Oclusion training as rehabilitation after ACL-injury, a review and meta-analysis.

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Abstract
A common issue after injuries with or without surgery is muscular atrophy. Every year approximately 8000 individuals injure their ACL only in Sweden and 4000 undergo surgery. Rehabilitation usually consists of strength training and 70 % of 1RM is a preferred weight when trying to build strength and muscle.
This systematic review and meta-analysis were investigating the effect of occlusion training after ACL injury compared to traditional rehabilitation, measured with knee function, muscle strength, pain and muscle mass.
In this review PubMed, Cinahl, Sportsmedicine & Education index, Cochrane Library, Sport Discus and Web of Science were used for the database search. Two independent authors performed the selection process, GRADE and risk of bias assessment. A total of nine studies were included for the synthesis where four could be included in the meta-analysis. No significant difference were found in the meta-analysis looking at muscle mass. No meta-analysis could be performed on knee function, muscle strength or knee pain. There was a significant difference in the intervention group performing occlusion training compared to the control group when looking at knee pain and knee function, but could not be verified by meta-analysis.
In conclusion occlusion training compared with traditional rehabilitation occlusion training seem to reduce experienced pain during training, increase knee function, preserve more muscle mass and give similar results in strength after 16 days to 16 weeks post ACLR.

Keywords: BFRT, knee function, knee pain, PRISMA, GRADE
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Introduction

A common issue after injuries with or without surgery is muscular atrophy, which causes weakening and reduction in muscle mass. Anterior cruciate ligament (ACL) injuries account for about 40% of all sports related knee injuries and is therefore one of the most common knee injuries (Nicolini et al. 2014). In Sweden, about 8000 injuries and 4000 surgeries are performed every year of which 20% of these need a second surgery, the reason for a second surgery is usually because of other complications such as mobility restriction and poor function (Svenska korsbandsregistret 2020). Only around 64% of the ACL injured individuals return to their previous activity level and 44% returns to their competitive sport (Ardern et al. 2011). Quadriceps atrophy is common post ACL injury and has been associated with reduced knee function and increased risk of both knee osteoarthritis and re-injury (Buckthorpe, La Rosa & Della Villa 2019). To minimize muscular atrophy, one should begin with rehabilitation and muscle strength training as early as possible post ACL injury (Lisee, Birchmeier, Kuenze 2019).

Knee function can be evaluated with self-assessment forms such as Knee Injury and Osteoarthritis Outcome Score (KOOS), The Knee Self-Efficacy Scale (K-SES) and the International Knee Documentation Committee (IKDC) (Thomeé et al. 2010). Another less subjective way to measure knee function is by the use of Single leg bend test with Electromyography (EMG) and video. The knee function is evaluated by measuring how much the knee is moving from side to side relative to the starting point (Kotsifaki, Korakakis, Whiteley, Van Rossom, & Jonkers 2020). Another commonly used tool for evaluating mainly peak torque is BIODEX (van Tittelboom et al. 2022).

Traditional rehabilitation

The traditional rehabilitation for musculoskeletal injuries usually consists of muscle strength training and for effective results you should be training at around 70% of 1RM (Dahl 2018). However according to Ladlow et al. (2017) high intensity training may be a contraindication in some situations, for example the early stages in rehabilitation when high intensity training is a risk for re-injury and causes pain. In a review from Hughes et al. (2018) a load of around 70% of 1RM may cause to much strain on the graft and prolong the rehabilitation or even rupture the ACL-reconstruction (ACLR) in the earlier stages of rehabilitation.
rehabilitation time varies between six to twelve months regardless of undergone an ACL surgery or not (Norouzi et al. 2013). The traditional rehabilitation after an ACL-injury usually consists of strengthening of the musculature around the knee but mainly the quadriceps muscle, also mobility training for the knee (Kvist 2004). It begins with very basic and simple exercises such as pressing the back of the knee towards the floor while sitting or lying down to restore the mobility in knee extension, progressively intensifying the load and complexity of the exercises from mainly mobility focus to strength, proprioception and plyometrics (Filbay & Grindem 2019; Micheo, Hernández & Seda 2010). The rehabilitation time and intensity depend on the individual and the end goals, it will differ heavily between a returning soccer player and an office worker for example (Cimino, Volk & Setter 2010). As mentioned before around 70 % of 1RM is shown to be a preferred weight for building strength and muscle tissue, according to Buckthorpe et al. (2019) occlusion training can result in better strength and hypertrophy compared to regular low intensity training 20-30 % of 1RM, it has also shown similar results to high intensity, 70 % 1RM.

Oclusion training
Traditionally occlusion training is known as Kaatsu and originates from Japan, Occlusion training means manipulating the bloodflow, the venous bloodflow should be completely inhibited whilst the arterial bloodflow is partly limited but still maintained into the active muscle. This can be done using an elastic band or pressurized cuff put around the proximal part of the extremity (Yasuda et al. 2012; Yamanaka, Farley, & Caputo. 2012). The bands and cuffs can consist of different materials which may influence the standardization and amount of restriction between individuals, thus leading to different results (Abe, Kearns & Sato. 2006). The blood pressure increases during exercise and physical activity, it usually rises to between 160 to 220mmHg (Carpio-Rivera, Moncada-Jiménez, Salazar-Rojas, & Solera-Herrera 2016). The cuff pressure is usually 1.3 times the individuals resting systolic blood pressure, around 110-270mmgh. The pressure is set higher to ensure the complete restriction of the venous bloodflow (Qerqueira et al. 2021). According to Das & Paton (2022) the cuff pressure should be set at 50-80 % restriction of the systolic blood pressure for optimal results.

Training with occlusion allows for low intensity training, in low intensity training a load of 20-
30 % of 1RM is used and when utilizing occlusion training with low intensity load the physiological response is similar to high intensity training when looking at hypertrophy and muscle strength (Thomeé, Augustsson, Wernbom, Augustsson & Karlsson 2008; Ladlow et al. 2017). However a minimum of 30 % 1RM during training is recommended and 40-60 % seems to be optimal to even get better results in muscular strength gains than regular high intensity training (Das & Paton 2022). This makes a possibility for occlusion training to be used in rehabilitation and minimize the risk of injury or re-injury and potentially earlier initiation of strength training in the rehabilitation (Takarada et al. 2017). Training with occlusion also causes close to none muscular damage compared to both high intensity and low intensity strength training without occlusion while still inducing similar effects on muscular hypertrophy and muscle strength (Buckthorpe et al. 2019).

