

# The Ottawa panel clinical practice guidelines for the management of knee osteoarthritis. Part two: Strengthening exercise programs

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## Abstract

**Objective:** To identify effective strengthening exercise programs and provide rehabilitation teams and patients with updated, high-quality recommendations concerning traditional land-based exercises for knee osteoarthritis.

**Methods:** A systematic search and adapted selection criteria included comparative controlled trials with strengthening exercise programs for patients with knee osteoarthritis. A panel of experts reached consensus on the recommendations using a Delphi survey. A hierarchical alphabetical grading system (A, B, C+, C, D, D+ or D-) was based on statistical significance ( $p < 0.5$ ) and clinical importance ( $\geq 15\%$  improvement).

**Results:** The 26 high-quality studies identified demonstrated that various strengthening exercise programs with/without other types of therapeutic exercises are generally effective for improving knee osteoarthritis management within a six-month period. Strengthening exercise programs demonstrated a significant improvement for pain relief (four Grade A, ten Grade B, two Grade C+), physical function (four Grade A, eight Grade B) and quality of life (three Grade B). Strengthening in combination with other types of exercises (coordination, balance, functional) showed a significant improvement in pain relief (three Grade A, 11 Grade B, eight Grade C+), physical function (two Grade A, four Grade B, three Grade C+) and quality of life (one Grade A, one Grade C+).

**Conclusion:** There are a variety of choices for strengthening exercise programs with positive recommendations for healthcare professionals and knee osteoarthritis patients. There is a need to develop combined behavioral and muscle-strengthening strategies to improve long-term maintenance of regular strengthening exercise programs.

## Keywords

Therapeutic exercise, strengthening exercises, knee osteoarthritis, clinical practice guideline, systematic review

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## Introduction

Strengthening exercises in people with osteoarthritis of the knee may increase joint stability and confidence owing to the muscle's capacity to generate greater force via increased muscle strength, power and endurance.<sup>1</sup> Strengthening exercise programs aim to strengthen leg muscles while reducing the load and limiting direct knee joint stress during movement.<sup>2,3</sup> A list of definitions related to strengthening exercise programs can be found in Appendix 1, available online.

This is the second of three Ottawa Panel clinical practice guidelines for patients with osteoarthritis of the knee, and it provides the most recent quantitative evidence on short- and long-term benefits of strengthening exercises on joint health of individuals with knee osteoarthritis. Existing

high-quality guidelines<sup>4,5</sup> and systematic reviews<sup>2,6,7</sup> have reported unanimous positive recommendations on strengthening exercise programs for knee osteoarthritis management. While strengthening exercise programs have been recommended<sup>6,8-12</sup> or strongly recommended<sup>13-15</sup> to improve clinical outcomes, such as pain relief, physical function and quality of life, these recommendations have not always been based on systematic reviews or are currently outdated.

The objective of this guideline was to identify effective strengthening exercise programs and provide both healthcare professionals and knee osteoarthritis patients with updated, high-quality recommendations supporting traditional land-based exercises for knee osteoarthritis.

## Methods

Further details on the Ottawa Panel evidence-based guideline methodology used for this systematic review comprised of five steps evaluating the existing evidence (Steps 1–3) followed by the creation of the recommendations (Steps 4–5), and can be found in Brosseau et al.<sup>16</sup>

## Results

### Step 1 – Systematic search and selection

A total of 35 studies with at least one positive recommendation were included in our analysis and 26 of these were studies with a strengthening exercise program (Appendix 2, available online). The reasons for exclusion of studies and the PRISMA flow diagram are available in Brosseau et al.<sup>16</sup> The characteristics related to studies with negative ( $n=1$ ) and neutral recommendations ( $n=74$ ) can be found in Appendix 2 and their respective figures and tables can be found in supplementary material.

All 26 studies were randomized controlled trials<sup>17–42</sup> and only included patients that were clinically diagnosed with knee osteoarthritis. Nine high-quality randomized controlled trials with a strengthening exercise program had neutral recommendations only.<sup>43–51</sup>

### Methodological quality (PEDro scores of included studies)

The methodological quality of the 26 included studies<sup>17–42</sup> received PEDro scores varying from six to eight out of 10. Additional information on the methodological quality can be found in the characteristics of included studies in Appendix 2,

available online. Appendices, tables and figures for neutral recommendations are available in the supplementary file, available online.

### Characteristics of included randomized controlled trials on strengthening exercise programs

Strengthening exercise programs and control/comparator groups varied widely among included studies (Table 1, available online). A description of the characteristics of strengthening exercise programs for included trials is provided in Table 2, available online.

**Steps 2 and 3 – Systematic review: Statistical analysis and clinical importance.** In order to examine the effectiveness of strengthening exercise programs for knee osteoarthritis management, the statistical and clinical importance were assessed. The grades, mean and relative differences as well as the absolute benefit for each included trial were calculated (available online in the supplementary material). The statistical significance of each outcome is presented in Figure 1, available online. The summary results with at least one positive recommendation are as follows. The following recommendations were approved by the Delphi panelists in regards to content and format. The Delphi results section for the strengthening exercises can be found in Brosseau et al.<sup>16</sup>

**Steps 4 and 5 – Ottawa Panel recommendations.** The Ottawa Panel recommendations are listed here. Additional information on the characteristics of included studies can be found in Appendices 2 and 3, available online.

