Rehab and the Kinetic Chain: An Orthopaedic Surgeon's Guide to Diagnosing and Treating Overuse Injuries

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Introduction

As surgeons, we undoubtedly enjoy operating. Surgery is what we "do." Fixing things gives us satisfaction, and for the most part our patients are happy as well. However, there is another group of patients that we see in clinic too: patients with non-operative problems. For example, overuse injuries. These visits can be quite frustrating, not only for us, but also for the patient. If we don't have a surgical "fix" we often feel like we didn't "do" anything to help, leaving both us and the patient feeling let down.

The purpose of this article is to provide a background on some concepts rarely discussed during orthopaedic training: overuse injuries, biomechanics, kinesiology, fascia, and a functional exam of the kinetic chain. Using these concepts, I have outlined five fundamental points to cover with a patient presenting with an overuse injury. The goal being that both you, the practitioner, and the patient have a more satisfying and productive encounter because you will have done something: educate.

Please note that as a runner, I chose to use running as my example throughout the article, while the specific injuries differ between sports, many of the concepts I present will be generalizable.

Overuse Injuries

Overuse injuries, generally speaking, are a group of disorders related to overdoing physical activity. Overuse injuries have many pseudonyms including cumulative trauma disorder. A cumulative trauma disorder is defined as a harmful and painful condition caused by overuse or overexertion.[1] About.com defines overuse injury as "an injury to a part of the body that is caused by overusing or exerting too much stress on that body part".[2] Medscape defines overuse injuries as "tissue damage that results from repetitive demand over the course of time".[3]

Overuse injuries are due to "overdoing" an activity, but how much is too much?

Clearly this differs by sport, but overall, there is no standard definition of "too much." In a systematic review of running related injuries by Lopes et al, the incidence of running injuries was 6.5-59 injuries per 1,000 hours of training.[4] This number was not chosen as a magical number of hours where the incidence running injury increases, instead it is a commonly used quantification of the incidence in running injuries.

While defining overuse is problematic, we do know that there are many commonly seen injuries that fall into this category. According to a systematic review, the top eight most common overuse injuries seen in runners include[4]:

1. Medial tibial stress syndrome (shin splints)
2. ITB
3. Achilles tendinopathy
4. Plantar Fasciitis
5. Patellafemoral syndrome
6. Patellar Tendonopathy
7. Hip and Lower Leg tendonopathies
8. Stress fractures

The study included a heterogeneous population of runners; from amateur runners, to marathon runners, to ulta marathon runners. However, there were no significant differences in the types of injuries between these different levels of runners.

According to the website "Stop Sports Injuries", sponsored by the AAOS, overuse injuries can be classified into four stages based on presenting symptoms[5]:

Stage 1: Pain after activity, no functional impairment

Stage 2: Pain during and after activity with minimal functional impairment

Stage 3: Pain during and after activity that persists throughout the day, significant functional impairment

Stage 4: Significant functional impairment with all daily activities

While the site did not provide an algorithm for treatment based on the classification, they do point out that treatment "early" (stage 1 or 2) results in a shorter duration of symptoms and faster return to sport.[5]

This point is important to note because it is a shift in our typical paradigm. Acute severe injuries such as fractures and dislocations require immediate treatment. Overuse injuries, which are cumulative traumas, often present less severely, but require the same aggressive treatment. The sooner you catch a LESS severe overuse injury and treat it, the sooner the individual will get better. This requires the physician to be aggressive EARLY in the course of the disease, as opposed to waiting for a catastrophic injury to initiate treatment.

The Mayo Clinic defines two common causes of overuse injuries: training errors and technique errors.[6] Training errors involve doing too much, too soon, too fast, or too much of one type of activity. Technique errors involve poor form or technique in repetitive activities. With these two concepts in mind, they suggest that participants: pace themselves with gradual increase in activity, use proper form and gear, include coaching when necessary, and mix up a training routine.

Point #1

Overuse injury is a poorly defined and non-specific term that we, as clinicians, use to describe a group of injuries we tend to see in patients who participate in endurance sports or sports with repetitive activity. They are usually the result of over training or training with poor technique. Understanding where the breakdown in the training is, and treating the injury aggressively early can lead to a quick recovery and return to play.

