Clinical recommendations for prescribing exercise therapy for patellofemoral pain – based on RCTs evaluating exercise in patellofemoral pain and exercise prescription literature

	Range prescribed in previous studies	**Components for exercise prescription (based on American College of Sports Medicine Guidelines[1,6] and s)**	**Specific considerations for PFP (based on Best Practice Guide for Conservative Management of PFP[2] and other PFP literature)**
Load magnitude (item 1)	**Defined:** in 15/38 studies **<u>Range of loads relative to 1 repetition maximum (1RM)</u>**: 10 to 75% of 1RM **<u>Number of repetitions to failure at a given load</u>**: 6 – 10 repetitions (see: http://www.ideafit.com/fitness-library/muscular-fitness-tests and http://www.exrx.net/Calculators/OneRepMax.html).	Should be tailored to desired goals & baseline assessment. For highly trained individuals, incorporating a variety of loading strategies targeting specific areas of the force-velocity relationship is required [4]. **<u>Strength:</u>** Higher load is more effective at increasing strength e.g.: 60-70% 1RM for novice to intermediate >80% 1RM for advanced or experienced **<u>Endurance:</u>** <50% of 1RM **<u>Power:</u>** As increasing maximal strength is an important basis for muscular power [4], training muscle power should comprise of standard high-load strength training, in addition to lighter training conducted at faster velocities, such as the following recommended by ACSM guidelines: Lower limb = 0–60% of 1RM at fast contraction velocity Upper limb = 30–60% of 1RM at fast contraction velocity	1. Consider patient motivation and willingness to exercise, along with previous resistance training history. 2. Consider starting at lower loads, sets and/or repetitions than recommendations, based on presence of kinesiophobia and pain. 3. Modify starting point if needed based on pain response (see pain scale below[13]) before gradual progression to the desired goal. 4. Progress the load, number of repetitions and/or number of sets based on the pain response in individual patients (see pain scale below[2] 5. Consider potential pain inhibition during assessment to determine program prescription, particularly for the knee musculature
Sets and repetitions (items 2 and 3)	**Defined:** in 22/38 and 23/38 studies respectively	**<u>Strength:</u>** 8-12 repetitions 1-3 sets for novices	

	3 sets of 10 repetitions was the most commonly prescribed (12 studies) **Range:** Sets = 1-5; Repetitions = 5-30	1 set can be effective in untrained individuals, but multi-set programmes appear to be more effective, with 3-4 sets producing greatest effect **Endurance:** 15-25 repetitions Higher volumes (sets X repetitions) are recommended, which can be achieved by increasing no. of sets and/or repetitions **Power:** 3-6 repetitions, low intensity, fast velocity 3-6 sets	
Rest in between sets (item 4)	**Defined:** in 7/38 studies **Range:** 30 seconds–2 minutes	Importantly, acute performance may be impaired with short rest periods. **Strength:** 2-3 minutes **Power:** 3-5 minutes **Endurance:** Shorter rest intervals may be beneficial for endurance performance (30-90 seconds)[5] **Additional consideration:** Shorter breaks may be preferable to induce an anabolic environment if hypertrophy is desired [3,5]	1. Consider patient motivation and willingness to train, along with previous resistance training history. 2. If training key muscle groups in isolation (e.g. hip and knee), consider prescription order to improve time efficiency – i.e. alternate between hip and knee exercises (or left versus right side).
Number of exercise interventions (per week) (item 5)	**Defined:** in 35/38 studies	**Untrained individuals:** Minimum 2-3 non-consecutive days/week to increase address strength, power and/or endurance **Advanced or experienced individuals:**	1. Consider patient motivation and willingness to train, along with previous resistance training history. As 2 days per week appears to be a sufficient stimulus to promote adaptation for novices,

	3 times per week was the most commonly prescribed (15 studies) **<u>Range:</u>** 3–21 times per week	Increase number of sessions per week (e.g. 4-6)[3] to ensure adequate progression and overload, whereas less may be needed for maintenance	consider on an individual basis if the time-commitment will impact adherence and training consistency, compared to more frequent sessions. 2. Consider more sessions per week if aiming to address kinesiophobia 3. A greater number of exercise sessions per week are associated with an increased odds of recovery[9,12]
Duration of rehabilitation period (weeks) (item 6)	**Defined:** in 38/38 studies Although there was much variability, a high proportion of studies used 3-4 week intervention periods (12 studies) **<u>Range:</u>** 3–16 weeks	**<u>Neural changes:</u>** Improvements in muscle function in early stages of resistance training are due primarily to neural changes **<u>Muscle hypertrophy:</u>** Hypertrophic changes are measureable from around 6 weeks. Beyond this point, an interplay of neural and hypertrophic adaptations may occur	1. Progressions to loads sufficient to facilitate hypertrophic changes may take longer than recommendations due to prescription considerations related to pain and kinesiophobia 2. Consider chronicity of condition, with greater chronicity likely to lead to greater muscle atrophy, thus taking longer to address
Fractional and temporal distribution of the contraction modes per repetition and	**Defined: in** 2/38 studies While some studies reported isometric holds during both isometric and dynamic exercises, varying from 2–20 seconds no studies	A combination of eccentric, isometric and concentric muscle actions with moderate velocity is recommended. As adaptations following training are maximized at or near the velocity of movement used during training, a continuum of velocities from slow to fast is recommended for advanced training, to maximise strength and power gains at a specific velocity [3].	1. Consider deficits identified and function required for each individual patient 2. Consider pain response and any potential kinesiophobia initially