#### *Home-based progressive strengthening exercise program*<sup>18</sup>

**Recommendations:** A four-month home-based progressive strengthening exercise program (isotonic and resistance exercises of hips and knees with ankle weights and functional strengthening) (three days per week) for knee osteoarthritis management for pain relief (Western Ontario and McMaster Universities Arthritis Index (WOMAC) subscale)<sup>52</sup> and improved physical function (WOMAC subscale)<sup>52</sup> at four months end of treatment is **recommended**. There is a neutral improvement for quality of life (Short Form 36 (SF-36) SF-36 mental health component subscale (MCS) subscale)<sup>53</sup> at end of treatment of four months.

*Progressive hip muscle strengthening home-based exercise program*<sup>19</sup>

**Recommendation:** A 12-week progressive hip muscle strengthening home-based exercise program (isotonic resisted with ankle weights or therapeutic elastic bands) (five days per week at home plus seven physiotherapy consultations of 15–30 minutes during two months) for medial knee osteoarthritis management for pain relief (WOMAC subscale)<sup>52</sup> and improved physical function (WOMAC subscale)<sup>52</sup> at the one-week follow-up is **recommended**.

*Group education program followed by an unsupervised home-based exercise program*<sup>20</sup>

**Recommendations:** A four-week group education program followed by eight weeks of the unsupervised home-based exercise program (active range-of-motion exercises, muscle strengthening and muscle stretching) (45 minutes one day per week) for the management of knee osteoarthritis for pain relief (WOMAC subscale)<sup>52</sup> and improved physical function (WOMAC subscale)<sup>52</sup> after those eight weeks of home exercises is **recommended**. There is a neutral improvement for pain relief (WOMAC subscale)<sup>52</sup> at end of treatment of four weeks. The Ottawa Panel does **not suggest** physical function (WOMAC subscale)<sup>52</sup> at end of treatment of four weeks.

*Isokinetic strengthening exercise program*<sup>21</sup>

**Recommendation:** A eight-week isokinetic strengthening exercise program (including heat; passive knee Range of Motion (ROM) concentric and eccentric exercises) (three times weekly) for the management of knee osteoarthritis for pain relief (Visual Analogue Scale (VAS))<sup>54</sup> and improved physical function (Lequesne Index (LI) subscale)<sup>55</sup> at eight weeks end of treatment and at six-months follow-up is **recommended**.

*Physiotherapy intervention program*<sup>22</sup>

**Recommendations:** A three-month physiotherapy intervention program (manual therapy; patellar taping; osteoarthritis education; functional and strengthening exercises for the quadriceps and hip muscles) (60 minutes once a week for four weeks followed by once bi-weekly for eight weeks for each group) for patella-femoral knee osteoarthritis management for pain relief during motion (VAS)<sup>54</sup> at three months end of treatment is **recommended**. The use of this program is also **suggested** for pain relief during motion (VAS)<sup>54</sup> at the six-month follow-up. There is a neutral improvement for pain relief (Knee injury and Osteoarthritis Outcome Score (KOOS) pain subscale)<sup>56</sup> and physical function (KOOS in daily living subscale)<sup>56</sup> at end of treatment of three months and follow-up six months. There is also a neutral improvement for quality of life (KOOS quality of life subscale)<sup>56</sup> at three months end of treatment and six-months follow-up.

*Progressive quadriceps strengthening exercise program with nonsteroidal anti-inflammatory drugs*<sup>23</sup>

**Recommendations:** A eight-week progressive quadriceps strengthening exercise program with Nonsteroidal anti-inflammatory drugs (NSAIDs) (quadriceps exercises while sitting on a chair or in a supine position using ankle weights) for the management of knee osteoarthritis for pain relief (VAS)<sup>54</sup> at eight weeks end of treatment is **suggested**. There is a neutral improvement for physical function (WOMAC global score)<sup>52</sup> at end of treatment of eight weeks.

*Group-based supervised progressive strengthening and coordination exercise program*<sup>24</sup>

**Recommendation:** A 12-week group-based supervised progressive strengthening and coordination exercise program (circuit training) (one hour sessions three days per week) for the management of knee osteoarthritis for improved quality of life (KOOS quality of life subscale)<sup>56</sup> at 12 weeks end of treatment is **suggested**. There is a neutral improvement for pain relief (KOOS pain subscale)<sup>56</sup> and physical function (KOOS in daily living subscale)<sup>56</sup> at end of treatment of 12 weeks.

*Osteoarthritis education and supervised strengthening exercise program with home exercises*<sup>25</sup>

**Recommendations:** A six-week osteoarthritis education and supervised strengthening exercise program with home exercises (resistance exercises for the knee and hip independently of the site of major pain) (one two-hour session per week) for the management of adults with knee osteoarthritis for pain relief (VAS)<sup>54</sup> at the six-month follow-up is **suggested**. There is a neutral improvement for pain relief (VAS)<sup>54</sup>, quality of life (VAS subscale)<sup>57</sup> and quality of life (Quality of life scale)<sup>57</sup> at six weeks end of treatment. There is also a neutral improvement for quality of life (Quality of life scale)<sup>57</sup> and Quality of life (VAS)<sup>57</sup> at six-months follow-up.

