Injury management

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What should you do when you get injured? The politically correct advice is usually to go see a doctor, because you can't diagnose an injury without seeing someone. Typically, the doctor then tells you to take a break from training with stay-at-home RICE treatment (rest, ice, compress, elevate) and gives you some anti-inflammatories. In this module, we'll cover why **every** part of the above advice is misguided for most strength trainees and how instead to deal with orthopedic (musculoskeletal) problems.

The faceless diagnosis

The first step where most people go wrong is that they think they can't treat their own injury without diagnosing it first and they can't diagnose it themselves.

First, you can diagnose your injuries yourself. The vast majority of common injuries are easy to diagnose or at least classify. During strength training, most injuries come down to simple overuse [2]. (Note though that from a legal point of view, you may not be able to provide an official diagnosis even if you know in practical terms what's wrong.)

How can you diagnose an injury without even seeing it? You cross-reference the symptoms with those reported in the literature to see which injury it is. Diagnostic statistical models using this method can outperform doctors. In some studies, even simple, non-Bayesian models that basically just tally up symptoms and compare them to existing illnesses' symptoms without taking their probability into account, are as accurate as doctors at diagnosing pathologies. In one study, an artificially intelligent Bayesian model was nearly twice as accurate as doctors at diagnosing illnesses. It even outperformed doctors at making decisions about the best course of treatment, resulting in up to 50% better outcomes for the patients with less than half of the medical costs. Another Bayesian model rivaled doctors at making very complex decisions where the best treatment depends on the exact severity of the disease. And these are older models, nothing compared to the current AI models like ChatGPT.

See, a doctor often doesn't have more information than you do. You can't see inside someone's body. He does the same thing you can do: assess your symptoms and see which pathology they correspond with. Unless they're ordering bloodwork, imaging studies or other tests that provide new information, they're limited to manual and visual inspection and your self-report, just like you are. And only you know how you feel.

So Dr. House was right. You don't need to see someone for a diagnosis. In fact, a lot of research suggests that much of the benefit patients get from in-person treatment is a placebo effect. Simply the idea that you're being cared for, that you're in control and that you're actively involved in the recovery process can speed up your physical recovery. Voltaire famously said: "The art of medicine consists in amusing the patient while nature cures the disease." In support of this, a 2023 meta-analysis found "no clinically significant differences in pain, function, and quality of life between single and multiple physiotherapy sessions for musculoskeletal disorder management." The most charitable explanation for this finding would be that a single visit is enough to get your diagnosis and action plan. However, self-education and management may serve the same purpose as visiting a professional. A 2022 meta-analysis found that 'booster sessions' with a professional after self-management of musculoskeletal pain "had no evidence of an effect on improving patient-reported outcomes on physical function, pain-related disability and pain self-efficacy". Booster sessions did reduce patient-reported pain catastrophizing. Visiting a professional thus made patients feel a bit more reassured, but it did not improve their objective functioning. Modern evidence-based physiotherapists therefore often primarily recommend patient education and self-management for non-traumatic musculoskeletal pain [2].

There are only 4 primary things you really need to know about an injury. These are the questions you should ask yourself whenever you feel pain or get injured during a workout.

1. Where is the pain/injury?
2. How bad is the pain on a scale of 1 to 5? How would you describe the pain?
3. When does it hurt? During which exercises? (Be careful when testing.)
4. Has this injury occurred before? Re-injury is a major risk factor for future injury and will require far more conservative treatment.

Some injuries are of course more severe and physical than others. The following symptoms warrant seeking urgent medical attention.

- Complete loss of range of motion in a joint.
- Internal damage to a muscle or joint that presents with skin discoloration.
- Any serious symptom that grows in severity for longer than 72 hours.

As a tip, other than the presence of pain, the type of pain can also tell you something about your injury. Over time, many trainees learn to differentiate between the 'good' pain associated with muscular exertion, like that from metabolic stress and muscle damage, in contrast to 'bad' pain, like that in joints.

- If the pain is sharp and shooting, like an electric shock or hitting the funny bone in your elbow, there is likely damage to neural tissue. The pain may also be radicular: it may radiate down or sideways along the nerves.
- If the pain feels similar to extreme muscle soreness, there is likely damage to muscular tissue.

- If it's neither of the above and you feel stiffness or a dull ache, the damage is likely to connective tissue, specifically a tendon or ligament.

Treatment without diagnosis

Let's take things one step further and forget about the diagnosis in the first place. In many cases, you don't need an exact diagnosis. Say someone has relatively mild knee pain and you suspect it's a partial meniscus tear based on the symptoms, like which movements hurt. It could also be the medial collateral ligament (MCL). Or it could be patellar tendinopathy. Or arthritis.

So you go to a doctor. Most likely, the doctor tells you to stop training, suggests RICE treatment and prescribes some anti-inflammatories to get the 'magic pill' placebo effect and give you the impression that it was useful to go to the doctor (we'll discuss anti-inflammatories in a bit). The only alternative is usually surgery. The other alternatives come with as many risks as benefits, like cortisone injections, or are largely untested, if they're available at all, like shockwave therapy. The best-case scenario is that you get an actual diagnosis. The doctor MRIs your knee and finds out: it wasn't the meniscus. It's a partial tear of the MCL.

Now what? The treatment for both is to wait until it heals. The body is very good at healing itself. 2 out of 3 herniated spinal discs fix themselves by reabsorbing and even massively prolapsed discs often don't require surgery [3, 4]. If the injury doesn't heal on its own with conservative management, surgery is often your only option. That's what you'd do anyway. So often, a formal diagnosis offers no practical benefit for rehab [2]. In fact, for nonspecific back pain, there is currently strong medical consensus that people should not get imaging or diagnostic tests, such as MRI scans, done, unless the symptoms are severe or persist for months. Imaging typically shows more false positives than useful information.

On an added note, doctors are great mechanics, but it's good to realize they're just working people that likely gained most of their knowledge from medical textbooks written many years if not decades ago. They’re not magicians, they’re often not specialized in sports injuries or even biomechanics and perhaps most importantly, their job is first and foremost to prevent and treat medical problems, not optimize your performance or your wellbeing. So when treating you, this is what they have in mind, not if and how soon you can squat again. Plus, rational doctors will act out of self-interest and will recommend a treatment that covers themselves: they’ll generally err on the side of rest and treatments that cannot go wrong. They have little to gain from recommending more aggressive rehab exercise, because if it goes wrong, they’re to blame, and if it goes well, you won’t know it worked better than complete rest so you won’t appreciate them more.

So what then should you do when you’re injured but you don’t know what the exact injury is?

Rest vs. active recovery

Many people see injury as an excuse to stop exercising altogether. This is foolish and weak.

It's weak, because only very few injuries make it impossible to train any part of your body. Leg in a cast? You don't need your legs to do chin-ups. Broke your hand? Do cable work with ankle straps for the upper body. Paralyzed from the neck down? … Ok, that's difficult.

It's foolish to stop training when you can, because active recovery speeds up the recovery of neuromuscular fatigue and performance [2, 3, 4, 5]. Holwerda et al. (2023) found that connective muscle protein synthesis decreased substantially after immobilization. Restoring normal daily activity levels also restored extracellular protein synthesis, along with collagen mRNA expression. This occurred despite doing non-weight bearing 'exercise' 3x per day with the immobilized leg and these were healthy, young adults with just 7 days of immobilization. The same should apply to other connective tissues, like your tendons. Staying active stimulates a significant increase in blood flow to your connective tissue during exercise. Connective tissue has very little blood flow when the surrounding muscles are inactive: oxygen delivery to tendons and ligaments is 7.5 times lower than to muscle tissue. The lymphatic system, which is in significant part responsible for draining swelling around inflamed areas, is even more passive at rest, as unlike blood, it has no heart to pump it through its circulatory system. Bodily movement serves as the 'pump' of the lymphatic circulatory system.

Active recovery needn't be fancy. Electro-myo-stimulation works no better than light activity. Basically any activity that speeds up blood flow without causing tissue damage can function as active recovery.

Active recovery is the closest we have to a panacea. Exercise is basically the only type of rehabilitation that is uncontroversial and it's effective for virtually every type of injury. Even in people with knee osteoarthritis, the more walking they do, the fewer symptoms they have.

The positive effects of exercise even outweigh the potential harm of frequent spinal loading. Many people believe that manual labor, especially when you're lifting things with poor form, is stressful for the spine. It's easy to imagine a picture of a hunched over farmer in agony with his hand on his back. Yet the truth is that rates of back pain are 2-4 fold higher in Western First World countries than in farmers in Third World countries and there's little relation between low back pain and lifting posture during everyday life or between low back pain and sitting or standing posture. Even poor physical activity is better than being sedentary.

So the first rule of injury is: don't train through an injury, but don't stop training altogether either. Be creative and work *around* the injury. You'll find that if you apply the guidelines from this course module, you'll recover much faster than traditional guidelines propose and you can normally do so without any complete downtime from the gym.

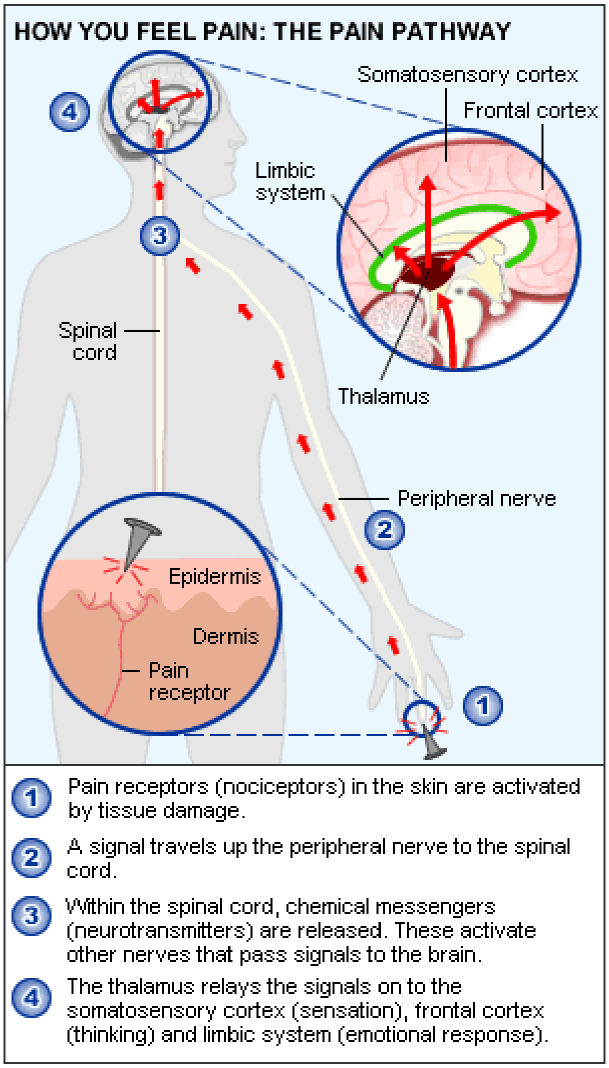
The next question is: how do we determine the right amount of exercise? Too little and you won’t heal as fast as possible; too much and you’ll make the injury worse.

Pain science

Sitting on the couch is bad for your recovery, but the people that intuitively train when injured also tend to push through pain. That's not weak, but it's even more foolish than not training at all. There's a fine line between being hardcore and being a dumbass.

Pain is an evolutionary mechanism to cease potentially harmful activities. Pain says 'stop'. Pain does not always correlate with tissue damage, however. Pain is biopsychosocial, meaning the experience of pain is a combination of biological (e.g. tissue damage), psychological (e.g. nocebo effects) and social effects (e.g. not wanting to show pain). Pain is triggered by pain receptors (nociceptors) in the nervous system and ultimately, it's the brain that decides whether you experience pain. Pain receptor activation does not always correspond to physical tissue damage. You can have pain in the absence of injury. You can also be injured without damage to nerves or with complete destruction of the nerves so you don't feel the damage. You can even experience pain in body parts you no longer have after extreme trauma or surgery (phantom limb pain). But those are all exceptions for strength trainees with acute injuries. The effect of cognitive, emotive and behavioral factors on recovery from musculoskeletal injury is modest and insignificant in many scenarios.

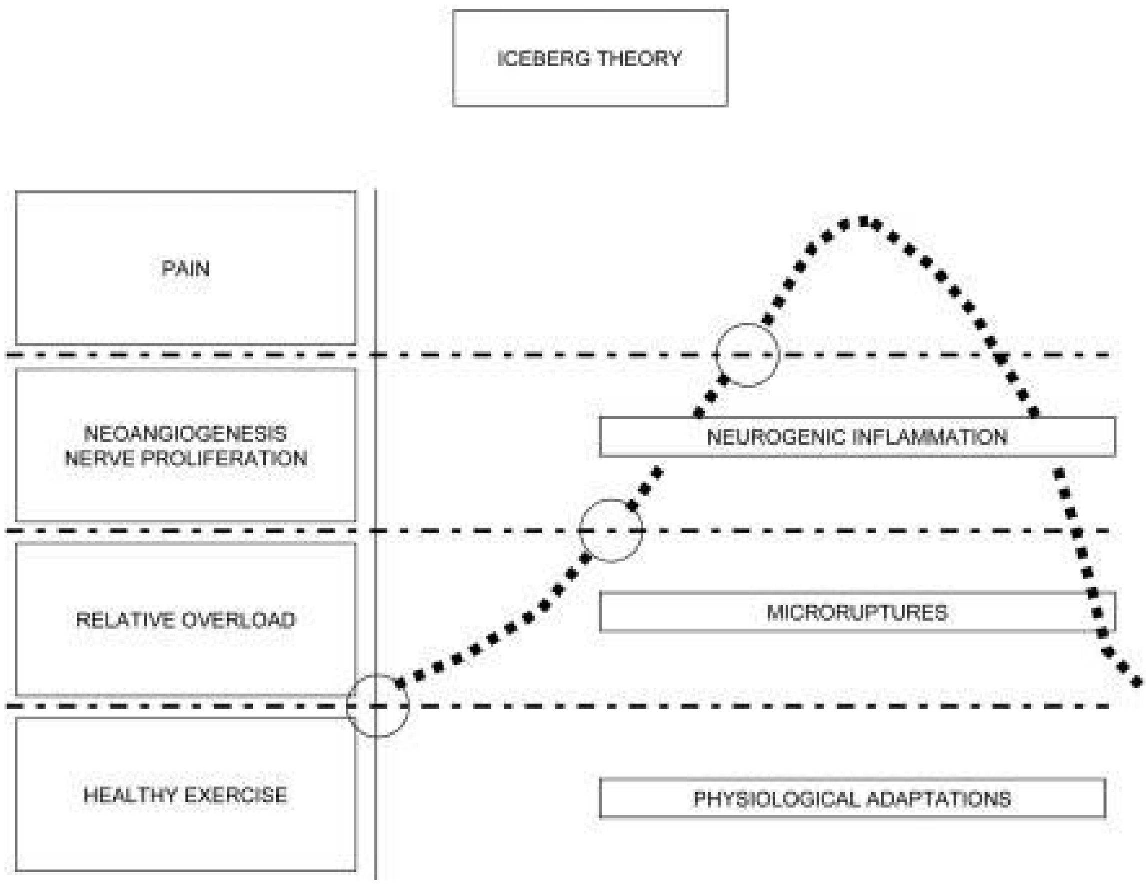
Under normal circumstances for strength trainees, listening to your body and avoiding pain is a very good way to autoregulate your training when you're injured [2, 3, 4]. For example, Long et al. (2004) evaluated 312 people with back pain for their directional preference: which movements caused pain and which did not, such as spinal flexion vs. extension. The researchers then had the patients perform an exercise program that was either not related to their pain preference, in line with their movement preference or directly opposite their movement preference. The patients that exercised so as to avoid pain improved on every outcome, including a decrease in pain and disability. The patients that did not heed their pain signals for their exercise programs improved around 3-fold less. In fact, a third withdrew from the study within 2 weeks due to worsening or persistence of their symptoms. Even in cases where training through pain can be beneficial for short-term recovery from musculoskeletal injuries, not training through pain provides similar long-term results according to a 2017 meta-analysis, so not training through pain is safer. This is especially true for strength training injuries, as most strength training injuries by far are overuse injuries [2].



How tissue damage stimulates pain. Note how ultimately it's the brain that decides whether you experience pain. Image credit to myDr.com.au

Any pain is generally bad. During exercise, you're aroused and your blood is full of analgesics, so you're relatively insensitive to pain. It takes a significant amount of pain to cross your pain threshold and become noticeable. That means when you feel pain, at the cellular level you may have already inflicted significant damage.

The 'iceberg model' of tendinopathy illustrates the relation between pain and tissue damage. After overuse of the tendon resulting in microtrauma "In the second phase, a pathogenetic cascade involving the production of pro-inflammatory cytokines, vascular growth factors, and oxygen free radicals will take place, resulting in degradation of the tendon, neovascularization and possibly nerve proliferation. However, in this phase **the subject is still asymptomatic until a new threshold in neovascularization and neural in-growth is reached and pain occurs**." In other words, often when you experience pain, it's already too late to prevent injury. You're already injured. The focus should now be on letting the tissue heal and preventing further damage.



‘Listen to your body’ without specification of when ranks up there with ‘just be yourself’ on the useless advice list. Obese people listen to their body all the time. That’s why they give in to their emotions and instant gratification and they end up obese. However, you *should* listen to your pain. If everyone did this, the vast majority of injuries would not occur and rehabilitation would often be rapid and uneventful.

