POWER TRAINING AND THE EFFECT ON PAIN IN OSTEOARTHRITIS

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SUMMARY

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Aims. Power training as a suitable training method for older adults but power training is not yet included in exercise recommendations for persons with osteoarthritis. Since many patients with osteoarthritis suffer from pain, the purpose of this study was to investigate if power training can decrease pain in persons with knee or hip osteoarthritis.

Methods. This study was undertaken as a systematic review. MEDLINE and EBSCO online databases were searched from the earliest date available until 31 October 2019. The search strategy returned a total of 118 trials and 5 articles were eligible for inclusion. 4 studies were RCT-studies and 1 study used a one group before-after design. The means and SD:s of pain as the outcome measure was extracted from the studies.

Results. Significant differences in pain scores between intervention and control group was only observed in one of the RCT studies. The results of the three other RCT-studies did not observe any group differences. All included studies demonstrated pain reduction in the power training intervention groups.

Conclusions. Power training can decrease pain in clients with hip or knee osteoarthritis, but it is not more effective than slow speed strength training, warm up combined with stretching or power training combined with balance training. The results of this study did not indicate any association of differences in movement velocity during training with the extent of pain reduction. This study did not indicate any benefit in pain reduction when adding balance training to power training. A combined intervention of stretching and warm up was equally effective as power training in reducing pain. Power training, slow speed resistance training, and warm-up combined with stretching resulted in similar pain reduction.

Keywords: osteoarthritis, power training, pain

LIST OF ABBREVIATIONS

ACR	American College of Rheumatology
BMI	body mass index
HHS	Harris Hip Score
HOA	Hip osteoarthritis
HOOS	Hip disability and osteoarthritis outcome score
KOA	Knee osteoarthritis
KOOS	Knee injury and osteoarthritis outcome score
1 RM	One repetition maximum
PT	Power training (resistance training performed with high velocity of movements during the concentric phase with a resistance of 40-80% of 1RM)
SSST	Slow speed strength training where the concentric phase of the movement is performed in a slow and controlled manner lasting ≥ 2 seconds
NRS	Numerical pain rating scale
OA	Osteoarthritis
VAS	Visual analogue scale
WOMAC	The Western Ontario and McMaster Universities Arthritis Index

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1 INTRODUCTION

Knee and hip osteoarthritis (OA) are the most common joint disorders in Finland (Tarnanen et al. 2018). Among adults over 30 years 5-6% are diagnosed with OA in Finland. The incidence rates rise with age and 32% of women and 16% of men above the age of 75 suffer from OA in Finland (Tarnanen et al. 2018). The prevalence and incidence of OA will continue to grow due to population ageing and increasing obesity (Kaplan et al. 2013). Many patients with OA suffer a considerable amount of pain and reduced physical function (Kersten et al. 2010) . Since there is no cure for OA, rehabilitation to reduce pain and improve physical function are recommended (Uthman et al. 2013; Bennell et al. 2014; Tarnanen et al. 2018). Results from several RCT: s and reviews demonstrate that resistance training programs, including low-, moderate- and high-resistance exercises performed in a slow and controlled manner, can improve both muscle strength and reduce pain in older adults and adults with knee osteoarthritis (KOA) (Lange et al. 2008; Latham & Liu 2010; Uthman et al. 2013; Pelletier et al. 2013; Bennell et al. 2014)

In recent years, interest in power training (PT) as a suitable method for older adults has been growing. (Pelletier et al. 2013). PT has been showed to be more effective for increasing power in healthy older adults compared to traditional slow velocity strength training. (Tschopp et al. 2011; Orsatto et al. 2019). Among healthy older seniors PT and resistance training can improve functional capacity, reverse age-related changes in functional mobility and improve gait speed, static and dynamic balance and reduce the risk of fall (Fragala et al. 2019). PT is a safe training form for older adults, but no systematic review has focused specifically on the benefits and risks of PT when performed by older adults with OA.

Since OA is painful, the disease can cause fatigue, reduce quality of life and make it difficult to begin or maintain regular physical activity, it is of great importance to find safe and effective training methods that can decrease pain but also maintain muscle strength, power and physical function (Kaplan et al. 2013; Physical Activity guidelines for Americans 2nd edition 2018). This review will explore and evaluate the strength of the evidence from identified studies regarding the effect power training can have on pain in clients with hip or knee OA.

2 OSTEOARTHRITIS

Osteoarthritis (OA) is a long-term chronic disease that can affect a single joint or multiple joints (Pohjolainen 2018). OA most commonly affects the joints in the knees, hips, fingers and spine (Pohjolainen 2018). The cause of OA is unknown but an abnormal mechanical load or normal load on an abnormal cartilage surface can cause a biochemical process that finally leads to OA (Polvi- ja lonkkanivelrikko 2018). Risk factors for the development of osteoarthritis are age, sex, obesity, genetics, joint injuries and heavy physical work (Neogi & Zhang 2013; Polvi- ja lonkkanivelrikko 2018). Some of the risk factors are nonmodifiable as age, sex and genetics while the rest are modifiable risk factors (Kaplan et al. 2013). Protective factors for OA are healthy diet and weight management. (Kaplan et al. 2013; Tarnanen et al. 2018). When being overweight already a decrease by 5 kg can decrease the risk of developing OA by 50% among women (Neogi & Zhang 2013). Healthy characteristics of cartilage are best preserved and restored with regular exercises and suitable load. Repetitive squatting and work tasks consisting of heavy lifting should be avoided or minimized (Tarnanen et al. 2018; Polvi- ja lonkkanivelrikko 2018).

2.1 Characteristics and symptoms of osteoarthritis

There are two types of OA: primary and secondary OA (Altman et al. 1986; Kujala 2005). Primary OA develops with wear and tear as people age while secondary OA can be caused by an injury or a fracture that trigger joint changes (Altman et al. 1986; Kujala 2005). In both types of OA, a breakdown of cartilage occurs that is greater than the repairing of cartilage (Pohjolainen 2018). In OA a continuous detoriation of cartilage takes place where the thinned cartilage does no longer restore. (Pohjolainen 2018). Reduced joint space, bone erosion, development of bony spurs and bone ends rubbing together causes stiffness, pain and impaired movement (Kujala 2005; Kaplan et al. 2013). The disease does not only affect the bone surface but also ligaments and muscles surrounding the osteoarthritic joint are affected. The synovial membrane often gets inflamed and thickens (Pohjolainen 2018).

