2016•2017
FACULTEIT GENEESKUNDE EN LEVENSWETENSCHAPPEN
master in de revalidatiewetenschappen en de kinesitherapie

Masterproef deel 1

Muscle imbalance of the m. gluteus maximus, m. tensor fasciae latae and m. iliopsoas in patients with hip complaints

Promotor :
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Eerste deel van het scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie

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universiteit hasselt
KNOWLEDGE IN ACTION

Part one: Muscle imbalance of the m. gluteus maximus, m. tensor fasciae latae and m. iliopsoas in patients with hip complaints

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Research question: "Does exercise therapy have an influence on muscle imbalance of the m. gluteus maximus/medius, m. tensor fasciae latae, and m. illiopsoas for patients with hip dysplasia or hip osteoarthritis?"

Highlights:

- Hip dysplasia is a significant risk factor for hip osteoarthritis.
- Patients with hip osteoarthritis often suffer from muscle imbalance or atrophy of the muscles surrounding the hip.
- Important muscles concerning the muscle imbalance of people with hip osteoarthritis or hip dysplasia are: m. gluteus maximus/medius, m. tensor fasciae latae and m. iliopsoas.
- The impact of exercise therapy on the muscles surrounding the hip of people with hip osteoarthritis or hip dysplasia should be investigated more.

Students: Vankriekelsvenne Thomas & Verbruggen Bob

Promotor: Prof. Dr. Vandenabeele Frank

Co-promotor: Prof. Dr. Corten Kristof & Dr. Agten Anouk

Content

Part I

Part II

Research Framework

This literature study fits in the research domain of musculoskeletal diseases and physiotherapy department of Hasselt University and is constructed according to the “central format.” The effect of exercise therapy on muscle imbalance of the m. Gluteus maximus/medius, m. Tensor fasciae latae and m. Iliopsoas of people with hip osteoarthritis (OA) or hip dysplasia was studied through a review. Outcome measures are: muscle strength, function, pain, activities of daily living (ADL), quality of life (QOL), range of motion (ROM) and walking.

Exercise therapy was chosen because people with hip dysplasia or hip OA are often correlated with atrophy of the muscle or muscle imbalance. It could be interesting to see if exercise therapy is a good alternative treatment for hip OA instead of chirurgical treatment.

The research topic was provided by our promotor Prof. Dr. Frank Vandenabeele. The final research question, literature study and research protocol was specified and completed by master students Thomas Vankriekelsvenne and Bob Verbruggen in co-operation with the promotor. Part two of this thesis will be executed in cooperation with “Ziekenhuis Oost-Limburg (ZOL)” and the KUL.

1. Abstract

Background: Hip dysplasia has been a significant risk factor of hip osteoarthritis (OA), therefore hip OA is often a secondary consequence of congenital dislocation or dysplasia of the hip. Previous research showed that people who suffer from hip OA, also suffer from atrophy of muscles surrounding the hip which can lead to joint instability. As an alternative management exercise therapy is suggested as a first line treatment for hip OA. Evidence has been gathered about the impact of exercise on patients with knee OA. However, the evidence of the effect of exercise on the muscles which surround the hip, targeting people who suffer from hip OA or hip dysplasia, isn't clearly described.

Methods: The databases Pubmed and Web of Knowledge (WoK) were scanned for literature on hip dysplasia, hip OA and the effect of exercise training on the surrounding muscles. Research was based on a repeatable search strategy with a wide array of MeSH-terms.

Results: Exercise therapy seems to improve ADL, QOL and seem to enlarge ROM, with a reduction of pain as well. Furthermore, walking, muscle strength and function seem to improve after exercise therapy in people with hip OA or hip dysplasia.

Discussion and conclusion: Exercise therapy seems to have a beneficial effect on pain, ADL, QOL, ROM, walking, muscle strength and function in people with hip dysplasia or hip OA. However, further research on different exercise modalities and other forms of therapy for patients with hip dysplasia or hip osteoarthritis is needed to supplement the amount of evidence.

Operationalization: Sixty individuals will be included of which 20 healthy individuals, 20 with knee osteoarthritis (KOA) which are on a waiting list for a total knee arthroplasty and 20 individuals with hip osteoarthritis (HOA) which are on a waiting list for a total hip arthroplasty. All subjects will fill up four clinical questionnaires, which will be repeated every visit. Aside from this, every subject will be executing a functional movement protocol wherein the movements will be registered using a mobile movement registration system. Furthermore, a power platform will be used and an electromyography to measure the ground reaction force and muscle activity. The healthy individuals will be measured twice, subjects with OA will be measured 1x pre-operative and 5x post-operative.

Primary outcome measures will be: pain ADL, QOL, ROM, walking, muscle strength and function.

Keywords: Hip dysplasia, hip osteoarthritis, exercise therapy, muscle imbalance.

2. Introduction

Osteoarthritis (OA) of the hip, a common musculoskeletal disease, is present in 5-11% of the general adult population and has a global impact on healthcare costs.[2;5;9;11-13;15] OA prevalence increases with the age and is more common in women than in men. Hip dysplasia, also known as developmental dysplasia of the hip (DDH) is a deformation or misalignment of the hip and has been a significant risk factor for the development of hip OA. Eighty percent of all cases of OA of the hip is caused by congenital dislocation or dysplasia of the hip.[8] Mechanical stress and dynamic instability are two significant factors contributing to hip OA secondary to hip dysplasia.[8] It clinically presents itself as pain in the groin, lateral hip and regions of the medial thigh. It also presents itself as reduced mobility, muscle function and activities of daily living (ADL).[6;9;11;12;15]

Muscle imbalance or atrophy of the muscles surrounding the hip like the m. gluteus maximus/medius, m. tensor fasciae latae and m. iliopsoas are frequently found in people with hip OA which can lead to joint instability. Moreover, range of motion (ROM) and aerobic fitness are also impaired.[5] For this reason, exercise therapy is considered to be an important nonpharmacological treatment to reduce pain and disability in people with hip OA.[14] Therefore, alternative treatment like exercise therapy and education are a first line treatment for hip OA. This can delay or even prevent the impact of instability. Several studies showed that exercise therapy has a positive effect on self-reported hip function.[2;3;5;11;12;15] Multiple therapeutic exercises are reported for people with hip OA. The exercises aim to improving muscle strength, ROM and stability.

It has been noted that individual exercise 1-3 times a week for 12 weeks improves the reduction of pain and disability in patients with hip OA.[15] According to Jigami et al. it is important to make a difference between the effects of training on muscles, pain and quality of life (QOL) when trained on land or when trained under water. Roddy et al. described that exercise may reduce pain and disability also in patients with hip OA.[10] Evidence has been gathered about the positive impact of exercise on pain, activity limitations and muscle strength in patients with knee OA. However, the effect of exercise on the muscles surrounding the hip, in people with hip OA or hip dysplasia, isn't clearly described. Therefore, this review is aiming to describe the effects of exercise on muscles surrounding the hip in people with hip OA or hip dysplasia. It is important to know if this conservative treatment (exercise therapy) can improve the QOL and reduce pain in patients suffering from OA. The main goal is to prevent hip replacements.

3. Methods

3.1 Research question

Does exercise therapy have an influence on muscle imbalance of the m. gluteus maximus/medius, m. tensor fasciae latae, and m. illiopsoas for patients with hip dysplasia or hip osteoarthritis?

The research question is shaped by the following acronym PICO:

P: Patients with hip dysplasia or hip osteoarthritis.

I: Exercise therapy for the m. gluteus maximus/medius, m. tensor fasciae latae, and m. illiopsoas.

C: No exercise therapy.

O: Muscle imbalance of the m. gluteus maximus/medius, m. tensor fasciae latae, and m. illiopsoas.

3.2 Literature search

The databases PubMed (PM) and Web of Knowledge (WoK) were used for this topic.

The following combinations of Medical Subject Headings (MeSH) and keywords were used for this topic.

1. Hip
2. Exercise Therapy
3. Exercise
4. Resistance training
5. Muscle imbalance
6. Muscle weakness
7. Muscle Strength
8. Psoas Muscles
9. Iliopsoas
10. Gluteus maximus
11. Gluteus medius
12. Tensor fascia latae
13. Hip abductor
14. Hip extensor
15. Hip flexor

All these terms were combined with “AND” or “OR”. (table 1) The titles of the resulting hits were screened based on using the selected inclusion and exclusion criteria for relevance. When hits were potentially relevant, they were sent to EndNote X8. Once collected in Endnote X8, the abstracts were screened based on the selected inclusion and exclusion criteria again. When there was lack of information in the abstracts, the full texts were screened to check the relevance of the article.

3.3 Selection criteria

The following inclusion criteria were used to select the articles:

- Does the study describe humans?
- Does the study describe people with hip dysplasia or hip osteoarthritis?
- Does the study include exercise training?
- Does the study describe the effect of exercise on muscle?

The following exclusion criteria were used to exclude the articles:

- Animal studies.
- Review.
- Studies in languages other than Dutch and English.
- No relevant population.
- No relevant intervention.

3.4 Quality assessment

A quality assessment was executed using the Cochrane checklist RCT, a self-made checklist for a Case report study based on “JBI Critical Appraisal Checklist for Case Series”, a self-made checklist for Cohort studies and a checklist for pilot studies.[17] The quality assessment was performed and discussed independently by two researchers.

- The Cochrane checklist randomized controlled trial (RCT) reviewed 8 studies. (table 2)
- The Case report checklist reviewed one study. (table 3)
- The Cohort checklist reviewed two studies. (table 4)
- The Pilot checklist reviewed one study. (table 5)

3.5 Data extraction

All eligible studies were processed and data was elaborated into tables. The studies of lower quality were discussed with the promoter of this study and excluded if necessary. These publications are focusing on the effect of exercise on muscles on patients with hip dysplasia or hip osteoarthritis. The primary outcome to be investigated is the effect of training on muscle strength and function, other important outcome measures were ROM and the SF - 36 questionnaire.

4. Results

4.1 Results of literature search

In search for articles about the effect of exercise on the muscle of people with hip osteoarthritis or hip dysplasia, 1296 results were found using several keywords. Nine hundred and eighty-two of these publications were found on PubMed and 314 were found on Web of Science (WoS). All 1296 publications were screened on title, only 56 publications were chosen for further screening. After excluding the duplicates, 46 publications were leftover. Titles and abstracts were screened using our inclusion and exclusion criteria. The most common reasons to exclude publications were no relevant intervention, outcome or population. (table 8)

As a result, there were 12 publications left, of which eight randomized controlled trials, two cohort study, one pilot study and one case report. (Figure 1)

4.2 Results quality assessment

To check the quality of the 12 included articles, four different checklists were used. Those checklists rate the quality of different studies. Eight included publications were randomized controlled trials (RCT's). The scores of those RCT's were relatively high. The lowest score was 3/11 (27%). The other scores varied from 6/11 to 9/11 (54%-82%). The publications of lower quality were not excluded because of the paucity of the usable studies. There were two cohort studies included and both have a high rating of 8/10 (80%) and 9/10 (90%). Finally, there are two studies with a lower level of evidence but a strong quality. These two studies are a case report and a pilot study. These studies respectively scored 5/6 (83%) and 7/7 (100%) on their checklists.