Pain reporting

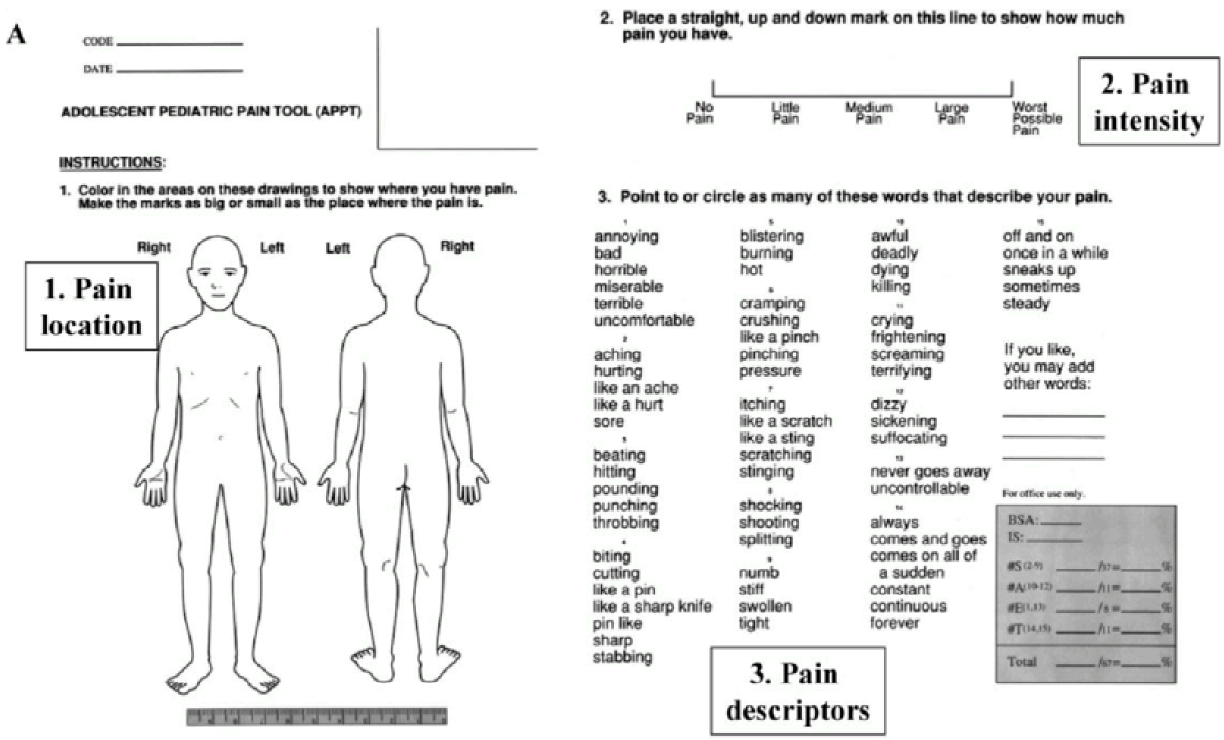
Since pain is an inherently subjective experience, it can be difficult to communicate how painful something is or what type of pain someone’s experiencing, especially when you’re coaching someone via email. Different people often use different adjectives to describe the same experience. To standardize pain assessment, the 2 most important things you should ask for are the pain intensity on a scale (e.g. 1 to 10) and the location of the pain. A useful tool is the Adolescent Pediatric Pain Tool (APPT). The APPT is a standardized format to ask for

1) the location of pain, using an image of the body to avoid confusing descriptions,

2) the intensity of the pain, using a standardized scale, and

3) a verbal description of the pain (the least useful component).

While originally developed for children and adolescents, it has been validated in clinical practice for adults and it's much simpler, quicker and widely applicable in use than complex inventories like the Sports Inventory for Pain (SIP). See the image below for an example pain report using the APPT.



An example implementation of the APPT. Source

Muscular pain

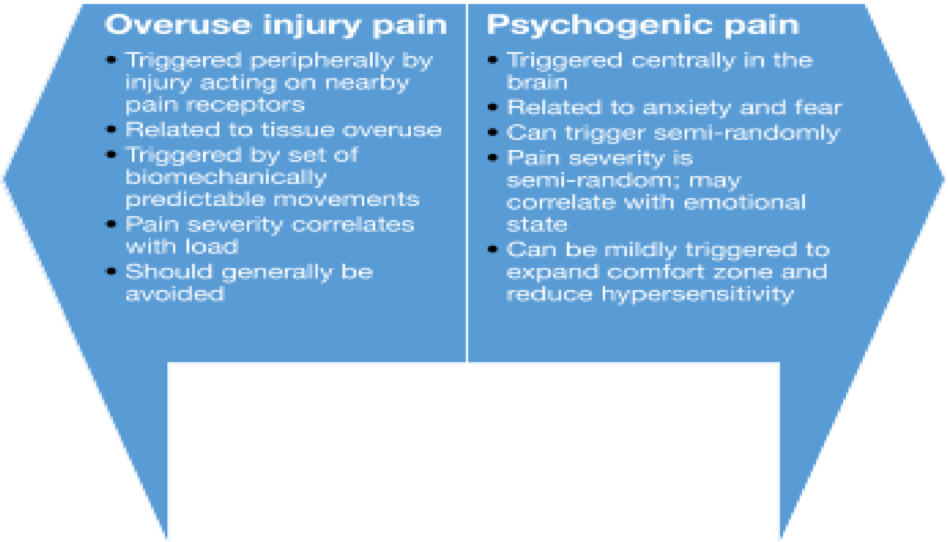
Purely muscular injuries, such as strains and intense delayed onset muscle soreness (DOMS), are an exception to the rule of avoiding pain altogether. Muscle tissue is more plastic than connective tissue, heals much faster and responds very well to active recovery. For purely muscular injuries, rehabilitative exercise can push to the point of mild pain without hindering recovery. However, when in doubt, it's safest to err on the side of no pain. As a rule of thumb, keep pain below a 3 out of 10 even for purely muscular injuries.

Psychosomatic pain

Pain can be psychosomatic, meaning it's not just triggered by the activation of pain receptors in a damaged body part but also influenced by your mental state. The brain always modulates the activity of pain receptors and it doesn't always directly give you the experience of pain in direct correlation with the activity on pain receptors. The pain can even be fully psychogenic or 'in your head'. Although the term psychogenic pain is contested, it's illustrated well by phantom limb pain, like the experience of pain in an amputated hand. Pain is particularly likely to become psychosomatic or fully psychogenic during prolonged injuries that caused anxiety. During a prolonged injury, you may become extra sensitive to pain: there is sensitization of the nociceptive nervous system [2]. The pain can then persist even after the original tissue damage has healed. Psychosomatic pain can be difficult to rehab. Experiencing pain while training is often a sign you need to back off, but if you get too anxious and fearful about the pain, that may in itself cause the pain to continue in psychosomatic fashion.

To assess if your pain is still likely related to tissue damage or if it has become psychosomatic ('in your head'), use the following checklist.

1. Is the pain stimulated by consistent stressors? Tissue damage related pain plays up during certain movements and generally only those movements. Certain movements hurt, others don't. The fine/not fine selection doesn't change normally. If it does, the set of painful exercises expands. For example, elbow pain during pulling movements may start becoming painful during presses too if you keep training through the pain and make the injury worse. If the pain plays up during random movements and certain movements are sometimes painful but otherwise ok, this suggests there's a psychosomatic component.
2. Does the set of painful exercises have a theoretical explanation? If you have a physical knee injury, you'd expect exercises with higher knee torques or knee joint stresses in general to be painful, whereas exercises like Romanian deadlifts that barely involve the quadriceps should be pain-free. If the pain does not scale with estimated joint forces, the cause may not be physical.
3. Is the pain correlated with load? If there's tissue damage, the pain should intensify with exercise intensity (%1RM). Heavier exercise typically causes more pain than lighter exercise. If the pain severity does not scale with how much weight you're lifting, it may very well be psychosomatic.



The continuum of psychosomatic pain. Pain can be triggered by tissue damage acting on nearby pain receptors, originate entirely in the head or, most commonly, have a peripheral origin but central modulation.

If your pain is psychogenic, realizing that the pain is mostly in your head and not associated with tissue damage is the first step to get rid of psychosomatic pain. In this scenario, you can start carefully pushing up to the pain threshold, focusing on exercise performance and technique, not the injury. Some of the residual pain is likely caused by hypersensitization and an ingrained expectation of the pain (nocebo), not an actual cause for alarm anymore.

It may also help a lot to get tissue imaging done, such as an MRI scan, especially if the pain persists for months. When you can see objectively there is no damage to the tissue, pain hypersensitivity often resolves quickly. However, MRI scans for this purpose can also backfire, because imaging can show abnormalities that aren't a problem and this knowledge can create psychosomatic pain. For example, many people's spines show signs of degeneration, even full-blown disc herniations, that are completely asymptomatic. So don't freak out if your scan shows something other than what you expected. Similarly but to a lesser extent, absence of damage on imaging scans does not guarantee there is no damage. Scans can miss (small) injuries.

In the following section we'll go into how to modify your program to train around pain that's likely related to tissue damage.

Rehabilitation programming

The use of fossil fuels is not a sustainable activity in economic terms, because we use fossil fuels at a faster rate than they are formed in nature. We can apply this same concept to the human body. A training program is sustainable if its damage to your tissues over time does not exceed their rate of recovery.

Iceberg theory says the same thing: “Under physiological conditions, exercise increases the strength of the tendon, but when the individual threshold is overcome, microdamage may occur. If the tendon is given adequate time to recover, in good local conditions of blood flow and nutrition, the healing machinery will prevail with complete repair. However, if the recovery time is too short and blood flow is inadequate, the repetitive strain will lead to microdamage inside the tendon (the first phase of tendinopathy: a very thin line, indeed, divides healthy and non-healthy physical exercise). Therefore, **tendinopathy appears to result from an imbalance between protective and regenerative changes and the pathological responses to tendon overuse.**”

Rehabilitation thus comes down optimizing your recovery and limiting training stress.

What makes exercise rehabilitative?

Exercise helps you avoid and recover from injuries. That is the very premise of the field called physical therapy. How can exercise get rid of injuries, when it’s often also the cause of injury? Broadly speaking, there are 3 mechanisms by which exercise can be rehabilitative.

1. Active recovery, as we’ve discussed, can stimulate repair processes without aggravating the injury.

2. Strengthening a tissue makes it harder to damage it. Tendons increase in cross-sectional area just like muscles with strength training. Bone density also increases as a result of strength training. A clear illustration of the protective effect of stronger tissues is that strength training reduces collision injury risk, like when tackled during rugby.
3. Increasing muscular strength can help your muscles control your joints [2], improving joint stability, and shifting the balance of stress toward your muscle tissue and away from your connective tissue. Muscles heal far more rapidly than connective tissue, so this is generally beneficial.

Since strength training accomplishes all of the above, strength training is a highly effective way to reduce sports injury risk and low strength predicts high injury risk. Strength training is much more effective than most other treatment modalities to prevent and rehab injuries.

- Several studies have found that strength training is more effective than staying generally active or performing endurance training in the treatment of painful muscles.
- Another study's conclusion reads: "stretching and aerobic exercising alone proved to be a much less effective form of training than strength training."
- Anderson et al. (2008) compared the effectiveness of strength training to health counseling with ergonomics to improve posture and stress management as treatments of neck and shoulder pain in office workers. You might expect that posture was the problem, so targeting this directly with improved workplace ergonomics should be most effective. Wrong. Strength training was more effective at relieving pain in the shoulders and neck. It was also easier to stick to for the participants.
- A systematic review and meta-analysis found that Pilates exercise does not improve back pain or functionality.

- The evidence for spinal manipulation and mobilization, e.g. chiropractic, is also mixed, especially as a long-term treatment. It could well be argued that it mainly just provides acute pain relief. (See chiropractic section later on.)
- The evidence for massage is even more questionable. (See massage section later on.)
- Most invasive treatments for pain management work no better than placebo.
- A 2019 systematic review on the treatment of subacromial shoulder pain (SSP) concluded exercise therapy is highly effective and of all other treatments, only manual therapy had convincing support, not laser therapy, extracorporeal shock wave therapy, pulsed electromagnetic or ultrasound.

When you look at the kind of strength training that's best, it's clear there are no such things as 'healing exercises'. Rehabilitative exercise should make body parts stronger without damaging them. That's mostly it. There is very little scientific support for muscular imbalance, inflexibility or joints being out of place as primary causes of injury.

- Rotator cuff isolation exercises have a reputation as magic shoulder healers in some circles, but compound exercises are just as effective at improving muscular balance in the shoulder and compound exercises are more effective at improving overall strength.
- Littlewood et al. (2014, 2016) compared 2 treatments of rotator cuff tendinopathy. One group underwent a full, traditional physiotherapy program including advice, stretching, exercise, manual therapy, massage, strapping, acupuncture, electrotherapy and possible corticosteroid injection at the discretion of the treating physiotherapist. The other group just did lateral raises. In both studies, the full physiotherapy program was no more effective at reducing the shoulder pain and disability than just doing lateral raises up to a year of treatment. In both studies, the 'just lateral raises' group actually had

slightly better outcomes in absolute terms, but these were not statistically significant.

- For the treatment of subacromial (shoulder) pain syndrome, a 2018 meta-analysis by Saito et al. found specific scapular stability exercises were no more effective than general shoulder strengthening exercise.
- For the treatment of idiopathic scoliosis (a curved spine), general core stabilization training is at least as effective as specific scoliosis bracing techniques (the Scientific Exercises Approach to Scoliosis). The general core stability training group in fact achieved a greater reduction in pain.
- Saner et al. (2015) compared a fancy rehab physiotherapy program to a general strength training program in patients with low back pain. They followed the patients for a year. At every measurement point, the general strength training program was just as effective as the special physiotherapy protocol at relieving pain and disability.
- Ojoawo et al. (2017) found that exercise was equally effective for the treatment of non-specific chronic low back pain regardless of the position it was carried out in (supine vs. prone or both).
- Multiple reviews have similarly concluded that exercise is effective to manage back pain, but no type of exercise seems to be inherently better than another. For the treatment of non-specific low back pain, a meta-analysis by Smith et al. (2014) concluded: "There is strong evidence stabilisation exercises are not more effective than any other form of active exercise in the long term." For chronic low back pain, a 2016 Cochrane meta-analysis found most forms of exercise provide similar outcomes. A 2020 meta-analysis by Thornton et al. found that exercise improved low back pain and functionality in athletes, but no type of exercise was clearly best.
- A RCT by Hott et al. (2019) found no difference in the effectiveness of 3 different programs for the rehabilitation of patellofemoral pain: it didn't matter whether the

subjects performed knee-focused or hip-focused training or even free physical activity.

- Esculier et al. (2018) found no benefit of gait retraining or knee strengthening exercise in addition to education about load management in runners with patellofemoral pain. Reducing the training stress from running based on their knee pain was enough to reduce the symptoms and improve functionality.
- A 2020 review on isometric vs isotonic contractions for the treatment of pain from patellar tendinopathy in athletes found that both were effective. Isometric contractions seemed to result in more acute pain relief though.

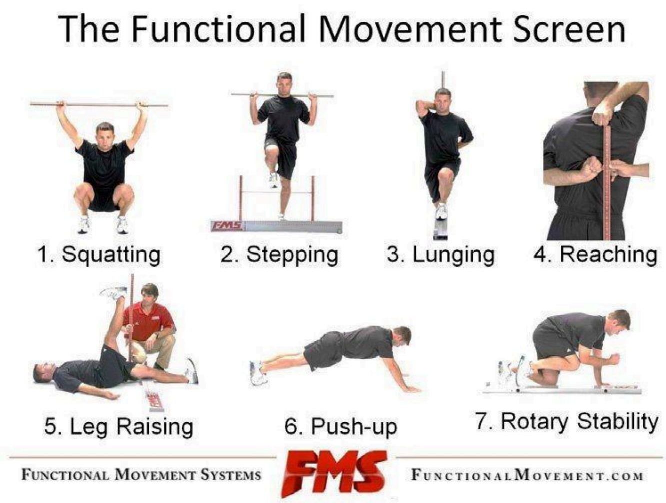
If you logically think about it, beyond some active recovery you can only cause further damage with exercise. There is no such thing as a 'healing' exercise. At best, exercise is hermetic: a little stress can stimulate the repair processes without aggravating the injury. But most high-intensity weightlifting is far beyond hermetic: it's stressful. That's why it causes neuromuscular adaptations to begin with.

In sum, recovery doesn't take place in the gym: it's mostly a matter of sleep, stress, nutrition and patience. In the gym, we should be training *around* the injury, not adding more volume to the injured body part.

This begs the question: which types of activity are the most stressful for our connective tissue?

What causes injuries?

Many screening tools have been developed to predict injury risk, the most well-known of which is arguably the Functional Movement Screen (FMS). These tools generally consist of a set of 'functional' tests of flexibility, mobility and symmetry. You don't have to know any of them in detail, because none of them have been successful at predicting who gets injured and who doesn't. Even the most advanced machine learning algorithms can't successfully predict injury risk from FMS scores and most estimates are barely better than a coin flip [2, 3, 4, 5].



An implementation of the Functional Movement Screen

Instead, most injuries are predicted far better by mechanical factors than any 'functional' tests. The following table compiles data on training injury rates from several types of physical activities. As you can see, bodybuilding is extremely safe compared to the other sports. (Is bodybuilding a sport?) The injury rate per thousand hours is only 0.2-1 in bodybuilders, compared to around 3 for powerlifting, Olympic weightlifting and CrossFit and over 5 for Strongman and Highland Games, depending on which study you look at [2, 3]. Strength sports injuries occur most commonly in the lower back/pelvis, shoulders and elbows. Most team sports have an injury rate at least as high as the barbell sports during training, but injury rates rise manifold during matches, especially for contact sports. Rugby, for example, has an injury rate per thousand hours of 3 during training but **83** in competition. Soccer has an injury rate per thousand hours of 8.7 to 66.9 during matches and 1.4 to 5.8 during training, including similar levels for the referees [2, 3, 4].

Activity	Injuries per thousand hours
Popular team sports (Hootman et al. 2007)	13.8 (competition) / 4 (practice)
Running (Hespanhol Junior et al. 2014)	10
CrossFit, Powerlifting, Olympic Weightlifting (Hak et al. 2013)	3.1
Bodybuilding (Siewe et al. 2014)	0.2

How come the other sports are so much more injurious than bodybuilding? There are multiple plausible reasons.

Most team sports – soccer, American football, basketball, baseball, hockey, etc. – involve many uncontrolled and explosive movements. There is also a lot of direct impact on the body, whether it's with a basketball, the floor or a 300-pound linebacker.

Running is far more controlled, but the impact with the ground is unforgivingly repetitive.