Common symptoms in OA are pain, stiffness, muscle weakness, reduced physical function and quality of life (Bennell et al. 2014; Tarnanen et al. 2018). The pain typically worsens during weight bearing and resolves with rest (Tarnanen et al. 2018; Pohjolainen 2018). Pain in knee osteoarthritis (KOA) is mainly located around the knee area but it can also radiate to the upper shin (Polvi- ja lonkkanivelrikko 2018). Pain in hip osteoarthritis (HOA) is usually located in the groin thigh and upper part of the front thigh but the pain can also radiate towards the buttock and other parts of the thigh. (Tarnanen et al. 2018; Polvi- ja lonkkanivelrikko 2018). Pain by night is common when the disease progresses (Pohjolainen 2018). Morning stiffness and difficulty standing up and walking after prolonged inactivity, limitation of range of motion, crepitation and swelling are other common symptoms (Tarnanen et al. 2018). Walking both on flat ground and in stairs can be difficult for clients with OA (Polvi- ja lonkkanivelrikko 2018).

2.2 Classification of osteoarthritis

Osteoarthritis is frequently diagnosed by radiography and physical examination and, where necessary, with MRI and arthroscopy (Kaplan et al. 2013; Neogi & Zhang 2013). Radiographical changes are not always symptomatic and therefore physical examination is also needed in symptomatic OA. (Polvi- ja lonkkanivelrikko 2018). Disease severity can be classified using several systems. According to Neogi & Zhang (2013) the most commonly used radiographic grading system is Kellgren and Lawrence (KL) grade where the severity of OA is scored on a scale of 0-4. The KL grade is often used in KOA and definite radiographic OA is a KL grade ≥2 (Neogi & Zhang 2013). Another radiographic grading system used when diagnosing HOP is the Japanese Orthopaedic Association scale. The scale defines four stages of OA similarly to the KL grade (Fukumoto et al. 2017). Both scales defines grade one as the pre-osteoarthritis stage, in grade two possible narrowing of the joint space and osteophytes can be seen, grade three is moderate to advance stage of with partial narrowing of joint space while stage four defines severe to terminal stage with great loss of joint space (Fukumoto et al. 2014; Kohn et al. 2016).

It is also possible to classify Osteoarthritis according to symptoms. Altman et al. (1986) have developed a classification system called American College of Rheumatology criteria (ACR-

criteria). The ACR criteria can be based on (1) clinical examination and laboratory tests, (2) clinical examination, laboratory tests and radiographs, (3) clinical examination alone (Altman et al. 1986) . The ACR criteria for KOA based on the clinical examination states that the patient should suffer from knee pain plus fulfil at least 3 of the following criteria: age > 50 years, crepitus during active motion, < 30min morning stiffness, bony tenderness, bony enlargement, no palpable warmth of synovium. (Altman et al. 1986).

3 ASSESSMENT OF PAIN

Good outcome measures that can distinguish effective interventions from those that are not are well needed both in research and clinical practise (Roos et al. 1988). Good outcome measures are also needed for identifying possible side effects of training (RACGP 2018). Basic criteria of outcome measures are that they are patient-centred, standardized, valid, reliable and responsive to patients with osteoarthritis (Roos et al. 1988).

3.1 General pain scales

The Visual analogue scale (VAS) can be used as a 10 cm or a 100 mm scale where 0 indicate no pain and 10 or 100 indicates the worst imaginable pain (Boonsta et al. 2008; Physiopedia 2019). A similar version to VAS, is the 0 to 10-point numerical pain rating scale (NRS) where 0 represents no pain and 10 worst possible pain (Levinger et al. 2018). VAS and NRS are both considered to be responsive outcome measures (Ferreira-Valente et al. 2011). The test-retest reliability of the VAS when assessing pain has also proven to be good in people with chronic musculoskeletal pain when assessing pain (Boonsta et al. 2008).

The estimation of the minimal clinically important change in VAS pain scores varies among researchers (Kelly 2001; Tubach et al. 2005). According to Kelly et al. (2001) 12 mm can be considered a minimal clinically important change for all pain severities while Tubach et al. (2005) suggest a limit of 10,8 mm for patients with less pain in KOA (lowest tertile) and for sever pain in KOA (highest tertile) 36,6 mm. For patients with HOA the limits could be 7,2 mm and 29,7 respectively (Tubach et al. 2005). For the NSR scale a change of one unit represents “slightly better” while a change of two units represents “much better” (Salaffi et al. 2004).

3.2 Specific pain scales

There are several self-assessment instruments that have been developed for measuring pain, stiffness and ADL performance (Roos et al. 1988; RACGP 2018). The pain subscales have

several questions covering areas as pain during walking, climbing stairs, sleeping at night, resting and standing (Kersten et al. 2010; Nilsdotter & Bremander 2011; Sayers et al. 2012). One of the most common outcome measures for patients with OA is the Western Ontario and McMaster Universities Arthritis Index (Womac) (Nilsdotter & Bremander 2011). The scale is used in two versions: the Likert and the VAS version (Kersten et al. 2010; Nilsdotter & Bremander 2011; Sayers et al. 2012). The Likert scale assess each item according to a 5-category Likert scale where 0 = none, 1 = mild, 2 = moderate, 3 = severe, 4 = extreme. The total pain score is derived by summation of the pain item scores. The Womac Likert scale has a maximum of 20 indicating the greatest level of pain (Thumboo et al. 2001). The Womac VAS scale scores each item by the VAS 100 mm-scale ranging from 0 to 100 (Kersten et al. 2010). Womac VAS pain has a maximum of 500 indicating the most severe pain level (Kersten et al. 2010; Levinger et al. 2017).

The knee injury and osteoarthritis outcome score (KOOS) and the hip disability and osteoarthritis outcome score (HOOS) are both further developments of the WOMAC scale. Both scales include the same questions as Womac with some extra questions added (Roos et al. 1988; Nildsdotter et al. 2003). Each question is answered with the same 5-category Likert scale as in Womac and the total score of KOOS and HOOS pain ranges from 0-100 where 0 indicates greatest level of pain and 100 indicates no pain (Roos et al. 1988; Nildsdotter et al. 2003). Harris Hip Score (HHS) is another self-assessment scale used amount patients with OA and the scales is a combined scale covering pain, function, absence of deformity and range of motion (Nilsdotter & Bremander 2011). The score has a maximum of 100 points that indicate the highest level of function (Fukumoto et al. 2014).

The minimal clinically important change for the WOMAC Likert version is considered to be 16% which reflects a slightly better result (Hmamouchi et al. 2012). For Womac VAS an improvement of 16% is needed in shorter interventions (6 months) and 14% in longer interventions (12 months) to reflect the minimal clinically important change (Greco et al. 2010). Categorical improvement of 8 points or more is considered to be clinically important on the KOOS pain subscale and 9 points or more on the HOOS pain subscale (Lyman et al. 2018). A change of 16-18 points on HHS is considered to be the minimal clinically important change and a change of 40 points is considered to be a moderate improvement (Singh et al. 2016).