Biomechanics and Kinesiology

In order to understand overuse injuries, it is important to understand some important principles relating to biomechanics and kinesiology.

Biomechanics is the application of the mechanics of motion to biologic systems.[7] Biomechanics involves taking principles from mechanics and physics and applying it to biologic systems. The body is made up of a system of levers (bones) rotating on fulcrums (joints). Torque is the force that rotates a lever arm around a fulcrum.[8] A moment arm is the perpendicular distance from the axis of the force to the fulcrum. A larger moment arm has a better mechanical advantage when it comes to creating torque at the joint of interest. Both the moment arm and torque are affected by the angle at which they are applied. Maximal torque is always created when the force is applied at 90 degrees to the lever.[8]

In human anatomy, a muscle with a larger moment arm gives a better mechanical advantage when it comes to creating torque at the joint of interest. Conversely, a larger moment arm can also result in a greater force through a joint (compression), which can be a disadvantage in repetitive activities. Two examples would be lifting a dumbbell and running with a shorter stride. Imagine the brachialis crossing the elbow joint. The moment arm is the distance from the center of rotation of the elbow joint to the bracialis.[9] This distance is short when the arm is extended and at its longest with the arm at 90 degrees. This means that the brachialis is at its greatest mechanical advantage to lift a heavy weight at 90 degrees of elbow flexion. In contrast, the moment arm of the lower extremity during foot strike is a line parallel to the ground running between the knee and the center of the foot strike. The longer the distance between the knee and foot (seen in long gait patterns), the higher the moment arm and the more force on the lower extremity. Shorter stride distances are therefore more energy efficient and in long distance running conserve more energy and likely prevent injury.[10]

Dr. Arthur Steindler, the chair of the Department of Orthpaedics at the University of Iowa between 1919-1949, introduced the idea of the kinetic chain.[7] Dr. Steindler envisioned limbs as "rigid overlapping segments" in a series.

"Each bony segment in the lower extremity such as the foot, lower leg, thigh and pelvis can be viewed as a rigid link with the subtalar, ankle, knee and hip joints acting as the connecting joints."

The idea behind the kinetic chain is that a break in the chain could effect the movement and function in other areas of the chain or the entire chain itself. Dr. Steindler identified the importance of looking at the entire chain when addressing pathology and rehabilitation.

The biomechanics of running differs from walking because there is a period of time in running where neither foot is on the ground, and because there is more energy in the system.[11] The foot and ankle see three times the body weight on impact. Starting from the bottom, the foot and ankle act as the energy absorbers, the knee helps place the foot in space and the hip is for propulsion.[11] During impact the subtalar joint is everted, the foot is in pronation, the forefoot is abducted and the ankle is dorsiflexed approximately 90 degrees. During toe off the subtalar joint inverts, the foot is supinated, the forefoot is adducted and the ankle is plantar flexed. It is important to recognize that these motions work in concert to lock and unlock the midfoot joints. An inverted subtalar joint with the forefoot in adduction locks the transverse tarsal joints, providing a stable platform for push off. An everted subtalar joint with the forefoot in abduction unlocks the transverse tarsal joint, allowing for a supple foot to absorb energy during heel strike.[12] The muscles of the lower extremity are working in concert with the joint motion. The gastrocnemius and posterior tibialis are eccentrically contracting during heel strike to help absorb energy and prevent over pronation. The tibialis anterior contracts during toe off to dorsiflex the ankle during swing.

The knee is in valgus and flexion during foot strike and in varus and extension during toe off. On impact, the quadriceps eccentrically contracts to resist the ground reactive force and to prevent the knee from collapsing. During the late swing phase the quadriceps contract to extend the knee to prepare for impact. Foot position can greatly impact the amount of knee varus and valgus during the cycle; the more pronation in the foot, the more valgus in the knee.

The hip joint provides propulsion during running. The hip adducts during stance phase and abducts during swing phase. The psoas muscle pulls the leg forward during swing phase. The hamstrings and gluteus maximus contract at the end of swing phase to place the foot under the center of gravity and during the beginning of stance phase to pull the body over the leg. The hip abductors and adductors work in concert during stance phase to stabilize the stance leg, with more abduction of the hip during swing phase and adduction during stance.