4.3 Results data extraction

Twelve articles were included and used for data extraction. The most relevant parameters based on the research question were: The effect of exercise on muscle strength and function, pain, ADL and quality of life, Range of motion and walking. These parameters were set in agreement with the promoter of this study. The most important parameter to be investigated according to the similarities in the included publications, is the effect of strength training exercises on muscle strength and function of patients with OA of the hip.

Exercise therapy is recommended as a first line treatment modality in lower limb OA and has been demonstrated to have a beneficial effect on self-reported hip function in patients with hip OA.[12] Almost eighty percent of all cases of osteoarthritis of the hip joint reported in Japan are developed secondary to congenital dislocation or dysplasia of the hip[8], therefor it needs to be investigated what effects of exercise therapy are on muscles of patients with dysplasia of the hip joint. Patients reported a decrease in hip pain after performing intensive exercise rehabilitation. Therefore, abductor muscle strengthening is considered an effective conservative therapy for treating dysplasia of the hip.[8]

4.3.1 Effect of exercise on muscle strength and function

The effects of exercise on muscle strength and muscle function done by people with hip osteoarthritis or hip dysplasia were measured using several methods. To detect the function of muscles they used, following criteria were measured: “physical function”, “Overall magnitude of acceleration”, “hip disability and osteoarthritis outcome score” (HOOS), “Observed disability” and the “WOMAC”. To detect the muscle strength, research was done for: “muscle thickness and echo intensity”, “muscle power”, “British Medical Research Councils (BMRC)” and strength has been measured of the “hip flexor”, “hip extensor”, “knee flexor”, “knee extensor”, “hip adductor”, “hip abductor”, “hip internal rotation”, “hip external rotation”, “leg extension power” and the general “muscle strength”.

Three articles used the HOOS questionnaire. Two of them showed a significant improvement of muscle strength and function (10.0 (3.7-16.3) Sport/Rec (p<0.03)6 and 4.73 (2.61;6.86) Sport/Rec (p<0.05)).[1] Bennell et al. showed no significant change within group (-1.6 (-11.5 to 8.3) Sport/Rec week 13 and -0.9 (-17.6 to 15.9) week 36). [2] Bennell et al. investigated the physical function after physiotherapy, but it did not show a significant improvement. (1.4 (-3.9 to 17,7) units week 13 and 4.3 (-9.9 to 18.6) units week 36)[2] Kuroda et al. found a significant decrease in the overall magnitude of acceleration after hip abductor strengthening exercises (1.82 m/s^2 ± 0.25 ($p < 0.0001$)).[8]
Disability was observed by one publication and presented a significant improvement (-0.19 (-0.38, -0.01) ($p = 0.04$)) when they compared individual exercise therapy plus education and education alone.[15] None of the two publications that used the WOMAC questionnaire did show a significant improvement (33.7 ± 13.8)[4] (375.0 (474.1))[13]. Fukumoto et al. used muscle thickness (MT) and echo intensity (EI) to determine the muscle mass and composition respectively. There was found a significant decrease in MT in no other muscles than the quadriceps femoris (2.97 ± 0.66 ($p< 0.01$)). The echo intensity was significantly greater in several muscles: the gluteus (91.2 ± 13.2 ($p< 0.05$)), the quadriceps femoris muscle (106 ± 14.9 ($p< 0.05$)) and the rectus abdominus muscle (117.4 ± 18.6 ($p< 0.05$)).[5]
BMRC was used by one article to determine the muscle strength while following education and exercise. It showed a significant improvement of the hip abductor muscles (increase of 0.36 (0.50) ($p=0.004$)) but it did not show a significant improvement of the quadriceps femoris muscle (0.73 (0.46)).[4] Six publications researched hip flexor strength as an outcome. One article showed a significant improvement (0.08 Nm ($p= 0.03$)) after exercise therapy.[11] Another study did show significant improvement of the hip flexor muscles when high-frequency resistance training was applied (20.1 ± 4.9 ($p< 0.002$).[7] Svege et al. did not show a significant improvement when they compared exercise therapy in addition to patient education or patient education alone. (85.0 Nm intervention group, 84.3 control group)[12] Two other publications did not show significant improvement, one publication used manual therapy, home exercise and education as an intervention (−0.01 (−0.12 to 0.10))[2], the other publication compared high-velocity resistance training with low-velocity training. (0.98 N/kg (0.35) high-velocity group and 1.07 N/kg (0.32) low velocity group)[5] One case report did show an improvement of the hip flexor strength but there was no reference available.[3]

Six publications researched hip extensor strength after exercise therapy, the outcome is as follows. One article showed a significant improvement of the hip extensor strength (21.5 ± 5.4(p= 0.001)).[7] Four other articles did not show a significant improvement (0.12 (-0.08 to 0.32))2 (-0.04 (-0.159, 0.068))5, (0.05 Nm)[11] and (145.6 Nm exercise group and 147.3 Nm control group).[12] One case report showed an improvement of the hip extensor strength but there was no reference available.[3] Three publications researched knee flexor strength, as a result one of them did show a significant improvement when comparing high-frequency resistance training with low-frequency resistance training (13.3 ± 2.8 (p=0.008)).[7] One article did not show a significant improvement after exercise therapy (76.9 Nm exercise group and 81.1 Nm control group).[12] One case report showed an improvement of the knee flexor strength but there was no reference available and even so for the knee extensor strength.[3]
Four publications researched knee extensor strength and as a result, one of them showed a significant improvement (29.4 ± 5.3 (p = 0.016)).[7] Two other publications did not show a significant improvement (136.8 Nm exercise group and 142.5 Nm control group).[12] (1.15 (0.44) high- velocity group and 1.21 (0.31) low velocity group).[5] One case report showed an improvement of the knee extensor strength but there was no reference available.[3] Only one publication researched the muscle strength of the hip adductor when patients followed an institutional supervised group-based exercise therapy. The article showed a significant improvement (0.15 Nm (p <0.0001)).[11] The hip abductor strength was researched by five publications. Two articles did show a significant improvement (0.12 Nm (p = 0.02))11 (22.7 ± 3.6 (p = 0.001))[7]. One other article did not show a significant improvement after hip-abductor strengthening exercises (124.3 N (76.8-188.8)).[8] Another publication did not show significant improvement after exercise either (0.03 (-0.11 to 0.17)).[2] Fukumoto et al. did not show significant difference after comparing high-velocity resistance training with low-velocity resistance training (0.96 (0.33) high-velocity and 0.99 (0.29) low-velocity).[5]
Internal and external rotation strength was researched by one publication after physiotherapy and did not show significant improvement for the internal rotation (0.04 Nm (−0.02 to 0.11)) or the external rotation (0.04 Nm (−0.01 to 0.08)).[2] One publication also researched the leg extension power, the result of this research showed that the leg extension power was significantly higher in the exercise intervention group compared to the control group (affected side: 0.6 Watt/kg (02-1.1) and unaffected side: 0.5 Watt/kg (0.1-1.1) (p < 0.0001)).[6] The general muscle strength of the hip was researched by one article. It did show a significant improvement when they compared individual exercise therapy plus education and education alone (0.21 exercise group and 0.19 control group) (p = 0.03)).[15]

4.3.2 Effect of exercise on pain

The results of pain were researched in different ways in multiple publications among people with hip osteoarthritis or hip dysplasia. Pain was investigated using different questionnaires: the "hip disability and osteoarthritis outcome score" (HOOS), the "Hip Harris Score (HHS) and the WOMAC-questionnaire. The "Visual analog scale (VAS)" was used to determine the level of pain.

Three articles used the HOOS questionnaire, two of them showed a significant relief of pain ((8.4 (2.5-14.3) (p<0.03))1, ((6.1(2.9-9.3))) (p<0.05)).[6] Bennell et al. did not show a significant between-group difference ((-0.9 (-10.2 to 8.4) in week 13 and -0.5 (-13.4 to 12.4) in week 36)).[2] Three different articles used the HHS which has five subcategories: ADL, gait, pain, joint mobility and stability. These two articles did not show a significant improvement of the HHS. One of the publications used education and physiotherapy as an intervention (43.6 ± 15.7 study group, 34.9 ± 15.5 control group).[4] Another publication compared high-velocity training with low-velocity training (-0.3 (-7.714, 5.823)).5 One case report did show an improvement of the HHS score on the subcategory pain, after therapeutic exercise but there was no reference available.[3]
Two articles used the WOMAC questionnaire but none of them showed a significant improvement (8.0 ± 3.8 study group, 11.0 ± 3.6 control group).[4] Even though it was not significant, one article showed that the subcategory of pain had reduced the most after the exercise program (27% (−4% to 57%) (p = 0.079)).[13] Four articles used the VAS scale to determine the level of pain after exercise. Three publications showed a significant improvement (5.5 ± 2.2, 7.3 ± 2.0 (p = 0.04))[4], (46.0 ± 25.0% to 23.1 ± 11.4% (p = 0.0005))[8] and (-9.3 mm (-18.1, -0.6) (p = 0.018))[12] which was determined during 6MWT. One case report showed an improvement of the VAS.[3]

4.3.3 Effect of exercise on ADL and quality of life (QOL)

The results of ADL and QOL were researched in multiple publications among people with hip osteoarthritis or hip dysplasia. ADL and QOL were researched using questionnaires like the “hip disability and osteoarthritis outcome score (HOOS)”, the “Barthel index”, the “hip harris score (HHS)” and the “WOMAC” questionnaire. Also, the “SF-36” and the “PASE” were used to determine the ADL and QOL.
Three articles used the HOOS questionnaire, two of them showed a significant improvement (10.0 (4.7-15.3) (p<0.001) ADL and 6.1 (0.7-11.5) (p<0.03) QOL))[1] (5.0 (1.7-8.3) (p<0.05) ADL and 7.1(3.7-10.6) (p<0.05) QOL))[6] Bennell et al. did not show a significant improvement, there was a positive change within groups for QOL (0.2 (-12.1 to 12.4) week 13 and 1.8 (-15.4 to 19.0) week 36)[2] Ferrara et al. used the Barthel index to determine ADL but this did not show a significant improvement after following an educational and physiotherapy program (84.5 ± 6.7 study group, 75.0 ± 16.2 control group).[4]
As mentioned above three articles used the HHS but none of them showed significant improvement (43.6 ± 15.7 study group, 34.9 ± 15.5 control group)[4], (65.6 ± 16.4)[5] ,(79 baseline, 96 after intervention and 91 after six-month follow-up).[3] Two articles used the WOMAC-questionnaire but none showed significant improvement following an exercise program (8.0 ± 3.8 study group, 11.0 ± 3.6 control group)[4] and (494.5 (413.9) baseline, 375.0 (474.1) end point).[13] Four publications used the SF-36 to determine the QOL. Jigami et al. used high or low frequently therapeutic exercise but there was no significant improvement (34.0 ± 17.6 33.1 ± 15.6 physical component, 55.6 ± 6.8 56.5 ± 6.8 mental component).[7] The Following publication used institutional supervised group-based exercise therapy as an intervention, but didn’t show a significant improvement either.[11] (table 7)