3.3 Validity, reliability and correlation of pain scales

The ability to detect change measured as responsiveness of both the Womac Likert scale, Womac VAS scale and KOOS has been reported to be good (Ornetti et al. 2007; Kersten et al. 2010). According to Thumboo et al. (2001) the Likert version of Womac pain demonstrated acceptable construct validity and Kersten et al. (2010) also found the VAS version of Womac pain to be internally valid and unidimensional. Both the French and the English version of the KOOS pain scale is reported to be a valid instrument for people with knee osteoarthritis (Roos et al. 1988; Ornetti et al. 2007). The Likert version of Womac and the KOOS pain scale have both demonstrated acceptable reliability for people with knee osteoarthritis (Thumboo et al. 2001; Ornetti et al. 2007). The test-retest reliability of both HOOS and KOOS pain and HHS has been reported to be high with intra-class correlations coefficients ranging from 0.75-0.97 indicating good reproducibility (Ornetti et al. 2007; Nilsdotter & Bremander 2011). No floor (worst possible score) effects were observed for HOOS, KOOS nor HHHS. No ceiling (best possible score) effects were observed for the KOOS pain subscale but unacceptable ceiling effects of 19% respectively 20% was reported for the HOOS and HHS (Nildsdotter et al. 2003; Ornetti et al. 2007; Nilsdotter & Bremander 2011). These ceiling effects limits the validity of the instrument (Nilsdotter & Bremander 2011).

Several studies have been comparing self-assessment instruments used in the OA population to Short-Form Health Survey (SF-36), that is a well validated instrument after total hip arthroplasty (THA) (Roos et al. 1988; Boonsta et al. 2008; Nilsdotter & Bremander 2011). The validity of VAS for assessing pain is considered to be good since the score strongly correlates with the Short-Form Health Survey (SF-36) pain scale (RACGP 2018). Boonsta et. al. (2018) reported correlations of VAS pain scores and SF-36 ranging from 0.64 to 0.8. The correlation between HOOS pain and SF-36 pain has also been reported to be good ($r = 0.61$) while lower correlations has been reported for KOOS pain and SF-36 ($r=0.46$) (Roos et al. 1988; Nildsdotter et al. 2003). The content validity of HHS has been tested by comparing the instrument to Womac and SF-36 and no major differences between the scores has been detected (Nilsdotter & Bremander 2011).

4 EXERCISE AND OSTEOARTHRITIS

For people with OA physical activity is both preventive and therapeutic and there is strong scientific evidence indicating that both aerobic activity and muscle-strengthening activity results in therapeutic benefits (American Geriatrics Society 2001; Bennell et al. 2014; Physical Activity guidelines for Americans 2nd edition 2018; RACGP 2018). The benefits of regular exercise are improvements in pain, physical function, quality of life, and mental health. According to the Physical Activity guidelines for Americans (2018) regular exercise can also help maintain a healthy body weight, improve physical function and lower the risk of getting other chronic diseases, such as heart disease or type 2 diabetes. Physical activity does not worsen the pain or the disease when done safely (American Geriatrics Society 2001; Kujala 2005; Bennell et al. 2014; RACGP 2018; Physical Activity guidelines for Americans 2nd edition 2018).

4.1 Exercise recommendations for persons with osteoarthritis

All clinical guidelines recommend physical activity and exercise for the management of OA irrespective of disease severity, joint involved, pain levels, and functional ability. (American Geriatrics Society 2001; Hochberg et al. 2012; Bennell et al. 2014; Physical Activity guidelines for Americans 2nd edition 2018; Polvi- ja lonkkanivelrikko 2018; RACGP 2018). Most people with OA can usually tolerate the current recommendations for older adults that consists of moderate-intensity activity for 150 minutes a week or more, some people with OA can even tolerate vigorous-intensity activity. (Physical Activity guidelines for Americans 2nd edition 2018). It is important that persons with OA exercise according to their personal abilities, preferences and the severity of their symptoms (Hochberg et al. 2012; Bennell et al. 2014). The training should be individually planned and focus on exercises that do not cause pain and have low risk of joint injury (American Geriatrics Society 2001; Hochberg et al. 2012; Bennell et al. 2014; Physical Activity guidelines for Americans 2nd edition 2018).

The guidelines of American College of Rheumatology (2012) and The American Geriatric society (2001) strongly recommends that patients with OA should participate in cardiovascular

and/or resistance land-based exercise. Other activities recommended are aquatic, balance, neuromuscular and flexibility training (Hochberg et al. 2012; Bennell et al. 2014). The American Geriatric society (2001) recommends that resistance training should involve all major muscle groups with a progression in both intensity and volume. Intensity should begin at 40% of 1RM and progress to 80% of 1RM. The starting volume should be one set of 4 to 6 repetitions with a frequency of 2 days per week (American Geriatrics Society 2001). These guidelines are very similar to the guidelines for healthy older adults but there is no specific recommendation on power training. According to several systematic reviews the reviews strength training in older adults with OA can result in significant improvements in strength and function and reductions in pain (Lange et al. 2008; Fransen & McConnell 2009; Latham & Liu 2010). The effect size for both strength, function and pain were shown to be moderate in the review of Latham & Liu (2010).

4.2 Power training

Muscle power is defined as the product of dynamic muscular force and muscle contraction velocity (Fukumoto et al. 2017). Muscle power declines earlier and more abruptly in adults compared to muscle strength (Tschopp et al. 2011). Leg extensor muscle power, contraction velocity and strength levels among subjects with OA has shown to be low when compared to reference values for healthy older adults which suggests that people with OA have a substantial and accelerated impairment in muscle power (Kostka et al. 2014; Reid et al. 2015). Muscle power is a good predictor of the level of functional movements as walking, climbing stairs and standing up from a chair and also an independent determinant of pain in knee OA (Pelletier et al. 2013; Kostka et al. 2014; Reid et al. 2015). Muscle power could therefore be an important factor when aiming at reducing the disease burden of OA (Reid et al. 2015).