Olympic Weightlifting and Powerlifting don't have much impact and are relatively controlled movements, so they have a severalfold lower injury rate. Yet when you're lifting heavy weights close to your maximum capacity, even a minor slip can result in a serious injury. CrossFit doesn't involve as much weight, but there is less control, more impact and more cardiovascular fatigue that makes it harder to maintain safe technique.

In contrast, bodybuilding training is very controlled, has almost no impact, doesn't involve much training with maximal weights and incorporates a much greater variety of movements, causing less repetitive strain.

A healthy body fat level helps to prevent injury as well, since being overweight by definition imposes a lot of unnecessary mechanical stress on your joints, tendons and other connective tissue. More importantly perhaps, being overweight is associated with chronic inflammation and impaired recovery capacity, as you learned in the course's module on energy. Overweight people experience more injuries than lean people, even if you adjust for many confounders.

Your strength level may also influence your injury risk, but this relationship is complex in practice. Tendons and probably other connective tissues don't grow as much from strength training as muscle tissue does. Strength generally increases significantly faster than tendon size, which may increase injury risk. Tendons can grow in size (cross-sectional area) in response to sufficiently high tension [2], but tendons adapt to exercise mostly by increasing in stiffness rather than by increasing in size. However, in practice we see that powerlifters suffer lower injury rates as they get more experienced. The higher mechanical risk may be offset by better injury management, smarter training program design and better exercise technique.

In sum, we can categorize the following aspects of exercise as risk factors of injury.

- Uncontrolled movement
- Explosive movement
- Pattern overload (repetitive impact or strain)
- Maximal force production

With this in mind, we can modify a training program in the following ways to make it more sustainable when discomfort beyond that of neuromuscular exertion is experienced.

Volume

Obviously, [training volume predicts injury risk]: the more training you do, the more likely you get injured during some of it. In fact, in a lot of research training volume is the only clear predictor of injury risk. However, since training volume is also the primary determinant of your rate of progression, we only want to compromise on training volume as a last resort. We should first try to modify other training program parameters to see if we can make the program sustainable without compromising on training volume. You can reduce the training volume per sensitive exercise though. Many overuse injuries start off very local and only aggravate one specific movement pattern. Reducing the volume of doing that specific movement pattern can be highly effective for rehabilitation. However, if an exercise already causes pain, it's often better to switch it out altogether, which brings us to exercise selection.

Exercise selection

The number one way in practice to create a sustainable program is to modify your exercise selection. Most injuries are very specific and often all it takes to prevent an ache or nagging pain from becoming a serious injury is to swap out the culprit exercise. This includes the powerlifts (bench press, squat and deadlift). They are not magical exercises and always having them in your program poses a high risk for overuse injuries. Powerlifters experience far more injuries than bodybuilders despite typically training with lower volumes and most injuries occur during the performance of the powerlifts.

We'll go into specific exercise substitutes later, but with some biomechanics knowledge you should be able to come up with reasonable substitute exercises to try. Even if you have no idea what the injury is, just carefully trying a bunch of similar exercises and seeing which one is pain-free often does the trick.

Also, it's generally a good idea for non-powerlifters to train exercises no more than twice per week to avoid pattern overload. You're better off adding another exercise if you want to increase the volume or frequency for that muscle group than loading more volume on that same exercise. Exercise variety is a good way to prevent pattern overload injuries.

Training intensity

Reducing your average training intensity is another way to make your program more sustainable. Volume is generally blamed, but intensity has a much stronger effect on connective tissue strain, as per the course module on training intensity.

Unless you are so severely injured that you cannot move a body part at all, there is by definition an intensity of work that you tolerate. Moving all the way up to 30 rep sets or a training intensity of 30-60% will greatly limit the damage to your connective tissues while preserving most of the stimulus for muscle growth.

With KAATSU training, you can go down all the way to 30% of 1RM for many exercises without losing any significant stimulus for muscle growth.

Always maintain good exercise technique though. Technical compound exercises like squats do not lend themselves well to be performed for high reps, as you'll be too out of breath to focus on movement quality.

Repetition proximity to momentary muscular failure

Other than your exercise selection and your training intensity, you can reduce your proximity to failure. Going to failure by definition means a loss of good technique. The worse your technique is, the worse the tissue stress distribution. Staying a few reps further away from failure goes a long way towards controlling your movements well and reducing connective tissue stress.

If you can't take your sets within 5 reps of failure though, it's probably not worth doing the sets at all and you're better off replacing the exercise altogether or resting the body part completely.

Rest intervals

When injured, make sure you're resting long enough to mentally focus on perfect technique. You can't focus on controlling the injured body part if you're still gasping for air.

Range of motion

Just like training volume, range of motion (ROM) should only be reduced as a last resort to allow for a sustainable training program, as compromising on these variables directly hurts muscle growth. However, certain injuries, especially strains and tendinosis, do not tolerate lengthening the tissue well. Tendons inherently experience higher strain when loaded at longer lengths. For severe injuries where pain intensifies at longer muscle lengths, it can be useful to temporarily limit ROM.

Repetition tempo

The last major variable to manipulate is tempo. As discussed in the course topic on repetition tempo, implementing very controlled eccentrics with correspondingly lower training weights will help you spare your joints while still reaching high levels of muscle activation compared to using a more explosive repetition tempo [2]. Incorporating pauses in the top and bottom position of an exercise also helps during (p)rehab. A more controlled tempo maintains high muscle activation levels while sparing your connective tissue from having to absorb the shocks of explosive training. As a result, emphasizing eccentric muscle contractions can help speed up the recovery of muscular injuries, although there's weak evidence to implement true eccentric overloading and you probably don't need to perform eccentric-only exercise. Beyer et al. (2015) found that heavy, slow strength training tended to be slightly more effective for the treatment of Achilles tendinopathy than eccentric-only training and the overall evidence for patellar tendinopathy also favors heavy, slow training over eccentric-overloading.

For very severe injuries, purely isometric or eccentric training can be warranted to start the rehab process. As the injury heals, you can gradually start incorporating more explosive type exercise.

In conclusion, essentially any training programing method that allows you to achieve effective muscle stimulation with lower weights is good for injury rehab. Effective rehab exercise is generally performed with low intensities (30-65% of 1RM), not taken to failure, with at least enough rest in between sets to catch your breath and with a very controlled tempo (or even isometrics/eccentrics). If all the above still doesn't make an exercise pain-free, you should almost certainly replace it. Only reduce volume or ROM as a last resort.

Post-pain rehabilitation

Let's say you've managed to make your exercise program sustainable: there's no more pain during exercise. Many people then conclude the injury has healed and they go back to their original program. This is a mistake. Remember the iceberg model: just because you are no longer reaching your pain receptors' threshold to actually feel the sensation of pain, your tissue has not necessarily fully healed yet: "The 'iceberg theory' can thus explain the frequent relapse of symptoms when athletes resume sport activities after too short a rehabilitation period, during which pain recedes to just below the detection threshold while most of the intratendinous abnormalities still exist."

Gradually working back up towards your pre-injury training level of stress for the damaged tissue is crucial. Injured body parts remain extra susceptible to injury for weeks after the pain has subsided, because it takes a while before the connective tissue is remodeled with full strength [2].

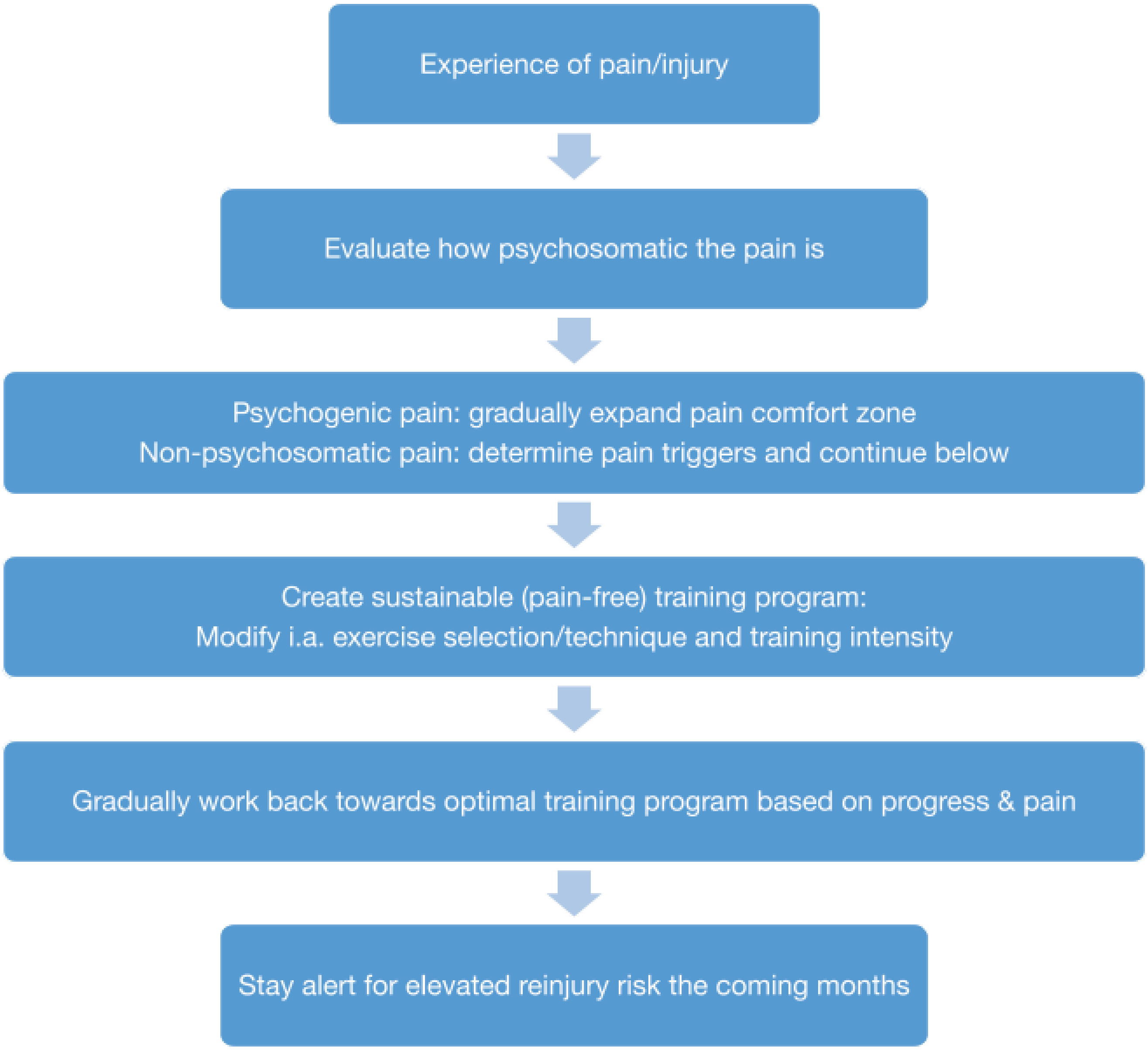
You still want to implement progressive overload during rehab, whenever possible. Rehab exercise without progressive overload is not only extremely ineffective to gain muscle and strength, non-progressive rehab exercise is not consistently significantly more effective than placebo for injury rehabilitation. You need to strengthen the tissues and for that, they need to be exposed to a certain level of stress that does not make the damage worse but does stimulate tissue remodeling.

To give a concrete example, let's say you have some mild upper back pain during Romanian deadlifts. Your regular heavy work with a progression at 8RM caused pain, but you found that sets of 30 with a more controlled tempo still allow you to train 1 rep to failure. Even when you do not notice any more symptoms at rest or during any exercise, it is prudent not to go straight back to sets of 8 with a more explosive tempo. Instead, just set 30 as your new rep target and progress from there as normal. Only implement intensification as needed for progressive overload and gradually let the repetition tempo increase in explosiveness as needed to progress in strength. This will ensure the injured tissue has more time to heal and can gradually adapt to more stress again. Especially if strength isn't your priority, you have little to gain from training with a higher intensity and much to lose.

In general, for muscle growth it's prudent to stick with exercises with a good tissue stress distribution, notably cable and suspended exercises, a controlled tempo and relatively light weights, for at least several weeks after you're fully pain-free. These strategies are highly effective to reduce connective tissue stress while having minimal effect on muscle growth, so it rarely pays off to take chances with riskier alternatives. As soon as you have a program that's sustainable and near-optimal for muscle growth, it's typically best to stick with that for as long as it results in good progression. Only start taking more risks when progress stalls.

For strength development, you may want to start incorporating higher-intensity exercise sooner, as lifting heavy is much more important for strength than for muscle growth. Given the high injury potential of exercises like the powerlifts, and most barbell exercises in general, you may have to compromise on volume to keep the overall connective tissue stress manageable.

The following flowchart summarizes the rehabilitation process of training injuries.



A general template for the rehabilitation process.

Nutrition

Since your diet affects your recovery capacity, your diet most likely influences the recovery from injuries as well. We say 'likely', because it's difficult to perform RCTs on overuse injuries: you can't ethically induce injuries after all to perform a study. As a result, there's little good research to say whether a good diet can significantly speed up your recovery from an injury. Mertz et al. (2025) no significant effect of protein intake on recovery from muscular strains. The body efficiently prioritizes resource allocation, so it's possible that injuries will heal well even with suboptimal nutrition, as the body may take protein and other substrate from other body parts to heal injuries. Thus, it's likely that anything you'd want to do diet wise to recover from an injury, you should be doing anyway. Concretely, research has identified the following factors as likely beneficial for musculoskeletal recovery [2].

- Consume enough protein.
- Consume an overall anti-inflammatory diet with plenty of vegetables and/or fruits.
- Consume enough omega-3s.
- Maintain good gut health by eating a varied whole-foods based diet rich in dietary fiber and possibly fermented foods with probiotics.

Again, these are all things you should be doing anyway for your recovery, health and wellbeing, so nutritionally, often nothing changes when you're injured.

During major injuries where you cannot train a significant part of your body, you should avoid high energy deficits to minimize muscle loss. However, high energy surpluses are also risky, as fat gain is more likely when your training volume is low. So regardless of whether you want to cut or bulk, you want to gravitate a bit closer to maintenance energy intake when seriously injured. For minor injuries that do not preclude you from training with your regular training volume, regardless of whether your program is altered, you generally don't need to change your energy intake for the injury. The injury might heal faster when bulking, but it often doesn't warrant a change in goals. Energy balance affects recovery capacity and protein balance, but your body should prioritize protein balance in damaged tissues over other tissues, so you can recover from an injury in energy deficit.

Surgery

In case the above approach does not result in significant rehabilitation over time, it is highly advisable to have imaging scans (e.g. MRI, x-ray) done on the injured body part to determine the extent of the damage, as surgery may be needed. Beyond a certain amount of tearing and especially in the case of a complete rupture of a muscle, bone, tendon or ligament, surgery is required to restore functionality. There is a limit to the amount of tearing that the body can naturally heal without mechanical assistance. Often the severity of pain and impairment in functionality make it obvious from the start of injury that you're dealing with a major injury. However, you should always do imaging scans first and you should view **surgery as a last resort** for when more conservative rehabilitation is highly unlikely to succeed. There is generally no harm in delaying surgery until less invasive options have been tried [2]: the surgery will be equally effective later on. Even grievous injuries often heal over time. For example, 2 out of 3 herniated spinal discs fix themselves by reabsorbing and even massively prolapsed discs often don't require surgery [3, 4, 5].

No NSAIDS?

Non-steroidal anti-inflammatory drugs (NSAIDs) are highly popular as a first-line treatment for pretty much any type of athletic injury. NSAIDs function as painkillers (analgesics) and anti-inflammatories. Note that these are different effects. Painkillers reduce pain directly in the nervous system or by reducing pain signaling compounds like prostaglandins, not as a result of actual healing of the injury. Many studies only look at improvements in pain as the patient outcome and then conclude that NSAIDs are a very effective treatment. And that's probably what most doctors only care about anyway: no more pain, the patient stops whining and over time the vast majority of injuries heal on their own, so case closed.

However, NSAIDs are not effective at speeding up actual tissue recovery from musculoskeletal damage [2]. For example, ibuprofen has no effect on gene expression of collagen and related growth factors in human tendon. It just numbs your pain. In fact, there are many studies in which NSAIDs **delay** the healing process. Inflammation is a critical component of the immune system and your body's healing process is thus suppressed when you take anti-inflammatory drugs.

NSAIDs can also suppress muscle growth at high doses. Ibuprofen in particular has been found to suppress muscle anabolic signaling, protein synthesis, muscle hypertrophy and strength development at doses of 1,200 mg per day. Ibuprofen has also been found to blunt muscle hypertrophy in rats. However, lower doses are likely not a problem. Multiple studies on 400 mg, the standard 1 tablet serving for mild pain, have not found any impairments of muscle growth. Aspirin doesn't appear to be any better: 1,200 mg of ibuprofen has similar effects on our muscles as 75 mg aspirin per day.

Paradoxically, one human study in older adults (60-77 years old) reported that 1,200 mg ibuprofen and 4,000 mg paracetamol consumption per day *improved* strength development and muscle growth. The authors speculated that since elderly individuals often have chronic inflammation, suppressing this inflammation may have been beneficial. In younger individuals, suppressing inflammation is more likely to be net detrimental, as there's little chronic inflammation to suppress, so NSAIDs will just suppress the acute inflammatory signal for muscle repair, thereby blunting strength training adaptations. (Remember the signal-to-noise theory of inflammation from the Energy module of the course?) However, since paracetamol/acetaminophen only has very weak anti-inflammatory effects and is often not even considered an NSAID, an alternative explanation for the greater gains in the elderly painkiller groups is that they could train harder without pain. Painkillers, including paracetamol, have been found to acutely improve exercise performance in some settings, although the effect is mostly limited to endurance training with minimal effects on strength training. An ergogenic effect is more likely in people with chronic pain or injuries. High doses of paracetamol could still reduce our gains though: 4,000 mg of paracetamol per day has been found to significantly blunt post-exercise muscle protein synthesis. It's still unclear by which mechanism paracetamol affects protein synthesis, so based on the current research, paracetamol is the painkiller of choice for lifters, assuming there are no other medical considerations.