**Physiological processes**

The hypothesis for this type of training is that the inhibition of bloodflow starts an anabolic process by stimulating the secretion of insulin growth factor-1 (IGF-1), inhibits the secretion of myostatin, induces cell swelling and recruits more muscle fibers (Pope, Willardson & Schoenfeld 2013; Bielitzki, Behrendt, Behrens & Schega 2021). These processes should inhibit catabolism which means that the body breaks down muscle tissue to use for energy and promote an anabolic response which in turn stimulates the build-up and reparation of muscle tissue.

**IGF-1**

IGF-1 is an important hormone with several functions, including stimulation of growth, specialization and transformation of cells and it also plays a part in the anabolic process for muscular hypertrophy. When performing low intensity training with occlusion the levels of IGF-1 inside the trained skeletal muscle has been shown to increase (Abe et al. 2005). According to Ascenzi et al. (2019) IGF-1 can play a big therapeutic part in rehabilitation because of its counteractive effect on sarcopenia, which in short means loss of muscle mass (Ascenzi et al. 2019).
**Musclefibers**

There are three different types of musclefibers: type I, IIa and IIx. These fibers have different functions and are recruited depending on what kind of exercise or task is performed. Type I is mostly recruited during cardiovascular exercise and is defined by a slow contraction rate and good endurance. Type IIx is recruited during explosive and high force output exercises such as powerlifting or sprinting. This type of fiber is defined by fast contraction rate, strong and explosive but bad endurance. Type IIa is a mix of I and IIx, they are fast twitch, larger than type I and can develop a high amount of power. Compared to IIx, IIa can develop less power but have more endurance (Talbot & Mayes 2016).

Musclefibers are recruited depending on the required force output, type I fibers are always recruited first, the force output is determined by the total amount of fibers recruited and which type. For example, when walking a low force output and a low amount of fibers is required, which is mainly type I. When performing a 1RM squat a large amount of muscle fibers have to get recruited and it is mainly type IIx (Winchester et al. 2008). When performing occlusion training the recruitment of type IIa and IIx is increased in low intensity training compared to regular low intensity training. The theory behind being that the occlusion fatigues the type I fibers early due to the lack of oxygen and forces the recruitment of other fibers (Loenneke et al. 2012).

**Myostatin**

Another physiological factor that occurs is the secretion of growth and differentiation factor-8 (MSTN) which is a protein that plays a role in both myogenesis, skeletal muscle and adipogenesis, fat mass. MSTN is defined as a negative muscle regulator regarding determination of skeletal muscle mass in size and amount of muscle fibers. If the secretion of MSTN is inhibited it could lead to an increase in skeletal muscle mass, fiber amount and size (Tobin & Celeste 2005).

According to Laurentio et al. (2012) the inhibition of MSTN by occlusion training may be the main factor for getting similar results in low intensity training compared to traditional high intensity strength training looking at strength and muscle mass (Laruentio et al. 2012).
**Cell swelling**

Cellular hydration (swelling) stimulates changes in protein catabolism and anabolism. According to Häussinger et al. (1993) the cell swelling inhibits catabolism and changes the blood balance into anabolism. This in turn leads to an increased response in muscular hypertrophy and muscle protein synthesis similar to high intensity strength training (Fry et al. 2010). The restriction of venous bloodflow forces extracellular water into the muscle cell which causes the cell to swell (Loenneke et al. 2012).

**Occlusion training in rehabilitation**

Wengle et al. (2021) performed a systematic review & meta-analysis to investigate the effect of occlusion training in patients undergoing knee surgery, ten out of eleven studies had patients undergoing an ACLR. The outcome measures were cross sectional area of the quadriceps muscle, quadriceps muscle strength, isotonic strength and knee function with KOOS (Wengle et al. 2021).

Wengle et al. (2021) concluded that occlusion training can reduce post-surgery muscle atrophy in the quadriceps compared to the control group. In a meta-analysis by Hughes et al. (2017) they concluded that occlusion training may be a more effective and tolerable intervention compared to traditional rehabilitation after an ACL-injury and surgery. But further research is needed and must focus on physical function of the knee (Hughes et al. 2017). In another review by Hughes et al. (2018) occlusion training were shown to reduce atrophy, induce strength and muscle activation. Training with occlusion after ACLR would also reduce the risk of reinjury during rehabilitation (Hughes et al. 2018). SHAM occlusion have been used in randomized controlled trials (RCT) to compare this intervention, SHAM in this case meaning the occlusion cuff not being set to a adequate pressure for the restriction of blood flow to be effective (Korakakis 2019).

According to Caetano et al. (2021) there is a knowledge gap in mainly how the knee function is affected during and after rehabilitation with occlusion training compared to traditional rehabilitation for individuals with an ACL injury. Considering how commonly occurring this injury is, about 8000 individuals every year in Sweden, it needs further investigation (Caetano et al. 2021).
The aim is to study if there are any differences in knee function, muscle strength, self-selected knee pain or muscle mass between the use of traditional rehabilitation and occlusion training after an ACL-injury with or without surgery.

**Questions at issue**
- Does occlusion training generate higher physical function than traditional rehabilitation after an ACL-injury?
- Does occlusion training generate a larger increase in muscle strength compared to traditional rehabilitation?
- Does occlusion training generate less knee pain during training compared to traditional rehabilitation?
- Does occlusion training generate a larger increase in muscle mass compared to traditional rehabilitation?
Method
The PRISMA checklist was used for the structure, formalia and presentation of the selection process in this essay (Page et al. 2021).

Eligibility criteria
A PICOS-model (Population, Intervention, Control, Outcome & Study design) was developed to aid in the formulation of relevant search phrases (Figure 1).

Inclusion criteria
The study compared occlusion training with traditional rehabilitation.
The study included subjects that have injured their ACL.
The study included men and women, athletes and non-athletes with a mean age of at least 18 years or higher.

