It is not all about strength: rethinking mechanistic assumptions in exercise-based rehabilitation for musculoskeletal pain relief

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Exercise is considered requisite in the management of most musculoskeletal (MSK) pain conditions.[1] It is the foremost treatment recommendation for conditions including rotator cuff-related shoulder pain, Achilles and patellar tendinopathy, MSK low back pain and osteoarthritis (OA).[2 3] Driven by its intuitive logic and communicative simplicity, the hypothesis that 'pain diminishes because strength increases' remains a prominent explanation for the effectiveness of exercise. In this editorial, we challenge the premise that strength gains mediate pain reduction and highlight alternative mechanisms with stronger empirical support.

THE MISMATCH BETWEEN OUTCOME AND MECHANISM

Evidence that exercise reduces pain across MSK conditions is increasing and consistent. However, evidence for how exercise achieves these outcomes is sparse, creating a reliance on implicit and (often) outdated biomechanical beliefs. A growing body of evidence challenges the common assumption that gains in strength are a key mechanism for clinical improvement. In Achilles tendinopathy, a systematic review found no evidence linking improvements in pain or disability with changes in muscle-tendon structure or strength.[4] Similarly, a causal mediation analysis in patellar tendinopathy showed the effect of a patella tendon loading regime was not mediated through improvements in quadriceps strength.[5] And there is no evidence causally connecting changes in strength for rotator cuff-related shoulder pain to improvements in pain outcomes.[6 7]

For patellofemoral pain, improvements in hip muscle strength do not explain the beneficial effect of hip resistance exercises,[8] and an individual participant data meta-analysis in knee OA reported that knee extension strength only mediated approximately 2% of the treatment effect of therapeutic exercise.[9]

Across conditions, the conclusion is similar: exercise therapy is modestly effective, but rarely because people get stronger. The chasm between belief and data warrants attention.

WHY MECHANISMS MATTER

Understanding how an intervention works matters for: (1) scientific rigour, (2) clinical integrity and (3) conducting responsible research.

1. **Scientific rigour:** Robust causal claims require more than a statistical correlation. Health sciences should integrate both probabilistic and mechanistic evidence to justify causal claims.[10] Without evidence of a valid mechanism, causal claims are shallow and unstable.
2. **Clinical integrity:** Mechanistic narratives shape how clinicians communicate, and patients understand their condition and the rationale for treatment. Emphasising strength as the primary treatment target risks demoralising patients who do not improve along that metric and constrains the clinician's ability to adapt exercise to the particular values and preferences of a unique patient. It can also reinforce inaccurate structural beliefs and protective behaviours about 'weakness' or 'fragility' causing pain.
3. **Responsible research:** Mechanistic insight supports improvements in intervention theory and design, which may lead to more efficient and effective treatments. Trials that report only the total treatment effect on selected outcomes miss opportunities to explain how and why exercise may or may not work.

EMERGING ALTERNATIVE MECHANISMS

Mediation analyses have identified a range of factors that likely contribute to clinical improvement beyond strength gains:

- **Pain self-efficacy, beliefs and catastrophising:** Evidence for their mediating role improving pain and function is seen across various conditions, including OA and low back pain.[11–13]
- **Inflammatory biomarkers:** In knee OA, reductions in inflammatory biomarkers have mediated improvements in pain and function through a diet and exercise programme.[11]
- **Kinesiophobia:** In rotator cuff-related shoulder pain and low back pain, a reduction in kinesiophobia explains the benefits of an exercise programme.[13 14]
- **Trust, motivation and confidence:** A realist review of persistent low back pain emphasised the importance of trust, motivation and confidence to optimise adherence to and clinical outcomes of exercise.[15]

Together, these findings suggest that clinical improvement in MSK pain is seldom explained by strength gains alone. Instead, benefits are more plausibly mediated through a combination of bio-psycho-social mechanisms, including improved pain self-efficacy, reduced fear and pain catastrophising, and dampened systemic inflammation. Moreover, the therapeutic relationship may exert a non-trivial influence on the clinical outcome (figure 1). A broader explanatory framework is needed for the effect of exercise on MSK pain, one that reflects the complexity of recovery rather than reducing it to muscle strength.