NSAIDs are not useless though. NSAIDs can sometimes facilitate healing during the acute stage of an injury and during very severe inflammation, when some injuries aggravate themselves. When swelling and inflammation are severe, they can damage the surrounding tissue. Temporarily suppressing inflammation prevents this from happening.

In the average person, suppressing pain also benefits the healing process by letting the person stay active. Mild activity can be beneficial, especially in an otherwise completely sedentary person, but it's not so beneficial when it makes you believe you can deadlift again when your spine is still damaged.

In further contradiction of always taking painkillers, NSAIDs can cause a wide range of side-effects. Most side effects aren't life threatening, so most doctors don't take them very seriously. One of the major side effects is damage to your stomach. For musculoskeletal injuries, you generally want to start with topical NSAIDs, like diclofenac cream, instead of the oral formulations, if you want to use them in the first place. Topical formulations can be just as effective in the injured body part without collateral damage in the whole body.

Alternatively, take paracetamol/acetaminophen. It is similarly effective as a painkiller and is safer and less likely to reduce your gains, because it's only weakly anti-inflammatory.

Cryotherapy

So far we've covered why most of the standard advice when you're injured is misguided for strength trainees. Now that we've covered the R (rest) in RICE, but what about icing and elevation?

These things all accomplish essentially the same thing: reducing blood flow and slowing down inflammation. A fundamental rule of chemistry is that the speed of a chemical reaction is proportional to the temperature in which it takes place, so lower temperatures slow down your biochemistry. That's great if you lost a finger and you need to preserve it until you can get it put back on, or if you're being operated on a large wound and you have a lot of exposed tissue that you don't want to rot or get infected, but slowing down your biochemistry means slowing down your recovery. Direct RCT studies in humans are scarce, because it's unethical to induce injuries, but the available research, in particular the animal research, demonstrates icing soft tissue injuries increases the time to full recovery by blunting immune system activity and muscular repair [2, 3]. Icing also seems to aggravate scar tissue formation. Furthermore, post-workout cryotherapy can reduce muscle growth and strength development [2, 3, 4] by blunting anabolic signaling and increases in muscle protein content [3, 4], though not all research finds negative effects. A 2022 meta-analysis compared cold water immersion AKA cold plunges to multiple other recovery methods. Cryotherapy did not significantly affect perceived recovery or strength recovery over 72 hours; however, all effect sizes for strength recovery were considerably negative, suggesting impaired recovery from the cold. (Don't be fooled by the abstract.) Any improvement in post-workout recovery with cryotherapy is likely a placebo effect. You may feel less pain, DOMS and swelling, but objective performance generally doesn't recover faster. Even after knee ACL reconstruction surgery, meta-analytic research finds no benefit of icing on objective recovery markers, including range of motion and drainage.

While cryotherapy does not have much use for general recovery enhancement, it has a niche application for athletes competing multiple times in the same day. The swelling and pain that occurs after tissue damage, whether it's from an injury or regular muscle damage, can limit your range of motion and performance. Cryotherapy can reduce the swelling and pain, essentially delaying the recovery process for a few hours, and thereby preventing maintaining neuromuscular performance at a higher levels during bidaily events in a sports competition. Endurance athletes training in the heat have the most to gain from this strategy, because cryotherapy helps the body recover from hyperthermia and reactivate the parasympathetic nervous system after intense central fatigue.

However, any such benefits after temporary. Effectively, the recovery process is simply delayed, not improved. In the hours and days afterwards, cold water therapy (cryotherapy) often does not improve muscular recovery after exercise [2]. Cold reduces the speed of cellular reactions, so it's more likely to slow down than to speed up recovery. Research has found that cold water immersion "greatly reduces microvascular blood volume, which is strongly related to a lower post-prandial amino acid incorporation in skeletal muscle protein in recreationally active males. Cold-water immersion should be avoided during post-exercise recovery". Suppressing swelling is also not desirable, because swelling is inherently a beneficial response to injury. Swelling is the result of blood vessel dilation and permeability during inflammation, effectively opening up the circulatory system so that white blood cells and proteins can easily reach the site of injury. The fluid that builds up in the surrounding area serves as a 'waste bin' for dead cells and other waste products. Much of this waste fluid ends up in the lymphatic circulatory system, which has no pump like the heart to keep it going. It relies on bodily movement to stay active. So the real problem is inactivity, not swelling. Swelling is beneficial for the injured site to get rid of its waste products, but without bodily activity, the waste accumulates and cannot be drained out. Icing can exacerbate the problem when there is already swelling by slowing down your biochemistry. A better approach normally is to allow any swelling to happen while implementing active recovery to facilitate the body's healing process and drainage of the swelling.

In conclusion, cryotherapy is inadvisable as a regular recovery strategy for muscular recovery or minor injuries, as it delays the healing process by suppressing the immune system, reducing muscle protein synthesis and slowing down biochemical reactions.

Heat therapy

If post-workout cryotherapy reduces muscle growth and strength development by slowing down our biochemistry, does heat therapy improve our gains?

Heat can speed up the body's recovery process, notably including the proliferation and differentiation of satellite cells that assist in muscular remodeling. Greater activity in individuals cells may not translate into more macro-level adaptations in the tissue as a whole though. While some research finds post-workout heat therapy can improve neuromuscular recovery, just like with cryotherapy, the benefits are inconsistent and relative to passive control groups. Most benefits are observed for subjective measures like pain without any effect on objective performance. Post-workout hot water immersion does not increase myofibrillary protein synthesis. Warmth can make us feel comfortable, but it doesn't seem to help our muscles recover faster in practical settings. The few studies that do find positive effects are for novel endurance training and eccentric-only training that induce major muscle damage. Even then, placebo effects are likely and the heat therapy protocols required wearing heat wraps for 8 hours or daily 14-minute hot water immersion up to the neck. That's a lot of effort for a likely trivial benefit.

Long-term research supports that any benefits of heat therapy are purely subjective: while subjects often report *feeling* better recovered, heat therapy does not seem to objectively increase muscle growth or strength development [2].

However, in rats, where researchers can do more controlled studies because they can induce injuries, we see much more significant benefits of heat therapy on muscular recovery.

In practice, heat therapy may be worth it if you can't implement active recovery. Active recovery likely makes heat therapy redundant in most cases, as it increases temperature and blood flow more effectively, but if you can barely move a body part at all or an injury has become very swollen, heat may slightly aid recovery.

For a full overview of the effects of heat and cold therapy related to strength training, see the research overview below. Contrast water therapy, which involves alternating heat therapy with cryotherapy, seems to have similar effects as heat therapy.

➢ Research overview

[Heat/cold therapy for strength training]

Low-level laser therapy

Lasers have a wide range of modern applications. The most established form of laser therapy is arguably high-level laser therapy. High-level laser therapy produces high heat and can be used to destroy tissue. In exercise science, cold low-level lasers have gained interest as a potential means to promote tissue activity and recovery. Low-level laser therapy (LLLT) specifically refers to the use of an (infra)red laser beam or light-emitting diodes (LEDs) with a wave-length of 600-1000 nanometers and power of 5-500 milliwatts. The laser is supposed to induce a photochemical reaction in our mitochondria whereby the power of the laser induces chemical reactions to increase cell energy production.

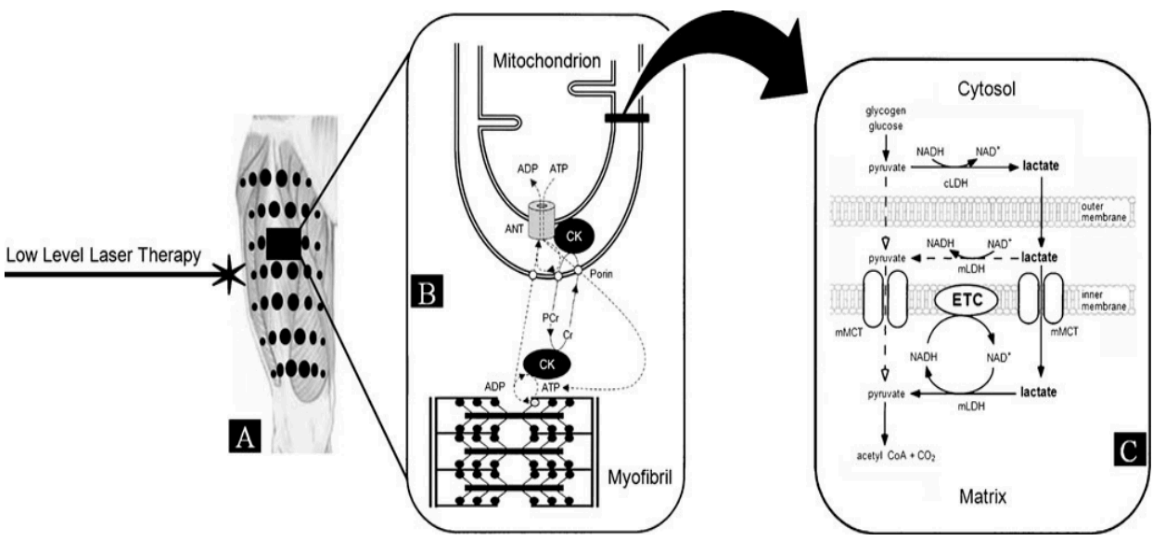


Fig. 5 *A* Application points for LLLT on the femoral quadriceps muscle. *B* Mitochondrial creatine shuttle mechanism. In this mechanism, creatine (*Cr*) is transported from the ATP-utilizing sites (e.g., myofibrils) to the mitochondria, and the phosphocreatine (*PCr*) is transported in the opposite direction. Due to the presence of creatine kinase (*CK*) in the inner mitochondrial membrane, the creatine reacts with ATP produced during oxidative phosphorylation and resynthesizes phosphocreatine. This process increases the ADP concentration and it in turn stimulates respiration. However, the phosphocreatine decreases the ADP concentration and respiration (*ANT* adenine nucleotide translocase) (modified from Tonkonogi and Sahlin [27]). *C* Lactate oxidation in the mitochondrial pathway. The lactate is transported to the intermembrane space or directly to the mitochondrial matrix, where it is oxidized to pyruvate by NAD^+ and this reaction is catalyzed by lactate dehydrogenase mitochondrial enzyme (*mLDH*). The reduced NAD (*NADH*) is oxidized in the electron transport chain (*ETC*) and provides electrons and protons for the aerobic production of ATP (*mMCT* mitochondrial monocarboxylate transporters) (modified from Brooks et al. [31])

Proposed mechanisms of action of LLLT. [Source]

The application of low-level laser therapy with a portable device. Source

Is LLLT another form of quackery or an upcoming wonder of modern technology?

Vieira et al. (2019) found that a minute or so of low-level laser therapy on the biceps significantly improved biceps 1RM strength development over an 8-week training program in untrained, young men. However, the difference was no longer significant compared to a sham, inactive laser group when controlling for baseline 1RM strength. The laser therapy group did not improve work capacity or increase training volume. Since the most plausible theory at the moment is that LLLT improves performance or recovery rather than somehow directly enhance neuromuscular adaptations, it's difficult to see how the laser therapy could have improved strength development.

Vanin et al. (2016) researched the effect of LLLT pre-, post-, pre- and post-workout and at neither time (4 groups) over a 12-week strength training program in untrained males. LLLT did not consistently improve 1RM leg press or leg extension strength, maximum voluntary contraction (MVC) strength or thigh muscle size (perimetry). While there was a significant effect of pre-workout LLLT compared to placebo for the strength measures, this group also outperformed the pre- and post-workout LLLT group, indicating the effect was probably not related to the LLLT. It was also a spurious effect – if you do enough tests, some will turn up significant – because the placebo group achieved significantly greater right leg 1RM leg press strength increases than the post-workout and pre- and post-workout LLLT groups.

Toma et al. (2016) tested the effect of post-workout LLLT on strength training adaptations over an 8-week training program in elderly women. While the researchers make it sound as if the laser therapy was beneficial, the cold laser therapy did not significantly improve work output, power, work capacity, peak torque, functional performance during a walking test or 1RM strength development compared to a sham laser.

Ferraresi et al. (2011) studied a 12-week leg press training program with or without post-workout LLLT on the quadriceps in recreationally active young men. LLLT improved 1RM leg press strength development but not peak torque of the knee extensors or thigh size (perimetry). Since there was no sham LLLT therapy group, the greater leg press strength gains may have been a placebo effect.

Baroni et al. (2015) studied an 8-week leg extension training program with or without pre-workout LLLT on the quadriceps in untrained, young men. There was no significant difference in the increase in the absolute sum of muscle thicknesses between groups, but when expressed as a percentage change from baseline, the LLLT group showed a significantly greater increase of 15% vs. 9%. Similarly, neither concentric, isometric or eccentric peak torque changes showed a significant between-group difference in absolute terms, but when expressed as a percentage, LLLT increased isometric and eccentric peak torque development. Since there was no sham LLLT therapy group, the potentially greater gains may have been a placebo effect.

Croghan et al. (2019) investigated the effect of 3 different LLLTs on body composition and mental health. None of the laser therapies significantly affected any marker of body composition, motivation, body satisfaction or quality of life, despite the authors' best efforts to make it sound like the laser therapy did something.

Several Cochrane meta-analytic reviews on LLLT for various musculoskeletal conditions have come to the conclusion of 'insufficient evidence for use'.

Overall, LLLT shows some promise, but any inconsistent benefits cannot be said to be more than placebo effects at this time. It's also unclear how exactly the laser therapy should be implemented (what wavelength etc.), if it should be applied pre- or post-workout and by which mechanism of action it could help muscle growth or strength development, as the proposed effects on performance and fatigue are unreliable.

Portable devices are commercially available for personal use, but few have been officially approved and validated in scientific research.

Rehabilitative equipment

Compression garments

Compression garments, such as knee and elbow sleeves or full-body compression suits (superhero style) could promote recovery via 2 mechanisms.

1. Promoting blood flow by keeping the compressed area warm.
2. Reducing swelling and edema, if there is enough compression.

Neither mechanism is particularly compelling for regular use. Warmth can also be obtained from regular clothing, movement or just the ambient temperature, if it's necessary in the first place to provide more than internal heat. Reducing swelling may reduce strength losses following exercise but does not promote actual tissue repair. Much like cryotherapy and NSAIDs, it may even impair tissue turnover by slowing down the healing process, as edema and inflammation are natural components of the body's healing process. Excess compression may also negate the benefits of the extra warmth, because excess compression can reduce blood flow.

Elbow and knee sleeves are popular forms of compression garments.

In line with the uncompelling theory, a 2022 meta-analysis concluded "wearing compression garments during or after training does not seem to facilitate the recovery of muscle strength following physical exercise.” An earlier 2017 meta-analysis did find slightly higher performance in the hours and days after exercise after the use of compression garments. The fact that performance was already higher in the hours after exercise suggests the main mechanism was suppressing swelling rather than promoting quicker recovery by enhancing blood flow. Thus, it may be more accurate to say the earlier analysis found evidence that compression ‘delays’ the healing process rather than promotes recovery, akin to cryotherapy.

Another benefit of mildly compressive garments unrelated to recovery is that they may promote proprioception. For example, knee sleeves have been found to increases proprioceptive awareness in the knee: it makes it easier to sense what position your knee is in. The word proprioception comes from the Latin *propius* meaning “one’s own” and *ceptus* meaning “the act of receiving”. Greater proprioception may enhance joint stability during exercise and thereby reduce connective tissue stress and injury risk.

In conclusion, compression garments won’t do much for your recovery, but it’s possible that they help a bit, primarily simply by keeping the compressed area warm. The compression garments have to be worn for many hours to have any considerable effects. As such, daily usage to improve full-body muscular recovery from regular workouts has a very poor cost-benefit, unless you enjoy going through life dressed as Spiderman. However, in the case of an injury, every little bit of help may be welcome. Wearing light compression garments that do not restrict movement or blood flow may slightly improve recovery of an injury. Light sleeves may also enhance proprioception, indirectly contributing to better recovery by reducing the stress on a damaged joint. There’s no need to buy expensive sleeves. There’s nothing magical about them. Cutting up an elastic sock can make for an excellent knee or elbow sleeve.

Wraps and tape

Wraps and tape are stronger forms of support. They are designed to provide stability to the joint and provide a considerable amount of passive, elastic force during exercise. The passive force contribution of wraps and tape can make you capable of lifting heavier weights, which can in turn put more stress on your connective tissues, much like powerlifting knee wraps (see course module on training gear).

Wraps generally also disrupt your natural biomechanics because they limit the freedom of motion around the joint.

Additionally, wraps generally occlude the muscles distal to the wraps, e.g. if you wrap your elbows, you prevent blood flow from returning from the forearms. (See the course topic on KAATSU training for more details on blood flow occlusion.)

These differences from sleeves make wraps ineffective at improving proprioception or blood flow and therefore unsuitable for use during musculoskeletal injury. Indeed, taping is generally no more effective than placebo at improving recovery from musculoskeletal disorders [2]. The placebo effect is powerful enough to make people feel stronger and more invulnerable though.

The effects of wraps and tape make them primarily suitable for severe joint injuries where the joint no longer has full function and full range of motion. By inhibiting the painful range of motion of the joint with wraps or tape, you prevent aggravating the injury.

For example, a thumb sprain during front squats due to the bar excessively stretching the thumb will generally benefit from taping to prevent the thumb being stretched to the injurious position again. This can allow you to keep training without having to worry as much about aggravating the injury.

Tape and wraps can often easily be applied yourself. Look at a few YouTube tutorials for that body part or just use common sense and apply the tape in a manner that limits any undesirable movement.

Braces and casts

Braces and casts are generally even more rigid than wraps and tape, rigid enough to practically completely prevent mobility in the joint, but they do not restrict blood flow.

They are thus suitable when an injury is severe enough that mobility needs to be limited chronically. This is often the case during joint sprains and broken bones. Bracing can also help when you tend to put your joints in stressful positions during your sleep, like when lying on your elbow.

Since braces immobilize a joint and thereby prevent blood flow and tissue turnover, they impair recovery, so you should take them off or loosen them as pain-free ROM increases.

Massage

Much like stretching, when it comes to massage, people rely heavily on how it feels instead of evidence. In this case the evidence, albeit inconsistent, does support a slightly beneficial effect of massage on muscular recovery after exercise [2].

