai, X., Liu, F., Ji, R., & Fan, Y. (2020). The effect of prosthetic alignment on hip and knee joint kinetics in individuals with transfemoral amputation. Gait & Posture, 76, 85–91. https://doi.org/10.1016/j.gaitpost.2019.11.006