Power training is a form of resistance training where the concentric phase is performed with maximal velocity (Fragala et al. 2019). The velocity of the concentric phase is critical when aiming at developing muscle power since the speed used will directly influence motor unit recruitment patterns (Sayers et al. 2012; Orsatto et al. 2019). When doing power training the concentric phase should be performed as fast as possible or last less than two seconds (Tschopp

et al. 2011; Fragala et al. 2019; Orsatto et al. 2019). Current guidelines for older adults recommend that the resistance training program should include power exercises performed at a high velocity in concentric movements with moderate intensity of 40-60% of 1RM (Fragala et al. 2019). Since OA is a painful musculoskeletal condition power training could in the worst-case cause unwanted side-effects as increased joint stress and pain and thereby result in decreased function and mobility (Pelletier et al. 2013; Fukumoto et al. 2014). On the other hand, if power training would be a safe and feasible training method for this patient group and decrease joint pain it could have great benefits for the OA population both in increasing physical functioning and lowering the risk of falls (Pelletier et al. 2013; Fukumoto et al. 2014; Levinger et al. 2017). In this systematic review feasibility of PT will be evaluated as a clinical meaningful improvement in pain levels throughout the intervention. Feasibility will also be evaluated according to adverse advents, training attendance and pain levels during and after training sessions.

5 METHOD

The aim of this study was to review and evaluate the strength of the evidence regarding the effect power training can have on pain in clients with hip or knee osteoarthritis. The research question was: Can power training decrease joint pain in clients with knee or hip osteoarthritis?

5.1 Selection criteria

Inclusion and exclusion criteria for selected studies are displayed in table 2. One assessor reviewed which studies to be included in this review. Where a single randomized controlled trial resulted in ≥2 publications, only the publication reporting the outcome of interest was included.

TABLE 2. Inclusion and exclusion criteria for selected studies

Inclusion criteria	Exclusion criteria
Full-article publication	Only abstract or study protocol published
Subjects with knee or hip osteoarthritis	No diagnosis
Subjects with no hip or knee arthroplasty	Subjects already undertaken arthroplasty
Power training of lower limbs with or without additional upper limb, trunk or abdominal strengthening	No lower limb power training
Exercises to be done as fast as possible or concentric phase <2 seconds	No info on exercise speed or concentric phase ≥2 seconds
One group performing power training only	Groups performing mixed methods training or other type of resistance training
RCT or quasi-experimental study	Other study design than RCT or quasi experimental study
Outcome of interest (pain) should be reported	Outcome of interest not reported
Peer-reviewed publication	Not peer-reviewed publication

5.2 Search strategy

MEDLINE and EBSCO online databases were searched from the earliest date available until 31 October 2019. The search strategy returned a total of 118 trials. Three possible records where identified when hand searching reference lists from relevant studies and review studies. Details on study selection can be found in figure 1. Five articles were eligible for inclusion with a total of 206 enrolled participants and 189 participants' data reported.

The search terms were chosen according to patient group: osteoarthritis, hip and osteoarthritis, knee. Secondly according to intervention: train*, resistance-training, resistance training, strength training, weight training, weight lifting, exercise training. Thirdly according to type of training: power, explosive, fast, speed, high velocity, high-velocity, increased velocity, velocity. Lastly according to outcome measure; pain*, ache*, VAS, visual analogue scale, HOOS, Hip disability and osteoarthritis outcome score, KOOS, knee injury and osteoarthritis outcome score, The Western Ontario and McMaster Universities Arthritis Index. The search terms and sentences used in the search can be found in appendix 1.

5.3 Study selection and data extraction

Data were extracted by one reviewer. Extraction from each trial included: (1) characteristics of participants (age, sex and level of normative physical activity), (2) Power training intervention and comparison program details (mode, intensity, repetitions and sets, duration, frequency, number of lower-limb exercises, equipment used and adverse events), (3) type of outcome measure(s) and (4) the trial's inclusion and exclusion criteria, analysis approach and results.