Physiologically, massaging muscles is effectively no more than the application of mechanical pressure. This increases skin temperature and may enhance blood flow, thereby speeding up the removal of metabolic waste products and tissue turnover. Massage's benefits are particularly evident during short-term recovery, such as in between sports matches, with far less notable benefits seem for longer term recovery.

Most of the benefits of massage are likely psychological, not physiological, since reductions in pain and improvements in subjective recovery are greater than the actual recovery of physical muscle functioning. Modulation of the muscle's neural state may also play a role, but this is of questionable practical relevance. In other words, a massage can make you feel more relaxed and reduce your perception of pain, but it doesn't do much to physically make your tissues heal faster. For athletes, reductions in DOMS can indirectly improve performance, as DOMS makes fine motor control and explosive movements more difficult, but the difference in repetition performance with strength training is often trivial.

The physical benefits of massage are comparable to or perhaps slightly greater than those of active recovery and almost any other recovery technique, such as heat-cold contrast water treatment [2]. In effect, massage is very much like heat therapy: it doesn't do much other than increasing a body part's temperature. So regularly spending money on a massage for better recovery is probably not worth it for most people. You'd be better off going for a walk, if the inconsistent and small benefit of either is worth even thinking about.

Overall, sports massage may have positive effects on muscular recovery that could speed up the rate of muscle strains. For other injuries and recovery from daily training, the cost-benefit of regular massages is arguably very poor for non-professional athletes. If you enjoy it, by all means get a massage, but physically it won't meaningfully improve your gains as a strength trainee.

Foam rolling

Foam rolling is an interesting and relatively recent form of massage or 'tool-assisted manual therapy'. It is a form of self-myofascial release. The mechanisms of how it works, not to mention whether it works at all, are still controversial. The essence of the practice is that you apply a great deal of pressure on 'trigger points', areas where applying pressure is particularly painful. This is supposed to somehow 'release' these areas and improve flexibility or muscle function. Foam rolling has quickly become very popular because it appeals to the gadget-loving functional training and rehab crowd, while simultaneously appealing to the hardcore strength training crowd due to the high amount of pain involved.

As discussed in the course section on weighted stretching, it is highly unlikely that the fascia can be effectively released or lengthened in any way: "a predicted normal load of 9075 N (925 kg) and a tangential force of 4515 N (460 kg) are needed to produce even 1% compression and 1% shear. Such forces are far beyond the physiologic range of manual therapy." As expected based on this knowledge, foam rolling does not increase muscle fascicle length or fascial stiffness in research. So any benefits of 'myofascial release' are probably due to manipulation of the neuromuscular system and the term myofascial release is a misnomer.

We really only know 2 things about foam rolling with a great deal of certainty [2].

1. Foam rolling acutely increases flexibility without decreasing muscle strength [2]. Much like stretching, foam rolling makes the nervous system more compliant with muscle lengthening, but foam rolling does not come with the downside of reducing performance [2].

2. Foam rolling increases your pain threshold (lots of pain tends to do this). This is a major red flag, because as we've seen in the research on stretching, many of the benefits of stretching are simply because of an increased pain threshold. This also explains many positive anecdotes about foam rolling where they feel immediate relief from an injury. Did it help the injury or did it just decrease the pain?

Foam rolling is thus very similar in effect to static stretching but without the negative effect on performance.

In line with its neural mechanism of action, foam rolling has partly systemic effects on flexibility and pain tolerance. Aboodarda et al. (2015) tested the effect of foam rolling a very painful spot on the calves (supposed trigger point). Foam rolling decreased pain sensitivity, which foam rolling proponents commonly attribute to the release of the fascia or breaking up of scar tissue. However, in another group of the study, the contralateral (other) leg was foam rolled. Foam rolling 'the wrong leg' also significantly reduced pain sensitivity in the trigger point of the other leg. There was also no difference in the effectiveness of foam rolling compared to heavy manual massage. Obviously, any effect of foam rolling one leg on the other leg can't be the result of scar tissue, fascial adhesions or any plausible local mechanical effect. These findings strongly support that foam rolling's mechanism of action is in large part a full-body increase in pain threshold, presumably regulated via activation of the parasympathetic nervous system.

Flexibility

Foam rolling increases flexibility. Compared to doing nothing, at least. Yet compared to a traditional low intensity cycling warm-up, foam rolling is not superior at increasing hamstring flexibility. Or compared to mock electrical stimulation (placebo). Or compared to a dynamic stretching warm-up. And compared to static stretching, foam rolling has no additive effect on strength, stiffness or flexibility. A 2024 systematic review and meta-analysis found that foam rolling was no more effective than any other warm-up intervention to improve range of motion and decrease muscle stiffness. Anything that increased muscle temperature had similar effects: jogging, bicycling, electrical muscle stimulation, even taking a warm bath. So foam rolling can be used as warm-up, but it doesn't seem to be any better than more conventional warm-ups for this purpose.

The flexibility enhancement of foam rolling also appears to be short term and passive in nature. Long-term foam rolling increases passive flexibility (though there's no additive effect when you're already static stretching), but foam rolling does not increase active range of motion. So foam rolling may make you better at stretching, but foam rolling doesn't normally increase your squat range of motion. This suggests again that, just like stretching, foam rolling increases your neural stretch tolerance without any actual benefit to tissue extensibility. The benefits for dynamic exercises are thus limited and transient.

Foam rolling any body part can also increase flexibility in another part of the body. For example, foam rolling the hamstrings can increase shoulder extension range of motion for ~10 minutes. Foam rolling's effect on untreated body parts supports that its mechanism is in significant part central, namely an increase in autonomic central nervous system activity AKA 'rest and digest mode'. Some of the effect may also simply be the result of increased body temperature.

In conclusion, unless you have a severe flexibility issue that prevents you from using full ROM during any exercise that you want to do and you've found that foam rolling noticeably improves this ROM, you probably don't have to bother with foam rolling to improve your flexibility.

Recovery

A 2019 meta-analysis found foam rolling does not improve the recovery of strength training performance [2]. Moreover, there is no established mechanism by which foam rolling would improve the recovery of our muscle tissue, only speculation. Muscle contractile properties seem to be either unaffected or even negatively affected by foam rolling.

Some inconsistent research shows promise for foam rolling to improve recovery of sports performance, notably sprinting, but since muscle contractile strength does not increase correspondingly, improved sports performance is likely the result of reduced pain and muscle soreness, rather than actually physiologically improved recovery. A higher pain threshold can improve muscle activation as well as willingness to exert force. This would also explain why pre-workout and post-workout foam rolling appear to be equally effective to reduce fatigue after a workout: there's no improved recovery, only reduced pain, which masks the effect of fatigue on performance. Placebo effects are also plausible.

Vibrating foam rollers might work better than regular foam rollers, as the vibration essentially adds massage and light active recovery to the foam rolling. However, a 2022 meta-analysis found that vibrating foam rollers still don't improve the recovery of objective performance, although they did seem to improve some indirect markers of recovery, such as pain.

In conclusion, foam rolling does not seem to improve physical muscular recovery.

Performance

A main benefit of foam rolling over static stretching is that foam rolling does not decrease neuromuscular performance the way static stretching does by creating a neural state of relaxation instead of excitability. However, there's also no established mechanism by which foam rolling could improve performance. Multiple meta-analyses from 2019 [2], 2020 and 2021 [2] and a 2022 systematic review support that foam rolling before a strength training workout does not significantly affect performance.

However, foam rolling performed during a workout in between sets decreases performance in multiple studies, even when you foam roll the antagonist instead of the agonist musculature [1, 2, 3, 4]. Leg extension performance can decrease when foam rolling either the quads (agonists) or hamstrings (antagonists), for example, indicating the negative effect may be due to induction of a parasympathetic state of the central nervous system ('relaxation mode'). In one study by Da Silva et al. (2019), the detrimental effect did not reach statistical significance though. Curiously, Santana et al. (2020) even found a positive effect of inter-set foam rolling on strength training repetition performance, but it didn't matter if the agonists, antagonists or both were foam rolled, so this was probably a general warm-up effect or a fluke.

Overall, the literature supports that foam rolling before your workouts does not affect performance but during your workouts it's detrimental.

Practical application

So what's the bottom line? Doing regular foam rolling without a specific purpose is most likely a waste of time, just like stretching. It mainly just increases your pain threshold and neural stretch tolerance. This can provide a sense of acute relief and pain reduction, but this is not indicative of actual tissue healing, just a change in the nervous system.

However, anecdotally, foam rolling can sometimes help when something feels off and tight in a muscle (as opposed to a tendon or joint) and especially when you can literally feel a hard bump or 'knot' in the muscle belly. Focus specifically on areas of pain or so called 'trigger points' that are only there on one side and not the other. Simply foam rolling what hurts isn't very instructive, as certain areas like your IT-band hurt like hell, but foam rolling that area generally doesn't achieve anything useful.

When you've found a potential trigger point, think massage, not mutilation. Foam rolling with only 4/10 pressure pain is just as effective as using higher and more painful pressures. You should assess improvements in symptoms, notably pain and ROM, over the span of the day and the next days, not acutely. Acute sense of relief and immediate pain reduction do not mean anything other than that your pain threshold has increased. Sometimes it helps, often it doesn't.

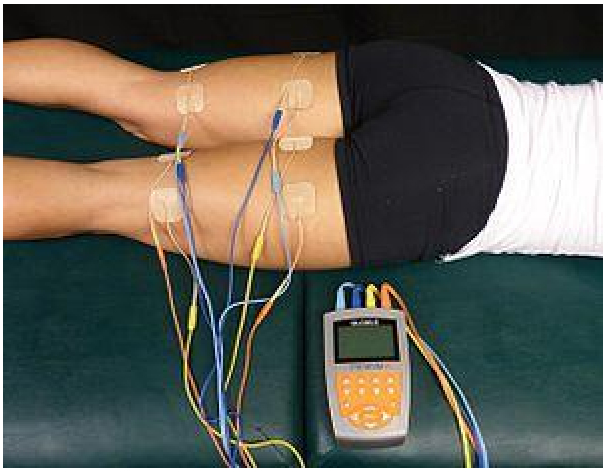
Chiropractic

For some reason, chiropractic has achieved the reputation of evidence-based medicine in the fitness community. It is not. It is alternative medicine and, in many aspects, it is right up there with homeopathy and acupuncture. Chiropractic doctrine teaches that virtually all pain is because either a nerve or a bone, often the spine even, has gotten out of place. Subluxation (dislocation) of a nerve or structural displacement of a bone is in fact a grievous injury and not remotely as common as many chiropractors say. So be critical of doctors, like anyone else, and be particularly critical of chiropractors.

On the bright side, there is a growing community of evidence-based chiropractors. If you're thinking of hiring a chiropractor, here's how to select a good one.

Electrical muscle stimulation

If you're so injured you can't do any resistance training, it's worth considering electrical muscle stimulation (EMS, also known as neuromuscular electrical stimulation (NMES)). An EMS device effectively takes over the role of your motor cortex by sending electrical signals from adhesive pads on your skin to the underlying muscle, thereby activating them. A 2021 systematic review concluded EMG can result in significant strength development and muscle growth, but some research finds EMG does not put enough tension on our muscle fibers to cause robust muscle growth and the gains are primarily neural adaptations. Electrically induced muscle contractions usually reach only 40–60% of the maximum voluntary contraction, so it's hard to see how EMS could rival maximal-effort strength training. In direct comparison to strength training, one study by Matos et al. (2022) found strength training did not cause statistically significantly more muscle growth than EMS training, yet the increase in muscle thickness was over twice as large in the strength training group as the EMS training group, and the strength training was not even performed to failure.



EMS.

EMS can also be combined with strength training: you can lift while the electrodes are stimulating your muscles to contract at the same time. A 2025 meta-analysis found that superimposing EMS during resistance training programs increased muscle growth and strength development. However, the effect sizes were small and in multiple studies, strength training with concurrent, superimposed EMS did not provide significantly greater gains than just strength training [2, 3]. Strength training should already result in maximal levels of muscle activation and muscular tension, so the use of EMS during strength training should be redundant. Most studies had the participants train very submaximally, not doing as many repetitions as they could. It's mechanistically highly questionable if EMS could improve upon maximal effort training. Plus, due to the involuntary activation of the muscle fibers, EMS can disrupt your motor patterns, so it's questionable to use it during complex, dynamic exercises. EMS is often only used for isometric exercise.

An isometric squat with EMS.

EMS training also does not provide significant 'functional' strength gains according to a 2022 systematic review, because it does not teach your body how to move. It only provides an electrical stimulus to activate a muscle, but it does not teach the body how to coordinate that activity along with other muscles. The strength development in the trained muscle thus carries over poorly to other exercises, daily life or sports activities.

In conclusion, EMS generally only useful as a last resort substitute for strength training when you're seriously injured. For healthy trainees, traditional resistance training is more effective and practical.

Motor imagery training

If you don't have an EMS device and you can't train a body part well, you can just imagine training it. That's not a joke. Motor imagery training constitutes of essentially nothing more than visualizing a training session in your head, and it works. A 2018 meta-analysis found that compared to not training at all, motor imagery training improves strength and power. Later research found motor imagery training also prevents the regression of strength and power during detraining in trained individuals. Of course, the effects are nothing like those of actual training and you're only training the nervous system, so it can help with performance but not with muscle growth. Adding motor imagery training to actual training also did not improve performance in the meta-analysis. One later study by Slimani et al. (2017) found that combining mental and physical training did lead to greater performance improvements than just physical training in kickboxers, but the mental training included not just visualization but also motivational self-talk, so it's plausible the benefits were primarily due to enhanced physical training rather than the imagined training. Overall, you likely don't have to bother with motor imagery training if you can still do real training.

The key to make motor imagery training successful is to make it very vivid. Imagine the feeling of the bar when you grab it, the cues you use when you squat down, the extra push during the sticking point, etc. You should visualize essentially your entire training session from a first-person point of view as if you were experiencing it. This will cause your brain to consolidate the motor pattern, similar to what happens during your sleep. The adaptations are highly specific, just like those of actual training. The strength you get from visualization is movement-specific and intensity-specific [2, 3, 4]: imagining heavy lifting is better for strength, whereas imagining power training is better for explosiveness. There is also a dose-response relation between the visualization practice and the strength increases: more practice results in greater strength gains. This means motor imagery training is just as time-consuming as real training yet far less beneficial. Since it also only aids strength development, it's arguably mostly relevant for elite athletes that absolutely have to minimize any detraining that occurs when they're injured. Wakefield & Smith (2012) provide extra reading on the implementation of motor imagery training for those interested.

Strains & sprains

Before going into specific joints and injuries, we have to discuss the distinction between sprains and strains. A strain is a damaged muscle, also called a pulled muscle. Very bad strains can result in muscle tears and a complete muscle tear off the bone is called a rupture. A sprain is a damaged ligament. Both are acute injuries and are generally caused by high forces on the tissue while it is stretched, especially after an insufficient warm-up. So you can sprain a joint and you can strain a muscle.

Common sprains as a result of weightlifting occur in the wrist, ankle and fingers. Unless they are extremely mild, they usually require some taping or bracing to avoid putting the joint in the position where it sprained before it has healed.

Strains can occur in all muscles and are often the result of overstretching under load or insufficient warm-up. They are usually mild and like all forms of muscular damage, they heal rapidly and respond well to active recovery and heat due to the high recovery capacity of muscle tissue.

The hamstrings strain relatively often because they can be stretched to great lengths, produce a lot of force and are involved in a lot of movements. However, there is nothing unique about them physiologically. The only significant predictors of hamstring strains are weak hamstrings (weaker muscles are easier to tear), previous injuries (previously torn muscles are easier to re-tear, especially during the rehabilitation period) and age (elderly individuals are generally at a greater risk of injury: see the course module on working with the elderly). To emphasize, **flexibility is not consistently associated with (hamstring) injury risk.**

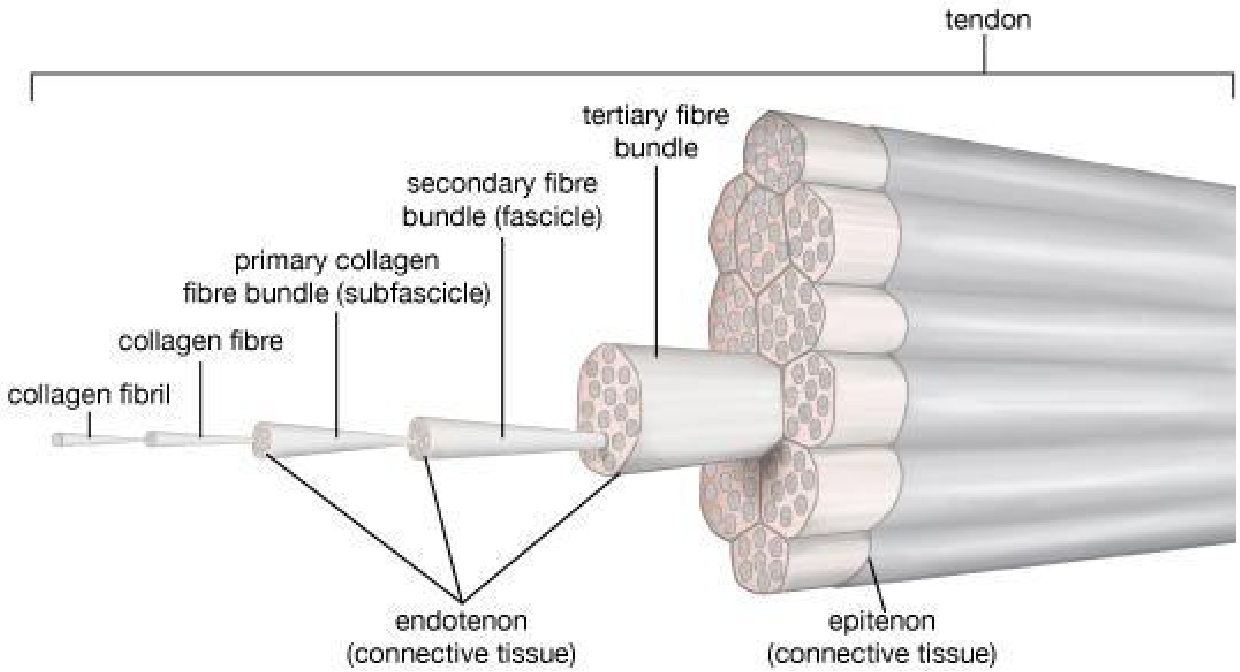
For mild strains without bruising and noticeable swelling, you can generally train through some pain as mentioned before. Instead of avoiding pain altogether, just avoid exercises that *aggravate* the pain.