*Supervised isokinetic, isotonic and isometric muscle strengthening exercise programs*<sup>26</sup>

**Recommendation:** An eight-week supervised isokinetic, isotonic or isometric muscle strengthening exercise programs (warm-up stationary bike; ROM assessment in each arthritic joint; stretching; hot packs) (three days per week) for the management of bilateral knee osteoarthritis for pain relief (VAS)<sup>54</sup> and for improved physical function (LI subscale)<sup>55</sup> at eight weeks end of treatment and at one-year follow-up is **strongly recommended**.

*Supervised isokinetic muscle strengthening exercise program and hot packs application*<sup>27</sup>

**Recommendations:** An eight-week supervised isokinetic muscle strengthening exercise program and hot packs application (concentric and eccentric exercises; warm-up stationary bike; ROM assessment in each arthritic joint; stretching; hot packs) (three days per week) for the management of knee osteoarthritis for pain relief (VAS)<sup>54</sup> and improved physical function (LI subscale)<sup>55</sup> at the one-year follow-up is **recommended**. There is a neutral improvement for pain relief (VAS)<sup>54</sup> and physical function (LI disability subscale)<sup>55</sup> at end of treatment of eight weeks.

*Progressive exercise program, education and usual care*<sup>28</sup>

**Recommendation:** A six-week progressive exercise program (warm-up, strengthening, balance and motor control exercises), education and usual care (45 minutes, two times per week), either in a group or individually, for the management of knee osteoarthritis for improved physical function (WOMAC subscale)<sup>52</sup> at the end of treatment of six weeks is **strongly recommended**. There is a neutral improvement for pain relief (WOMAC subscale)<sup>52</sup> and physical function (WOMAC subscale)<sup>52</sup> at six-months follow-up.

*High and low-resistance strengthening exercise programs*<sup>29</sup>

**Recommendation:** An eight-week high or low-resistance strengthening exercise program (10% and 60% 1-RM leg training) (both high and low-resistance groups completed it three times weekly) for the management of knee osteoarthritis for pain relief (WOMAC subscale)<sup>52</sup> and improved physical function (WOMAC subscale)<sup>52</sup> at eight weeks end of treatment is **strongly recommended**.

*Non-weight-bearing and weight-bearing exercise programs*<sup>17</sup>

**Recommendation:** An eight-week progressive non-weight-bearing or weight-bearing exercise program (including heat and ROM before; eccentric contraction during lower-extremity flexion/extension; ice after) (three days per week) for the management of knee osteoarthritis for improved physical function (WOMAC subscale)<sup>52</sup> at eight weeks end of treatment is **strongly recommended**.

*Quadriceps strengthening exercise program*<sup>30</sup>

**Recommendation:** A 24-month quadriceps strengthening exercise program (with graded therapeutic elastic bands exercises; flexibility exercises; functional strengthening exercises; stretching exercises (twice daily) plus a dietary intervention) for the management of overweight adults with knee osteoarthritis for pain relief (WOMAC subscale)<sup>52</sup> at 24 months end of treatment is **strongly recommended**.

*Progressive resistance exercise program of knees and hip muscles*<sup>31</sup>

**Recommendations:** A 12-week progressive resistance exercise program of knees and hip muscles (with machines and free weights) (two days per week) for the management of women with knee osteoarthritis for pain relief (VAS),<sup>54</sup> pain relief (WOMAC subscale)<sup>52</sup>, improved physical function (WOMAC subscale),<sup>52</sup> improved physical function (Short Form 36 (SF-36) subscale)<sup>53</sup> and improved quality of life (SF-36 subscale)<sup>53</sup> at 90 days end of treatment is **recommended**. There is a neutral improvement for physical function (Six Minute Walk Test (6MWT))<sup>58</sup> at end of treatment of 90 days.

*Strengthening and balance exercise program*<sup>32</sup>

**Recommendations:** A three-month strengthening (all Lower Extremity (LE) muscles with ankle weights, therapeutic elastic bands, non-weight-bearing and weight-bearing) and balance (gait training) exercise program (twice weekly) for knee osteoarthritis management for improved physical function (usual walking speed)<sup>59</sup> at three months end of treatment is **recommended**. The use of the program is also **suggested** for pain relief (VAS)<sup>54</sup> at three months end of treatment.

*Home-based physiotherapist prescribed supervised quadriceps strengthening exercise program*<sup>33</sup>

**Recommendations:** A 12-week home-based physiotherapist prescribed supervised quadriceps strengthening exercise program (using ankle weights, therapeutic elastic bands) (five days per week) for the management of knee osteoarthritis for pain relief (WOMAC subscale)<sup>52</sup> at 12 weeks end of treatment is **strongly recommended**. There is a neutral improvement for physical function (WOMAC subscale)<sup>52</sup> at end of treatment of 12 weeks.

*Concentric-eccentric quadriceps strengthening exercise program*<sup>34</sup>

**Recommendation:** A eight-week concentric-eccentric quadriceps strengthening exercise program (concentric quadriceps action followed by an eccentric quadriceps action) (50 minute classes three times a week) for the management of knee osteoarthritis for pain relief (WOMAC subscale)<sup>52</sup> and improved physical function (WOMAC subscale)<sup>52</sup> at eight weeks end of treatment is **recommended**.