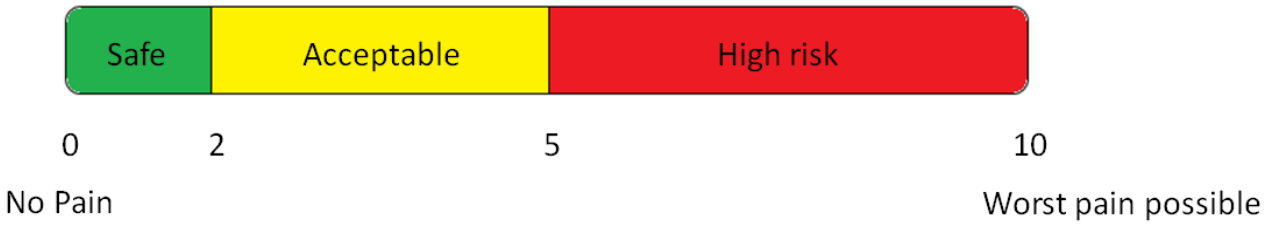
duration (s) of one repetition (item 7)	reported the complete tempo for dynamic exercises.		3. Consider and ensure movement quality when attempting faster velocity of movement 4. Slow movements may also be considered if the patients experience flair-ups of pain during exercises.
Rest in-between repetitions ((s) or (min)) (item 8)	**Defined:** in 6/38 studies Range: 2-10 seconds	Rest between repetitions may affect fatigue and subsequent load able to be lifted/moved Little (or no) rest between repetitions may be preferred if the goal is to increase muscle endurance or hypertrophy. Longer rest intervals may be preferred if the goal is to increase muscle strength or power.	1. Consider pain response and any potential kinesiophobia initially. Greater rest may help mitigate pain or kinesiophobia
Time under tension ((s) or (min)) (item 9)	**Defined**: in 2/38 studies	**<u>Strength:</u>** Slow and moderate velocities (1-2) seconds for eccentric and concentric phases) are recommended to increase max strength in untrained individuals For a given load and number of repetitions, longer total time under tension during a 6 week training period may be associated with larger strength gains[11] **<u>Power:</u>** For muscular power, incorporating high velocity (explosive) contractions are recommended, in addition to traditional high-load strength training.	1. Longer time-under-tension has been reported to have a greater analgesic effect.[8] If this is desired from an exercise, other prescription specifics such as load and contraction type (e.g. use isometric) in order to optimise time under tension.

		Total time under tension may be very short when training at the high velocity end of the force velocity curve. **<u>Endurance:</u>** Intentionally slow velocities are used for 10-15 repetitions. If targeting higher repetitions (15+), faster velocities are recommended.	
Volitional muscular failure (item 10)	**Defined**: in 1/38 studies	High-velocity training should not be completed to failure, in order to ensure velocity of the exercise is not compromised. Increasing evidence indicates completion of an exercise to failure has a strong influence on muscle protein synthesis, and may increase muscle mass and strength.	1. Consider pain response and any potential kinesiophobia. In the initial stages of initiating a resistance training program, training to muscle failure may be difficult or not well-tolerated. If needed/desired it may be preferable to slowly progress to this, for those who are unaccustomed to resistance training 2. Consider and ensure movement quality if working to muscle failure to reduce risk of pain aggravation 3. Although completing an exercise to failure may increase gains in strength, it is not essential, particularly in untrained individuals
Range of motion (item 11)	**Defined:** in 11/38 studies	**Specificity:** Adaptations to resistance training are specific to the stimulus applied. Although there may be some carryover to other ranges / activities, the range of motion prescribed should preferably be	1. Consider pain response and any potential kinesiophobia. In the initial stages of initiating a resistance training program, range of motion may be

		specific to the functional goals of the exercise, and the range in which the improvement is desired	controlled to avoid pain flares, and slowly progressed to desired ranges. 2. During open kinetic chain quadriceps exercises, avoiding terminal extension (0-45^{o}) in the early stages may be ideal to minimise potential lateral patellar tracking and increases to PFJ stress and pain flares[10]. 3. During closed kinetic chain quadriceps exercises, avoiding deeper knee flexion in the early stages may be ideal to minimise potential increases to PFJ stress and pain flares.
Recovery time in-between exercise sessions ((h) or (d)) (item 12)	**Defined:** in 2/38 studies	Inexperienced individuals should train 2-3 non-consecutive days / week	1. Consider patient motivation and willingness to train, along with previous resistance training history.

Anatomical definition of the exercise (exercise form) (item 13)	**Defined:** in 16/38 studies Varied greatly in studies reporting, dependent on exercise selection	Unilateral and bilateral exercises are recommended Both single and multi-joint exercises are effective for increasing strength in targeted muscles Multi-joint exercises may be more effective for increasing strength during functional movements Single joint exercises can be used to target specific muscle groups	1. Consider pain response and any potential kinesiophobia. 2. Exercise programs should include both hip and knee exercises. In the early stages, targeting the hip in preference of the knee may lead to better outcomes for pain and function.[7,14] 3. Consider exercise targeting distal and core muscle function based on individual assessment [2]. 4. There is no evidence to support either open kinetic chain (OKC) *or* closed kinetic chain (CKC) to be more effective.[14] 5. To address isolated deficits or avoid pain aggravation in the early stages, OKC may be more desirable. 6. CKC may be needed to enhance functional outcomes, and are recommended as the preferred exercise by international experts.[2]

Pain Scale: Visual analogue scale to monitor pain response during exercise prescription. Pain is acceptable during exercise (< 5/10), and should reduce to the same baseline level of pain as before starting exercises within 24 hours. If this does not occur, the exercise should be modified by reducing load, repetitions, or sets; or by changing exercise. Based on work by Thomeé (1997). [13]



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