The concert of movement required to run efficiently and effectively can therefore be greatly affected by a break in the chain, resulting in a variation in the running cycle, and ultimately injury.

Hip biomechanics have a powerful influence on knee mechanics, and abnormalities can result in knee injury.[13] Overall, the knee is the most common site for overuse injuries. A systematic review found 51 articles linking impaired trunk control (due to hip weakness) with knee injury. Some common patterns of injury relate to weak external rotators, weak abductors, and increased hip adduction and internal rotators.

When patients with weak external rotators and excessive hip adduction and internal rotation perform a box jump, they land with the knee center of rotation moved medial to the foot and valgus collapse at the knee.[13] The result of this faulty gait pattern includes patelofemoral syndrome, MCL tears/sprains, ACL tears, posterior tibialis tendonitis (as a result of trying to control over pronation of the foot), and lateral ankle impingement. Weak hip abductors can lead to increased pelvic tilt, resulting the center of gravity moving medially. This creates a varus moment at the knee, and increased internal rotation of the tibia. If this pattern is coupled with over pull of the adductors, iliotibial band syndrome (ITB) often results.

ITB syndrome tends to be related to adduction coupled with weak abductors and internal rotation of the tibia. A prospective study of 100 female runners found that excessive lower extremity adduction and internal rotation of the tibia were the strongest predictors of ITB syndrome. A case control study comparing injured and uninjured sides in patients with ITB syndrome found weaker abductors on the injured side.[14]

Studies have also indicated increased patellofemoral syndrome in patients with weak external rotators and abductors and over pull of the adductors.[15,16] Females with patellofemoral syndrome had greater peak internal rotation while running and jumping when comparted to controls.[15,16] Females with patelofemoral syndromes also had three and a half times greater adduction during running, hopping and single leg squat when compared to controls.[17]

Point #2

The human body is made up of a series of joints that work together to cause motion called the kinetic chain.

Although you have pain at one point in the chain (ex patellar tendon pain), it may be caused by faulty movement in another point in the chain, such as weak external rotators at your hip.

Fascia

Fascia, otherwise known as connective tissue or extra cellular matrix is made up of collagen produced by fibroblast and held together by glycoaminoglycans (GAGs).[18,19] Fascia makes up tendons, ligaments, and sheaths throughout the body. Depending on the environment, the glue, or GAGs, can be thick, sticky, fluid, or lubricating as a result of the chemical properties of the GAGs. "Stretch" or lengthening of your fascia is likely creep due to change in the GAGs allowing for movement.[18,19] Manual therapy involves manipulation of the fascia to make it more compliant, elastics, and resilient, resulting in more healthy and fluid movement.

Fascia is alive and it is important, biomechanically. Fascia was long believed to be an inert covering, however it is now believed to be an import structure capable of remodeling. Langevin et al noted that fibroblasts repair and build fascia and hypothesized that fibroblast remodeling contributes to viscoelastic behavior of fascia.[20] The basic science work indicates that fibroblasts can change stiffness of fascia with production of matrix proteins.

Modern neurophysiology recognizes that the brain see movement patterns, instead of individual muscles movements. It is hypothesized that fascia plays a significant role in this due to a larger number of mechanoreceptors in the fascia, almost ten times as many as in muscle. These receptors include golgi, pacini, ruffini, and interstitial receptors.[20] Mechanoreceptors relay information on stretch, proprioception, blood flow and can change from tonic to relaxed with pressure (e.g. massage).

Since fascia is alive and pliable, it is also trainable.[18] Fascia responds best to cyclic, quick repeated movements like running and bouncing. Preparatory counter movements load fascia, for example flexing down before extending up to stand or jump, or moving the kettle bell into body before moving it quickly away. Winding up fascia uses the elasticity in the fascia to its maximum. Metabolically, using fascia's elasticity is more efficient than muscle contractions alone. Engaging long myofascial chains in one exercise, such as in kettle bells, TRX, physioballs, pilates, and yoga are efficient ways to train fascia. Some important rules for training fascia include: start proximally in the direction of the movement, then terminally extend, mix up the routine as fascia can adapt to one routine and no gains will be made, and finally exercise the receptors by including balance, agility in work outs.