*Physiotherapy exercise program*<sup>35</sup>

**Recommendations:** A three-month physiotherapy exercise program (strengthening/endurance, balance and stretching exercises) (50 minutes classes twice a week) for the management of knee osteoarthritis for pain relief at rest (VAS)<sup>54</sup> at three-months follow-up is **recommended**. The use of the physiotherapy exercise program is also **suggested** for pain relief during motion (VAS)<sup>54</sup> at eight weeks end of treatment and at three-months follow-up and for pain relief at rest (VAS)<sup>54</sup> at eight weeks end of treatment. There is a neutral improvement for quality of life (KOOS quality of life subscale)<sup>56</sup> at end of treatment of eight weeks and follow-up three months. There is also a neutral improvement for pain relief (KOOS pain subscale)<sup>56</sup> at eight-weeks end of treatment and three-months follow-up.

*Lower extremity strengthening exercise program*<sup>36</sup>

**Recommendations:** A six-month lower extremity strengthening exercise program (isometric, isotonic and dynamic exercises) (one set of exercises performed daily) for the management of knee osteoarthritis for improved quality of life (Hospital Anxiety and Depression Scale (HADS) subscale)<sup>60</sup> at six months end of treatment is **strongly recommended**. The Ottawa Panel also **suggests** the intervention for pain relief (WOMAC subscale)<sup>52</sup> as well as improved physical function (WOMAC subscale)<sup>52</sup> at six-months end of treatment.

*Physiotherapy exercise interventions*<sup>37</sup>

**Recommendations:** A three-month physiotherapy exercise interventions (mobility training, venous therapy, lower extremity and trunk muscle strengthening, flexibility, coordination and balance exercises) (twice weekly for three months) for the management of knee osteoarthritis for pain relief at night (VAS)<sup>54</sup> at nine-months follow-up is **recommended**. Also, the Ottawa Panel **recommends** the intervention for pain relief weight-bearing (VAS)<sup>54</sup> and pain relief at rest (VAS)<sup>54</sup> at 12-weeks end of treatment as well as at nine-months follow-up. There is a neutral improvement for pain relief (pain at night VAS)<sup>54</sup> and physical function (algofunctional index (AFI) subscale)<sup>61</sup> at end of treatment of three months. There is also a neutral improvement for physical function (AFI subscale)<sup>61</sup> at nine-months follow-up and for physical function (usual walking speed)<sup>59</sup> at three-months end of treatment and nine-months follow-up.

*Mechanical diagnosis and therapy exercise program*<sup>38</sup>

**Recommendations:** A two-week mechanical diagnosis and therapy exercise program (end-range exercises; advice on exercises for aerobic as well strengthening of the quadriceps; biking; walking) (10 repetitions every 2–3 hours) for the management of knee osteoarthritis for pain relief (P4 subscale),<sup>62</sup> pain relief (KOOS pain subscale)<sup>56</sup> and improved physical function (KOOS in daily living subscale)<sup>56</sup> at two weeks end of treatment is **strongly recommended**. There is a neutral improvement for pain relief (P4 subscale),<sup>62</sup> pain relief (KOOS pain subscale)<sup>56</sup> and physical function (KOOS in daily living subscale)<sup>56</sup> at 10-weeks follow-up.

*Concentric-eccentric isokinetic and isometric exercise programs + paracetamol*<sup>39</sup>

**Recommendation:** A eight-week concentric-eccentric isokinetic or isometric exercise programs + paracetamol (cycling warm-up before the exercises; application of isokinetic dynamometer for exercises; cool-down after the exercises) (three days weekly) for the management of knee osteoarthritis for pain relief during rest (VAS),<sup>44</sup> pain relief during motion (VAS),<sup>54</sup> improved physical function (WOMAC subscale)<sup>52</sup> and improved quality of life (SF-36 subscale)<sup>53</sup> at eight-weeks end of treatment and at 12-weeks follow-up is **recommended**.

*Strengthening exercise program with patient education*<sup>40</sup>

**Recommendations:** A eight-week strengthening exercise program (stretching, strength, mobility, functional, balance, relaxation) with patient education (60 minute sessions completed twice weekly) for the management of adults with knee osteoarthritis for pain relief (LI subscale)<sup>55</sup> and suggests its use for improved physical function (LI subscale)<sup>55</sup> at eight weeks end of treatment is **recommended**. There is a neutral improvement for physical function (6MWT)<sup>58</sup> and quality of life (SF-36 MCS)<sup>53</sup> at end of treatment of eight weeks.

*Progressive supervised squat exercise program*<sup>41</sup>

**Recommendation:** A 12-week progressive supervised squat exercise program (bicycle warm-up; squat exercises with/without whole body vibration) (three days per week on alternate days) for the management of knee osteoarthritis for pain relief (WOMAC subscale)<sup>52</sup> and improved physical function (WOMAC subscale)<sup>52</sup> at 12 weeks end of treatment is **suggested**. There is a neutral improvement for physical function (6MWT)<sup>58</sup> at end of treatment of 12 weeks.

*Strengthening exercise program with home exercises and usual care, including patient education and medication if necessary*<sup>42</sup>

**Recommendation:** A 12-week strengthening exercise program with home exercises and usual care, including patient education and medication if necessary (exercises for muscle functions, mobility and coordination and instructions) (one to three days per week) for the management of elderly individuals with knee osteoarthritis for pain relief (VAS)<sup>54</sup> at 12 weeks end of treatment is **suggested**. There is a neutral improvement for physical function (self-reported disability IRGL)<sup>63</sup> at end of treatment of 12 weeks.