One article did show a significant improvement on the physical composite score (PCS) (34.4 ± 4.05 study group, 27.3 ± 10.3 control group) but not on the mental composite score (MCS) (51.1 ± 11.2 study group 40.9 ± 11.6 control group).[4] Also one case report showed an improvement of the SF-36 score as well but there was no reference available.[3] Two articles used the PASE to determine the ADL. One publication did not show a significant improvement after the intervention (8.7 (-19.0 to 36.3)).[2] One case report showed that there was a higher activity level score after intervention but a lower activity level after follow-up (111.59 baseline, 140.35 after intervention, 90.07 after 6-month follow-up).[3]

4.3.4 Effect of exercise on range of motion (ROM)

The effect of exercise on range of motion on people with hip osteoarthritis and hip dysplasia was researched in six publications. ROM was researched using the "Hip Harris score" (HHS), "WOMAC" questionnaire and by measuring ROM.

As mentioned above three articles used the HHS but none of them showed significant improvement of ROM (43.6 ± 15.7 study group, 34.9 ± 15.5 control group)[4] (65.6 ± 16.4)[5] (79 baseline, 96 after intervention and 91 after six-month follow-up).[3] The two articles that used the WOMAC-questionnaire didn't show a significant improvement (8.0 ± 3.8 study group, 11.0 ± 3.6 control group)[4] (99.1 (63.5) 76.8 (54.2))[13]. Six publications measured ROM as a result. In two articles hip ROM of the index joint was measured in all directions but none of the directions had significant improvement after exercise therapy (table)[12] or physiotherapy.[2] (Table 8) One article showed significant improvement of ROM external rotation (22.27 ± 7.86 study group, 14.58 ± 7.82 control group ($p = 0.03$)) but not for abduction of the hip (31.81 ± 10.55 study group, 2.08 ± 11.95 control group).[4] Another article showed a significant increase in ROM of hip extension as well (mean change of 30% (7% to 54%) ($p<0.05$)), but there were no significant changes found in other directions.[13] Another randomized controlled trial showed that there was no significant improvement of hip ROM after exercise therapy (0.15 (-0.03,0.32).[15] In one case report there was an improvement detected in the extension, the medial rotation and lateral rotation of the hip, from the baseline to after the intervention.[3] (Table 7)

4.3.5 Effect of exercise on walking

The result of walking was researched in multiple publications among people with hip osteoarthritis or hip dysplasia. Walking was measured using several tests: the "3-min walking test", "Timed up and go (TUG)" test, "20m walking test" and the "six minutes walking test (6MWT)". Measurements were made of the walking speed as well.

One publication researched walking by using the 3-min walking test and by measuring the maximum walking speed. Both tests did not show a significant difference after comparing high-velocity and low-velocity resistance training.[5] (table 7) Three publications used the TUG test. Two of them showed significant improvement of the TUG test after exercise (-0.23 (-0.343, -0.040) ($p = 0.012$))[5], (8.6 ± 3.3 before and 7.2 ± 2.5 after ($p = 0.002$)).[7] Uusi-Rasi et al. did not see significant improvement. Ageberg et al. used the 20-m walking test after following supervised neuromuscular training and found a significant improvement (-1.09 sec (-1.85; -0.32) ($p<0.05$) and -1.0(-1.9; -0.1) ($p<0.05$) steps (n)).[1]

The 6MWT was used in two publications but they did not show significant improvements (-0.2 (-40.7, 40.3) after four months, -1.8 (-46.6, 42.9) after 10 months and 8.7 (-42.7, 60.0) after 29 months.[12] One case report showed an improvement of the 6MWT but there was no reference available.[3]

5. Discussion

5.1. Reflection of the quality assessment

Twelve articles were included and assessed using five checklists due to different study designs. Each publication has been checked by two assessors. There were eight randomized controlled trials which had the highest level of evidence, followed by two cohort studies and one pilot study. A checklist for one case report publication was used as well. The Cochrane checklist used for the randomized controlled trials could not give a perfect view of the quality of the included publications. There was a lack of information in five out of eight publications, e.g. blinded randomizers or patients. One article scored a three out of eleven on the Cochrane checklist for randomized controlled trials.[7] There has been concluded that this publication is not a strong study and the result of this checklist should be considered when the results are discussed. It should be considered that there is a great variety of quality of the included articles.

5.2 Reflection of findings related to the research question

To discuss the findings related to the research question there will be several subsections in which there will be concentrated on the different outcome measures examined in this review. Due to the low amount of significant results there will be focused on particular parts of the included studies, for example the intervention or the study design, that could have been done better in our opinion.

5.2.1 The effect of exercise on muscle strength and function

The effect of exercise on muscle strength and function in patients with hip dysplasia or osteoarthritis appears to be positive in some of the publications. There are movements of the hip, like the internal and external rotation, which must be further investigated. Also, more specificity of which muscles are strengthened the most is needed in future studies. It is important to research which muscles are involved the most so it could be known if these exercises do not induce a muscle imbalance on patients with dysplasia of the hip or hip osteoarthritis. Kuroda et al is the only publication that focused on patients with hip dysplasia.[8] Because of the big number of people that are diagnosed with Hip OA secondary to congenital dislocation or dysplasia of the hip, it is suggested there need to be more studies in which exercise therapy on patients with hip dysplasia is investigated. In these studies many improvements are found, whether it is significant or not, on the effect of exercise on muscle strength and function on both patient groups. In our opinion there are more RCT's needed on this subject to find more significant results based on a higher level of evidence.

5.2.2 Effect of exercise on pain, ADL and Quality of life (QOL)

Pain is a consistent outcome measure as regards to patients with dysplasia of the hip or hip OA.

Pain as an outcome measure is directly correlated to the improvement of ADL and QOL. There is more investigation needed about the link between these outcome measures. As mentioned in the result section of this review, three articles used the HOOS questionnaire. In this questionnaire, pain, QOL and ADL can be measured. It may be concluded that all three of these outcome measures were improved when exercise therapy was applied on patients with hip OA. Also, the HHS is used to measure these outcome measures. They showed improvement but they weren't significant. It must be considered that there could be a strong correlation between these three outcome measures. Another questionnaire where pain, ADL and QOL were measured was the WOMAC questionnaire. No significant improvements were found of these outcome measures in the articles that used this questionnaire. There were also a few specific questionnaires used in the included studies: The VAS to measure pain and the SF-36 and PASE to determine the ADL and QOL. In these questionnaires, no significant differences were found in patients with OA of the hip between the control groups and the interventions. Kuroda et al was the only included study in this review that investigated the effect of exercise on patients with dysplasia of the hip.[8] In this article, the VAS was used to measure pain in patients with dysplasia of the hip. They found a significant improvement of this scale after a three-month long exercise program, applying hip abductor exercises. There was no measurement of ADL or QOL in this article, so no correlation between these two outcomes and pain could be found. It may be concluded there is a possibility of a strong correlation between pain, ADL and QOL. Although significant improvements were found of these outcome measures it must be considered there is only one study that showed an improvement of the VAS on patients with dysplasia of the hip. However, further research is needed to investigate the effect of different intervention methods on patients with OA of the hip and hip dysplasia.

5.2.3 Effect of exercise on Range of motion (ROM)

ROM is an important outcome measure for patients with hip dysplasia or OA of the hip. Muscle stiffness can lead to a lack of joint movement and more pain over a period of time. ROM is measured in three different ways. Like the pain, ADL and QOL, ROM is also measured by the WOMAC questionnaire and the HHS. No significant differences were found with these questionnaires. Another way to measure ROM was to look at the difference of the joint angles. There were significant improvements of the hip external rotation and hip extension only. This lack of significant results in ROM improvement could be due to the fact that most of the studies were focused on the improvement of muscle strength and function. More investigation is needed on whether stretching exercises should be considered or not. There are improvements of ROM according to all the studies but only a few of them showed significant improvements. Also, there are not many studies that showed a significant increase of ROM so further investigation is needed.

5.2.4 Effect of exercise on walking

Walking is an important outcome measure, because it's not only a daily activity but also a great exercise for patients with hip OA or dysplasia of the hip. To measure this outcome measure, several tests were used. The 3-min walking test and walking speed was used in one article, but no significant differences were found when comparing high-velocity and low velocity resistance training. In this study, they could have added a control group to search for a difference between the two training forms and the baseline.[5] Further, the TUG test was used in three articles. Two of them show a significant improvement after exercise. When Ageberg et al used the 20-m walking test, they found a significant improvement too.[1] The 6MWT did not show any significant improvements on long-term.[12] Because of the importance of walking in society, further research is needed. Also, it must be considered there should be more consistency in the use of which tests there need to be applied to measure the effect of exercise on walking on patients with hip OA or dysplasia of the hip.

5.3 Reflection of strengths and weaknesses of literature search

One of the strengths of this research is the use of two databases, PubMed and Web of Science, which resulted in 1296 hits. In both databases, the same repeatable literature search strategy was used. Another strength of the literature search is the quality assessment which was executed by two independent researchers. However, no studies were excluded on basis of quality assessment which was kept in mind during data extraction and interpretation of the results. One of the weaknesses of the literature search is the number of included articles. Also, only one publication researched the effect of exercise on people with hip dysplasia.

5.4 Recommendations for future research

After completing an extensive literature search as described above, research regarding the effect of exercise on walking, muscle strength and function in patients with hip dysplasia or hip OA, proved to be limited. Also, research regarding the effect of exercise on pain, QOL and ROM in patients with hip dysplasia or hip OA, proved to be scarce and needs to be further investigated. Only one article included hip dysplasia, therefore most conclusions can only be drawn from studies including hip OA. More publications, addressing the subject hip dysplasia, are needed to investigate the effect of exercise on walking, ROM, QOL, pain, muscle strength and function. In further RCT’s it is recommended to add a control group to measure changes between the control group and the intervention instead of comparing two interventions alone. The most effective exercise protocol for people with hip OA or hip dysplasia needs to be further investigated.