Treatment of strains and sprains, when surgery isn't needed, follows the general principles outlined above.

The elbows

The knees and the elbows are the hinge joints of the upper and lower limbs. Since they have a similar anatomy and function, they tend to suffer the same kind of injuries. And the most common injury by far is tendinopathy (‘tendon problem’), commonly misdiagnosed for tendinitis (acute inflammation). Tendinopathy is not merely an acute inflammatory problem (like tendinitis) but a chronic and degenerative condition involving tendinosis. Almost all tendon problems involve inflammation as well as degeneration, so tendinopathy (tendon problem) encompasses both tendinitis (inflammation of the tendon) and tendinosis (chronic degeneration of the tendon). The terms tendinitis and tendinosis have therefore fallen out of favor in evidence-based physical therapy.

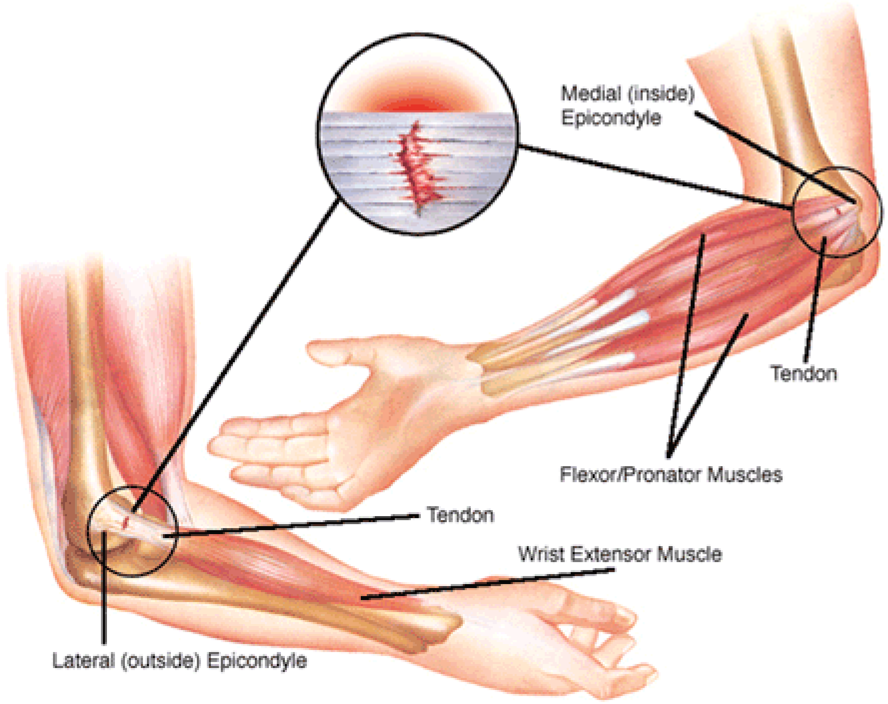
Whatever you call it, the cause is generally simple overuse: the tendon has become flayed from exposure to a level of tension that prevented it from recovering. As such, the treatment is switching to a sustainable training program with the aforementioned rehabilitation approach.

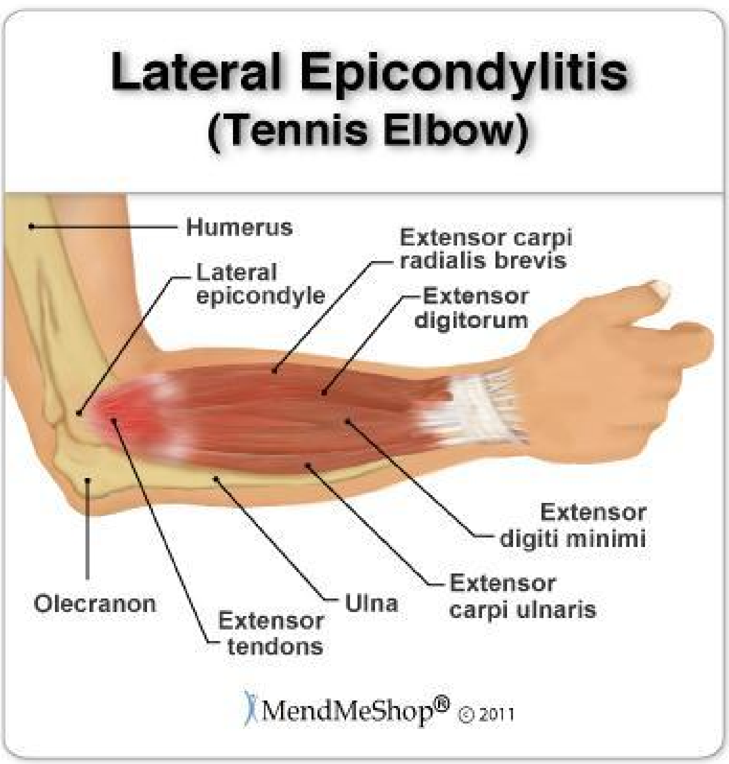


Elbow tendinopathy is generally on the outside of your elbow (lateral/tennis elbow) or on the inside (medial/golfer's elbow).

- Tennis elbow can easily feel like forearm pain. It commonly affects biceps and pulling exercises, particularly during the stretched positions near full elbow extension.
- Golfer's elbow is more easily diagnosed as an actual elbow problem. It commonly affects triceps and pushing exercises, particularly near lock-out of the elbow joint.

Tennis elbow seems to be more common in strength trainees, but it really doesn't matter which one it is, because you have to experiment with what you can do pain-free anyway.


Medial (inside)
Epicondyle
Tendon
Flexor/Pronator Muscles
Tendon
Wrist Extensor Muscle
Lateral (outside) Epicondyle


Lateral Epicondylitis
(Tennis Elbow)
Humerus
Lateral
epicondyle
Extensor carpi
radialis brevis
Extensor
digitorum
Extensor
digiti minimi
Olecranon
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tendons
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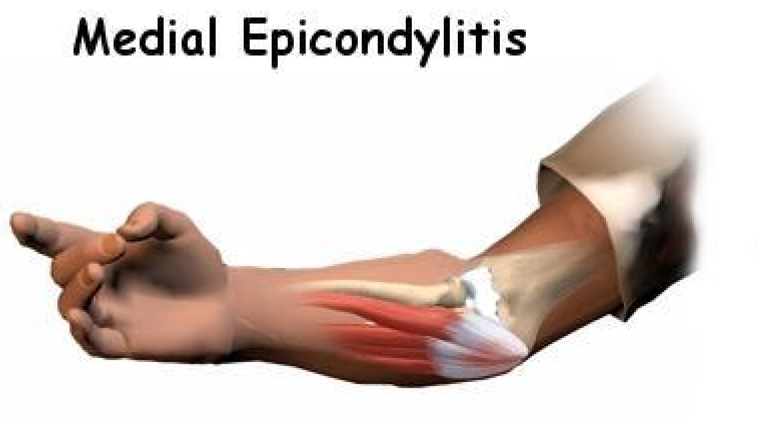


Other than the general advice, the following advice should help treat and prevent elbow pain in general.

- Make sure your wrists stay aligned directly over the elbow. People often slack their wrists backward during presses and flex their wrists to compensate for end-range shoulder extension (pulling the elbow behind the body) during pulls. This puts extra stress on the forearm muscles and their tendons. Note that this isn't specific to rehab: it's just good exercise technique.
- Firmly hold the bar or whatever implement you're holding. Holding on as if your life depends on it will increase stability in the forearms, which should keep the tension on your muscles instead of your connective tissue.
- Switch to exercises that allow for natural rotation of the forearms, like ring and dumbbell exercises. If the wrists are forced into a fixed position, like with straight bars and barbells, the required rotation will have to come from elsewhere and the elbow is the next joint down in the kinetic chain. Since the elbow is designed for stability instead of mobility, this creates high torques and shearing stresses.
- Wear a loose elbow sleeve. You can wear it around the clock basically.

For tennis elbow specifically, the following biomechanical knowledge can help you switch to a more sustainable exercise selection.

- Stress on the damaged tendon tends to be less when the wrist is pronated, so switching from chin-ups to pull-ups tends to reduce the stress.
- Stress on the damaged tendon tends to be greatest near full elbow extension, so consider implementing exercises that are easier in the stretched position, like concentration curls instead of Bayesian curls. Avoiding full elbow extension is also an option but should be a last resort.
- Stress on the damaged tendon tends to be greater during pulling exercises with more biceps recruitment and more closed elbow angles. So a wider grip tends to make exercises easier on the elbow.
- If you don't have access to rotating handles, a thumbless grip can help increase mobility and take some stress of the arms in general. Think of pulling with your elbows rather than with your hands.
- KAATSU unilateral hammer concentration curls are one of Menno's favorite exercises during (p)rehabilitation of tennis elbow.

For golfer's elbow specifically, the following biomechanical knowledge can help you switch to a more sustainable exercise selection.

- Stress on the elbow tends to be greatest near lock-out, so consider implementing exercises that are easier in this position, avoiding the use of accommodating resistance or avoiding elbow lock-out entirely even if needed.
- Stress on the elbow tends to be greater during pushing exercises that activate the triceps more, especially when torque is high on the elbow. You can greatly decrease elbow stress by minimizing torque.
    - During free weight exercises like a dumbbell press, the forearms should stay vertical rather than slightly more flexed as it naturally tends to move.

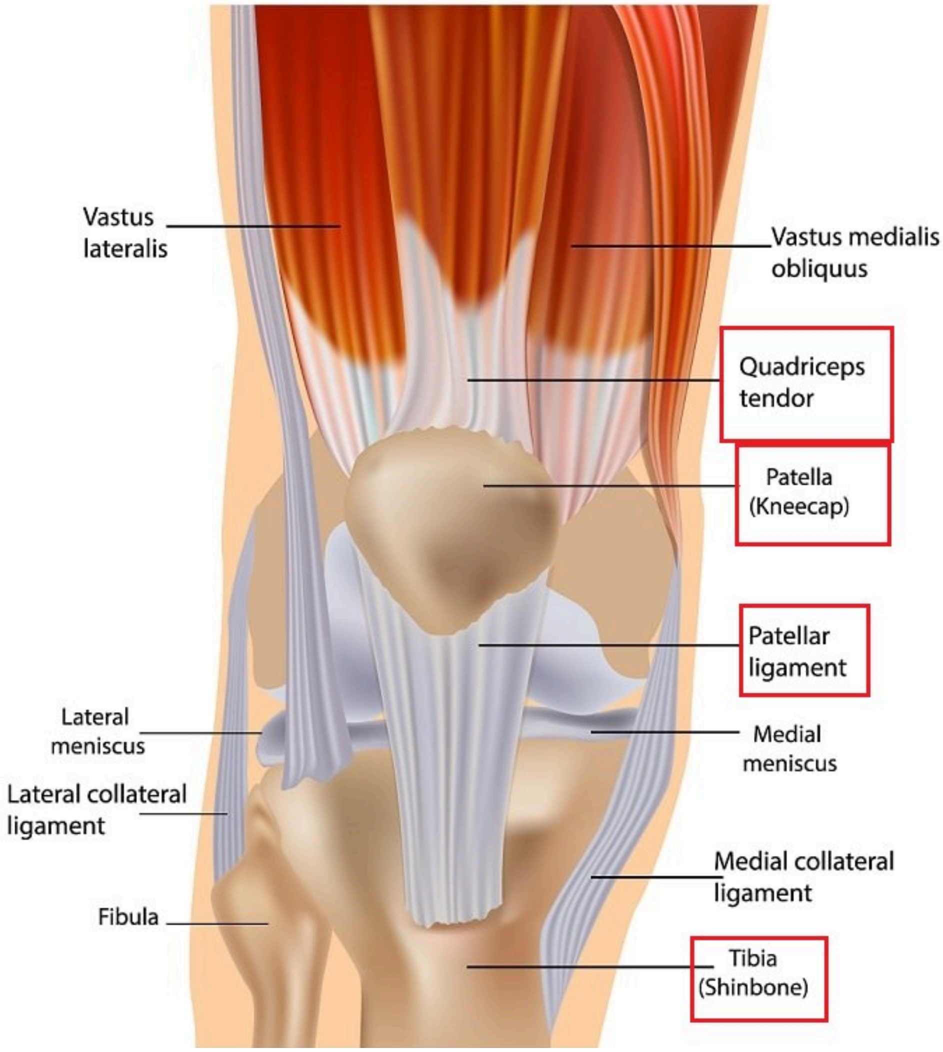
This will significantly decrease how much weight you can lift, but sometimes it's enough to completely remove the elbow pain.

- o Barbell exercises with a wider grip tend to be easier on the elbows.
- o Free weight triceps exercises like skull-crushers with the greatest resistance in the stretched position are very stressful for the elbow due to their high torque. Consider modified variants like skull-overs that have an elbow friendlier resistance curve.

- Cable exercises like the cable chest press tend to be a great and highly underrated way to keep presses in a program in the presence of golfer's elbow. Triceps push-downs with a rope are also relatively elbow friendly.
- Convergent chest press machines are often a great way to train the pecs with relatively little stress on the elbow due to the rotary movement component.

The knees

The most common causes of knee pain in strength trainees are [patellofemoral pain syndrome] (PFPS; runner's knee) and secondly patellar tendinopathy (Jumper's knee). They are very similar to tendinopathy in the elbow. In the case of patellar tendinopathy, the damage is in the patellar ligament (tendon) just below the knee cap. In the case of runner's knee, the damage is higher, possibly in the quadriceps tendon, but it's mostly a diagnosis by exclusion (meaning we don't actually know what's causing the pain).

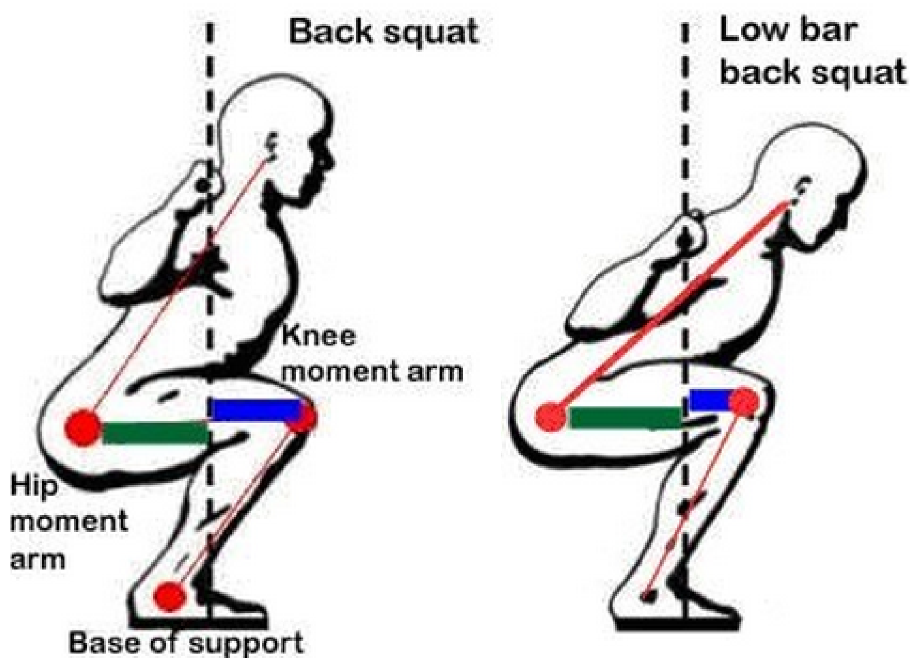


Other than the general advice, here are some specific tips to try for knee pain.

Squat hip-dominantly

The further the knee travels forward during a squatting motion, the higher the torque on the knee joint and the greater the stress on the patellar tendon. So you can reduce squatting knee joint stress by limiting ankle flexion: squat from your heels without any heel lift, engage your hips and use a low bar position.

There is no difference in muscle activity of the quadriceps between high bar, low bar and even front squats, in contrast to popular belief [1, 2, 3, 4, 5, 6, 7]. So squatting more hip dominantly allows you to destress the knee joint with relatively little change in the effectiveness of the exercise for the quads.



Moment arms in the squat as a function of bar position.

Source: Starting Strength

Incorporate both closed and open kinetic chain exercises

A systematic literature review of ACL injuries concluded good rehabilitation programs should include both open and closed kinetic chain exercises. Some KAATSU leg extensions are a great addition to most programs that are heavy on squat-type movements. Leg extensions activate your quads in a different manner and cause different patterns of compressive and shearing stresses in different parts of the knee. Leg extensions also allow you to overload the knee joint near full extension where knee pain is generally minimal and the ratio of VMO to VML of the quads is good.

Open-chain exercises are commonly shunned in physical therapy for outdated reasons. For example, some researchers were concerned that leg extensions don't activate the VMO very well, but leg extensions actually have a similar VMO/VML activation ratio as leg presses and squats.

There were also concerns about the effects of open-chain exercises on the anterior cruciate ligament (ACL). However, a 2019 meta-analysis concluded open- and closed-kinetic chain exercises are equally rehabilitative after ACL reconstruction. Even in a study on individuals with a healing ACL graft, leg extensions did not pure more strain on the anterior cruciate ligament (ACL) of the knee than squats did. In another study, mathematical modelling of knee joint forces showed that while ACL joint forces were on average higher during leg extensions than during squats, posterior cruciate ligament forces were much higher during squatting. The difference in force distribution during leg extensions vs. squats is to be expected based on the biomechanical fact that squats induce greater compressive forces on the knee joint (vertically downward force from gravity), whereas leg extensions induce greater shearing force on the joint. In any case, ACL joint strain generally does not exceed 4.4% during leg extensions, which is below the proposed 10% threshold of ACL failure.

Plus, ACL injuries are largely limited to field sports and are highly uncommon in strength trainees. ACL injuries most commonly occur during uncontrolled acceleration and deceleration, internal rotation and full extensions. In the gym, you can easily avoid these risks with the following cues.