### Types of exercise

**Strengthening exercises.** The majority of included studies<sup>17–20,22–25,28,29,31–38,40,42</sup> included isotonic exercises in their strengthening exercise programs and were effective (i.e. positive Ottawa Panel recommendation [A, B or C+] for at least pain relief, physical function or quality of life) compared with a control group. Isotonic exercises in their strengthening exercise programs were not effective in five trials.<sup>43,45–47,51</sup> A summary of the different components that were analyzed for included strengthening studies is provided in Table 2, available online.

Four<sup>21,26,27,39</sup> of five studies demonstrated that isokinetic concentric-eccentric strengthening exercises were effective compared with a control group. Isokinetic concentric-eccentric strengthening was not effective in Maurer et al.<sup>48</sup>.

Eight<sup>19,26,30,33,35,36,39,40</sup> of 11 studies demonstrated that isometric strengthening is effective compared with a control group. Isometric strengthening was not effective in three trials.<sup>49–51</sup>

Weight bearing as well as non-weight bearing exercises were part of the strengthening exercise program used in the majority of the trials.<sup>18–22,25,28,30,32,34–36,38,40,42,43,45,46,51</sup> Twelve trials

examined the effectiveness of non-weight bearing exercises only,<sup>17,23,24,26,27,29,31,33,37,39,47,48</sup> while another examined the effectiveness of weight bearing exercises only.<sup>41</sup>

Half of the included studies on strengthening exercises combined either coordination, balance and/or functional exercises,<sup>18,20,22,24,25,32,34–38,40–42</sup> which were effective compared with a control group. Three trials on strengthening exercises that combined either coordination, balance and/or functional exercises were not effective.<sup>43,49,50</sup>

### Types of equipment

**Therapeutic elastic bands.** One trial<sup>30</sup> that used therapeutic elastic bands solely as a resistance device for strengthening exercise led to either positive Ottawa Panel recommendations (A, B or C+) for at least one of the selected outcomes (pain relief, physical function or quality of life). Two trials<sup>49,50</sup> obtained neutral recommendations (C or D). However, when therapeutic elastic bands were combined with free weights<sup>19,24,32,33,40</sup> compared with the control, the combination of resistance devices also led to positive recommendations (A, B or C+) for at least one of the three outcomes of interest.

**Weights.** Four trials<sup>19,23,31,37</sup> that used weights solely as a resistance device for strengthening exercise led to a positive Ottawa Panel recommendation to one outcome of interest compared with the control. Only the trial by Ettinger et al.,<sup>45</sup> which used weights, led to neutral recommendations.

**Resistance devices.** Four trials that used isokinetic resistance machines<sup>21,26,27,39</sup> and four trials that used gym resistance machines<sup>17,28,29,35</sup> were recommended and used successfully to improve the three outcomes. Two trials that used gym resistance machines were not effective.<sup>46,48</sup>

#### *Types of setting*

**Home-based/non-supervised.** Several trials<sup>18–20, 22,23,30,33,36,37,40</sup> were comprised of a home-based/non-supervised strengthening exercise program component compared with the control and led to a positive Ottawa Panel recommendation (A, B or C+) for at least one of the selected outcomes (pain relief, physical function or quality of life). However, four trials<sup>44,45,50,51</sup> that examined the effectiveness of home exercise as part of their program led to neutral recommendations.

Several home-based trials included supervision from a health professional.<sup>18–20,36,37,40,43–45,50,51</sup> Home-based programs can be used alone<sup>18,23,30</sup> or as the main component<sup>25</sup> with periodic health professional visits,<sup>18,22,33</sup> telephone follow-up,<sup>33,36,45,50</sup> as a progression component<sup>40,45</sup> or as a concomitant intervention.<sup>19,20,37,40,42–44,51</sup>

**Clinic-based/supervised.** A total of 19 trials included a supervised strengthening exercise program component in a clinic-based setting with a health professional<sup>17,19–22,24,26–29,31,32,34,35,37–39,41,42</sup> and resulted in a positive Ottawa Panel recommendation (A, B or C+) for at least one of the selected outcomes (pain relief, physical function or quality of life) compared with the control. However, eight trials<sup>43–49,51</sup> that examined the effectiveness of facility-based exercise as part of their program led to neutral recommendations.

**Progressive program.** The majority of included trials<sup>17–19,21–24,26–31,33–37,40,44</sup> implementing progressive

strengthening exercise programs compared with the control resulted in a positive Ottawa Panel recommendation (A, B or C+) for at least one of the selected outcomes (pain relief, physical function or quality of life). The majority of trials<sup>43,45–51</sup> that led to neutral recommendations had no progressive program.

**Exercise program duration.** Furthermore, 31 studies<sup>17–29,31–35,37–43,45–49,51</sup> had an active intervention duration of less than six months and therefore, were identified as short-term. Three included trials<sup>30,44,50</sup> had an intervention duration of greater or equal to six months and were considered as long-term. Once again, positive recommendations (A, B or C+) for at least one of the selected outcomes (pain relief, physical function or quality of life) were obtained either with a shorter duration based on 26 trials as well as with a longer duration based on two trials compared with the control. However, the trials<sup>44–51</sup> had mainly neutral recommendations.