Exclusion criteria
The language in the article were not English or Swedish.
The article did not evaluate knee function, muscle strength, knee pain or muscle mass.
The article were not a Randomized Controlled Trial (RCT).
Information sources

The searches were done in six different databases: PubMed, Cinahl, Sportsmedicine & Education index, Cochrane Library, Sport Discus and Web of Science.

Search strategy

Two different database searches were performed, one test search and one head search. The test search was performed in a pilot study that was executed on the 6th of January 2022 to investigate how much material is available within the inclusion criteria and which databases seem most relevant and resulted in a total of 351 potentially relevant studies from six different databases, after the selection process seven relevant studies remained (Figure 2). Words used in both the test search and head search were occlusion training, vascular occlusion, blood flow restriction training, blood flow restriction, kaatsu, hypoxia, anterior cruciate ligament, acl.
OR, the delimitation filter *peer reviewed* were used as well.

The exact search were as following:

```
("Occlusion training" OR “vascular occlusion” OR “blood flow restriction training” OR “blood flow restriction” OR katsu OR hypoxia) AND (“anterior cruciate ligament” OR acl))
```

The strategy, filters and search string were identical in each database.

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**Data collection process**

The selection process and quality assessment were performed by two different independent authors (IA & MN)
Data items
Knee function, muscle strength, knee pain during training and muscle mass.

Study risk of bias assessment
Cochrane risk of bias tool were used by both authors IA and MN to evaluate the risk of bias of each included study.

Effect measures
Statistical analyses was executed for the outcome muscle mass but not for knee function, muscle strength and knee pain. For the statistical measures meta-analysis was executed with Revman 5 (Cochrane Training, The Cochrane Collaboration, London, United Kingdom). The forest plot presents standardized mean difference (SMD) and 95% confidence interval (CI) for which group the results favours, left favours occlusion training and right favours traditional rehabilitation. Furthermore heterogeneity were measured and presented in Chi² and I², going from low heterogeneity (< 40%) to high heterogeneity (>70 %), p<0.05 represents a significant result and Z represents the overall effect where the null hypothesis is no effect between the groups with p<0.05 indicating a significant overall effect (Huedo-medina et al. 2006). The rhomb represents the SMD indicating which intervention the results are favouring, rhomb crossing both sides of the 0 line means there is no significant difference between the groups.

Synthesis methods
This study used a narrative synthesis on knee function, muscle strength and knee pain. For muscle mass a synthesis and meta-analysis were used.

Reporting bias assessment
The combined results from both authors from the Cochrane risk of bias tool assessment was presented in a trafficlight plot. Robvis 2.0 was used to generate this traffic plot to summarize and present the risk of bias assessment (riskofbias.info). Robvis 2.0 presents a risk of bias
grading going from low risk of bias to high risk of bias, Figure 3.

Judgement

- High
- Some concerns
+ Low

Figure 3: Presentation of the three different overall results from RoB 2.0.
High; Indicates a high risk of bias. Some concerns; Indicates some concerns regarding the risk of bias. Low; Indicates a low risk of bias.

**Certainty assessment**

Grading of Recommendations, Assessment, Development and Evaluations (GRADE) were used for the certainty assessment. The certainty indicated how confident the authors are that the true effect are similar to the estimated effect with the rating going from “very low” to “high” (Guyatt et al. 2013). The studies looking at each outcome from the questions at issue were assessed in GRADE to get a combined score of evidence and certainty.
Results
The literature search resulted in a total of 411 hits, after exclusion of duplicates and screening of title and abstract 75 full text articles were assessed where eleven ended up being relevant to this review and meta-analysis (Figure 4). Two studies were not available in full text, after requesting access and contacting the authors without receiving access to these two studies in full text they had to be excluded (Figure 4) (Curley et al. 2021; Paton & Hughes 2022). Meaning a total of nine studies were included in this study. One study evaluated knee function, four studies evaluated muscle strength, four studies evaluated knee pain and four studies evaluated muscle mass. Furthermore the study characteristics is presented in Table 1.
Figure 4: Selection process performed by both authors IA & MN using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) flowchart of the selection process from head search.
### Table 1: Presentation of the included studies