6. Conclusion

The effect of exercise on people with osteoarthritis or dysplasia of the hip showed positive results on different outcome measures: muscle strength and function pain, ADL and QOL, Range of motion and walking but further research on different exercise modalities and other forms of therapy for patients with hip dysplasia or hip osteoarthritis is needed to supplement the amount of evidence.

Part two: research protocol

Ambulatory motion analysis in healthy persons and persons with degenerative joint disorders

1. Introduction

Osteoarthritis (OA) is a degenerative, chronic disease of the entire joint that is characterized by progressive articular cartilage loss and bone degeneration. The disease might progress rapidly or remain static over a period of time. Moreover, OA is painful and leads to functional impairment during walking and other activities of daily living. Besides relief of pain, treatment of OA is focused on the improvement of the patients' capability to carry out activities and tasks for the participation in daily-life environments, thereby focusing on the function, activity and participation level. Although, these treatments are not curative and therefore patients with end stage OA will eventually receive partial or total joint replacement to restore function and quality of life. Multiple non-modifiable factors like age, gender, obesity, previous injury, bone density and genetic joint laxity play a role in the development of OA. However, there are also risk factors such as malalignment, increased biomechanical joint loading and muscle weakness, that could be modified.

The quality of lower limb joints movement during gait has been extensively assessed for both OA and arthroplasty patients. Laboratory instruments such as an optical motion analysis system, force plate technology and surface electromyography (EMG) provide the possibility to evaluate joint kinematics, kinetics and muscle activation patterns. Based on objective assessment in the laboratory aberrant gait patterns such as altered joint angles, increased adduction moments, increased joint loading, reduced walking speed, smaller step and stride lengths were detected. The advantage of these laboratory motion analysis systems is that they measure within a few degrees of error and are therefore accepted as the gold standard. However, the drawback of these systems is their complexity, expensiveness, requirement of extensive lab space, and limited area wherein motion can be performed. Additionally, optical motion analysis systems require specific expertise, making it available for only a limited number of patients and caregivers. Mobile measurement systems might provide an alternative for these disadvantages.

The advantage of a mobile sensor system, also known as inertial and magnetic sensor system (IMMS) is that the sensors are light, small, relatively inexpensive, easy to use (e.g. sensors can be placed directly on the skin) and that they can be used outside the laboratory setting. This makes it highly accessible for orthopedic specialists and/or physical therapists to use in their practice, creating the opportunity to measure larger cohorts of OA patients. Even though inertial sensor systems are commercially available, limited research has been focused on the assessment of knee and hip biomechanics during functional movements in both healthy participants as patients with degenerative knee / hip disorders. Moreover, the assessment of the lower limb joints for patients with degenerative knee / hip disorders is currently limited to observations during regular physiotherapy practice. In addition, in the current practice there is no standardized protocol that is focused on the improvement of functional movements. Therefore, studies within this project will focus on the evaluation of kinematics (i.e. joint angles and spatiotemporal parameters) and kinetics (joint force and moments) during functional tasks for lower limb joints. Furthermore, the joint loading of the (degenerative) joint will be determined. With this knowledge, we aim to gain more insights in the compensation strategies adopted by the patients and to improve rehabilitation for therapists and patients with degenerative joint disorders.

2. Research Goal

2.1 Research question

What is the reliability and validity of the Inertial and magnetic sensor system (IMMS's) kinematic outcomes during the functional movement protocol and to which extent these kinematics are relevant to the parameters related to patients with hip or knee OA?

2.2 Hypothesis

We hypothesize that the IMMS's are reliable and valid to evaluate functional movement of patients with hip or knee OA.

3. Method

3.1 Study design:

Longitudinal study

1. To investigate to what extent the IMMS is sensitive to detect changes in the lower limb joints as assessed during the functional movement protocol before, during, and after the rehabilitation of patients that underwent knee / hip arthroplasty.

2. To determine to which extent there is a relationship between patient relevant parameters and functional parameters (e.g. kinematics, kinetics, knee joint loading, muscle activation patterns and muscle strength), during the rehabilitation in persons with a knee / hip arthroplasty.

3. To investigate to what extent the patient relevant parameters and functional parameters can be used to classify knee / hip arthroplasty patients into different categories of functional impairment.

We would like to follow up patients after the joint replacement in a longitudinal study. Pre-operative measures, will take place in the Movement and posture Analysis Lab Leuven, KU Leuven. The post-operative measures take place at the movement laboratory at Hasselt University.

3.2 Participants

Within this project a total of 60 participants will be recruited (20 knee OA patients (listed for total knee replacement surgery), 20 Hip OA patients (listed for hip replacement surgery) and 20 healthy individuals).

3.2.1 The inclusion criteria are listed below

Healthy persons:

- Between 50 – 75 years old.
- Understand the Dutch language.
- Able to walk 10m and ascent/descent the stairs.

Persons with Knee osteoarthritis:

- Being 50 – 75 years old.
- Diagnosed with knee OA.
- BMI < 30 kg/m^2.
- Awaiting of total knee replacement surgery.
- Understand the Dutch language.
- Able to walk 10m and ascent/descent the stairs.

Persons with Hip osteoarthritis:

- Being 50 – 75 years old.
- Diagnosed with Hip OA.
- BMI < 30 kg/m^2.
- Unilateral joint disease.

3.2.2 Exclusion criteria are listed below

Healthy persons:

- Diagnosed with musculoskeletal or neurological disorders.
- Pain in hips, knees or ankles, which affect normal movement.

Persons with Knee osteoarthritis:

- Corticosteroid injection 3 months before inclusion to the study.
- Joint replacement in other lower limb joints.
- Diagnosed with symptomatic knee OA on the contralateral knee.
- Symptomatic degenerative disorders in other lower limb joints.
- Neurological conditions that could alter movement pattern.
- History of pathological osteoporotic fractures (in hip, knee or ankle joints).

Persons with Hip osteoarthritis:

- Previous surgery in the ipsilateral leg.
- Abnormalities in the lower spine or contralateral leg.
- Neurological conditions that could alter movement pattern.
- History of pathological osteoporotic fractures (in hip, knee or ankle joints).

3.2.3 Recruiting

The healthy population will be recruited from relatives and acquaintances, which will be matched to age and gender to the OA population. Knee / hip OA patients will be recruited from Jessa Hospital (Hasselt) and Ziekenhuis Oost Limburg (Genk).

3.3 Intervention and study protocol

For the reliability study, each of the healthy participants will perform the protocol twice on two different days (~7 days apart). On day one, two assessors will measure each participant to test inter-observer and intra-session reliability. Assessor one will position the IMMS's sensors on the lower limbs and trunk, and the participants will execute the functional movement protocol. When the protocol is finished, the motion trackers will be removed and 15 minutes of rest will be given. After the break, assessor two to will place the IMMS's sensors (i.e. similar as assessor one) and the participants will again perform the functional movement protocol, with five repetitions for each task. Intra-session

reliability will be determined for each task, from the repeated measurements. Inter-observer reliability will be determined based on the average values from the repeated measures (of each task) between the two assessors.
On day 2 (~7 days later), the exact same routine of assessor 1 on day one will be repeated. Additionally, for the second trial on day two, optoelectronic markers will be placed according to the plug and gait model and EMG sensors will be added on the participants lower limbs. In addition, the ground reaction (GRF) will be registered via a force plate system. Participants have to execute the protocol with these additional sensors, in order to compare the outcome of the IMMS's sensors with the optoelectronic system and determine the knee joint loading.

<u>OA patients</u>
For the validity study, each of the OA patients, will perform the protocol once. Before preparation of the participant, the KOOS / HOOS, SF36, PASIPD and CSI questionnaires will be completed and baseline characteristics (gender, age, length, weight, affected joint) will be collected. Additionally, a VAS score will be measured after every activity. Besides the baseline characteristics and clinical questionnaires, a clinical investigation will be executed (i.e. to investigate the ROM of the lower limb joints and proprioception). Subsequently, the patients will be instrumented with IMMS's sensors, optoelectronic markers and EMG sensors in order to compare the inertial sensor system with the optoelectronic system. In addition, the ground reaction (GRF) will be registered via a force plate system. Recording motion (by an optoelectronic system), GRF and EMG opens the opportunity to create a musculoskeletal model and to calculate the knee / hip joint loading profile. With the marker data from the optoelectronic system in combination with GRF, a patient specific 3D musculoskeletal model of the lower limbs will be created with the OpenSim software. Based on multiple routines within the OpenSim software knee / hip joint loading will be calculated. Finally, the EMG measurements will be used to evaluate the designed musculoskeletal model.
Based on the findings of a systematic review a functional movement protocol has been developed for the evaluation of kinematic parameters during functional tasks for the lower limb joints. The functional movement protocol includes the following activities. (Table 9)

Activity	Description	Repetitions
Level walking	Walk back and forward over the walkway on your own preferred walking speed.	5
Forward stepping	Step forwards, make sure you land on the force platform and move the weight of the upper body to the front leg (while keeping the trunk upright)	5

Sideward stepping	Step sideward, make sure you land on the force platform and move the weight of the upper body to the side leg (while keeping the trunk upright)	5
Stairs	Walk the stairs up and down as you would do normally (if possible without holding the rail)	5
Sit to stand	Sit down on the stool (without looking) and move your weight on the stool (like you go and sit to the back). Then stand up again.	5
Stand on 1 leg	Stand on the force platform, switch from 2 legs to 1 leg and back and keep balance on the stand leg for 2-3 seconds.	3
Squat on 1 leg	Stand on the force platform, switch from 2 legs to 1 leg and back and keep balance on the stand leg, make a squat and try to keep balance.	3

Table 9: The functional movement protocol

<u>Healthy participants</u>

Before the participants start, four questionnaires, the KOOS / HOOS, SF36, PASIPD and CSI will be completed and baseline characteristics (gender, age, length, weight) will be administered. Additionally, a VAS score will be measured after every activity.

1. The Knee injury and Osteoarthritis Outcome Score (KOOS) / Hip injury and Osteoarthritis Outcome Score (HOOS) questionnaire will be administered to assess pain and symptoms, function in daily living, function in sport and recreation and knee related quality of life.

2. The SF36, is a questionnaire that assesses quality of life. It consists of 36 items that are grouped into eight domains: functional capacity, physical aspects, pain, general health, vitality, social aspects, emotional aspects and mental health.

3. The Physical Activity Scale for Individuals with Physical Disabilities (PASIPD) questionnaire assesses the self-reported physical activity level of persons with a disability over the past 7 days.

4. The Central Sensitization Inventory (CSI) will we administered to assess central sensitization, i.e. hypersensitivity / chronic pain.

5. The Visual Analog Scale (VAS) will be administered after every activity to monitor the perceived pain.

3.4 Outcome measurements

There are several devices and questionnaires used which are described in the following subsections. The outcome measures which are measured by these devices and questionnaires will be the outcome measures for this study.