- Retain control of the weight: you should be able to stop the eccentric phase of any movement at any point generally and you shouldn't deload the weight in the bottom for machine exercises.
- Have your knees track roughly over your toes: avoid major knee valgus.
- Avoid knee hyperextension (straightening the knee beyond anatomical position). This goes for every exercise, not just leg extensions.

In the gym, patellar tendon injuries are far more common and anecdotally, knee injuries are far more common during squatting than during leg extensions. One of the most common knee injuries is jumper's knee or patellar tendinopathy. In research we see that leg extensions are just as effective in athletes for jumper's knee rehabilitation as the closed-chain and 'functional' jump squats. So for most strength trainees, leg extensions do not pose an extraordinary knee injury risk.

Wear a loose knee sleeve

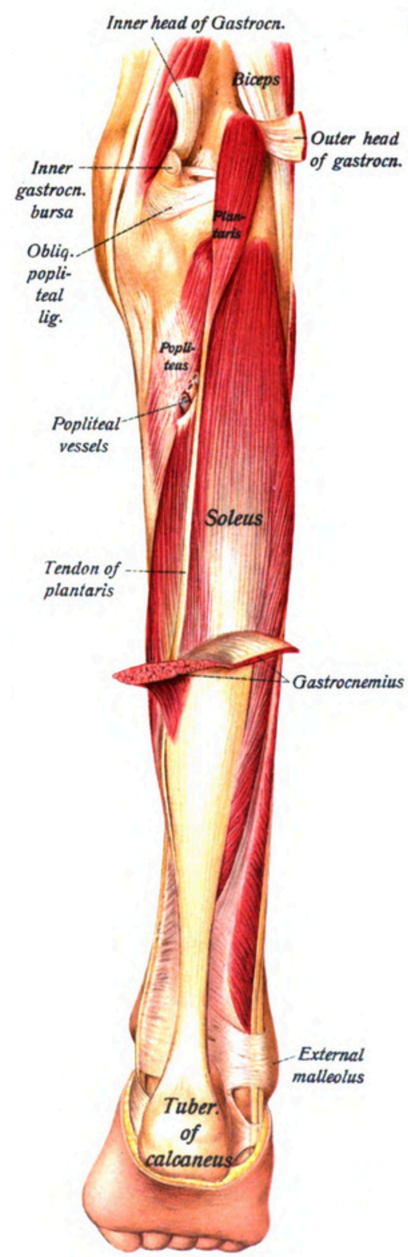
You can wear it around the clock basically.

Check for strength and technique asymmetries

Make sure your glutes, hamstrings and quadriceps are all functioning effectively and that your strength level is symmetrical. Many people eventually develop strength asymmetries from doing nothing but bilateral exercises for the lower body. This causes them to shift to one side during bilateral exercises, which can overload one knee during the training program. Here's an example of someone leaning more on his right than his left side.

Control knee valgus

Make sure your knees aren't caving in too much during the squat (knee valgus). A little knee valgus is fine and arguably natural. It can improve strength due to improving our leverage. However, major knee valgus can theoretically increase stress on the medial tissues of the knee joint substantially without any benefit to show for it.



Conventional wisdom says knee valgus is a result of weak hip muscles, but it's often largely a technique issue. Actual hip external rotation and hip abduction strength is only poorly related to knee valgus, especially in trained populations. So strengthening the glutes often doesn't help to reduce knee valgus: technique improvements do, specifically pushing the knees out more and keeping your center of gravity over your midfeet or heels.

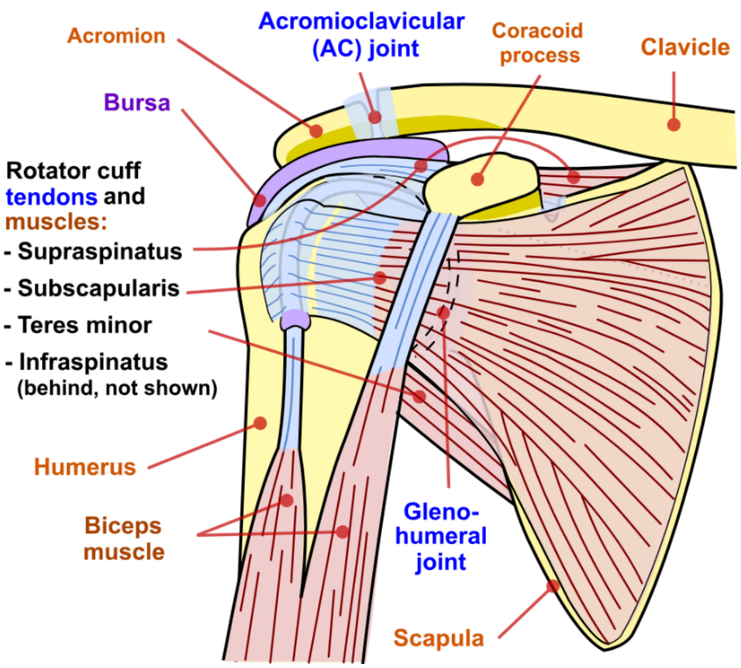
Plantaris strains

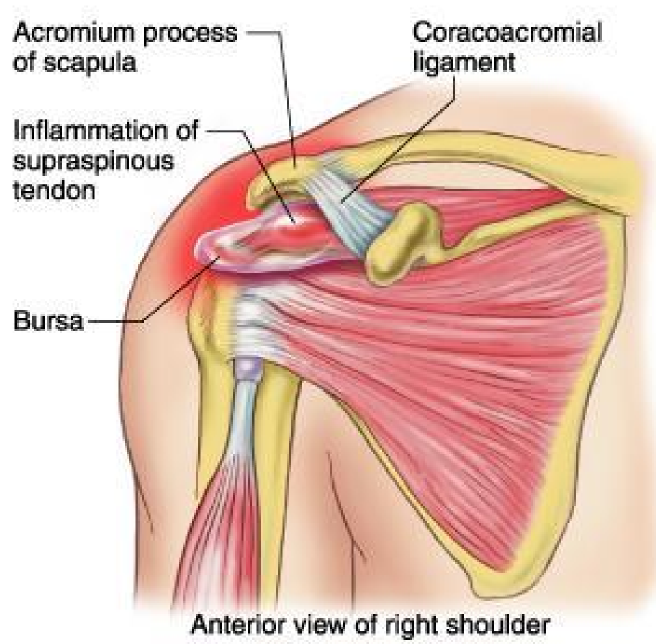
Another relatively common source of posterior knee pain is a plantaris strain. The plantaris muscle is a weak plantar- and knee flexor depicted on the right. It's basically a little helper of the gastrocnemius of the calves. A plantaris strain causes pain during calf raises and leg curls. The pain is usually most severe during seated calf raises, but it's very specific to the type of movement with walking sometimes being completely pain-free. It’s similar to ‘tennis leg’.

Treatment follows the above principles: avoid exercises that aggravate the pain, like calf raises and leg curls and keep the area warm with a knee sleeve. It should heal within a few days.

The shoulder region

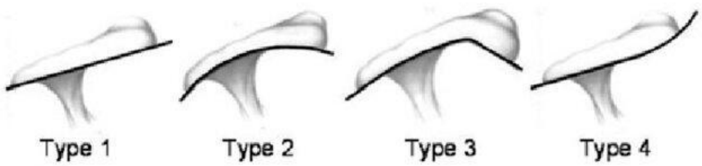
Shoulder injuries vary considerably due to the complex anatomy and wide range of functions of the shoulder region (scapulae + glenohumeral joint + acromioclavicular (AC) joint). During strength training, many injuries are related to shoulder impingement. Shoulder impingement syndrome involves tendinopathy of the rotator cuff muscles that pass through the subacromial space beneath the acromion, in particular the supraspinatus. It's also called swimmer's or thrower's shoulder. Severe damage to one of these muscles is called a rotator cuff tear.





Causes of shoulder impingement

Impingement is technically normal for the shoulder. All tissues in the area rub over each other during normal shoulder movement. However, excessive friction can damage the tissues. A major factor that's out of our control is your acromion type. The shape of your acromion determines how much internal space your shoulder has to function and thus your susceptibility to shoulder impingement. This means some people will get their shoulders injured much more easily while lifting than others. Nevertheless, good exercise technique can significantly reduce the risk of injury for anyone. Menno has had countless clients that thought they were screwed still be able to press pain-free by improving their technique.



Acromion shapes. [Source]

Diagnosis

You can test for shoulder impingement as follows. See how far you can raise your arm with a lateral raise motion with your thumbs pointing towards the floor (empty can test/shoulder internally rotated) and then again with your thumbs pointing towards the ceiling (full can test/shoulder externally rotated). If it hurts or there is significant weakness with your thumbs down but not with your thumbs up, that suggests shoulder impingement. There are many variations of this test (Job's/Neer's/Hawkin's, etc.) but they mostly all come down to seeing if it hurts to raise your arm in a position of internal rotation. You can also test if internal and external rotation themselves are painful.

Prevention and treatment

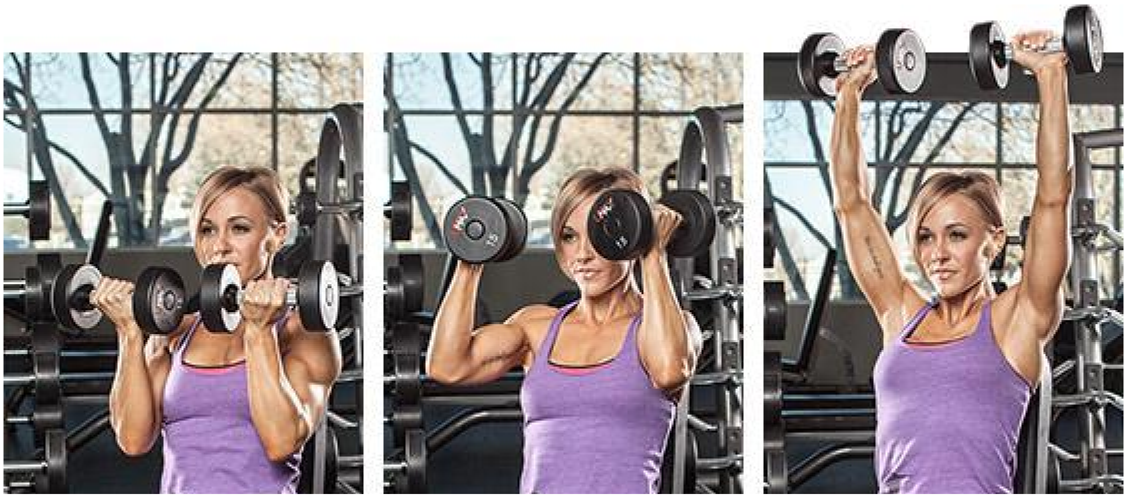
To reduce excessive shoulder impingement, press your shoulder blades together and arch your upper back. Scapular retraction increases the internal room your shoulder has to function and avoids impingement by increasing subacromial space width by up to threefold.

Arching your upper back and extending your thoracic spine also increases subacromial space and thus helps prevent impingement.

Limiting transverse flexion/adduction during presses can help as well. This generally means using a narrower grip. This is suitable for overhead pressing, but it somewhat defeats the purpose of bench pressing. The bench press is a mediocre exercise for all muscles except the pecs, so if you can only bench press with your elbows tucked against your sides, you may be better off just finding a different exercise, unless you're a powerlifter of course. Closed chain exercises like push-ups are generally much shoulder friendlier, though sometimes the higher instability is exactly what's problematic during the initial phase of the injury.

A narrower grip also helps during overhead pulling exercises. A wide grip decreases scapular retraction and increases deviation from the scapular plane, thereby increasing the risk of shoulder impingement. A behind-the-back pull ticks all the boxes for shoulder impingement, so you almost certainly want to avoid that (for practically everyone in general, as there's no meaningful upside).

A final way to prevent impingement is to keep the shoulder out of internal rotation and abduction, especially the combination. As such, the Arnold press is arguably the safest overhead press.

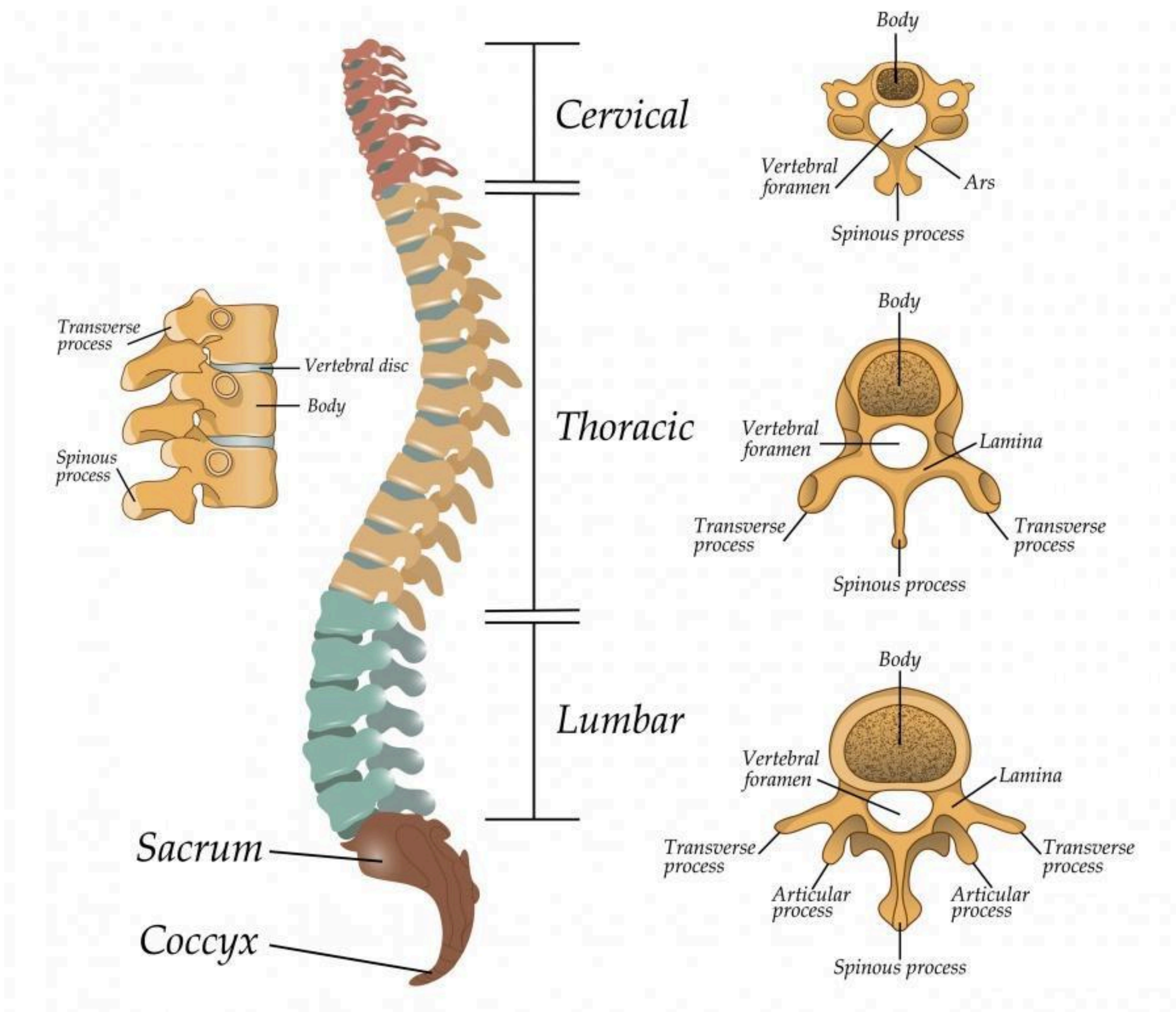


The Arnold press.

Treatment of shoulder injuries, when surgery isn't needed, follows the general principles outlined before.

The back

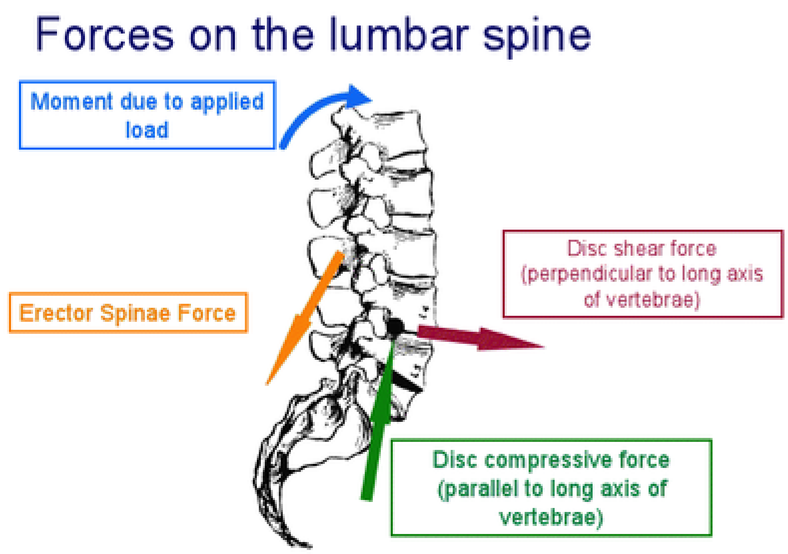
What most people refer to as 'back pain' is often a problem in the spine. The lower, lumbar spine specifically is commonly injured during strength training with far fewer injuries in the upper, thoracic region. This is logical, as the lower the disc, the more pressure it experiences from being stuck under all the discs above it.

