Review of Effective Injury Preventing and Performance Enhancing Strategies for Runners

By

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A Literary Review Thesis

Submitted to the Department of Sport, Exercise, Recreation, and Kinesiology

East Tennessee State University

In Partial Fulfilment of the requirements for the Degree of Bachelor of Science

January 2022

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From beginning generations of the human species to today's world of modern day individuals, running continues to be an innate and commonly used ability in the humankind. Whether one is an elite Olympic sprinter, a pastime long-distance runner, a young toddler, or an elderly individual, humans run for recreation, sport, exercise, mental health, socialization, and a plethora of other reasons. But as much as humans perform this activity, there exists a high rate of injury prevalence caused by running, and furthermore, many individuals, at all levels, have untapped potential of athletic running performance. The purpose of this research is to piece together proven techniques for injury prevention and rehabilitation in runners and use this information to outline the best techniques to make invulnerable the body of a runner and maximally enhance his or her performance. This review will cover the specific muscles that, when strengthened or stretched, are closest linked to improved performance when running. Furthermore, shared characteristics of specific running injuries will be made, as well as examinations of debates for effective running injury rehabilitation strategies. By doing this, an understanding of running related injuries, and the studied exercises and techniques that can treat them, can be created. In order to prevent injury and improve the efficiency of a runner's body, it is vital to piece together unique contemporary beliefs and disprove or uphold certain old views on which exercises work to build specific muscles involved in running mechanics within a variety of populations.

This topic is relevant to discuss mainly due to the significance of running in the majority of individuals worldwide. Because running is a common form of exercise and pastime for average individuals as well as a popular sport within the world, it is important for elite and

mediocre runners to understand specific techniques that can help them stay healthy and agile. To elaborate on the commonness of running within just the United Sates alone, 50 million Americans participate in some form of running a year, which is 15% of the United States' total population (Galic, 2022). Yet, we see running within all parts of the world and within a variety of cultures. In consideration of the entire world's running habits, as well as the financial assets running generates economically, 36.8 billion dollars has been spent from 2016 to 2022 on running gear alone, not to mention the money generated by running events or running related functions (*Running Gear Market: Global Industry Trends, share, size, growth, opportunity and forecast 2022-2027*, n.d.). This number is estimated to be around 55.8 billion in less than just five years *(Running Gear Market: Global Industry Trends, share, size, growth, opportunity and forecast 2022-2027*, (n.d.). This multi-billion dollar running industry is sustained by the abilities of every runner, furthering the importance of this topic and the importance of making the best in the world better and reaching new levels of athleticism. Not only is this important for the athletes or the big brands they work for to understand, but also for the coaches, athletic trainers, and physical therapists who treat these athletes' injuries. Because the health of these athletes is in the hands of these professionals, it is imperative they understand how to prevent common running injuries and also how to maximally enhance running performance. Lastly, this topic is important because the average human has an inherent right to know and access information on improving their running skills and recovering from or preventing injury. Athletes of all levels, no matter how many trainers are available, should know how to properly run and train for running because of their health, safety, and personal reasons. If every human had the

opportunity to seize this knowledge and ability, the running industry and athletic performance in general would, with no doubt, grow exponentially in the future.

The populations discussed in this literary review include males and females aging from 18-70 years old. Populations further include professional and elite runners and sprinters, collegiate athletes, and individuals who enjoy running as a hobby. Some of the populations studied during the articles mentioned were either injured at the time of the study or fully able. Populations participating in sports, such as basketball or football, that require running in multiple directions and not solely a straight line will also be included. Moreover, the term runner or sprinter within this review does not strictly apply to those who perform in a straight line race, but to any human who runs or sprints. Of course, looking at skilled runners and sprinters yields advice that can then be inferred for other populations.

In order to help prevent injury in runners, it is not only important but logical to know what regions of a runner's body are most commonly injured. According to a study conducted in 2021 that performed an electronic database search of the most common running injuries during clinical studies, the knee and ankle regions had the highest percentage of injuries relative to the other areas of the body for non-ultramarathon and ultramarathon runners (Kakouris et al, 2021). Interestingly, Kakouris et al found that for non-ultra-marathon runners, Achilles tendinopathy is among the highest proportion of injuries experienced (Kakouris et al, 2021). In ultra-marathon runners, anterior compartment syndrome, patellofemoral pain syndrome, and Achilles tendinopathy were the most common and highest proportioned injuries experienced (Kakouris et al, 2021). This is significant as much more research supports this theory of the knee being the anatomical region of highest injury rates. For example, another article states that for runners of