3.4.1 Devices

- MVN Biomech Awinda – Xsens technologies:

  MVN Awinda is based on fully wireless motion trackers, allowing full freedom of movement. MVN Awinda features on-body straps and eliminates battery packs and cables for even faster setup, easier operation and unconstrained range of motion. This portable system can be used indoors and outdoors. In total 9 wireless motion trackers will be positioned on the trunk, pelvis, thighs, shanks, and feet of the participants.

- Trigno wireless EMG sensors – Delsys:

  The surface electrodes are attached the skin overlying the muscle belly. In this way, muscle function can be evaluated through the analysis of the timing and amplitude of the electrical activity coinciding with force generation. With this wireless, surface EMG system the activity of up to 16 muscles of the participants lower limbs will be measured.

- Optoelectronic system – VICON:

  To measure 3D segmental movement, a 10 Vicon camera system is in place that measures the 3D position of passive markers placed on the test-subject to quantify orientation and rotation of the body segments. By combining the information of adjacent segments, joint angle trajectories can be calculated.

- Force plate – AMTI:

  The force plates are integrated in the walkway. These quantify the 3D interaction forces between the test-subject and the ground during functional motion (e.g. gait or jumping). To accurately measure impact forces during sports activities, at least one force plate with specific high frequency characteristics is in place.

3.4.2 Questionnaires

- KOOS / HOOS

  The Knee injury and Osteoarthritis Outcome Score (KOOS) / Hip injury and Osteoarthritis Outcome Score (HOOS) is a patient-reported outcome measurement instrument, developed to assess the patient's opinion about their knee / hip and associated problems. The questionnaire evaluates both short-term and long-term consequences of knee /hip injury and consequences of primary osteoarthritis (OA). It holds 42 items in five separately scored subscales: Pain, Symptoms, Function in daily living (ADL), Function in Sport and Recreation (Sport/Rec), and knee-related Quality of Life (QOL). The questionnaire is intended to be used over short and long time intervals; to assess changes from week to week induced by treatment (medication, surgery, physical therapy) or over the years due to a primary knee / hip injury, posttraumatic OA or primary OA.

- SF-36

  The Short Form 36 is a widely used self-reported questionnaires to measure health related quality of life. The SF-36 assesses eight health concepts, including: 1) limitations in physical activities because of health problems; 2) limitations in social activities because of physical or emotional problems; 3) limitations in usual role activities because of physical health problems; 4) bodily pain; 5) general mental health (psychological distress and well-being); 6) limitations in usual role activities because of emotional problems; 7) vitality (energy and fatigue); and 8) general health perceptions. Each scale will be transformed into a 0-100 scale, in which a lower score is related to more disability and a higher score to less disability.

- PASIPD

  The Physical Activity Scale for Individuals with Physical Disabilities (PASIPD) is a self-reported questionnaire to measure physical activity over the past 7 days. Within the questionnaire five different dimensions of physical activity will be assessed, including home repair, lawn and garden work, household work, vigorous sport and recreation, moderate sport and recreation and occupation and transportation. Besides the frequency (number of days a week) and duration (hours a day) are included within the answer options. The questionnaire consists of 13 questions, in which first the frequency will be administered and secondly the duration will be administered (if applicable). The duration will eventually be converted to a metabolic equivalent (MET), which is associated with the intensity of the activity.

- Central Sensitization Inventory

The clinical goal the Central Sensitization Inventory or CSI, is to help assess symptoms thought to be associated with CS to aid physicians and other clinicians in syndrome categorization, sensitivity, severity identification, and treatment planning, to help minimize, or possibly avoid, unnecessary diagnostics and treatment procedures. The CSI consist of two parts (A and B).

Part A of the CSI assesses 25 health-related symptoms common to central sensitivity syndrome (CSS). Responses are recorded about the frequency of each symptom, with a Likert scale from 0 (never) to 4 (always), resulting in a total possible score of 100. Higher scores are associated with a higher degree of self-reported symptomology. Part B asks if subjects have previously been diagnosed with 1 or more specific diagnoses, including 7 CSSs (tension headaches/migraines, fibromyalgia, irritable bowel syndrome, restless leg syndrome, TMD, chronic fatigue syndrome, and multiple chemical sensitivities) and 3 CSS-related related disorders (depression, anxiety/panic attacks, and neck injury). Subjects are asked 1) if they have previously been diagnosed by a doctor with each of the disorders; and 2) what year they were diagnosed.

3. 5 Data analysis

Inter-observer, intra-session and inter-session reliability will be determined by calculating intra class correlations (ICC) coefficients, standard error of the measurement (SEM), smallest detectable difference (SDD) and 95% limits of agreement.
To determine the validity waveform similarity and differences in range of motion with the max & min values of joint angles will be determined. Additionally, root mean square error (RMSE), coefficient of multiple correlation (CMC) and Pearson's correlation coefficient will be calculated. Based on the findings in the validity study (i.e. correlation, CMC, RMSE) we will determine which variables recorded with the IMMS are related to joint loading as determined by the gold standard outcomes. Similar statistics will be applied to evaluate the association between EMG, joint loading and the IMMS kinematics.
Differences in the kinematic and kinetic waveforms, that will be collected throughout the longitudinal study will be tested by using Statistical Parametric Mapping (SPM) analysis. Assessing the entire waveform, instead of isolated events within the waveform (e.g. the maximum or minimum value) could explain differences between the multiple follow up measures. Additionally, the ANOVA and correlation coefficient will be applied to test differences in the clinical questionnaires and the relationship between outcomes of the questionnaires and kinematics and kinetics, respectively. Beside the above described statistics, the effect size (e.g. hedges 'g) and 95% confidence intervals will be determined.

<u>Justification of sample size</u>
The average medial compartmental force of 1.61 (±0.305) body weight during gait was reported in subjects after total knee replacement. Assuming an increase of 1 standard deviation (0.31 BW) to be clinically significant in subjects suffering from medial compartmental OA, a sample size of 14 subjects was calculated with a of 0.05 and power level of 0.8. Nevertheless, it is expected that some will stop

participation during the follow-up and there will be no replacement for the participants we lose during the follow up. Therefore, some additional participants will be recruited.

4. Time table

Assessment T0:

Before this assessment starts, the informed consent will be discussed and signed and subsequently the questionnaires will be completed. After finishing the questionnaires, the sensors (Xsens and EMG) and markers (Vicon) will be positioned on the participants. Before starting the functional movement protocol, the clinical investigation of the participant will be executed. Then the participant will complete the functional movement protocol (figure 2), while the kinematics, kinetics and EMG are measured. Additionally, all the tasks will be performed on the force plate, to measure the GRF. After every task a VAS score will be administered.

Assessment T1:

Four weeks after surgery, another assessment will be scheduled. This assessment will take place at REVAL, Hasselt University. During this assessment, the questionnaires (KOOS, SF36, PASIPD and CSI) will be completed. After the questionnaires, the clinical investigation will be executed and Xsens and EMG sensors will be positioned. Subsequently the participants need to complete the (shortened) functional movement protocol (Figure 2). This shortened functional movement protocol was established in agreement with the orthopedic surgeon. After every task a VAS score will be administered.

Assessment T2-T5:

The final assessments will be scheduled 3, 6, 12 and 18 months post-operative. During this assessment, the questionnaires and clinical investigation will be completed first and afterwards the functional movement protocol will be performed. During these assessments, Xsens and EMG sensor will be positioned on the participants to analyze motion and muscle activity. Again, after every task a VAS score is administered.

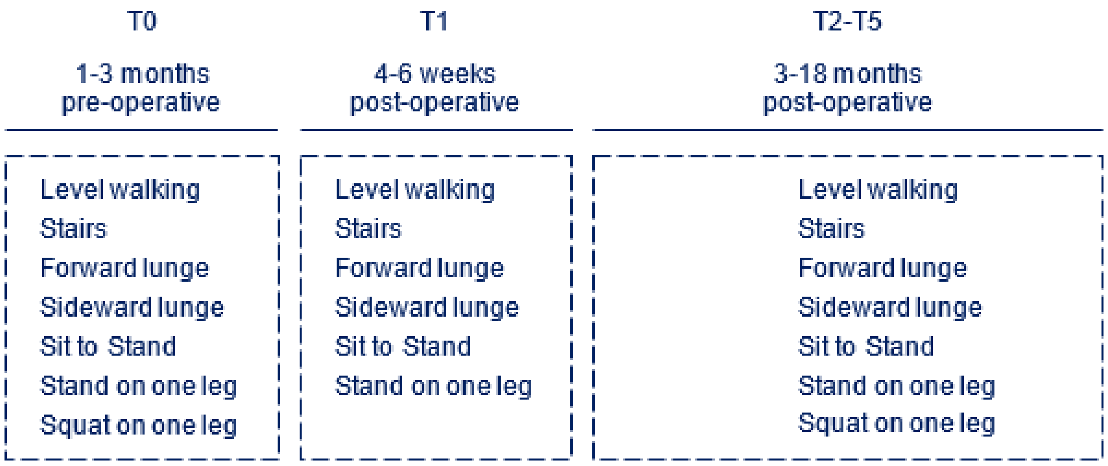

Figure 2: Tasks functional movement protocol

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Appendices

Table 1.1: List of search terms used in PubMed

Table 1.2: List of search terms used Web of Science (WoS)

Table 2: Checklist for RCT

Table 3: Checklist for case report

Table 4: Checklist for cohort

Table 5: Checklist for pilot study

Table 6: Description of included articles

Table 7: Results

Table 8: Inclusion and exclusion

Table 10: Progress form

Figure 1: Flowchart

Table 1.1: List of search terms used in PubMed

	Pubmed: filter (dutch, english, human)	Hits
#1	"Hip"[MeSH]	6457
#2	“Hip”[Title/abstract]	79042
#3	"Exercise Therapy"[MeSH Terms]	30637
#4	"Exercise"[Mesh]	116583
#5	"Resistance Training"[Mesh]	5006
#6	“Exercise”[Title/Abstract]	150070
#7	“Resistance training”[Title/Abstract]	3993
#8	“Muscle imbalance”[Title/Abstract]	338
#9	“Muscle weakness”[Title/Abstract]	7609
#10	"Muscle Strength"[Mesh]	21323
#11	"Muscle Weakness"[Mesh]	5831
#12	"Psoas Muscles"[Mesh]	853
#13	“Iliopsoas”[Title/Abstract]	959
#14	“Gluteus maximus”[Title/Abstract]	963
#15	“Gluteus medius”[Title/Abstract]	724
#16	“Tensor fascia latae”[Title/Abstract]	52
#17	“Hip abductor”[Title/Abstract]	431
#18	“Hip extensor”[Title/Abstract]	273
#19	“Hip flexor”[Title/Abstract]	266
#20	#1 OR #2	80524
#21	#3 OR #4 OR #5 OR #6 OR #7	219990
#22	#8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19	36264
#23	#20 AND #21 AND #22	982