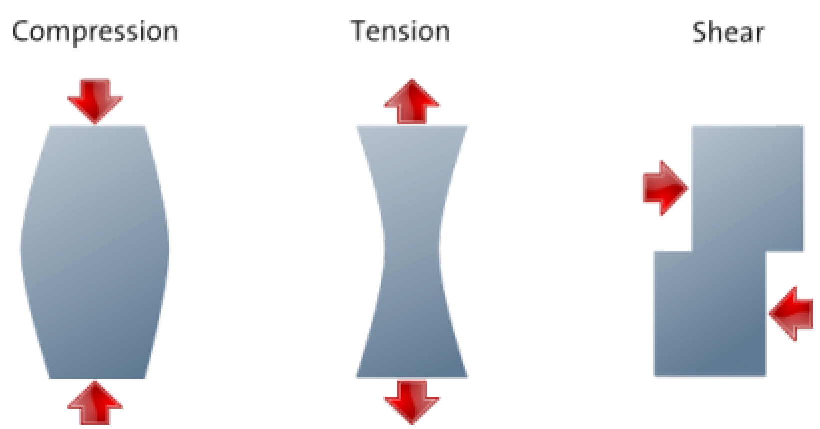


The anatomy of the spine.

For spinal injuries, exercise technique and overuse are often the culprits. In contrast to popular belief, daily life posture, back strength and muscle length have very little relation to back pain [2, 3, 4, 5, 6, 7, 8] outside of pathological weakness. The degree of spinal loading during daily life also has no causal relation with back pain according to a 2024 review of reviews, not even during manual labor. It takes a lot of force to damage the spine and not a lot of strength or mobility to move it without external loading, so for most people, especially for strength trainees, muscular issues are not plausible culprits. The spine adapts to loading just like our muscles and the stresses on the spine from daily life are well below its recovery capacity. In fact, most chronic back pain without a clear acute onset – an 'oh, crap' moment – seems to be psychosomatic rather than mechanical.

The key technique consideration for spinal injury prevention is spinal posture under load, in particular during squats and deadlifts. When the spine is in a neutral, anatomical position, such as when you're standing upright, the spine is very sturdy. In anatomical or neutral position, the strain on the passive structures of the spine is minimal and compressive forces going down the spine are relatively well-tolerated. The risk seems to increase dramatically when we flex the spine based on the limited modeling, animal and human cadaver studies we have. Spinal flexion in the lumbar region – such as when letting your lower back round over during squats or deadlifts – exponentially increases shearing stress on the spine, and this significantly reduces the load required to injure a disc [2, 3, 4]. The greater the spinal flexion, the fewer spinal extension repetitions are required to injure a disc, ex vivo. The annulus fibrosus, the outer rim of the spinal discs, also seems to be more prone to damage when the spine is flexed.





The limited human research we have on occupational lifting and manual labor is quite contradictory but tentatively agrees. A 1999 meta-analysis concluded lifting while bending over from the spine (Stoop lifting) increases shearing forces on the spine without significantly affecting compressive forces or net moments compared to squat lifting. A 2020 review of the effectiveness of teaching manual laborers to lift from the legs with a straight back found that about half of all studies report positive effects and a quarter report a reduction in injury rates with virtually no evidence of harmful effects. For example, a RCT by Loisel et al. (1997) found that ergonomic counseling of manual laborers with back pain was significantly and considerably more effective to facilitate return to work than usual care from a physician. Importantly, ergonomic counseling had additive effects to clinical intervention that included possible physical and cognitive behavioral therapy. A secondary subgroup analysis by Loisel et al. (1997) of the same dataset looked at nurses with back pain from heavy shifts. The researchers compared nurses with vs. without core training designed to teach them how to keep their spine neutral (much like the McGill method). The nurses doing core training achieved a greater reduction in pain. How come some studies have such clear results whereas others don't? The lower than theoretically expected effectiveness of some of the programs may be in large part due to workers' non-compliance with the recommended lifting technique. Lifting purely from the legs requires more effort than involving the back as well and it's not even possible in the first place for many tasks, such as lifting boxes from the floor. An RCT by Suni et al. (2013) also found that back movement training, including in particular the avoidance of full lumbar flexion, reduced lower back pain in military personnel.

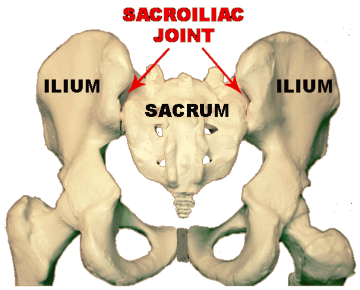
Unfortunately, there is virtually no direct research relating exercise technique to injury risk in healthy strength trainees. While spinal flexion is not significantly associated with injury prevalence during daily life movements, anecdotally, many coaches report a relation between squat and deadlift technique and injury rates: injuries seem to be more common when lifters have more movement in the spine and pelvic. Most high-level Powerlifters and Olympic Weightlifters also keep their spines relatively rigid during lifting. Moreover, people with low back pain often experience more pain when lifting with greater spinal flexion, often to the extent they're pain-free only when keeping their spine visibly neutral. In one study too, one Powerlifter reported low back discomfort precisely when he exceeded maximal lumbar flexion range of motion during the deadlift. To minimize back injury risk, our lumbopelvic posture should generally be kept as close to neutral as feasible during squats and deadlifts based on the available evidence.

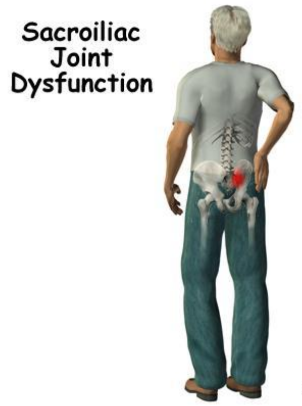
Virtually nobody will be able to keep their spine and pelvis in perfectly anatomical position while lifting. Some spinal flexion occurs even when you focus on trying to minimize spinal movement and no movement may be visible from the outside [2, 3]. One study reported that a pelvic tilt over 36° is required for physical therapists to accurately identify it in weightlifters, and the physical therapists were overall poor at detecting pelvic and spinal motion. It's not necessary and probably even counterproductive to try to lift with absolutely zero lumbopelvic movement, because the neutral 'position' of the spine where passive structures are under minimal strain is actually a neutral range with around 2-20° lumbar spinal flexion-extension range of motion. Most research finds that weightlifters and Powerlifters have their spine go a bit beyond this range while lifting, but the risk is generally contained as long as the spinal movement is not readily apparent from the outside. Still, in practice, many individuals have to focus with all their attention to keep their spine arched to prevent it from rounding excessively under the load. Excessive spinal *extension* or *anterior* tilt is rarely a problem in practice. Almost nobody ever herniates a disc anteriorly. If your back arch causes pain or limits strength, however, it's probably excessive (or you're still flexing a lot during lifting, i.e. not maintaining your set-up).

Spinal flexion per se is not inherently harmful during movements when there is no major compressive load, such as crunches or daily life activities, including picking up objects. The spine can adapt well to these low stresses, as long as the total amount of activity is limited to a reasonable level. A thousand sit-ups per day is neither effective for muscle growth nor injury-friendly, but a moderate volume of crunches or even back extensions in the 30-70% intensity range can be incorporated into most programs with little risk. Then again, there is often also little benefit to be gained from them for aesthetical purposes, as discussed in the functional anatomy module.

Ironically, low back pain or an inability to maintain neutral lumbopelvic positioning during squats and deadlifts is often said to result from a weak anterior core. This makes absolutely zero sense. The anterior core muscles, including the obliques and rectus abdominis, flex the spine, so their activation actually causes you to round over your back and they perform the exact opposite movement of what you want: spinal extension. Unsurprisingly then, [training your anterior core is no more effective than any other form of exercise to reduce low back pain](). There might be merit to including some anterior core work in sedentary individuals with pathologically weak abdominal muscles, but for strength trainees, it's the erector spinae in your back, not the abdominal muscles, that keep your spine safe.

While many lower back injuries are spinal injuries, many other lower back injuries are sacroiliac (SI) joint sprains. The sacroiliac functions much like the spine during spinal loading. It provides stability. When the pelvis tilts posteriorly ('butt wink'), such as in the bottom position of a deep squat with questionable form, this creates motion and friction in the SI joint. This can damage the ligaments, often causing pain to [one side of the lower back near the hips]().





Treatment of spinal and SI joint injuries, when surgery isn't needed, follows the general principles outlined above.

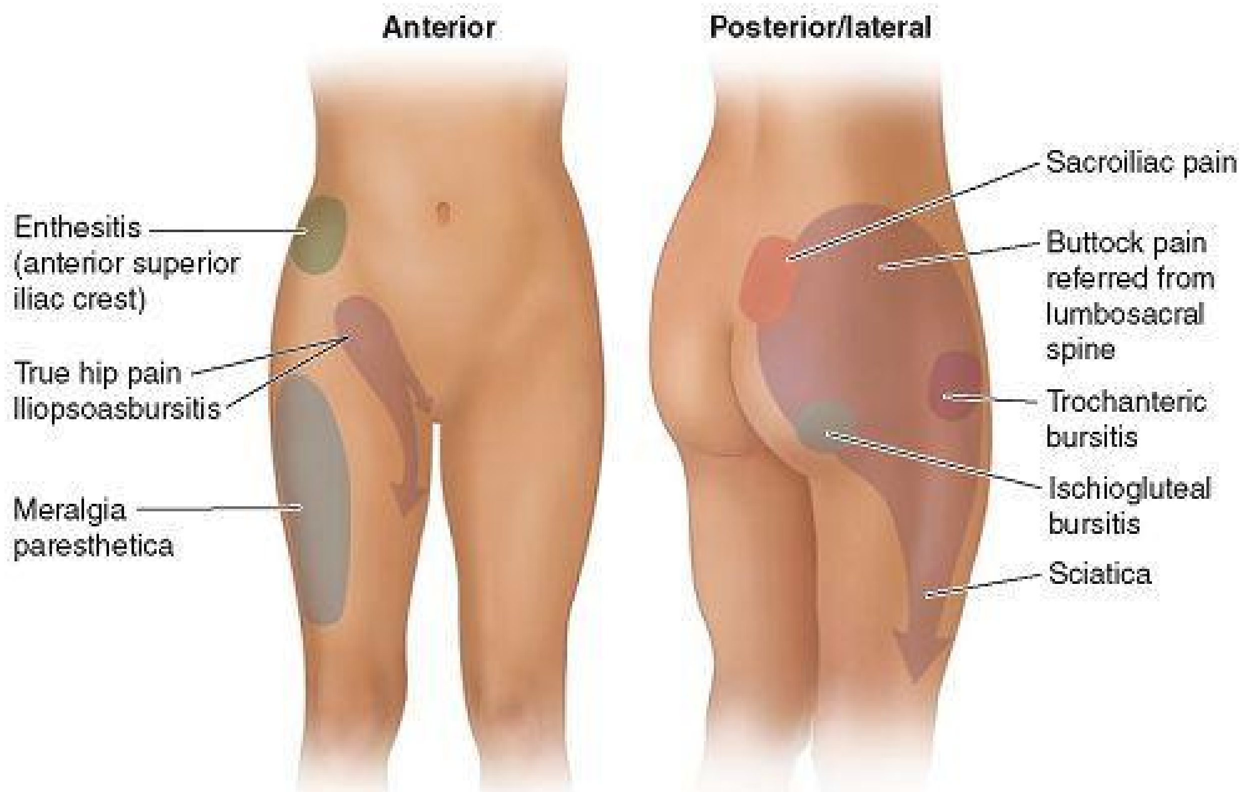
Here are some more specific tips.

- The order of stress on the lumbar spine during squatting is as follows: low bar back squats > high bar back squats > front squats > leg presses, hack squats and most unilateral squats. When low back pain presents, switching to a low back friendlier variation is often a good idea.

- One of the most common technique problems during squatting is not pushing out the knees enough, which causes posterior pelvic tilt and a loss of the anatomical arch in the lumbar spine. Pushing out the knees externally rotates the hips, which makes it easier to retain a lordotic spine.
- Similarly, when back pain presents during deadlifting, switching to a hip extension exercise with less spinal loading is often advisable. A great and convenient option that generally doesn't require any other program modifications is simply switching to one-legged deadlifts. Other options include pull-throughs, (45°) hip extensions, reverse hyperextensions and cable hip extensions.
- The spine is less tolerant to stress in the morning [2]. Overnight, the spine hydrates and increases in length as a result of not being compressed. This is why you're taller in the morning than at night. While that may seem nice, this hydration of the discs decreases range of motion and stress tolerance of the spine. The difference is substantial, with one paper finding 300% greater stresses when bending in the morning than in the evening. An 18-month RCT by Snook et al. (1998) found that instructing patients with nonspecific back pain not to flex their spines in the mornings led to significantly faster recovery of pain and disability than a sham control intervention. The spine's fragility in the morning is another reason not to train in the morning and extra care should be taken to warm up properly, ensure good squatting and deadlifting technique and to limit spinal stress when you do have to train in the morning. Over 50% of the spinal hydration after sleeping dissipates within the first hour after awakening, so the risk of back injury may be significantly lower when exercising at least an hour after awakening.

The hips

Hip pain is quite rare as a result of weight training and usually it's not the actual hip bone that is damaged. Every case is therefore highly individual and often serious, but here's a useful illustration to help differentiate between different causes of what people may describe as hip pain to start your research.

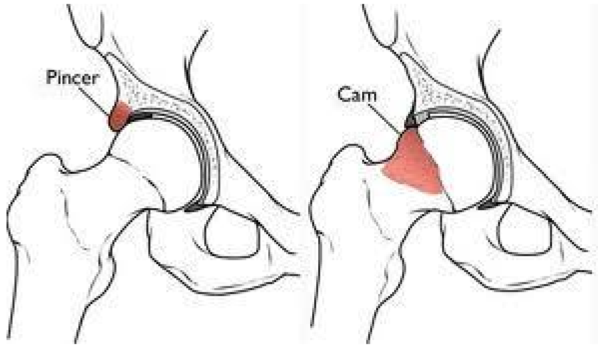


Here are some more concrete tips:

- Anterior hip pain often occurs as a result of overstretching the hip flexors. This can occur during stretching exercise and exercises such as Bulgarian split squats. During split squats, pulling the rear bench further towards you so that your rear knee stays roughly below your hips rather than way behind it, reduces stress on the hip flexors.

Hip flexor strains are far more common when not properly warmed up, so sufficient warm-up is crucial during rehab.

- Hip impingement (femoroacetabular impingement) generally occurs when the head of your femur does not have enough space to move in its socket. You can distinguish between cam and pincer type hip impingement depending on where the problem lies, but regardless of diagnosis, the solution is often simply to stick to your active and pain-free range of motion. More upright squatting variations result in less impingement. A wider stance during both squats and deadlift movements also tends to help.



- True hip bone pain is the only type of hip pain where you actually want to reduce stress on the hips themselves. A narrower stance during squats and deadlifts achieves this.

The groin

Groin pain during squatting is a common injury in men. The cause is usually a strained adductor or hip flexor. Since these muscles are rarely stretched in daily life, insufficient warm-up of these muscles leaves them prone to micro-tearing when stretched during the squat. So the treatment and prevention follow the guidelines provided for muscle strains, notably including thorough warming up.

The injury is less common in women because women are naturally more flexible than men and women are more resistant to muscle damage than men. However, women do experience hip flexor strains relatively frequently when overstretching them during split squats from a deficit, as they are prone to rely on their greater flexibility and naturally perform the exercise in a more hip-dominant fashion than men.

Scapular region/ribs

There is a specific injury that occurs relatively frequently but is rarely discussed: tears in the small muscles and ligaments attaching the ribs to the spine and each other. Even though the injury is acute, there is often no discernable cause. It can happen during almost every exercise where significant intra-abdominal pressure is required. It hurts like hell, but it tends to affect only a few movements with no clear trend between which biomechanical functions and motor patterns are affected. Fortunately, it heals rapidly on its own, generally within days.

Neurological conditions

Clients with neurological conditions obviously require special considerations. Most of these come down to using common sense, but it's good to be aware of some terminology and specific advice.

Clients that cannot walk

Clients in wheelchairs or on crutches obviously cannot normally train their lower bodies, but it's important to be creative and still train the upper body. Not being able to use your legs does not mean you cannot exercise. This also applies to clients with spinal cord injury, which can disrupt motor control below the site of injury (paraplegia if they cannot use their legs and tetraplegia if they cannot move their arms either). If the client is in a manually-powered wheelchair or on crutches, be a little conservative with their upper body training too, because their upper body will be taxed much more in daily life than that of the average person. This can limit recovery capacity and also make upper body injuries far more debilitating.

One specific thing to be aware of if you ever happen to have a client with a spinal cord injury in the upper back (at or above T6) is potential episodes of autonomic dysreflexia, as it can be life-threatening. You can read up on that here.

Poor motor control

Neurological conditions can impair someone's ability to control their movements. If someone suffers from spasms (like with cerebral palsy), seizures (like with epilepsy) or very poor coordination, you obviously don't want to have them do barbell deficit Bulgarian split squats with a barbell on their back. A bit of common sense goes a long way. Machine and cable exercises are generally advisable instead of free-weight exercises to prevent accidents.

One specific thing to be aware of if you ever happen to have a client with multiple sclerosis (MS) is that their symptoms often deteriorate in high temperatures (Uhthoff's Phenomenon), so keep temperatures cool when exercising.

Take-home messages

- Most weightlifting injuries do not need to be diagnosed accurately. In practice, you just need to know the location and severity of the pain and then work around the pain.
- Most injuries are overuse injuries, so rehabilitation comes down to modifying your training program to make it sustainable again.
- Most injuries have a very specific cause, a certain movement pattern that resulted in accumulation of tissue damage. Switching out the exercise to something targeting the same musculature with different biomechanics is often all you need to do if you catch on to the accumulating injury early on while maintaining the stimulus for muscle growth. Other good strategies are lowering the intensity (with KAATSU) and implementing a very controlled repetition tempo with pauses. Proximity to failure, ROM and volume should only be reduced as a last resort.
- Remission of pain does not mean there is no more tissue damage, just not that it’s no longer above your pain threshold, so stick with the sustainable program as long as it works and only gradually transition to a program involving higher connective tissue stress as needed for progressive overload and optimal muscle stimulation.
- Beware of ‘treatments’ that mainly numb pain without improving tissue healing. These include stretching, foam rolling, icing and NSAIDs. Icing and NSAIDs are typically best reserved to the acute phase of sterile injuries to avoid excessive swelling.
- Heat, massage, active recovery, sleeves and mild compression may slightly improve injury healing rates and thus should be considered.
- Surgery should be a last resort for injury management, as most injuries heal by themselves, albeit slowly, if you let them.