**Attrition rate and adherence rate.** Several included high-quality trials with positive recommendations had drop-out rates ranging from 1% to 31%.<sup>17–42</sup> Several included high-quality trials with negative recommendations had drop-out rates ranging from 5% to 24%.<sup>43–51</sup> Further, exercise adherence/compliance was reported in 16 trials with positive recommendations<sup>18,19,21,22,24,26,28–33,35–37,41</sup> with rates ranging from 45% to 100%.

Exercise adherence/compliance was reported in seven trials with negative recommendations<sup>43–47,50,51</sup> ranging from 4% to 90%.

**Sample size.** Eleven trials with positive recommendations<sup>17,23,25,26,28–30,33,36,38,42</sup> had a large sample size ( $n > 100$ ). However, 15 trials<sup>18–22,24,27,31,32,34,35,37,39,40,41</sup> had a relatively small sample size ( $n < 100$ ). Five studies with neutral recommendations<sup>44,45,47,48,50</sup> had sample sizes of greater than 100 participants and four studies<sup>43,46,49,51</sup> included smaller sample sizes ( $n < 100$ ).

**Ottawa Panel Grades.** Of these 26 high-quality trials that obtained positive recommendations (14 for Grade A; 36 for Grade B; 14 for Grade C+), 16



of them<sup>18,20,23–25,27,31,33,35,37,38,40–42,45,49</sup> had neutral recommendations (59 for Grade C and 15 for Grade D) and there was only one negative recommendation (Grade D+)<sup>20</sup> (online supplementary file).

## Discussion

Based on 26 high-quality trials, this Ottawa Panel guideline on strengthening exercise with other types of therapeutic exercises<sup>20,22,24,25,28,32,35,37,38,40,42</sup> or without other types of therapeutic exercises<sup>17–19,21,23,26,27,29–31,33,34,36,39,41</sup> obtained a total of 64 positive recommendations for either pain relief, improved physical function or enhanced quality of life. This guideline recommends muscle-strengthening exercises with or without other types of therapeutic exercises as an effective non-pharmacological intervention for pain relief, improved physical function and quality of life in adults with knee osteoarthritis.

There were nine high-quality strengthening exercise trials that obtained neutral grades only<sup>43–51</sup> and 17 others with both positive and neutral recommendations<sup>18,20,23–25,27,28,31,33,35,37,38,40–42,45,49</sup> (two for Grade C and 15 for Grade D). There was only one negative recommendation (D+)<sup>20</sup> that did not contradict the Ottawa Panel recommendations.

The neutral grades of these eight trials could be explained by one or more of the following reasons: (1) some characteristics of these studies<sup>44,45,47,48,50</sup> were of lower methodological quality (PEDro score of six out of 10); (2) description of exercise programs in some studies was imprecise and lacked sufficient details; (3) strengthening exercise techniques/methods may have been problematic for potentially developing chondromalacia (i.e. patella-femoral osteoarthritis) in some participants with knee osteoarthritis, such as those that involved repetitive movements in activities involving knee flexion.<sup>44,46</sup> Other studies did not mention the intensity applied when using therapeutic elastic bands<sup>50</sup> or the studies had a low exercise frequency (nine exercise sessions over 10 weeks and effect measurements at only five to 12 months).<sup>49</sup>

There appears to be potential contradiction within and between studies that can be explained by: (1) the use of different outcome measures for

the same concept (e.g. pain measured at rest or during activity; physical function measured with KOOS instead of WOMAC etc.), or (2) the effect of the time period (e.g. pain relief at six weeks, but not observed at follow-up). Bezalel et al.<sup>20</sup> is the only trial that obtained a negative recommendation representing a Grade D+ for improved physical function after four weeks of supervised exercises and then a positive recommendation of Grade B ( $n < 100$ ) after eight weeks of follow-up at home. It seems to take longer to measure the beneficial effects of strengthening exercises. It is also important to mention that this trial was of low methodological quality (PEDro score of six out of 10).

A deeper examination of the characteristics of individual strengthening exercise programs revealed that various types of exercise (e.g. resistance vs. functional vs. mixed (resistance and balance and coordination), types of muscle contractions (e.g. concentric vs. eccentric vs. isometric); exercise intensity, program duration, mode of supervision, exercise progression, types of resistance (e.g. therapeutic elastic band vs. weight vs. resistance machine) and delivery modes (e.g. home vs. clinic) can be effective for at least one of the three outcomes of interest (pain relief, physical function or quality of life) compared with the control.

Unfortunately, no specific recommendation can be generated because it is not possible to attribute a greater weight to particular components of the strengthening exercise program compared with others; although there are other studies showing that individual exercise supervision by a healthcare professional has a greater effect size than group supervision and unsupervised home-based exercise compared with the control.<sup>6</sup> Similarly, no strong recommendation related to exercise intensity can be made since the comparison between low-intensity and high-intensity was inconclusive according to several investigators.<sup>6,29,64</sup>

Continued regular exercise participation seems to be an important element in strength training for improving joint health among individuals with knee osteoarthritis. For instance, several trials<sup>22,25,28,38</sup> with follow-up periods, indicated no retention effect for pain relief, physical function and quality of life at

follow-up. Ettinger et al.<sup>45</sup> concluded that to obtain a long-lasting benefit in the management of knee osteoarthritis, therapeutic exercise needs to be completed indefinitely to continue the positive benefits of exercise on joint health as well as general health. Indeed, despite the fact that there is sufficient evidence to suggest that various land-based exercises are associated with pain relief, physical function and quality of life benefits, the majority of individuals suffering from knee osteoarthritis adopt a sedentary lifestyle.<sup>65,66</sup> Health counselling, goal-setting, problem-solving support, telephone contacts, face-to-face visits, exercise logs, social/peer support and positive feedback either alone or in various combinations, have been studied<sup>67-70</sup> and can be adopted to promote long-term use of land-based exercises in the management of knee osteoarthritis.