Table 1.2: List of search terms used Web of Science (WoS)

	Web of Science: filter (dutch, english)	Hits
#1	TITLE: (hip)	51205
#2	TOPIC: (exercise therapy)	29561
#3	TOPIC: (exercise)	328292
#4	TOPIC: (resistance training)	18501
#5	TITLE: (muscle imbalance)	160
#6	TOPIC: (muscle strength)	42147
#7	TOPIC: (muscle weakness)	16007
#8	TOPIC: (psoas muscle)	2607
#9	TITLE: (gluteus maximus)	505
#10	TITLE: (iliopsoas)	237
#11	TITLE: (gluteus medius)	233
#12	TITLE: (tensor fascia latae)	99
#13	TITLE: (hip abductor)	232
#14	TITLE: (hip extensor)	94
#15	TITLE: (hip flexor	82
#16	#2 OR #3 OR #4	335978
#17	#5 OR #6 OR #7 OR#8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15	58352
#18	#1 AND #16 AND #17	314

Table 2: Checklist for RCT

Articles RCT	Ferrara, P. E., et al. (2008).	Bennell et al., 2014	Steinhilber et al., 2011	Fukumoto, Y., et al. (2014).	Van Baar, M. E., et al. (1998).	Svege et al., 2015	Hermann, A., et al. (2016).	Jigami et al., 2012
Are the patients randomized?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Are the randomizers blinded?	/	/	Yes	No	/	Yes	Yes	/
Are the patients blinded?	/	Yes	Yes	Yes	/	No	/	No
Are the therapists blinded?	No	No	No	No	No	No	No	No
Are the effect reviewers blinded?	Yes	Yes	Yes	No	Yes	No	Yes	No
Were the group characteristics comparable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the size of population and follow up sufficient?	No	Yes	No	No	Yes	Yes	Yes	/
Are all patients analyzed in the group they were randomized in?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	/
Are the groups equally treated (besides intervention)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are the results valid and reliable?	/	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are selective publications of results enough excluded?	Yes	Yes	/	/	/	Yes	Yes	/
	7/11	9/11	8/11	6/11	7/11	8/11	9/11	3/11

Table 3: Checklist for case report

Case report checklist	Fernandes, L., et al. (2010)
Was there clear criteria for inclusion in the case report?	Yes
Was the condition measured in a standard, reliable way for the participant included in the case report?	Yes
Were valid methods used for identification of the condition for the participant included in the case report?	Yes
Was there a clear reporting of the clinical information of the participant?	Yes
Were the outcomes or follow up results of the case clearly reported?	Yes
Was statistical analysis appropriate?	/
	5/6

Source:(http://joannabriggs.org)

Table 4: Checklist for cohort

Referentie	Ageberg et al., 2013	Kuroda et al., 2012
The group is clearly defined?	Yes	Yes
The follow up is complete?	Yes	Yes
The outcome is objective?	No	Yes
The outcome is explicit?	Yes	Yes
The outcome is valide and reliable?	Yes	Yes
The outcome is independently determined?	Yes	Yes
The prognostic factor is objective and explicit?	/	Yes
The proportion of included patients is sufficient?	Yes	No
The measurements were the same for all patients?	Yes	Yes
The measurements were valid and reliable?	Yes	Yes
	8/10	9/10

Table 5: Checklist for pilot study

Pilot study checklist	Uusi-Rasi et al., 2017
Aims and objectives are clearly stated	Yes
Collected data are consistent with goals	Yes
No statistical hypothesis is tested	Yes
Sample size is justified (not necessarily in a statistical sense)	Yes
The way in which the data collected will be used in the design of a larger study has been addressed	Yes
This study will answer the question of whether a full scale trial/experiment is worth pursuing	Yes
Criteria that will determine continuation to a larger study are specified	Yes
	7/7

Source: (http://health.bsd.uchicago.edu)

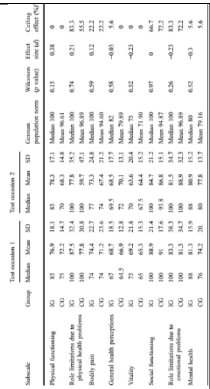
Table 6: Description of included articles

Year/auteur	Population/type of patient	Guidelines	Intervention
Ageberg, E., et al. (2013)	Severe primary OA of the hip or knee awaiting TJR		Supervised, neuromuscular training
Bennell, K. L., et al. (2014).	Hip pain levels over 40 and hip OA		Manual therapy techniques, 4 to 6 home exercises, education and advice
Fernandes, L., et al. (2010)	Women with hip OA		12 Weeks therapeutic exercise program with 6 months follow up
Ferrara, P. E., et al. (2008).	End stage hip OA	Ottawa Panel evidence-based clinical practice guidelines	Educational and physiotherapy program one month before surgery
Fukumoto, Y., et al. (2014).	Hip OA		Resistance training program: High-velocity or Low-velocity
Hermann, A., et al. (2016).	Hip OA and scheduled for THA		Supervised, preoperative progressive explosive-type RT 2/week for 10 weeks
Jigami, H., et al. (2012).	Hip OA		High or low frequently therapeutic exercise
Kuroda, D., et al. (2013).	Patients with hip joint symptoms and acetabular dysplasia		Hip-abductor therapy followed by exercises to maximize strength and ROM
Steinhilber, B., et al. (2012).	Patients with OA or THR		Institutional supervised group-based exercise therapy
Svege, I., et al. (2016).	Patients with hip OA		Exercise therapy in addition to education compared to patient education alone
Uusi-Rasi, K., et al. (2017).	Patients with hip OA		Exercise program in relieving hip pain and improving function
Van Baar, M. E., et al. (1998).	Hip or knee OA		Exercise therapy individually compared to education and GP

Table 7: Results

Author and year	Ageberg et al., 2013	Ferrara et al., 2008	Bennell et al., 2014	Fukumoto et al., 2014	Van Baar et al., 1999	Fernandes et al., 2010	Hermann et al., 2016	Jigami et al., 2012	Kuroda et al., 2013	Steinhilber et al., 2012	Svege et al., 2015	Uusi-Rasi et al., 2017
HOOS/ KOOS Mean diff (95% CI)	**Pain** 6.1(2.9;9.3) **Symptoms** 4.7(0.1;9.4) **ADL** 5.0(1.7;8.3) **Sport/Rec** 6.9 (1.1;12.8) **QOL** 7.1(3.7;10.6)		**Week 13** **Pain** -0.9 (-10.2 to 8.4) **Symptoms** -0.8 (-8.6 to 7.1) **Sport/Rec** -1.6 (-11.5 to 8.3) **QOL** 0.2 (-12.1 to 12.4) **Week 36** **Pain** -0.5 (-13.4 to 12.4) **Symptoms** -2.9 (-15.1 to 9.3) **Sport/Rec** -0.9 (-17.6 to 15.9) **QOL** 1.8 (-15.4 to 19.0)				**ADL** 10.0 (4.7-15.3) **Pain** 8.4 (2.5-14.3) **Symptoms** 10.4 (4.4-16.5) **Sport/Rec** 10.0 (3.7-16.3) **Hip related QOL** 6.1 (0.7-11.5)					
20-m walk test Mean diff (95% CI)	**Time (sec)** -1.09 (-1.85; -0.32) **Steps (n)** -1.0(-1.9; -0.1)											

Barthel Index		**Study group** 84.5 +/- 6.7 **Control group** 75.0 +/- 16.2										
Hip Harris Score		**Study group** 43.6 +/- 15.7 **Control group** 34.9 +/- 15.5		-0.3 (-7.714, 5.823) (between groups)		**Baseline** 79 **After intervention (12w)** 96 **6-Month Follow-Up** 91						
6MWT						**Baseline** 665.4 **After Intervention** 720.0 **6-Month Follow-up** 748.2					**After 4 months** (-0.2 (-40.7, 40.3) **After 10 months** -1.8 (-46.6, 42.9) **After 29 months** 8.7 (-42.7, 60.0)	
WOMAC		**Study Group** 8.0 +/- 3.8 **Control group** 11.0 +/- 3.6										**Pain** 27% (−4% to 57%)
Abductor Muscle strength			0.03 (-0.11 to 0.17)	-0.02 (-0.138, 0.082)				22.7 ± 3.6 **P-value** 0.001	124.3 (76.8-188.8)	0.12Nm **P-value** 0.02		
SF-36		**PCS study group** 34.4 +/- 4.05 **control group** 27.3 +/- 10.3 **p-value**				**Physical function Baseline** 85 **After Intervention** 95 **6-Month**		**PCS** 34.0 ± 17.6 33.1 ± 15.6 **MCS** 55.6 ± 6.8 56.5 ± 6.8		Not significant		

		0.048 **MCS study group** 51.1 +/- 11.2 **Control group** 40.9 +/- 11.6 **p-value** 1.14				**Follow-up** 100 **General health perception** **Baseline** 95 **After intervention** 95 **6-month Follow up** 75						
VAS		5.5 +/- 2.2, 7.3 +/- 2.0 **P-value** 0.04				**Baseline** 22 **After Intervention** 0 **6-Month Follow-up** 11			**decreased** 46.0 to 23.1 **P-value** 0.0005		**During 6MWT** -9.3 mm (-18.1, -0.6) **P-value** 0.018	
ROM		**Abduction Study group** 31.81 +/- 10.55 **control group,** 2.08 +/- 11.95 **P-value** 0.53 **External rotation study group** 22.27 +/- 7.86 **control group** 14.58 +/- 7.82 **P-value** 0.03	**Flexion** -5.3 (-12.1 to 1.5) **Extension** 1.6 (-4.4 to 7.7) **Internal rotation** 0.6 (-2.2 to 3.5) **External rotation** -2.5 (-6.4 to 1.4) **Abduction** -0.8 (-6.5 to 4.8)		**Hip P-value** 0.10	Increase					**P-value** >0.072	**Hip abduction:** 33,2 ==> 33,8 **Hip flexion**: 96,2 ==> 98,8 **Hip extension:** 12,1 ==> 15,8