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<th>Author/Year</th>
<th>Study Design</th>
<th>Population</th>
<th>Pre or Post ACLR</th>
<th>Intervention</th>
<th>Cuff Pressure (mmHg)</th>
<th>Duration</th>
<th>Outcome Measures</th>
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<tr>
<td>Hughes &amp; Rostenblatt 2019</td>
<td>Two arm single assessor blinded RCT</td>
<td>Men=17 Women=7 Age=29±7 Post ACLR</td>
<td>(1) n=12 Low load BFRT unilateral legpress (2) n=12 High load BFRT unilateral legpress</td>
<td>Automatic personalized torniquet set to 80%</td>
<td>16 sessions through 8 weeks</td>
<td>Strength, muscle mass, pain &amp; knee function</td>
<td></td>
</tr>
<tr>
<td>Hughes &amp; Patterson 2019</td>
<td>RCT</td>
<td>Men=17 Women=7 Age=29±7 Post ACLR</td>
<td>(1) n=12 BFRT 30% of 1RM unilateral legpress on both limbs (2) n=12 HLAT 70% of 1RM unilateral legpress on both limbs</td>
<td>Automatic personalized torniquet set to 80%</td>
<td>16 sessions through 8 weeks</td>
<td>Pain</td>
<td></td>
</tr>
<tr>
<td>Kacin 2021</td>
<td>Single blinded, quasi RCT</td>
<td>Men=6 Women=6 Age=38±8 Pre ACLR</td>
<td>(1) n=6 BFRT unilateral knee extension and leg flexion machine at 40RM (2) n=6 Sham BFRT unilateral leg extension and knee flexion machine at 40RM</td>
<td>150mmHg</td>
<td>9 sessions through 3 weeks</td>
<td>Strength</td>
<td></td>
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<tr>
<td>Lambert 2019</td>
<td>RCT</td>
<td>Men=8 Women=6 Age=23±7 Post ACLR</td>
<td>(1) n=7 BFRT quadriceps contractions wk1-3, bilateral legpress wk3-12, eccentric leg press wk4-12, hamstring curl wk4-6, eccentric hamstring curl wk7-12 4 sets of 30-15-15-15 with 20% of 1RM (2) n=7 Same training protocol without BFR</td>
<td>Automatic personalized torniquet set to 80%</td>
<td>12 weeks</td>
<td>Muscle mass</td>
<td></td>
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<tr>
<td>Melo 2021</td>
<td>RCT</td>
<td>n=24 Age=18-59 Post ACLR</td>
<td>(1) n=12 BFRT 30% of 1RM 30-15-15-15 in leg press and knee flexor machine (2) n=12 70% of 1RM 3x10 same exercises</td>
<td>80% of complete arterial occlusion</td>
<td>Twice a week for 12 weeks</td>
<td>Strength &amp; Pain</td>
<td></td>
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<tr>
<td>Žargi 2018</td>
<td>Quasi RCT</td>
<td>Men=16 Women=4 Age=35±5 Pre ACLR</td>
<td>(1) n=10 BFRT unilateral leg extension at 40RM (2) n=10 Sham BFRT unilateral leg extension at 40RM</td>
<td>150mmHg</td>
<td>8 days prior to surgery until 12 weeks post surgery</td>
<td>Strength</td>
<td></td>
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<tr>
<td>Iversen 2014</td>
<td>RCT</td>
<td>n=24 Age=18-39 Post ACLR</td>
<td>(1) n=12 BFRT 5x20 Isometric quadriceps contractions, leg extension &amp; single leg-raises (2) n=12 Regular training, same exercise protocol</td>
<td>130-180mmHg</td>
<td>2 sessions per day for two weeks</td>
<td>Muscle mass</td>
<td></td>
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<tr>
<td>Author/Year</td>
<td>Study Design</td>
<td>Population</td>
<td>Pre or Post ACLR</td>
<td>Intervention Description</td>
<td>Cuff Pressure (mmHg)</td>
<td>Duration</td>
<td>Outcome Measures</td>
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<tr>
<td>Korakakis 2021</td>
<td>Two arm RCT</td>
<td>Men=15 Women=0</td>
<td>Post ACLR</td>
<td>(1) n=7 LL-BFRT open chain knee extensions, 4 sets, maximum repetitions-15-15-15 (2) n=8 LL training without BFRT, same exercise protocol</td>
<td>80% of complete arterial occlusion</td>
<td>8 weeks</td>
<td>Pain</td>
</tr>
<tr>
<td>Ohta 2003</td>
<td>RCT</td>
<td>Men=25 Women=19</td>
<td>Post ACLR</td>
<td>(1) n=22 BFRT Straight leg-raise+hip abduction wk 1-8, isometric hip adduction wk 1-12, half squats &amp; step ups wk 5-16, elastic tube exercise wk 9-16, knee bending walking wk 13-16 (2) n=22 Same training protocol without BFRT</td>
<td>~180mmHg</td>
<td>1-2 sessions daily 6 times/wk during 16 weeks</td>
<td>Strength &amp; muscle mass</td>
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*RCT randomized controlled trial; ACLR anterior cruciate ligament reconstruction; BFRT blood flow restriction training; 1RM one rep max; Unilateral means performing the exercise with one leg at a time; HLRT high load resistance training; LL low load; HL high load; Wk week.*
A total of 201 individuals with an ACL injury participated in the nine included studies and 31 individuals did not complete the whole study protocol. Seven studies presented gender, out of those 154 individuals, 49 were women and 104 were men, the mean age of all nine studies were over 18 years old (Table 1). Seven studies compared the interventions post surgery, two studies compared the interventions pre surgery. The intervention groups performed occlusion training and the control groups performed either SHAM-occlusion training or traditional rehabilitation without occlusion (Table 1). Most studies compared occlusion training with traditional rehabilitation without occlusion after ACLR, Zargi et al. (2018) and Kacin et al. (2021) did however compare occlusion training with SHAM-occlusion, meaning the occlusion cuffs were applied but the assessor applied less pressure so the arterial and venous blood flow was not adequately restricted for the physiological processes to take action.

One study evaluated knee function, five studies evaluated muscle strength, four studies evaluated experienced knee pain during exercise with Borg CR10 (Shariat et al. 2018), Numeric Rating Score (NRS) or Knee injury and Ostheoarthritis Outcome Score (KOOS) (Salavati et al. 2011) and lastly four studies evaluated muscle mass (Table 1).

**Risk of Bias Assessment & Quality Assessment**

The risk of bias assessment score using Cochrane risk of bias tool is presented in Figure 5, this figure were generated with RoB 2.0 (riskofbias.info).

Nine studies were assessed with the Cochrane risk of bias tool, no studies had a high risk of bias. One out of nine studies had a overall low risk of bias and the remaining eight had some concerns, majority being from domain four regarding bias in the measurement of outcomes (Figure 5).

One study, Korakakis et al. (2018) had low risk in every aspect in the Cochrane risk of bias tool, which indicated an overall low risk of bias (Higgins et al. 2011). Furthermore one study had bias arising from the randomization process (Melo et al. 2021) while the remaining eight did not have any concerns in the randomization process. In the second domain where deviations from the intenedt intervention were assessed Lambert et al. (2017) & Zargi et al. (2018) were unable to present any considerations about this matter, therefore some concerns. Four out of nine studies had some concerns due to missing data and five had a low
risk of bias in this matter. In domain four where the risk of bias in measurement of the outcome is assessed, four studies had some concerns and the remaining five had low risk of bias. The fifth and last domain there were four studies with some concerns considering result reporting, the remaining five had low risk of bias in this matter (Figure 5).

![Risk of bias domains](image)

**Figure 2**: Cochrane Risk of Bias tool generated with Robvis, RoB 2.0.

D1; Bias arising from the randomization process. D2; Bias due to deviations from intended interventions. D3; Bias due to missing outcome data. D4; Bias in measurement of the outcome. D5; Bias in selection of the reported result.

Certainty & quality assessment of each outcome with GRADE presented in Table 2. Four studies evaluated pain with a total of 65 participants, an unclear effect due to heterogeneity in the outcome measure and moderate certainty. Muscle strength were evaluated by five studies with a total of 128 participants, an unclear effect due to heterogeneity in the outcome measure and this outcome had moderate certainty. Knee function were evaluated by one study, with 24 participants, an effect of 1.49 (CI 0.57, 2.42) and low certainty. Five studies evaluated changes in muscle mass with a total of 110 participants, an effect of -0.34 (CI -0.87, 0.20) and moderate certainty (Table 2).
Table 2: Study evidence assessment by both IA & MN using Grading of Recommendations, Assessment, Development and Evaluations (GRADE).