The positive recommendations identified by the Ottawa Panel guideline show a large variety of beneficial strengthening exercise programs. This gives healthcare professionals, as well as individuals with knee osteoarthritis, a range of exercise choices. Thus, patients can choose the exercise program of their preference, which may potentially improve exercise adherence.<sup>71</sup>

### **Comparisons with previous clinical practice guidelines**

This updated Ottawa Panel guideline provides recommendations regarding specific types of strengthening exercise programs compared with more global recommendations on therapeutic exercises (e.g. land-based or aerobic). Owing to the presence of heterogeneity, each high-quality trial was individually graded to offer end-users the opportunity to apply with confidence the unique content of each specific strengthening program that was identified as effective. The pooling of several trials with diverse strengthening exercise programs in a meta-analysis did provide the end-user with an overview of the benefits of land-based therapeutic exercise in general as shown in Fransen's review.<sup>6</sup> In comparison, this guideline provides more specificity as to the components of the strengthening exercise programs and ultimately, better applicability for clinicians interested in implementing these programs based on their patients' preferences.

More importantly, this updated Ottawa Panel guideline agrees with previously published guidelines<sup>2,8,10,13-15,72-76</sup> and systematic reviews<sup>6,7,9,12</sup> on the management of knee osteoarthritis, which unanimously recommended the use of strengthening exercises with and without other types of therapeutic exercises.

There is no need to conduct additional trials or to develop new guidelines on short-term clinical effects of strengthening exercises for the management of knee osteoarthritis.<sup>6</sup> However, there is still a need to conduct more well-designed trials with active exercise interventions lasting longer than six months to confirm and assess long-term benefits since only two randomized controlled trials<sup>30,36</sup> were longer than six months. Additionally, more trials should be developed to assess long-term adherence using behavioral interventions, since only two trials used this type of intervention in addition to the strengthening exercise programs.<sup>18,25</sup>

### ***Physiological effects of therapeutic exercises***

This systematic review revealed that any type of strengthening exercise is effective for reducing pain as well as for improving physical function and quality of life for individuals with knee osteoarthritis. This can be explained physiologically. Indeed, several studies observed that anti-nociception is produced with resistance exercises, resulting in decreased pain.<sup>77,78</sup> The exercise-induced endogenous analgesia is presumed to be owing to the release of endogenous opioids and growth factors<sup>77,79</sup> and owing to the activation of spinal nociceptive inhibitory mechanisms orchestrated by the brain.<sup>80,81</sup> Improvements can also be explained biomechanically by increasing stability of the joint.<sup>82</sup>

Based on these results, it can be concluded that strengthening exercises also have beneficial effects on knee osteoarthritis pain. The trials included in this guideline have shown that pain relief occurs, but the amount is variable depending on the characteristics of different therapeutic exercise programs performed. The diverse array of evidence in support of strengthening exercise programs to effectively manage knee osteoarthritis pain suggests that future research should

investigate more thoroughly the interaction between dosage and pain (i.e. effect of increased or reduced level of pain).<sup>83</sup> The results of such research could advise clinicians and patients on exercise progression to limit potential flare-ups and determine the optimal dosage for physical functioning.<sup>83</sup>

## Limitations

### *Limitations of the Ottawa Panel guideline*

According to the methodology of the Ottawa Panel guidelines, if a Grade A recommendation is based on a trial that has a total sample of less than 100 participants, the Grades A, initially obtained, needed to be downgraded to a Grade B<sup>18-22,27,31,32,34,35,37,39,40</sup> and can lead to a problem of statistical power.<sup>84</sup>

According to the Ottawa Panel grading system, Grade D always favors the control and Grade C always favors the intervention. Statistical comparison analyses are calculated at the end of the study for the two groups for a specific outcome, whereas the relative difference (clinical importance) involves analyses at both the end of study for the two groups for a specific outcome and also at baseline. In four trials,<sup>18,24,40,42</sup> even though the randomization was performed properly, there was a difference between groups at baseline for a few outcomes. This situation leads to contradiction between clinical relevance that favors intervention and non-statistical significance that favors the control. Despite this rare problem owing to baseline values, none of these situations led to a positive recommendation. A detailed description of the differences between the Ottawa Panel grading methodology and the Cochrane Grade approach can be found in Brosseau et al.<sup>16</sup>

Head-to-head trials that compared two different types of strengthening exercise programs (e.g. high-intensity exercises vs. low-intensity exercises) or different types of resistance equipment (e.g. therapeutic elastic bands vs. strengthening machines) were not considered in this Ottawa Panel guideline because it would not have targeted the specific effects of the intervention compared with the control. It would have been interesting for clinicians and patients to obtain this relevant knowledge. Further, it would have been useful for the end-users to learn if resistance exercises are as effective with therapeutic

elastic bands as with free weights or with machines. However, the existing trials were rarely designed this way, except for few studies using three arms that compared different exercise programs, such as: (1) weight-bearing quadriceps exercises vs. non-weight bearing quadriceps exercises vs. control in one study;<sup>17</sup> (2) concentric-eccentric strengthening exercises vs. isometric strengthening exercises vs. control;<sup>39</sup> and (3) aerobic vs. resistance exercises vs. control.<sup>45</sup> According to the conclusions of these studies, none of the comparisons between the different possible pairs were statistically different, but they were significant when compared with a control. The relative effect between different characteristics could be examined in future reviews.