Subscale	Group	Test occasion 1 Median	Test occasion 1 Mean	Test occasion 1 SD	Test occasion 2 Median	Test occasion 2 Mean	Test occasion 2 SD	German population norm	Wilcoxon (p value)	Effect size (d)	Ceiling effect (%)
Physical functioning	IG	85	76.9	18.1	85	78.3	17.1	Median 100	0.15	0.38	0
	CG	75	72.2	14.7	70	68.3	14.8	Mean 96.61			0
Role limitations due to physical health problems	IG	100	87.5	32.4	100	77.8	35.2	Median 100	0.74	0.21	83.3
	CG	100	77.8	30.8	100	59.7	47.1	Mean 96.89			55.5
Bodily pain	IG	74	74.4	22.7	77	73.3	24.8	Median 100	0.59	0.12	22.2
	CG	74	71.2	23.6	74	67.4	21.2	Mean 94.60			22.2
General health perceptions	IG	67	68.7	18.5	69.5	68.5	17.7	Median 82	0.58	−0.03	5.6
	CG	64.5	66.9	12.8	72	70.1	13.1	Mean 79.89			0
Vitality	IG	75	69.2	21.8	70	63.6	20.4	Median 75	0.52	−0.23	0
	CG	65	65.3	15.3	67.5	64.4	15.2	Mean 71.90			0
Social functioning	IG	100	88.9	21.4	100	84.7	21.2	Median 100	0.97	0	66.7
	CG	100	91	17.6	93.8	86.8	15.1	Mean 94.87			72.2
Role limitations due to emotional problems	IG	100	83.3	38.3	100	81.5	34.7	Median 100	0.26	−0.23	83.3
	CG	100	81.5	34.7	100	88.9	32.3	Mean 96.89			72.2
Mental health	IG	88	81.3	15.9	88	80.9	15.2	Median 80	0.52	−0.3	5.6
	CG	76	74.2	20.	80	77.8	13.7	Mean 79.16			5.6

Overall magnitude of acceleration									1.82 m/s² +/- 0.25 **P-value:** <0.0001			
BMRC		**Quadriceps** 0.73 (0.46) **P-value** 0.37 **Hip abduction** increase of 0.36 (0.50) **P-value** 0.004										
Physical function			**Week 13** 1.4 (-3.9 to 17,7) **Week 36** 4.3 (-9.9 to 18.6)									
Self-efficacy			**Week 13** **Pain** 0.3 (-0.7 to 1.3) **Function** -0.2 (-0.6 to 0.3) **Week 36** **Pain** 0.1 (-1.1 to 1.3) **Function** 0.1 (-0.4 to 0.6)									
PASE			**Week 13** 8.7 (-19.0 to 36.3)			**Baseline** 111.48 **After intervention** 140.35 **6-Month Follow-up** 90.07						

Adductor muscle strength										0.15Nm **P-value** <0.001		
Hip flexor strength			−0.01 (−0.12 to 0.10)	0.98 N/kg (0.35) **High-velocity group** 1.07 N/kg (0.32**)** **Low velocity group**		Increase		20.1 +/- 4.9 **P-value** <0.002		0.08Nm **P-value** 0.03	**Intervention group** 85.0Nm **Control group** 84.3Nm **P-value** 0.472	
Hip extensor strength			0.12 (-0.08 to 0.32)	-0.04 (-0.159, 0.068)		Increase		21.5 ± 5.4 **P-value** 0.001		0.05 Nm **P-value** 0.6	**Intervention group** 145.6Nm **Control group** 147.3Nm **P-value** 0.45	
Knee flexor strength						Increase		13.3 ± 2.8 **P-value** 0.008			**intervention group** 76.9Nm **Control group** 81.1Nm **P-value** 0.647	
Knee extensor strength				1.15 (0.44) **High-velocity group** 1.21 (0.31) **Low velocity group**		Increase		29.4 ± 5.3 **P-value** 0.016			**intervention group** 136.8Nm **Control group** 142.5Nm **P-value** 0.672	
Muscle power W/kg				0.13 (-0.136, 0.329)								
Max walking speed m/s				0.00 (-0.114, 0.012)								

TUG				-0.23 (-0.343, -0.040)				**Forthnight group P-value** 0.012 **Weekly group** 8.6 ± 3.3 **Before** 7.2 ± 2.5 **After P-value** 0.002				**Baseline** 9.1 **Endpoint** 10.5
3-Min walking test				4.8 (-11.739, 15.219)								
Muscle thickness				**Gluteus Maximus** 0.12 (-0.096, 0.276) **Gluteus medius** 0.07 (-0.219, 0.687) **QF** 0.05 (-0.121, 0.192) 2.97 +/- 0.66 **P-value** <0.01								
Muscle echo intensity				**Gluteus** -91.2 +/- 13.2 **QF** 106 +/- 14.9 **Rectus abdominus** 117.4 +/- 18.6								

Observed disability					-0.19 (-0.38, -0.01) **P-value** 0.04								
Muscle strength					**Exercise group** 0.21 **Control group** 0.19 **P-value** 0.03								
Leg extension power Watt/kg							**Affected side** 0.6 Watt/kg (02-1.1) **Unaffected side** 0.5 Watt/kg (0.1-1.1) **P-value** <0.0001						
Internal and external rotation strength			**Internal** 0.04 Nm (−0.02 to 0.11) **External** 0.04 Nm (−0.01 to 0.08)										

Table 8: Inclusion and exclusion

Article	Source + included or excluded	Reason
Bennell, K., et al. (2011). "Exercise and osteoarthritis: cause and effects." Compr Physiol **1**(4): 1943-2008.	Source: Pubmed Excluded	No relevant population
Bennell, K. L. and R. S. Hinman (2011). "A review of the clinical evidence for exercise in osteoarthritis of the hip and knee." J Sci Med Sport **14**(1): 4-9.	Source: Pubmed Excluded	Review
Cambridge, E. D., et al. (2012). "Progressive hip rehabilitation: the effects of resistance band placement on gluteal activation during two common exercises." Clin Biomech (Bristol, Avon) **27**(7): 719-724.	Source: Pubmed Excluded	No relevant population
Dekker, J., et al. (2011). "[Exercise therapy in hip or knee osteoarthritis]." Ned Tijdschr Geneeskd **155**(30-31): A3462.	Source: Pubmed Excluded	No relevant outcome
Dwyer, M. K., et al. (2013). "Comparison of gluteus medius muscle activity during functional tasks in individuals with and without osteoarthritis of the hip joint." Clin Biomech (Bristol, Avon) **28**(7): 757-761.	Source: Pubmed Excluded	No relevant intervention
Fernandes, L., et al. (2010). "Development of a therapeutic exercise program for patients with osteoarthritis of the hip." Phys Ther **90**(4): 592-601.	Source: Pubmed Excluded	No relevant outcome
Ferrara, P. E., et al. (2008). "Effect of pre-operative physiotherapy in patients with end-stage osteoarthritis undergoing hip arthroplasty." Clin Rehabil **22**(10-11): 977-986.	Source: Pubmed Included	
French, H. P., et al. (2015). "Normalisation method can affect gluteus medius electromyography results during weight bearing exercises in people with hip osteoarthritis (OA): a case control study." Gait Posture **41**(2): 470-475.	Source: Pubmed and WoK Excluded	No relevant outcome
Fukumoto, Y., et al. (2014). "Effects of high-velocity resistance training on muscle function, muscle properties, and physical performance in individuals with hip osteoarthritis: a randomized controlled trial." Clin Rehabil **28**(1): 48-58.	Source: Pubmed and WoK Included	
Gremeaux, V., et al. (2008). "Low-frequency electric muscle stimulation combined with physical therapy after total hip arthroplasty for hip osteoarthritis in elderly patients: a randomized controlled trial." Arch Phys Med Rehabil **89**(12): 2265-2273.	Source: Pubmed and WoK Excluded	No relevant intervention
Hermann, A., et al. (2016). "Preoperative progressive explosive-type resistance training is feasible and effective in patients with hip osteoarthritis scheduled for total hip arthroplasty--	Source: Pubmed and WoK	

a randomized controlled trial." <u>Osteoarthritis Cartilage</u> **24**(1): 91-98.	Included	
Hinman, R. S., et al. (2007). "Aquatic physical therapy for hip and knee osteoarthritis: results of a single-blind randomized controlled trial." <u>Phys Ther</u> **87**(1): 32-43.	Source: Pubmed Excluded	No relevant intervention
Hopman-Rock, M. and M. H. Westhoff (2000). "The effects of a health educational and exercise program for older adults with osteoarthritis for the hip or knee." <u>J Rheumatol</u> **27**(8): 1947-1954.	Source: Pubmed Excluded	No relevant outcome
Jacobsen, J. S., et al. (2013). "Changes in walking and running in patients with hip dysplasia." <u>Acta Orthop</u> **84**(3): 265-270.	Source: Pubmed and WoK Excluded	No relevant intervention
Jensen, C., et al. (2013). "The effect of education and supervised exercise vs. education alone on the time to total hip replacement in patients with severe hip osteoarthritis. A randomized clinical trial protocol." <u>BMC Musculoskelet Disord</u> **14**: 21.	Source: Pubmed and WoK Excluded	Study protocol
Jigami, H., et al. (2012). "Effects of weekly and fortnightly therapeutic exercise on physical function and health-related quality of life in individuals with hip osteoarthritis." <u>J Orthop Sci</u> **17**(6): 737-744.	Source: Pubmed and WoK Included	
Kemp, J. L., et al. (2015). "A phase II trial for the efficacy of physiotherapy intervention for early-onset hip osteoarthritis: study protocol for a randomised controlled trial." <u>Trials</u> **16**: 26.	Source: Pubmed and WoK Excluded	Study protocol
Kim, J., et al. (2013). "Unsupervised virtual reality-based exercise program improves hip muscle strength and balance control in older adults: a pilot study." <u>Arch Phys Med Rehabil</u> **94**(5): 937-943.	Source: Pubmed Excluded	No relevant intervention
Minns Lowe, C. J., et al. (2009). "Effectiveness of physiotherapy exercise following hip arthroplasty for osteoarthritis: a systematic review of clinical trials." <u>BMC Musculoskelet Disord</u> **10**: 98.	Source: Pubmed Excluded	Review
Regnaux, J. P., et al. (2015). "High-intensity versus low-intensity physical activity or exercise in people with hip or knee osteoarthritis." <u>Cochrane Database Syst Rev</u>(10): Cd010203.	Source: Pubmed Excluded	Review
Steinhilber, B., et al. (2012). "Feasibility and efficacy of an 8-week progressive home-based strengthening exercise program in patients with osteoarthritis of the hip and/or total hip joint replacement: a preliminary trial." <u>Clin Rheumatol</u> **31**(3): 511-519.	Source: Pubmed and WoK Included	
Steinhilber, B., et al. (2014). "Stiffness, pain, and hip muscle strength are factors associated with	Source: Pubmed and WoK	No relevant intervention