<table>
<thead>
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<th>Outcome</th>
<th>Certainty assessment</th>
<th>Summary of findings</th>
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<tr>
<td></td>
<td>No. Of studies</td>
<td>Study Design</td>
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<tr>
<td>Knee function</td>
<td>1</td>
<td>RCT</td>
</tr>
<tr>
<td>Muscle strength</td>
<td>4</td>
<td>RCT</td>
</tr>
<tr>
<td>Pain</td>
<td>4</td>
<td>RCT</td>
</tr>
<tr>
<td>Muscle mass</td>
<td>4</td>
<td>RCT</td>
</tr>
</tbody>
</table>

BFRT blood flow restriction training; TR traditional rehabilitation; RCT randomized controlled trial. CI Confidence interval
**Knee Function**

One study evaluated knee function where the function were self assessed with IKDC. IKDC is scored 0-100 where 0 indicates a low knee function and 100 indicates good knee function with no limitations in daily activities. After eight weeks of training Hughes & Rosenblatt et al. (2019) found a significantly greater IKDC score for the experimental group performing occlusion training, 35.63±7.06 p<0.01 compared to the control group performing traditional rehabilitation 23.33±8.76 p<0.01 (Table 3).

**Table 3: Presentation of results from the studies evaluating knee function.**

<table>
<thead>
<tr>
<th>Studies</th>
<th>No. Of participants</th>
<th>Outcome measure</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hughes &amp; Rosenblatt et al. 2019</td>
<td>BFRT: n=12&lt;br&gt;HL-RT: n=12</td>
<td>Knee function evaluated with self reporting scale IKDC. IKDC is scored 0-100 with 100 indicating higher knee function.</td>
<td>Overall IKDC score week 0-8:&lt;br&gt;BFRT – 35.63±7.06*&lt;br&gt;p&lt;0.01&lt;br&gt;HL-RT – 23.33±8.76 p&lt;0.01</td>
</tr>
</tbody>
</table>

BFRT blood flow restriction training; HL-RT high load resistance training; IKDC international knee documentation committee.

*; indicating a significantly greater change than the control group.

**Muscle Strength**

Four studies evaluated muscle strength with either 10RM leg press or knee extension (KE) and knee flexion (KF) peak torque. After eight weeks of training there was no differences between the groups in 10RM strength (Hughes & Rosenblatt et al. 2019).

Knee extensor peak torque were significantly larger in the occlusion group at both 60° and 120° compared to sham occlusion three weeks post surgery, knee flexor peak torque were similar between the groups (Kacin et al. 2021). Melo et al. (2021) found a significant difference between the groups in peak torque after 12 weeks of training. Both KE and KF peak torque were significantly higher on the injured limb in the experimental group compared to the control. There was no group difference in peak torque on the uninjured limb.
Zargi et al. (2018) found a significant difference in both muscle endurance and strength between the groups four weeks post surgery, this significant difference diminished at eight and twelve weeks post surgery followups (Table 4).
Table 4: Presentation of results from studies evaluating muscle strength.

<table>
<thead>
<tr>
<th>Studies</th>
<th>No. Of participants</th>
<th>Outcome measure</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hughes &amp; Rosenblatt et al. 2019</td>
<td>BFRT: n=12</td>
<td>Muscle strength measured with 10RM unilateral leg press.</td>
<td>10RM unilateral leg press&lt;br&gt;BFRT injured limb – 104±18% p=0.22 BFRT uninjured limb – 33±12% p=0.39&lt;br&gt;HL-RT injured limb – 106±21% p=0.22 HL-RT uninjured limb – 40±16% p=0.39</td>
</tr>
<tr>
<td></td>
<td>HL-RT: n=12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hughes &amp; Patterson et al. 2019</td>
<td>BFRT: n=6</td>
<td>Isokinetic strength presented in peak torque at 60° and 120° pre ACLR.</td>
<td>Peak torque % increase at 60° and 120° after 3 weeks of training.</td>
</tr>
<tr>
<td></td>
<td>SHAM BFRT: n=6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melo et al. 2021</td>
<td>BFRT: n=6</td>
<td>Peak torque measured with isometric dynamometer post ACLR.</td>
<td>Peak torque (Newton) 12 weeks post surgery.</td>
</tr>
<tr>
<td></td>
<td>TR: n=6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zargi et al. 2018</td>
<td>BFRT: n=10</td>
<td>Maximal voluntary isometric torque of QF with static dynamometer pre and post ACLR.</td>
<td>Maximal voluntary isometric torque (Newton meter) 12 weeks post surgery.</td>
</tr>
<tr>
<td></td>
<td>SHAM BFRT: n=10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


*; indicating a significantly greater change than the control group.
Knee Pain

All four studies evaluating pain found significant decrease in pain for the intervention group performing occlusion training. Three out of four presented significant decrease in experienced pain in the occlusion group compared with the control group (Table 5) (Hughes & Rosenblatt et al. 2019; Korakakis et al. 2018; Melo et al. 2021). The group performing BFRT and the SHAM BFRT group significantly decreased their pain during training with no significant difference between the groups (Hughes & Patterson et al. 2019). Melo et al. (2021) only saw a significant difference in KOOS score at week 4 and 6 but at week 8 and 12 there was similar values between the groups. Single leg deep squat (SLSd), single leg shallow squat (SLSs) and step down test (STD) were performed by Korakakis et al. (2018) intervention group and control group. This to later assess experienced pain during these exercises on a scale from 0-10. The experimental groups experienced pain were lower in every test with a significant difference compared to the control group (Table 5).
Table 5: Presentation of results from the studies evaluating knee pain