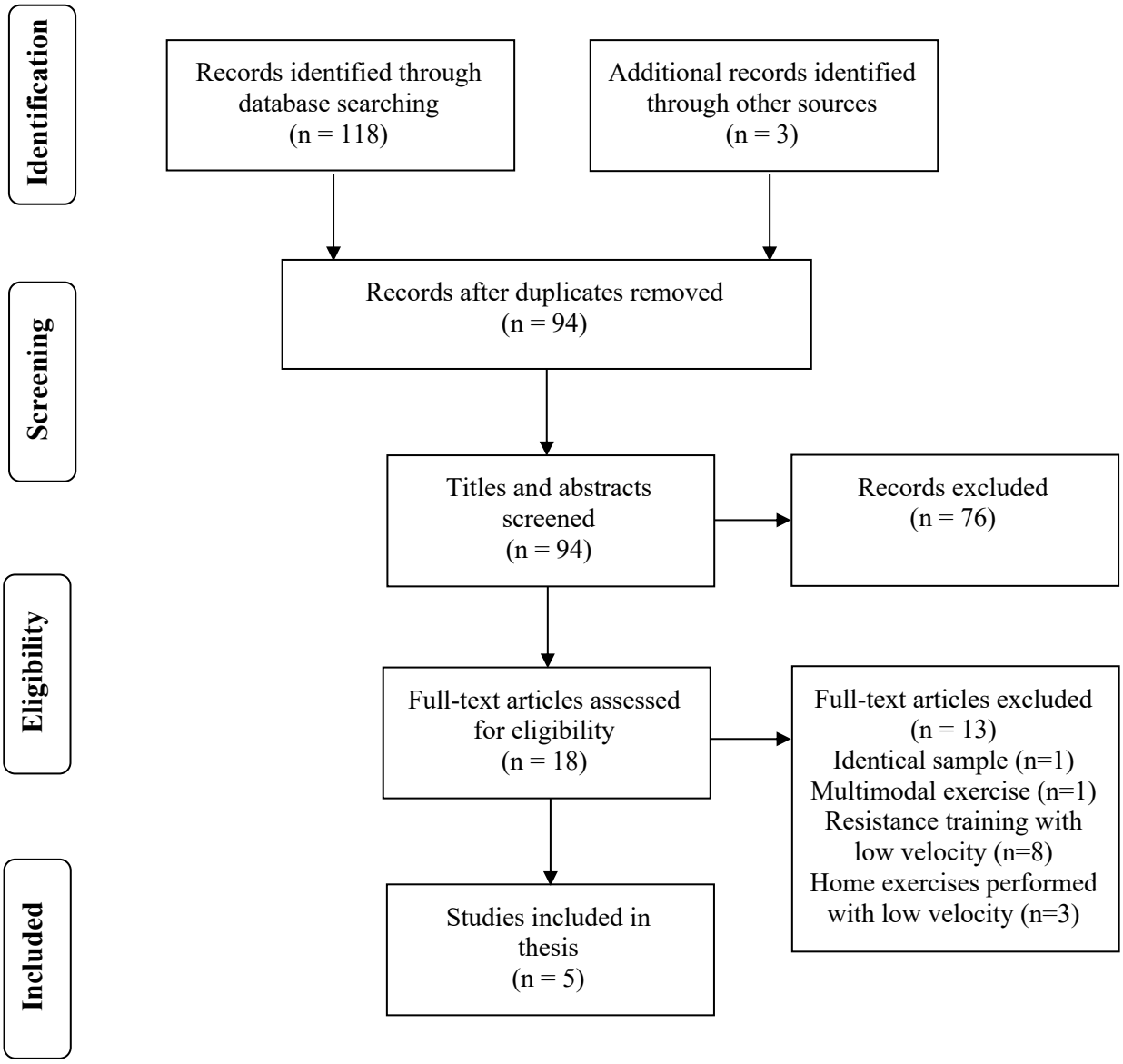

FIGURE 1. Study selection process

5.4 Quality assessment / Assessing Risk of Bias

Methodologic quality assessment was conducted by 1 reviewer, using the Furlan scale (Furlan et al. 2015). Results of quality assessment can be found in table 2. Most studies had limited methodologic quality. No study involved blinded participants or therapists because of the nature of the interventions. Only one study used blinded assessors, but three studies employed concealed allocation. Intention-to-treat analysis was only applied in two studies. The timing of the outcome assessment was different in one of the studies.

One study (Pelletier et al. 2013) used a one group before-after design. The quality of this study was evaluated according to a checklist for Quasi-experimental study designs (Reeves et al. 2017). Factors that improve the quality of the study of Pelletier et al. (2013) was that the same individuals were included in both pre- and post-test. The pain assessment was also performed weekly for all study subjects. Factors that limit the quality of the study is the absence of a control group, small sample size and the fact that included participants volunteered and were recruited through newspaper advertising.

TABLE 2. Quality assessment

Quality criteria	Fukumoto et.al. (2014)	Herrmann et.al. (2014)	Levinger et.al. (2018)	Sayers et al. (2012)
1. Was the method of randomization adequate?	Yes	Yes	Yes	Yes
2. Was the treatment allocation concealed?	No	Yes	Yes	Yes
3. Was the patient blinded to the intervention?	No	No	No	No
4. Was the care provider blinded to the intervention?	No	No	No	No
5. Was the outcome assessor blinded to the intervention?	No	No	No	Yes
6. Was the drop-out rate described and acceptable?	Yes	Yes	Yes	Yes
7. Were all randomized participant analysed in the group which they were allocated to?	No	Yes	No	Yes
8. Are reports of the study free of suggestion of selective outcome reporting?	Unsure	Yes	Yes	Yes
9. Where the groups similar at baseline regarding the most important prognostic indicators?	Yes	Yes	Yes	Yes
10. Where cointerventions avoided or similar?	Unsure	Yes	Unsure	Unsure
11. Was the compliance acceptable in all groups?	Yes	Yes	Yes	Unsure
12. Was the timing of the outcome assessment similar in all groups?	Unsure	No	Yes	Yes
13. Are there other sources of potential bias unlikely?	Yes	Yes	Yes	Unsure

6 RESULTS

The trials of Fukmoto et.al (2014) and Sayers et.al. (2012) compared power training (PT) to slow speed strength training (SSST), Sayers also included a third group receiving stretching and warm-up exercises. Herrmann et.al (2016) compared PT to conventional care while Levinger et.al (2018) compared PT, PT combined with balance training to no training. The trial of Pelletier et.al (2013) investigated PT but did not included a comparison group.

The study population included more women than men and the study of Pelletier et.al (2013) and Fukumoto et al. (2014) included only women. The mean age of the participants varied from 53,4 to 70,4 years and there were no statistically significant differences between the study groups at baseline. Pain at baseline and disease severity varied among the studies. Levinger et al. (2018) and Fukumoto et al. (2014) reported low pain scores while the three other studies reported moderate pain scores. Two of the studies included patients with initial stage of OA, Fukumoto et al. (2014) included patients with either initial stage or terminal stage while Hermman et al. (2016) included only symptomatic HOA patients awaiting total hip arthroplasty. Levinger et al. (2018) did not provide any information on disease severity. The study populations had high body mass indexes (BMI) ranging from 27.4 ± 3.8 to 34.0 ± 3.8 in all studies except of Fukumoto et al. (2014) who reported BMI: s ranging from 21.7 ± 3.5 to 22.1 ± 3.5.

Programs were carried out in university, hospital or outpatient rehabilitating clinics but in the study of Fukumoto et al. (2014) the training was performed in homes without supervision. The equipment used varied, Levinger et.al (2018) used training machines combined with weighted wests, Herrman et al. (2016) training machines only. Sayers et.al. (2012) used pneumatic training machines while Fukumoto et al. (2014) and Pelletier et al. (2013) used elastic bands. Some programs included a warmup prior to power training and a cool down after training consisting of low-intensity cardiovascular exercise and stretching. Table 1 summarizes details from included trials, group characteristics and intervention details and table 2 summarizes study results.

TABLE 1. Study details

Study Design	Intervention type, no. of participants (n), sex (F/M)	Diagnosis, Age	Power training intervention					
			No. of weeks	Times/ week	Length (min)	No. of exercises, sets, reps, intensity, progression	Equipment	Comments
Fukumoto et.al. (2014) RCT	I: PT, n=23 (23/-) C: SSST, n=23 (23/-)	Hip OA 53.4 ± 9.8	8	7	-	4 exercises. 2 sets of 10 reps (week 1-2) 3 sets of 10 reps (week 3-8) PRE somewhat hard.	Elastic bands	Home-based, no supervision
Herrmann et.al. (2014) RCT	I: PT, n=40 (27/13) C: care as usual, n=40 (25/15)	Hip OA 70.4 ± 7.6	10	2	60	4 exercises, 3 sets of 8-12 reps with 80% 1RM. Loading increased if reps >12.	Training machines	Training groups of max 8 patients supervised by 2 physical therapists
Levinger et.al. (2018) RCT	I: PT, n=9 (5/4) I_2: PT&B, n= 9 (4/5) C: no intervention, n=10 (6/4)	Knee OA 67.8 ±6.5	8	2	-	6-8 exercises, week 1-2 2 sets of 8-12 reps with 20-40% 1RM, week 3-5 2 sets of 5-8 reps with 40-60% 1RM, week 6-8 2 sets of 2-5 reps with 60-80% 1RM.	Training machines and vest weights	Interventions supervised by an exercise physiologist
Pelletier et.al. (2013) One group before-after design	I: PT, n=17 (17/-) No control	Knee OA 60.3 ± 6	8	3	30	1 exercise (KE), 3 sets of 10 reps with 40% 1RM.	Elastic bands	One-on-one, supervised by physical therapist
Sayers et.al. (2012) RCT	I: PT, n=12 (9/3) I_2: SSST, n=10 (8/2) C: S&W, n=11 (8/3)	Knee OA 67.6 ± 6.8	12	3	-	2 exercises, (LP, KE), 3 sets of 12-14 reps with 40% 1RM.	Pneumatic training machines	No info on group size nor supervision