Point #3

Fascia is the connective tissue that ties together the kinetic chain. It is also a common site of injury (eg. tendonitis, ITB syndrome, joint contractures). Therefore fascial health is key to your recovery as well. Fascia training, myofascial release, massage, and/or foam rolling are all important parts of injury recovery and maintenance.

Physical Exam

The Functional Movement Screen (FMS) developed by Gray Cook, a PT and trainer, is a series of exams used to help identify weak links in the kinetic chain. The goal was to create a reliable exam that could be reproduced by any individual who was appropriately trained in order to guide treatment or prevention on an individual basis. The inter and intrarater reliability for the FMS is 0.7.[22]

While the entire FMS screening exam is cumbersome, requires specific materials and training and can be too much for a standard visit in an orthopaedics office, a few simple maneuvers from this test can give the physician some valuable information in diagnosing the cause of an overuse injury in a patient.

Core strength is hugely important as a stabilizer against which the hip can flex and extend. Have the patient stand and look at them from the side to assess their sagittal balance while standing. Look specifically at the pelvis for anterior or posterior tilt.

Anterior tilt is common and can indicate several things: a weak core, quadriceps dominance pulling down on the pelvis, or psoas tightness. A lying straight leg raise can rule in or out core strength. If hyper lordosis occurs with a straight leg raise, it is likely that the patients core is weak and unable to provide counter stability against the strong hip flexors.

A deep squat is another simple test that can be done in the office. With a deep squat, watch specifically the feet and the trunk. Are the feet pointed forward or do they splay out or in? Are the feet symmetrical? Does the heels rest on the ground or lift off? Where is the trunk, straight up and down or is it pulled forward over the feet towards the knee? What is their terminal knee flexion, is it symmetrical? If a patient splays one foot out, it is possible they have a contraction of the external rotators at the hip on that side. If their heels are off the ground, they likely have a tight achilles tendon or soleus. Patients who fall forward and can not place their trunk straight up and down usually have hip flexor contractures. Terminal knee flexion should allow the patient to nearly sit on the ground, but decreased knee flexion can result in the patient not being able to squat fully.

Finally, a one legged squat provides a good side to side comparison. Have the patient perform a one legged squat (they may need to hold on to the table). Watch their balance, depth and the squatting knee. Weak abductors and external rotators results in increased knee valgus and foot pronation during a one legged squat. Pelvic obliquity can be due to weak abductors on the contralateral side. After an injury, patients tend to loose proprioception on the injured side and will likely find a one legged squat much more difficult on that side.

Point #4

These three simple exam maneuvers (lying straight leg raise, deep squat and single leg squat) may help you identify a break in the kinetic chain and will help you SHOW the patient that there is an imbalance which needs to be addressed.

Use this as an opportunity to educate patients and to introduce the idea of therapy as treatment.

"As we saw in your exam today you have X (ex. weak hip abductors as was indicated by the drop in your hip with a one legged stance, or weak abdominal muscles and over pull of your quads as we can see with your increased anterior tilt and increased lordosis on your straight leg raise)."

Point #5

Here's your prescription for physical therapy. My goals for you would be: to work on some of the asymmetries and weaknesses we saw today. Remember, neglecting these areas are what got you here today and will bring you back again so maintenance will be key for you. Cross train so that you stay symmetrically fit and hopefully prevent injury.

Conclusion

In conclusion: overuse injury is a poorly defined catch all term that we use to describe injuries due to deficiencies in training or technique and typically do not require a surgical intervention. Biomechanics and the kinetic chain can help us better understand these injuries. A break in the chain (hip external rotator weakness) can result in injury at a different level in the chain (patellofemoral syndrome or posterior tibialis tendonitis). It is important to address this break in the chain when treating the injury. Fascia is alive and important, and should not be neglected when treating the kinetic chain. Finally, a straight leg raise, deep squat and one legged squat can help us, the physician, identify some areas of weakness in patients presenting to us with overuse injury which both builds their confidence in us, but increases our own satisfaction that we are treating these patients, even if that treatment just involves sending them to a physical therapist that we know and trust.

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