<table>
<thead>
<tr>
<th>Studies</th>
<th>No. Of participants</th>
<th>Outcome measure</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hughes &amp; Rosenblatt et al. 2019</td>
<td>BFRT: n=12 HL-RT: n=12</td>
<td>Self evaluated knee pain with KOOS.</td>
<td>KOOS score after 8 weeks of training. BFRT – 39.75±11.74* p&lt;0.05 HL-RT – 22.00±7.48</td>
</tr>
<tr>
<td>Hughes &amp; Patterson et al. 2019</td>
<td>BFRT: n=6 SHAM BFRT: n=6</td>
<td>Knee pain during training session evaluated with Borg CR10 scale.</td>
<td>Mean session knee pain 8 weeks post surgery BFRT – 1.38±0.96* p&lt;0.01 SHAM BFRT – 3.43±1.64* p&lt;0.05</td>
</tr>
<tr>
<td>Melo et al. 2021</td>
<td>BFRT: n=6 TR: n=6</td>
<td>Self evaluated knee pain with KOOS.</td>
<td>Pain 12 weeks post surgery. BFRT – 100.00±0.00* p&lt;0.01 TR – 88±2.35 p&lt;0.01</td>
</tr>
<tr>
<td>Korakakis et al. 2021</td>
<td>LL BFRT: n=7 LLT: n=8</td>
<td>Knee pain during SLSs, SLSd and SDT. Pain were self assessed on a scale from 0-10 post ACLR.</td>
<td>Experienced knee pain during exercise 8 weeks post surgery Pain during SLSs LL-BFRT – 2.0±1.6* p&lt;0.001 LLT – 2.6±2.7 Pain during SLSd LL-BFRT – 2.9±2.3* p&lt;0.001 LLT – 4.2±2.2 Pain during SDT LL-BFRT – 2.2±2.2* p=0.001 LLT – 3.0±2.5</td>
</tr>
</tbody>
</table>

BFRT blood flow restriction training; HL-RT high load resistance training; KOOS knee injury and osteoarthritis outcome score; TR traditional rehabilitation; LL BFRT low load blood flow restriction training; LLT low load training; SLSs single leg squat shallow; SLSd single leg squat deep; SDT step down test.
**Muscle Mass**

A total of four studies evaluated muscle mass using ultrasound, magnetic resonance imaging (MRI) or DEXA scan. After eight weeks of training there was a significant increase in the vastus lateralis muscle mass in both groups with no group differences (*Hughes & Rosenblatt et al. 2019*). Leg lean muscle mass six and twelve weeks post surgery compared to pre surgery were similar in both groups measured with DEXA (*Lambert et al. 2019*).

16 days post surgery Iversen et al. (2014) compared anatomical cross sectional area (ASCA) with before surgery and measured this with MRI. The muscular atrophy 16 days post surgery were similar between the groups performing occlusion training or traditional rehabilitation and between men and women regardless of their group (*Iversen et al. 2014*). When measuring KE muscle mass 16 weeks post surgery with MRI Ohta et al. (2003) found a significant difference between the occlusion group and control group, in knee flexor (KF) + adductor muscle groups there was no significant differences between the groups (Table 6).
Table 6: Presentation of results from the studies evaluating muscle mass

<table>
<thead>
<tr>
<th>Studies</th>
<th>No. Of participants</th>
<th>Outcome measure</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hughes &amp; Rosenblatt et al. 2019</td>
<td>BFRT: n=12</td>
<td>Muscle thickness in the vastus lateralis muscle measured with B-mode ultrasonography ultrasound.</td>
<td>Muscle mass gained after 8 weeks of training.</td>
</tr>
<tr>
<td></td>
<td>HL-RT: n=12</td>
<td></td>
<td>BFRT – 5.8±0.2%* p=0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HL-RT – 6.7±0.3%* p=0.33</td>
</tr>
<tr>
<td>Lambert et al. 2019</td>
<td>BFRT: n=7</td>
<td>Whole leg lean mass compared to pre surgery measured with DEXA.</td>
<td>Lean leg muscle mass difference after 6 and 12 weeks of training.</td>
</tr>
<tr>
<td></td>
<td>TR: n=7</td>
<td></td>
<td>BFRT week 6 – -0.19±0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TR week 6 – -0.72±0.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BFRT week 12 – -0.11±0.17 p&lt;0.05 TR week 12 – -0.48±0.21 p&lt;0.05</td>
</tr>
<tr>
<td>Iversen et al. 2014</td>
<td>BFRT: n=12</td>
<td>Quadriceps muscle mass measured with anatomical cross sectional images with MRI.</td>
<td>ACSA of the quadriceps 16 days post surgery compared to pre surgery</td>
</tr>
<tr>
<td></td>
<td>TR: n=12</td>
<td></td>
<td>BFRT men – -12.8±1.1% p=0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TR men – -12.2±0.8% p=0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BFRT women – -15.3±2.1% p=0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TR women – -14.3±2.2% p=0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BFRT total – -13.8±1.1% p=0.6265</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TR total – -13.1±1.0% p=0.6265</td>
</tr>
<tr>
<td>Ohta et al. 2003</td>
<td>LL BFRT: n=7</td>
<td>Knee extensor muscle group and knee flexor+adductor muscle group cross sectional area measured with MRI, comparison on the injured limb with the healthy limb.</td>
<td>Femoral muscle mass 16 weeks post surgery compared to pre surgery.</td>
</tr>
<tr>
<td></td>
<td>LLT: n=8</td>
<td></td>
<td>LL BFRT KE – 101±11%* p=0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LLT KE – 92±12%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LL BFRT KF+A – 105±19%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LLT KF+A – 102±23%</td>
</tr>
</tbody>
</table>

BFRT blood flow restriction training; HL-RT high load resistance training; TR traditional rehabilitation; MRI magnetic resonance imaging; ACSA anatomical cross sectional area; LL BFRT low load blood flow restriction training; LLT low load training; KE knee extensors; KF+A knee flexors + adductors.
**Meta-Analysis**

Four out of nine studies were included in the meta-analysis. The outcome measured were muscle mass comparing occlusion training with traditional rehabilitation. Two studies resulted in favour of the experimental group with a standardized mean difference (SMD) of -3.41 and -0.64 respectively although only Hughes & Rosenblatt et al. (2019) was significant (Hughes & Rosenblatt et al. 2019; Iversen et al. 2016). The remaining two studies were in favour of the control group with a SMD of 1.81 and 0.73 respectively but only Lambert et al. (2019) were significant (Lambert et al. 2019; Ohta et al. 2003) The SMD effect size showed no significant differences in the four studies, the SMD were -0.34 p<0.00001 which however have a tendency to favour the experimental group performing occlusion training.