self-reported physical disability in hip osteoarthritis." J Geriatr Phys Ther **37**(3): 99-105.	Excluded	No relevant outcome
Wang, T. J., et al. (2007). "Effects of aquatic exercise on flexibility, strength and aerobic fitness in adults with osteoarthritis of the hip or knee." J Adv Nurs **57**(2): 141-152.	Source: Pubmed and WoK Excluded	No relevant intervention
Zacharias, A., et al. (2014). "Efficacy of rehabilitation programs for improving muscle strength in people with hip or knee osteoarthritis: a systematic review with meta-analysis." Osteoarthritis Cartilage **22**(11): 1752-1773.	Source: Pubmed Excluded	Review
Ageberg, E., et al. (2013). "Effects of neuromuscular training (NEMEX-TJR) on patient-reported outcomes and physical function in severe primary hip or knee osteoarthritis: a controlled before-and-after study." Bmc Musculoskeletal Disorders **14**.	Source: WoK Included	
Amaro, A., et al. (2007). "Gluteus medius muscle atrophy contralateral and ipsilateral hip is related to joint osteoarthritis." International Journal of Sports Medicine **28**(12): 1035-1039.	Source: Wok Excluded	No relevant intervention
Bennell, K. L., et al. (2014). "Effect of Physical Therapy on Pain and Function in Patients With Hip Osteoarthritis A Randomized Clinical Trial." Jama-Journal of the American Medical Association **311**(19): 1987-1997.	Source: WoK Included	
Bennell, K. L., et al. (2010). "Efficacy of a multimodal physiotherapy treatment program for hip osteoarthritis: a randomised placebo-controlled trial protocol." Bmc Musculoskeletal Disorders **11**.	Source: WoK Excluded	No relevant outcome
Bijlsma, J. W. J. and K. Knahr (2007). "Strategies for the prevention and management of osteoarthritis of the hip and knee." Best Practice & Research in Clinical Rheumatology **21**(1): 59-76.	Source: WoK Excluded	No relevant intervention
Fernandes, L., et al. (2010). "Development of a Therapeutic Exercise Program for Patients With Osteoarthritis of the Hip." Phys Ther **90**(4): 592-601.	Source: WoK Included	
Giemza, C., et al. (2007). "The effect of physiotherapy training programme on postural stability in men with hip osteoarthritis." Aging Male **10**(2): 67-70.	Source: WoK Excluded	No relevant outcome
Grimaldi, A., et al. (2009). "The association between degenerative hip joint pathology and size of the gluteus maximus and tensor fascia lata muscles." Manual Therapy **14**(6): 611-617.	Source: Wok Excluded	No relevant intervention
Jansen, M. J., et al. (2010). "Quality indicators indicate good adherence to the clinical practice	Source: WoK	No relevant intervention

guideline on "Osteoarthritis of the hip and knee" and few prognostic factors influence outcome indicators: a prospective cohort study." European Journal of Physical and Rehabilitation Medicine **46**(3): 337-345.	Excluded	
Krauss, I., et al. (2011). "Efficacy of conservative treatment regimes for hip osteoarthritis - Evaluation of the therapeutic exercise regime "Hip School": A protocol for a randomised, controlled trial." Bmc Musculoskeletal Disorders **12**.	Source: WoK Excluded	Study protocol
Kuroda, D., et al. (2013). "Dynamic hip stability, strength and pain before and after hip abductor strengthening exercises for patients with dysplastic hips." Isokinetics and Exercise Science **21**(2): 95-100.	Source: WoK Included	
Lyp, M., et al. (2016). "A Water Rehabilitation Program in Patients with Hip Osteoarthritis Before and After Total Hip Replacement." Medical Science Monitor **22**.	Source: WoK Excluded	No relevant intervention
MacDonald, C. W., et al. (2006). "Clinical outcomes following manual physical therapy and exercise for hip osteoarthritis: A case series." Journal of Orthopaedic & Sports Physical Therapy **36**(8): 588-599.	Source: WoK Excluded	No relevant outcome
Maniwa, S., et al. (2007). Muscle exercise using Tai Chi in the patients with osteoarthritis of the hip.	Source: WoK Excluded	No relevant intervention
Ohashi, H., et al. (1993). BIOMECHANICAL ANALYSIS OF THE DYSPLASTIC HIP - PRE-PELVIC AND POST-PELVIC AND FEMORAL OSTEOTOMY.	Source: WoK Excluded	No relevant intervention
Pua, Y. H., et al. (2009). "Association of Physical Performance With Muscle Strength and Hip Range of Motion in Hip Osteoarthritis." Arthritis & Rheumatism-Arthritis Care & Research **61**(4): 442-450.	Source: WoK Excluded	No relevant intervention
Steinhilber, B., et al. (2011). "Reproducibility of concentric isokinetic and isometric strength measurements at the hip in patients with hip osteoarthritis: A preliminary study." Isokinetics and Exercise Science **19**(1): 39-46.	Source: Wok Excluded	No relevant intervention
Svege, I., et al. (2016). "Long-Term Effect of Exercise Therapy and Patient Education on Impairments and Activity Limitations in People With Hip Osteoarthritis: Secondary Outcome Analysis of a Randomized Clinical Trial." Phys Ther **96**(6): 818-827.	Source: WoK Included	
Unlu, E., et al. (2007). "The effect of exercise on hip muscle strength, gait speed and cadence in	Source: WoK	No relevant population

patients with total hip arthroplasty: a randomized controlled study." Clinical Rehabilitation **21**(8): 706-711.	Excluded	
Uusi-Rasi, K., et al. (2017). "Exercise Training in Treatment and Rehabilitation of Hip Osteoarthritis: A 12-Week Pilot Trial." Journal of Osteoporosis.	Source: WoK Included	
Van Baar, M. E., et al. (1998). "The effectiveness of exercise therapy in patients with osteoarthritis of the hip or knee: A randomized clinical trial." Journal of Rheumatology **25**(12): 2432-2439.	Source: WoK Included	
Veenhof, C., et al. (2006). "Effectiveness of behavioral graded activity in patients with osteoarthritis of the hip and/or knee: A randomized clinical trial." Arthritis & Rheumatism-Arthritis Care & Research **55**(6): 925-934.	Source: WoK Excluded	No relevant intervention

Figure 1: Flowchart

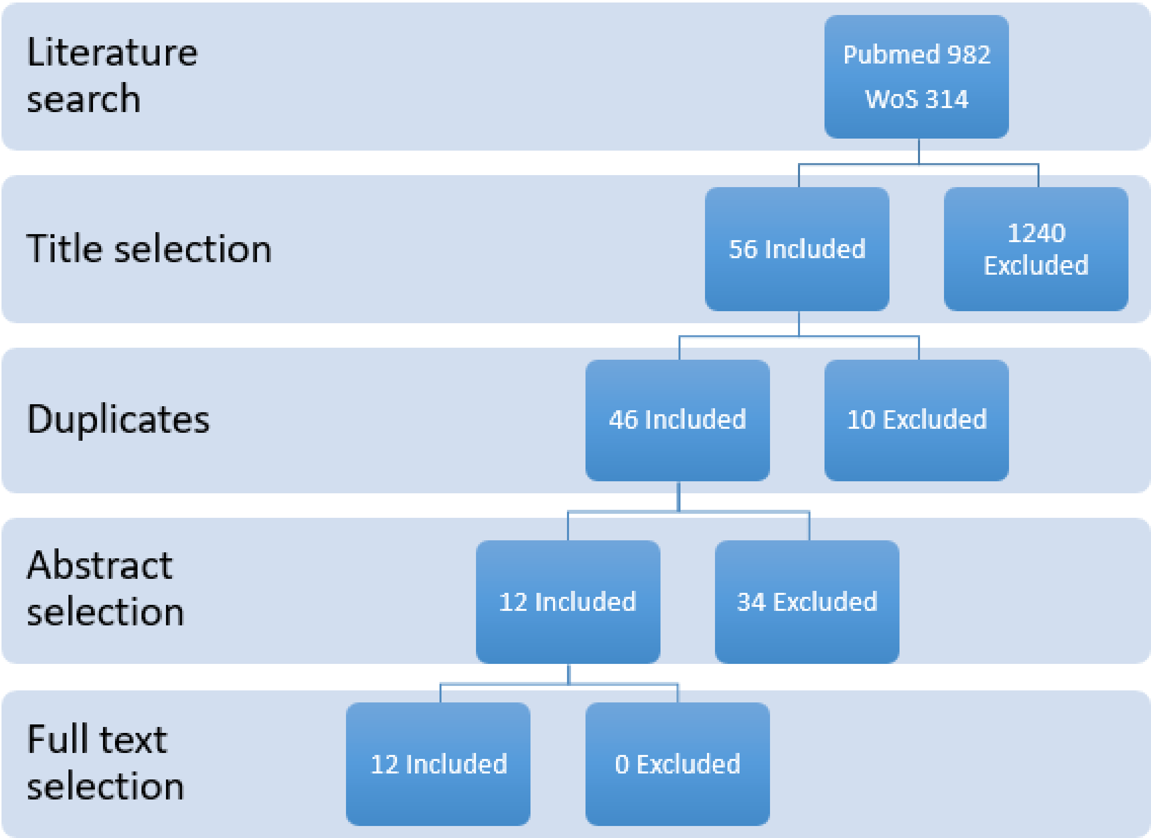


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Table 10: Progress form

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
24/10/17	- Kennismaking promotor - Ondertekenen contract wetenschappelijke stage deel 1 - Afspraken omtrent masterproef met promotor	Promotor: Prof. Dr. F. Vandenabeele Copromotor: Dr. Agten Student(e): Thomas Vankriekelsvenne Student(e): Bob Verbruggen
06/02/17	- Bespreking literatuurstudie - Bespreking voortgang - Vastleggen deadlines	Promotor: Prof. Dr. F. Vandenabeele Copromotor: Dr. Agten Student(e): Thomas Vankriekelsvenne Student(e): Bob Verbruggen
20/02/17	- Korte presentatie voortgang (PICO, inclusie, exclusie, etc.) - Vastleggen nieuwe deadlines	Promotor: Prof. Dr. F. Vandenabeele Copromotor: Dr. Agten Student(e): Thomas Vankriekelsvenne Student(e): Bob Verbruggen
06/03/17	- Bespreking voortgang	Promotor: Prof. Dr. F. Vandenabeele Student(e): Thomas Vankriekelsvenne
20/03/17	- Korte presentatie voortgang - Vastleggen nieuwe deadlines	Promotor: Prof. Dr. F. Vandenabeele Copromotor: Dr. Agten Student(e): Thomas Vankriekelsvenne Student(e): Bob Verbruggen
22/05/17	- Bespreking protocol masterproef 2	Promotor: Prof. Dr. F. Vandenabeele Student(e): Thomas Vankriekelsvenne Student(e): Bob Verbruggen
29/05/17	- Presentatie volledige masterproef deel 1 - Bespreking aanpassingen	Promotor: Prof. Dr. F. Vandenabeele Copromotor: Dr. Agten Student(e): Thomas Vankriekelsvenne Student(e): Bob Verbruggen

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Richting: **master in de revalidatiewetenschappen en de kinesitherapie-revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen**
Jaar: **2017**

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Voor akkoord,

Vankriekelsvenne, Thomas **Verbruggen, Bob**