I=intervention group (Power training, concentric phase performed as fast as possible), I_2= 2nd intervention group, C=control group, SSST=Slow speed strength training, B=Balance training, S=Stretching, W= Warm up

TABLE 2. Study results (values are mean ±SD)

Study, design	Ana-lysis*	Out-come	Intervention 1 (PT)			Intervention 2		Control			Mean difference between groups [95% CI]
			Pre	Post	Change	Pre	Post	Pre	Post	Change	
Fukumoto et.al. (2014)	1	VAS HHS	32.0 ± 24.9 75.4 ± 17.7	24.7 ± 24.6 80.0 ± 15.5	-7.3 ± 21.7 4.6 ± 10.5			21.2 ± 1.80 77.2 ± 13.3	14.0 ± 20.6 82.2 ± 13.4	-7,2 ± 20.3 5.0 ± 11.2	-0.01 [-8,730, 18,430] -0.3 [-7.714, 5.823]
Herrmann et.al. (2014)	2	HOOS pain (range 0-100)	48.0 ± 12.7	55.4 ± 16.9				46.3 ± 14.4	45.9 ± 14.1		8.4 [2.5, 14.3]**
Levinger et.al. (2018)	3	Womac pain, VAS (range 0-500)	181.6 ± 111.4	117.0 ± 132.6		127.3 ± 107.8	97.3 ± 127.1	153.7 ± 91.1	249.7 ± 309.3		
Pelletier et.al. (2013)	4	KOOS pain (range 0-100)	53.65 ± 14.93	69.97 ± 12.51	16.32 ± 11.20***						
Sayers et.al. (2012)	3	Womac pain, Likert (range 0-20)	11.5 ± 2.8	9.3 ± 3.3		12.2 ± 3.4	10.4 ± 2.8	11.7 ± 2.6	10.2 ± 2.5		

*1= Covariance analysis, 2= Multilevel random effects model (STATA xtmixed) 3=Repeated measures Anova analyses, 4=Wilcoxon signed-rank test, **p-value 0.05, ***p-value 0.001

6.1 Between group differences (pre and post) in pain level

The only study that showed significant reduction of pain when comparing the intervention group to the control group was the study of Herrmann et al. (2016). The effect size of the pain reduction expressed by Hedge's g was 0,6 [0.2, 1.1]. Levinger et al. (2018) also estimated the effect size of the pain reduction by Partial Eta Square. They reported a large effect size of pain reduction for the power training groups but the effect was not statistically significant (0.14, p-value 0.15). Levinger et al. (2018) observed a decrease in pain score among the two PT intervention groups while the control group that did not receive any intervention reported an increase in pain. Levinger did not report any significant difference between these groups. Sayers et al. (2012) and Fukumoto et al. (2014) also reported decreases in pain scores among all groups but there were no significant differences between the groups. Sayers et al. (2012) did not observe any significant group main effects or group by time interaction for pain reduction (all $p > 0,05$).

6.2 Within group changes (pre and post) in pain level

All power training groups experienced a reduced pain score. In three of the studies a significant reduction of pain scores within the groups was reported. Pelletier et.al (2013) and Herrman et. al. (2016) reported significant decrease on pain intensity ($p<0.001$ and $p<0.03$ respectively) when comparing pre- and post-measurements. Sayers et al. (2012) reported a significant reduction of pain when comparing across all of the groups (p-value 0,02). Levinger et al. (2018) and Fukumoto et al. (2014) also reported reduced pain levels in the intervention groups, but they did not provide information on the significance of within group changes.

A significant decrease in mean weekly pain scores when comparing the first week to the last week ($p<0.01$) was reported by Pelletier et.al (2013). Based on the figure in their article the mean and SD of the VAS score decreased from 28,3 (±10,2) to 10,8 (±4,6). The mean weekly pain score was recorded daily by the participants themselves.

The studies of Herrman et al. (2016) and Levinger et al. (2018) also evaluated the acute training effect on pain levels. Substantial increase in pain was present in ≤17% of the training sessions. Most of these sessions took part in the initial phase of the studies. In the study of Herrmann et al. (2016) the VAS readings were ≤5 immediately after training in 95% of the sessions. The VAS readings during the training day and the following day was scored as ≤5 in 83% of the sessions. 34% of the VAS readings > 5 during the training day and the following day, were reported during the early sessions (week 1 -2). Levinger et al. (2018) reported substantial increase in pain on 52 occasions from a total of 298 sessions. A substantial increase was considered to be an increasement of three points or an increase above 7/10 measured on the NRS scale during training. On 45 occasions the pain resolved within the training session. The lasting 7 occasions consisted of one patient that experienced pain in the contralateral limb and one participant that reported initial high level of pain, 7-9/10 on the NRS scale. These situations were solved by a reduced load, rest and paracetamol.

7 DISCUSSION AND CONCLUSION

The aim of this study was to investigate if power training can decrease pain in clients with knee or hip osteoarthritis and thereby be a feasible training method for this patient group. The research question was: Can power training decrease joint pain in clients with knee or hip osteoarthritis?

7.1 Comparison to other research

This systematic review found evidence from one RCT indicating significant differences in pain scores between the PT and control group receiving no intervention. The results of the three other RCT-studies included did not observe any group differences. All included studies demonstrated pain reduction in the PT intervention groups. In three of the studies a significant reduction of pain scores within the groups was reported but only Fukumoto et al. (2014) and Pelletier et al. (2013) reached the minimal clinically important change for pain reduction. The size of the pain reduction in the PT groups was small to moderate ranging from 7,4 % to 16,3%. The Royal Australian College of General Practitioners (RACGP 2018) have collected the best available, current scientific evidence for different OA interventions. Their recommendations indicate that there is evidence supporting that land-based exercise overall has a significant and clinically relevant effect on pain in people with hip and knee OA. According to Uthman et al. (2013) and Fransen & McConnell et al. (2009) there is already enough evidence that land-based exercise programs as strengthening, aerobic and flexibility exercise intervention results in significant benefits for people with KOA in terms of reduced pain and physical disability when compared to no exercise. According to Uthman, there is unlikely that any new study would overturn the positive results. There is yet limited evidence for the benefits of PT in the management of OA, but the results of this systematic review indicates that PT is as effective as other forms of resistance training and combined interventions for management of pain.