Heterogeneity I² were 92% and overall effect Z were 1.24 p=0.21 (Figure 6).

*Figure 6: Presentation of meta-analysis on muscle mass.*
Discussion

The aim of this review and meta-analysis was to investigate the effect of occlusion training after an ACL injury and compare it with traditional rehabilitation. This effect was evaluated with four different outcomes, knee function, muscle strength, knee pain and muscle mass.

Knee function

One study evaluated knee function with the self reporting questionnaire IKDC (Hughes & Rosenblatt et al. 2019). According to Hughes et al. (2017) knee function have not been studied enough in previous studies and meta-analyses, probably because a low availability of studies. That was also the case in this study, where no meta-analysis were performed because only one study were included. However in this one study there was a significant difference between the groups, favouring the intervention group performing occlusion training. Since IKDC is a self reporting questionnaire the results may vary alot based upon the individuals activity level before their ACL injury, for example a soccer player compared to an individual that only takes walks as physical activity (Table 4). IKDC have however according to Higgins et al (2007) and Ebrahimzadeh et al. (2015) been shown to have good reliability and validity, ICC=0.845 p<0.001 r=0.522 respectively.

Muscle strength

One study found a significant group difference in peak torque favouring the intervention group in both KE and KF on the injured limb three weeks post surgery (Melo et al. 2021). Kacin et al. (2021) also found a significant group difference but only in KE peak torque 12 weeks post surgery (Table 5). One reason may be the different intervention length, although this have not been studied there seem to be a higher impact by occlusion training compared to tradititonal rehabilitation during the first few weeks post surgery. Because all studies looked at individuals that underwent a ACLR it is difficult to draw any conclusion on individuals that have not performed a ACLR. Two studies that investigated muscle strength found no significant increases or group differences after eight and twelve weeks of training testing isometric torque and 10RM strength, these diversified results are interesting since the intervention were similar in all studies (Hughes & Rosenblatt et al. 2019; Zargi et al.)
The only difference in the interventions is that Melo et al. (2021) had a shorter intervention period and Hughes & Rosenblatt et al. (2019) had a different type of outcome measure. The cuff pressure did not seem to affect the results since there were individualized cuff pressure in both the significant results and the non-significant results. Even though four included studies investigated muscle strength a meta-analysis could not be performed because of a high heterogeneity in the outcome measures, which means the outcome measures were to different for a meta-analysis to be performed.

**Knee pain**
A total of four studies evaluated knee pain in this review, the outcome measures did however have to much heterogeneity. All four studies found significant decreases in pain during exercise in the intervention group performing occlusion training and three studies found a significant difference between the groups (Table 6). One study also found a significant decrease in pain on the control group (Hughes & Patterson et al. 2019). These results support the statement from Takarada et al. (2000) and Hughes et al. (2017) that occlusion training may allow for lower risk for injury and potentially earlier initiation of strength training in the rehabilitation because of a more tolerable and effective intervention.

KOOS self assessment-scale have been shown to have good reliability and validity (ICC=0.866 SEM=2.58) after an ACL injury and ACLR (Salavati et al. 2011). Borg CR10 scale have been shown to have good retest reliability (ICC=0.898) and the validity seem to be good when comparing to the visual analog scale (VAS), \( r=0.754 \ p<0.01 \) (Shariat et al 2018). The numeric pain rating scale (NRS) used by Korakakis et al. (2018) have been shown to have good reliability and validity ICC=0.95 SEM=0.48 (Alghadir et al. 2018).

**Muscle mass**
Two studies found a significant increase after eight and 16 weeks of training in the vastus lateralis and KE muscle group (Hughes & Rosenblatt et al. 2019; Ohta et al. 2003). There was only a significant difference between the groups in the KE muscle group after 16 weeks and vastus lateralis muscle mass had similar increase in mass in both groups (Table 6). Even though, Lambert et al. (2019) only had 20 % of 1RM as resistance during training both in the occlusion group and control group training without occlusion they had similar results at both
eight and 12 weeks post surgery. Using MRI, ultra sound and DEXA scan to measure muscle mass have been shown to have good to excellent reliability and validity, \( r > 0.91, r > 0.83 \) & \( r > 0.91 \) respectively (Mijnarends et al. 2013). DEXA scan does however seem to be the best and most accurate way to measure muscle mass in the lower limbs (Pons et al. 2018).

**Meta-analysis**

This outcome were the only outcome that the meta-analysis could be applied on, because the amount of studies were four in total (>3) and the outcome measures had enough homogeneity to get a reliable result. With a SMD of \(-0.34 \ p < 0.00001\) the meta-analysis indicated a better result in the intervention group (Figure 6). When looking at the forest plot the majority of the rhomb is favouring the experimental group, it is however crossing the the midline which directly indicates no significant difference between the groups (Figure 6). The reason for this could be due to a large standard deviation (SD) and the included data and results not being normally distributed. The meta-analysis did however show a clinical significance in the favour of occlusion training when looking at the SMD and forest plot, meaning that the result may have a positive effect for the patient (Kazdin 1999). The heterogenity were very large, \( I^2 = 92 \ % \ p < 0.00001 \) which makes the results questionable.

**Cuff pressure**

The cuff pressure when performing occlusion training is very important due to the physiological effects to take place. A preferable cuff pressure is between 50-80 % of complete restriction of the current systolic blood pressure (Das & Paton 2022). The included studies had different types of cuffs and different amount of pressure, going from 130 mmHg to 80% of systolic blood pressure, measured with a self adjusting personalized torniquet (Table 1). Since the blood pressure increases gradually during exercising the self adjusting personalized torniquet should be the most accurate and reliable method for occlusion training, setting the cuff pressure to a set amount for the whole exercise duration should be an inaccurate and unrealiable way to perform occlusion training (Carpio-Rivera et al. 2016). The author was not able to find any studies evaluating the reliability and validity of the different types of occlusion cuffs which makes it unclear.