IMPLICATIONS FOR CLINICAL PRACTICE AND RESEARCH

1. **Do not default to strength-based explanations.** While getting stronger is good for general health and a strong indicator of longevity,[16] it is currently not a valid or reliable causal explanation for pain relief in most MSK conditions. An alternative message

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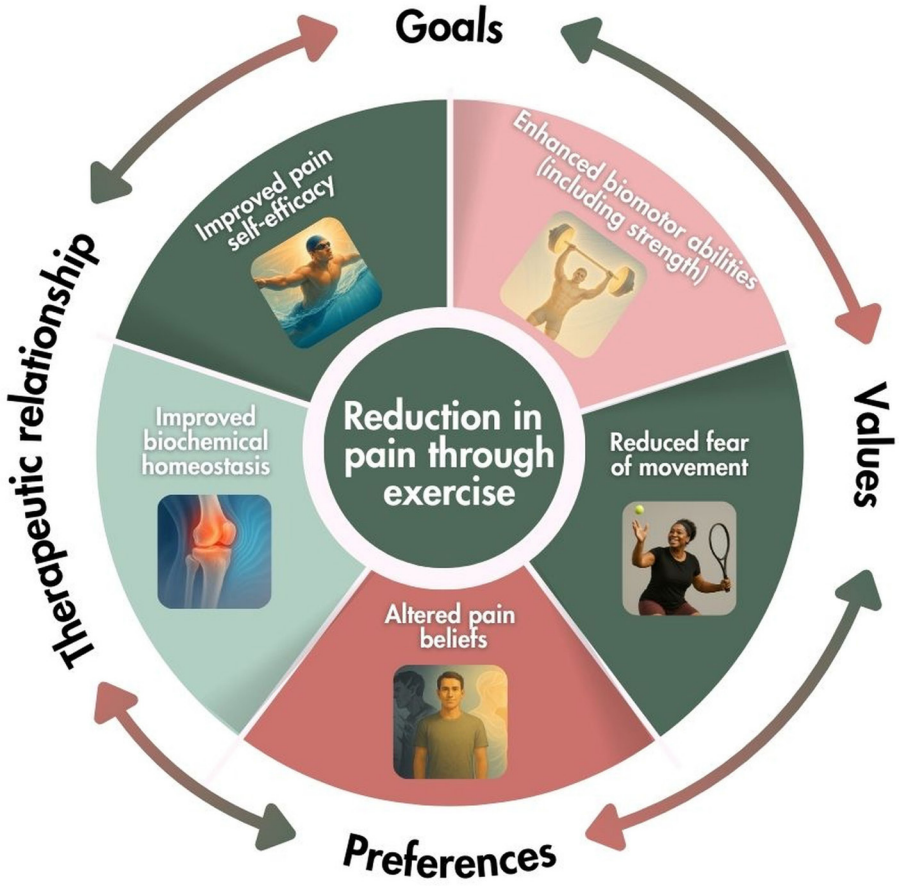

Figure 1 The diagram highlights potential mechanisms by which exercise may contribute to a reduction in the experience of pain associated with the musculoskeletal system. These mechanisms are not exhaustive but represent those supported as mediators of exercise-induced pain reduction. Importantly, their effectiveness may be shaped by contextual factors including the therapeutic relationship and alignment with the patient's goals, values and preferences. Lead author JP created and owns the figure in this manuscript.

clinicians may consider using with patients is: 'Exercise can benefit many people with MSK pain, even when underlying mechanisms vary or remain unclear. Through keeping active and gradually challenging your body, exercise can help you adapt in ways that build confidence, reduce pain and improve function, ultimately helping you get back to doing the things you want and need to do. The key is finding the type of exercise that works for you, your goals, your experience and your interests'.

2. **Continue to broaden intervention targets**. Address psychosocial factors, metabolic health and movement confidence, not just muscle performance.
3. **Design trials that test mechanisms, not just effects**. Mediation analysis should be prospectively planned, adequately powered and include plausible, multidimensional mediators.
4. **Refine communication**. Until and unless sufficient causal evidence supporting the claim accumulates, reconsider saying 'you need to get stronger to feel better'. Clinicians should absolutely continue to champion exercise, but with an updated narrative: one that highlights strength gains as a marker of improved physical robustness and health, rather than a prerequisite for being pain-free.
5. **Strength still matters**. While strength gains are unlikely to be the main driver of pain relief from exercise in MSK conditions, the general biomotor abilities (including strength) developed through various exercise modalities remain important for other clinical outcomes. For example, improved strength and balance supports functional independence and reduces falls risk in older adults[17] and is associated with lower risk of all-cause mortality.[18] In some clinical contexts, such as anterior cruciate ligament reconstruction rehabilitation, increased strength is associated with better functional outcome.[19] Acknowledging these broader benefits allows us to contextualise the limited role of strength gains in pain reduction, without diminishing its clinical importance.

CONCLUSIONS

Exercise therapy is effective across a range of MSK conditions, but its effects are likely mediated by a constellation of biopsychosocial mechanisms. Both clinicians and researchers must continue to prescribe a range of exercises, including resisted exercises, geared towards maximising strength gains. But we must move beyond simplistic assumptions about how it helps and accept the uncertainty related to exercise prescription and rigorously investigate how and why it makes a difference.

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