This systematic review found evidence from one RCT indicating a significant decrease in mean weekly pain scores when comparing the first week to the last week. Two studies also evaluated the acute training effect on pain levels and substantial increase in pain was present in ≤17% of

the training sessions. Most of these sessions took part in the initial phase of the studies. According to RACGP (2018) there is a very low likelihood of serious adverse effects when people with OA is performing strengthening exercises. Usually only minor events have been reported with a temporary increase of pain at the affected joint or at other sites.

This systematic review showed that power training interventions in general were well accepted according to adherence, drop-outs and absence of serious advents which indicates that PT can be a feasible training method for persons with OA. Sayers et al. (2012) did not report on adherence but in all other included studies the mean adherence was ≥ 81%. In the study of Sayers et al. (2012) one person out of 12 withdrew from the PT group but the reason was not reported. In the study of Fukumoto et al. (2014) two patients out of 23 withdrew due to hip pain. No patients withdrew from the PT-groups due to pain or musculoskeletal injury in the studies of Pelletier, Levinger and Herrman. No serious events were reported in any of the studies but one patient in the study of Herrmann et.al (2016) reported swelling and pain of the knee joint. Levinger et al. (2018) also reported high satisfaction (92%) among the participants in the power training group.

The results of this systematic review do not indicate any association of differences in movement velocity during training with the extent of pain reduction. Resistance training performed with both fast speed and slow speed training are equally effective in reducing pain. The study of Sayers et al. (2012) also showed that a combined intervention of stretching and warm-up exercises reduced the pain levels similarly to strength training interventions. The study of Levinger did not indicate any benefit in pain reduction when adding balance training to power training. The results of this systematic review indicate that the amount of pain reduction is similar in all interventions compared. Similar results were found in the meta-analysis of Uthman et al. 2013 which showed that aquatic strengthening, strengthening and aerobic training interventions was similarly effective in reducing pain and increasing function in persons with OA. There is also evidence from studies on KOA indicating that combined interventions including flexibility, resistance and aerobic training might be most effective. (Uthman et al. 2013; Bennell et al. 2014).

7.2 Explanation of study results

Significant differences in pain scores between intervention and control group was only observed in one of the RCT studies which can be due to that this study was the only study comparing PT to no intervention. The other three RCT studies was comparing PT to another strength training intervention or combined intervention. These interventions were equally effective in reducing pain when compared to PT. Lack of significant differences between different types of exercise intervention might be because of the small number of study participants and short interventions periods.

Substantial increase in pain during the training session was present in ≤17% of the training sessions in the studies of Levinger et. al. (2018) and Herrman et al. (2016). Levinger et al. (2018) reported substantial increase in pain on 52 occasions from a total of 298 sessions and on 45 occasions the pain resolved within the training session. Mild to moderate pain during training might be present in some people with OA but since the pain resolves quickly it is important to inform the patients that pain during training should not be perceived as damaging to the joint (Levinger et al. 2018). Overall pain reduction at the end of the exercise program was seen in all of the intervention groups which confirms the long-term pain reduction effect of PT.

The reduction of pain was small to average ranging from 7,4 % to 16,3% in the studies included in this systematic review. These effects were seen regardless of age, gender, disease severity and baseline pain levels. Minimal clinically relevant pain decrease was observed in the study of Fukumoto et al. (2014) where half of the study subjects were classified as initial stage of OA, second half advanced or terminal stage. The study of Pelletier et al. (2013) included study subjects with low pain scores measured on VAS but moderate pain scores measured by KOOS and the pain reduction in this study was reaching minimal clinically relevant levels despite of moderate baseline pain scores. All studies except of Fukumoto et.al (2014) had clients with high BMI:s ranging from 27.4 ± 3.8 to 34.0 ± 3.8. Both studies with overweight and normal weighted clients showed significant and clinically relevant results.

Both supervised, non-supervised, individual and group training sessions generated reduction of pain scores. All types of equipment used: elastic bands, weighted wests, training and pneumatic machines generated a similar decrease in pain levels. The results of this systematic review cannot indicate the adequate dose of exercise since the training program parameters differed greatly.

7.3 Study limitations

This review has some limitations. Only one person has conducted the data selection and quality analysis. According to Furlan et al. (2015) a minimum of two persons should independently extract the study data. The search terms used were adequate since the search in MEDLINE and EBSCO online databases was able to identify all includes studies. No additional studies were found though that records of relevant RCT and meta-analyses were scanned.

A disadvantage in this systematic review was that the included studied used several different outcome scales for pain assessment. Fukumoto et.al (2014) used the single-item assessment scale VAS to evaluate the pain reduction. This results in reduced information when one rating has to consider all aspects of a multidimensional pain phenomena and weight all relevant pain aspects at once (Boonsta et al. 2008). When VAS is used, it is unclear for the assessor which specific activities are the most difficult and painful (Boonsta et al. 2008). On the other hand, several studies show that the VAS scale and other outcome measures used in this systematic review demonstrates a high correlation with the SF-36 scale. Only for KOOS and the SF-36 scale lower correlations have been reported. This indicates that the results from the different outcome scales could measure same aspects of pain sensation and thereby be comparable.

Caution must be used when interpreting studies with low methodologic quality. According to Furlan et. al (2015) there is evidence that inadequate concealed allocation, inadequate double blinding and a high rate of dropouts or differences in number of reasons for dropouts between groups, are associated with bias. Only two of the included studies used intention-to-treat analysis and concealed allocation while only one study had blinded assessors. This reduces the internal validity an may have overestimated the effect of the intervention. The study

of Herrmann el al. (2016) had a shorter follow up time for the control group which might decrease the internal validity of their study. On the other hand, self-reported pain does not decrease during waiting times to total hip arthroplasty (Hermann et al. 2016). All studies included in this systematic review demonstrate a similar effect which makes the result of this review more reliable. All studies observe as a small to moderate pain reduction which indicates that PT can decrease pain in patients with OA.