### *Limitations of the primary included randomized controlled trials*

Better reporting of characteristics of the exercise application should be adopted in order to assess their therapeutic validity and potential of clinical replication,<sup>85-87</sup> especially with multiple types of exercise interventions (e.g. strengthening exercise combined with coordination exercises, or range-of-motion exercises or balance exercises, etc.). Liu and Latham<sup>88</sup> has also recommended that reporting adverse events during the progress of any type of therapeutic exercise program is mandatory.

Several included trials used adjunctive therapies in addition to land-based exercise, but their additional effect is unclear.<sup>89</sup> For example, patellar taping, manual-therapy and osteoarthritis education,<sup>22</sup> hot packs application<sup>27</sup> or medication uptake is added to a strengthening exercise with or without other types of therapeutic exercises.<sup>39</sup> Heterogeneity of therapies can represent real-world clinical situations, but additional specific effects are unclear. These, often passive, interventions are difficult to use for self-managing knee osteoarthritis because patients are not to apply these by themselves.

In order to measure the true effect of the exercise intervention, studies should be compared with non-active comparators (i.e. no intervention or waitlist); and if compared with an active non-exercise control, such as patient health education, a multifaceted intervention design (i.e. comparing

exercise plus patient health education vs. patient health education alone) is needed.

The use of patient health education in only the control group for two trials,<sup>45,48</sup> especially when it contains education modules on exercise and/or osteoarthritis information, might also be problematic and may reduce intervention effect estimates, since the intervention may have benefits among individuals with osteoarthritis.<sup>90</sup> Indeed, these two trials<sup>45,48</sup> led to neutral recommendations. However, the Ottawa Panel obtained positive recommendations after analyzing three other trials<sup>18,30,32</sup> involving a non-osteoarthritis and/or exercise patient education in the control group only. However, a recent review<sup>91</sup> found that self-management educational programs have no or only limited effects on osteoarthritis symptoms. The included trials examined in the review were not necessarily the same trials in the present review and are heterogeneous.

The choices of using short-wave diathermy therapy<sup>20</sup> is controversial, because electrotherapy may have a potential positive residual effect on pain relief and may lead to an underestimation of the effect size. However, the Ottawa Panel still obtained positive recommendations (Grade B for pain relief and physical function at the eight-week follow-up) with the use of this control condition.

Any type of strengthening exercise among the included trials on land-based exercise was identified as effective in this systematic review. However, some strengthening exercises, such the ones that require isokinetic resistance devices, have accessibility barriers for healthcare professionals and patients at the clinic or home settings. Furthermore, the level of resistance with the use of elastic bands as resistance devices is difficult to control and measure. The degree of force that the patient desires to generate will also influence findings.

Low exercise adherence can greatly affect the exercise dosage<sup>45</sup> and is rarely reported in the included trials of this review. Moderate to high drop-out rates can also lead to potential attrition bias. However, the Ottawa Panel did not examine adherence in depth, and consequently, this factor was not taken into account in the grading system.

The use of strengthening exercises with or without other types of therapeutic exercises for the

management of knee osteoarthritis has well-established short-term beneficial effects on pain relief, improved physical function or quality of life. Effective behavioral strategies adapted to this population need to be further studied and identified in order to promote the regular long-term practice of strengthening exercises among the large choice of positive recommendations.

A large number of strengthening exercise programs with or without other types of therapeutic exercises can have beneficial short-term effects on knee osteoarthritis clinical outcome measures and are available to healthcare professionals as well as for patients with knee osteoarthritis. The Ottawa Panel found evidence from 26 high-quality trials supporting the use of strengthening exercises to provide moderate to great improvements in pain relief, physical function and quality of life for individuals with knee osteoarthritis, especially for those who have at least one knee affected by osteoarthritis and have the capacity to exercise. It is recommended that these exercise interventions be supplemented with individualized medical advice and treatments in order to ensure safety and maximal benefit. Lastly, it would be interesting to explore the most effective behavioral strategies to encourage individuals with knee osteoarthritis to practice strengthening exercises on a regular basis in order to gain sustained improvements.

#### **Clinical messages**

- Strengthening exercises (with/without other types of therapeutic exercises), involving characteristics (type of resistance; type of contractions, modes of supervision, exercise program intensity and duration) can greatly reduce pain, improve physical function and quality of life for knee osteoarthritis patients.
- Contribution of adjunctive therapies (e.g. patellar taping, manual-therapy, etc.) combined with strengthening exercise need to be studied.
- There is a need to develop combined behavioral and muscle strengthening exercise strategies to improve long-term maintenance of strengthening exercise.

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