There does not seem to be a clear connection between the cuff pressure and the results,
looking at Zargi et al. (2018) for example they found no significant difference between the groups using 150mmHg when looking at strength while Kacin et al. (2021) on the other hand found a significant difference between the groups also using 150 mmHg of pressure. The difference between these studies were however big when looking at the intervention period, Zargi et al. (2018) evaluated strength twelve weeks post surgery and there was no significant differences between the groups while Kacin et al. (2021) had three weeks post surgery and at this time there was a significant difference (Table 5). It is unclear how the evaluation tests were performed in all studies which makes it difficult to compare the results and identify specific differences and similarities that could have affected the outcome. According to Hughes et al. (2018) another aspect that is important is the body position and that the occlusion is different depending on the using individuals body position. It is for example more cuff pressure needed in standing position compared to lying down (Hughes et al. 2018). This may have affected the results when using a pre-decided mmHg of pressure on every individual instead of using the automatic personalized cuff.

Methodological Reflection, Strengths and Limitations

The database search were executed in six different databases, this for the reason to minimize the risk of missing relevant studies due to a narrow search. Based on the pilot study that were performed by the author IA early January 2022 the decision were made to not use limitation filters such as publication year, the reason being lack in amount of literature. The decision to use more databases were based on the pilot study that was performed prior to this review and meta-analysis where several relevant studies were found in databases that usually would be considered as non-relevant or less relevant to the aim of this study, Web of Science compared to PubMed for example. This review and meta-analysis had two independent authors performing the selection process and quality assessment. The author IA and external part MN had no conflicts of interest or previous knowledge in this particular area.

A total of eleven studies were relevant and included after the selection process. However two of these eleven studies were only available in abstract (Curley et al. 2021 & Paton & Hughes 2022). The author then requested access via SAGE journals and by contacting the authors, there were however no success in this matter and therefore these two studies had
to be excluded and a total of nine studies remained to be included in this review. Counting these two excluded studies there was four more relevant studies found in this literature search compared to the pilot study, three of these were published before the pilot study was executed. One study were published on February 1st 2022 which were after the pilot study was executed (Paton & Hughes 2022). Two of the studies that not were included in the pilot study was Ohta et al. (2003) and Iversen et al. (2014) because they were included in previous meta-analyses. The last of the four studies was Curley et al. (2021), the author IA missed this in the selection process when executing the pilot study. Another reason for the increased amount of studies in this review and meta-analysis is a change in the exclusion criteria, in the pilot study all previously included studies in meta-analyses were excluded due to find out how much new research have been published. The decision were however made to include the previously studies anyway for a potentially larger power.

After excluding Curley et al. (2021) and Paton & Hughes (2022) the only outcome that had enough homogeneity in the outcome measure were muscle mass. Pain and muscle strength were sufficiently heterogenous to not be able to get a pertinent and reliable result from a meta-analysis. To have a good and transparent structure in this review PRISMA were used, this allowed for a pre-decided design that includes relevant headings and subheadings, mainly for the method (Page et al. 2021). Hughes & Rosenblatt et al. (2019) and Hughes & Patterson et al. (2019) included the same 24 individuals in their studies which may affect the power of this review and meta-analysis.

Ethical and Social Reflection

There was no included participants in this review and meta-analysis which had to be accounted for in a ethical or social aspect. However a rare side-effect that have been associated with occlusion training is blood clotting, in a study by Loenneke et al. (2011) the prevalence were shown to be 0.06 % of having a blood clot or deep vein thrombosis when performing 300 000 training sessions. If this intervention is applied as a rehabilitation guideline on a society level however there may be a more frequently occurring issue that have to be taken into great consideration. A high amount of lactic acid is developed when training with occlusion since the venous blood flow is completely restricted, this in combination with training high repetitions (usually 30-15-15-15) will in most cases cause
quite severe pain. It is however a different type of pain compared to joint pain post surgery caused by high load training during for example traditional rehabilitation. Looking at Table 5 occlusion training does seem more tolerable and undemanding in all studies compared to the non-occlusion groups when looking at experienced pain during exercise, this makes it feel reasonable to implement this type of training after an ACLR.

An interesting aspect is that only one study presented the results and differences between men and women even though seven out of nine studies presented the amount of men and women included in their study. A gender perspective could be of interest in this particular matter because of the muscular and hormonal differences between men and women (Haizlip, Harrison, & Leinwand 2015). One potential reason for not presenting the results in a gender perspective may be the relatively small included subject groups and separating the analyzes may reduce the statistical power.

**Practical Implementation**

Since ACL injuries occur very frequently, 8000 every year in Sweden and 4000 gets surgery only 64 % return to their previous level of activity a clear guideline and method for rehabilitation are of great importance (Svenska Korsbandsregistret 2018; Ardern et al. 2011).

A clear advantage of occlusion training after ACLR is the reduction in pain during training, the results of this study agrees with Hughes et al. (2017) and Takarada et al. (2000) that pain is significantly lower when training with lower load and occlusion compared to traditional strength training with high load at both eight and 12 weeks post surgery (Table 5). In the early stages post surgery there does seem to be a clear advantage of using occlusion training for rehabilitation, since the traditional rehabilitation usually consist of simple muscle contractions and mobility exercises training with occlusion would give better effect from training with this low load. Occlusion training gives similar results as traditional rehabilitation in muscle mass and muscle strength but significantly reduces the pain during training which clearly indicates a clinical significance. There seem to be a relationship between time post surgery and the difference between occlusion training and traditional rehabilitation where training with higher load in the later stages of these intervention studies seem to catch up in mainly muscle mass and strength gains. Occlusion training also reduces the risk for reinjury or jeopardizing the graft during the earlier stages of rehabilitation when a load of 70 % of
1RM may be a contraindication.

**Conclusion**

Occlusion training seem to be an effective intervention when it comes to reducing pain during rehabilitation after ACLR. It allows for similar results in strength as high load training while using lower loads. Only one study were looking at knee function but there was a significant group difference favouring occlusion training when evaluating knee function with KOOS. The meta-analysis did not display a significant difference between the groups but it may have a clinical significance. Further research with better homogeneity in the outcome measures and more studies evaluating knee function is however needed to reliably conclude this particular intervention after ACLR.
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