7.4 Recommendations and future research

There are yet no meta-analyses demonstrating the effectiveness of PT for persons with OA but there is much evidence indicating benefits for older healthy seniors (Tschopp et al. 2011; Fragala et al. 2019; Orsatto et al. 2019). Since these meta-analyses shows that PT is feasibly for healthy older adults and can improve functional capacity, gait speed, balance and reduce the risk of fall it is of great importance to continue research among the OA population. People with knee osteoarthritis experience falls more than twice as often as persons with no osteoarthritis and have lower levels of muscle strength and power compared to their healthy agemates so the effect of PT on falls is also an important research topic (Levinger et al. 2017; Levinger et al. 2018). According to Nilsdotter et al. (2011) pain and functional capacity are considered the two basic indicators for surgery. From this point of view, it is important to investigate which type of interventions are most effective in reducing pain and increasing functional capacity. With effective training methods it could be possible to increase the quality of life for the patient, postpone or even rule out the need of total hip arthroplasty. PT is not yet a customary rehabilitation approach for persons with OA in Finland. The result of this systematic review suggests that PT is a feasible, effective and well tolerated training method for persons with OA and could therefore be used more frequently in rehabilitation of persons with OA. The evidence from this review indicates that PT could generate benefits for all types of patients with OA regardless of weight, age, gender, level of pain and disease severity. The quality of evidence is low due to small studies and limited methodologic quality, but the result of all included studies is in line with each other.

In KOA exercise has to last at least 8 weeks before the benefits appear (Pohjolainen 2018). All studies included in this review had an intervention period lasting at least 8 weeks, but future studies should aim at an even longer intervention period because this might result in even greater improvements. When treating OA, it is recommended to strengthen all the muscles of the affected limb (Pohjolainen 2018). Pelletier et al. (2013) included only one exercise and Sayers et al. (2012) only two exercises. The benefits might have been even greater in these studies if several exercises would have been included. All studies included were small studies with participant numbers ranging from 17 to 80. More adequately powered studies would generate higher level of evidence.

Future research should focus on program parameters. According to Bennell et al. (2014) few studies have directly compared the effects of different types of exercise, but systematic reviews suggest clinical benefits from a range of exercise types. Future research needs to focus on which type of exercise program or combination of program types will generate the best results for patients with osteoarthritis. Future research should also focus on adequate intervention duration and frequency of the PT-intervention. Number of exercises needed, and optimal loading should also be evaluated.

7.5 Conclusion of results

The results from this systematic review indicate that PT can reduce pain when compared to no intervention since one study noticed between group differences, all five studies observed reduced pain within the intervention group, with a significant reduction of pain in three of the studies. Power training can also provide acute pain relief according to two of the included studies. Power training can decrease pain in clients with hip or knee osteoarthritis, but it is not more effective than slow speed strength training, warm up combined with stretching or power training combined with balance training. Power training, slow speed resistance training, and warm-up combined with stretching resulted in similar pain reduction. The amount of pain reduction from PT in this systematic review, was small to moderate in size but yet clinically significant in two out of the five includes studies.

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APPENDICIES

Appendix 1. Search terms

MEDLINE database – generated 60 results

(Osteoarthritis, hip OR osteoarthritis, knee) AND (train* OR resistance-training OR resistance training OR strength training OR weight training OR Weight lifting OR exercise training) AND (power OR explosive OR fast OR speed OR high velocity or high-velocity OR increased velocity OR velocity) AND (pain* OR ache* or VAS or visual analogue scale OR HOOS OR Hip disability and osteoarthritis outcome score OR KOOS OR knee injury and osteoarthritis outcome score OR The Western Ontario and McMaster Universities Arthritis Index)

CINAHL database – generated 58 results

("Osteoarthritis, hip" OR "osteoarthritis, knee") AND ("train*" OR "resistance-training" OR "resistance training" OR "strength training" OR "weight training" OR "Weight lifting" OR "exercise training") AND ("power" OR "explosive" OR "fast" OR "speed" OR "high velocity" or "high-velocity" OR "increased velocity" OR "velocity") AND ("pain*" OR "ache*" or "VAS" or "visual analogue scale" OR "HOOS" OR "Hip disability and osteoarthritis outcome score" OR "KOOS" OR "knee injury and osteoarthritis outcome score" OR "The Western Ontario and McMaster Universities Arthritis Index

Appendix 2. Inclusion and Exclusion criteria

Study	Inclusion criteria	Exclusion criteria
Fukumoto et.al. (2014)	Women, Patients with diagnosed unilateral or bilateral hip osteoarthritis, no prior Physical Therapy, ability to walk with or without assistive device, absence of dementia, ability to understand the informed consent procedure.	History of total hip arthroplasty, stroke, Parkinson's disease, neurological, gait disorders, vestibular problems or symptoms affecting the knees, ankles or back.
Herrmann et.al. (2014)	Patients diagnosed and scheduled for THA in the department of Orthopedic Surgery, Herlev University Hospital, Copenhagen, Denmark.	RA and other types of arthritis not diagnosed as OA, uraemia, cancer, treatment with systemic glucocorticoids >3 months the last 5 years with a dose ≥5mg, present or previous hip fracture (either side), other lower extremity fracture within 1 year prior to inclusion, body weight > 135 kg, severe walking deficits (dependency of two crutches or walker for mobilization), not speaking Danish language.
Levinger et.al. (2018)	Presence of clinical symptoms of KOA as defined by criteria of ACR. Age 60-90 years. Knee pain ≥ 6 months and current average pain ≥3 (11-point numerical rating scale), able to ambulate independently (single stick point allowed). In addition, on of following criteria indicating increased risk of falling: ≥1 fall in the past 12 months, limitation of activity due to concern about falling.	Uncontrolled non-musculoskeletal conditions (such as chronic obstructive airways disease and congestive heart failure), a pre-existing neurological condition that affected lower limb strength, balance or ambulation, any uncontrolled musculoskeletal or orthopedic condition that may affect ambulation (e.g. rheumatoid arthritis), current participation in structured resistance training and/or organized balance training ≥1 times/week, any documented medical condition or physical impairment contraindicating participation, mild cognitive impairment or dementia scored <25 on SLUMS.
Pelletier et.al. (2013)	Patient recruited through newspaper advertising, A score of ≤90 points on KOOS, questionnaire and radiological knee damage graded as stage 1 or 2 on Kellgren-Lawrence scale.	Acute or terminal phase illness; heart attack, unstable illness, lower limb fracture or amputation within 6 months before start of trial; participation in regular exercise program more than once a week; knee arthroplasty, neuromuscular illness or intake of drugs affecting neuromuscular function.
Sayers et.al. (2012)	55 years or older, physician-diagnosed KOA, meeting criteria of ACR classification of OA including knee pain and 3 of following 6 criteria: age >50 years, crepitus on active motion <30min morning stiffness, bony tenderness, bony enlargement, no palpable warmth of synovium. A qualifying level of pain or functional deficit noted on Womac pain or Womac function scale (pain: 1 response of at least "moderate" or 2 responses of "minimal"; function: 2 responses of at least "moderate" or 4 responses of "mild".	History of heart disease, severe visual impairment, neurologic disease, pulmonary disease requiring the use of oxygen, uncontrolled hypertension, hip fracture or lower extremity joint replacement in the past 6 months, current participation in structured exercise.