all speeds, knee pain is the most common symptom experienced by all runners (Jin, 2014). This article then goes on to state that patellofemoral pain syndrome is the most prevalent cause of knee pain, and that aside from this syndrome, Achilles tendinitis is an extremely common running injury (Jin, 2014). More evidence is found in an article written by Francis et al, who performed a database search of articles for the purpose of relating running injury anatomical locations and gender (Francis et al, 2019). This article articulates that the knee sustains the highest proportion of injury for runners of both genders, followed by the Achilles due to tendinopathy (Francis et al, 2019). A common theme of the knee and Achilles region as the most common sites of injury is made by these database searches and also by a 2008 study involving 291 elite runners. The athletes ran about 65 Km per week, and when questioned at their current skill level, the conclusion was that Achilles tendinopathy was the number one injury common to these athletes (Knobloch, et al, 2008). Fascinatingly, about 57% of these athletes had experienced this injury at a certain point in his or her running career (Knobloch, et al, 2008). The next highest reported injury in this study was anterior knee pain, with about 46% of the participants experiencing this. (Knobloch, et al, 2008). Not only does this study support that knee pain and Achilles pain are the most common issues experienced by runners, but also that past injuries can be used as predicters that an anatomical area will be injured again. By integrating the information from these studies and database searches, it is made evident that the most prevalent injuries a runner experiences are to the Achilles or the knee. Therefore, these issues should be a focal point when addressing sports performance of runners.

Interestingly, the review by Kakouris et al also concluded that the prevalence of injury to specific anatomical locations in ultramarathon runners and non-ultra-marathon runners was not

significantly different, meaning that these two types of runners experience the same issues regardless of running intensity and style (Kakouris et al, 2021). This is logical because running requires specific muscle groups to be used, no matter the distance or how fast one is running. The deductions made by Kakouris et al can possibly be used as evidence that a strategy for enhancing performance can be formed and used by any style of runner (Kakouris et al, 2021). This is because Kakouris et al narrows down the scope of injuries experienced by all runners, which in turn, can be used to determine specific tendons, muscles, and ligaments that need to be strengthened. (Kakouris et al, 2021).

In order to prevent these Achilles or knee injuries from occurring, one must not miss the key window of opportunity, which is before the injury occurs. Predicting injury before it happens is necessary to preventing most running injuries, and a major sign of an injury to a specific anatomical area is if the area has been injured before. The Knobloch et al article mentioned above supports this theory, but there are several studies that further elaborate on how to predict injury. One study conducted in 2013 involving 200 recreational runners with no musculoskeletal injuries that prevented them from running answering an online survey about past running injuries (Hespanhol Junior et al, 2013). This study took into account the 84 registered running related injuries reported by the runners and associated this with potential predictive factors. The study concluded that about 30% of the main running related injuries experienced were muscular injuries (Hespanhol Junior et al, 2013). There were several variables found to be associated with these running related injuries, which included previous running related injuries, training style, and duration of training. The two types of running training styles that were highest associated with running related injuries were speed training and interval

training (Hespanhol Junior et al, 2013). Although lengthy durations of training were a predictor of running related injuries, the effect was not as significant as the other variables (Hespanhol Junior et al, 2013). An important takeaway from this is that past running injuries increase the risk of repeating running injuries to that same area or to other areas of the body due to compensation patterns (Hespanhol Junior et al, 2013). From this, we can conclude that an important step in augmenting athleticism and finding peak performance is healing all running related injuries before running again. To no surprise, Hespanhol Junior et al also found that the anatomical region associated with the most running injuries is the knee (Hespanhol Junior et al, 2013). Again, since the knee seems to be a common culprit of running injury, it can be inferred that protecting the knee is integral to building peak performance. (Hespanhol Junior et al, 2013)

Thankfully, there are more ways to predict injury to an area than a history of injury to that area. Several articles point to there being a sort of formula to predicting injury, specifically by looking at tightness and weakness in specific agonist and antagonist muscle groups. Therefore, a key in predicting injury is to decrease muscle imbalances. CEO of Athletic Truth Group and number one best-selling exercise and fitness author Ben Patrick offers some thought-provoking insight on fixing muscle imbalances. Patrick describes that creating balance between antagonist and agonist muscle groups in the body can help reduce the chance of injury and increase performance by an astounding 70% (Patrick, 2020; *Ben Patrick, 2019).* Furthermore, Patrick suggests that runners can also benefit from training muscle groups through their entire range of motion as this will help to strengthen the muscles in a lengthened position (Patrick,2020). Strengthening the muscles while they are lengthened will improve flexibility and strength within a runner at the same time (Patrick,2020). Other tips for evening out muscle

imbalances are to start with the non-dominant side when performing uni-lateral exercises, such as lunges. This is because starting with the weaker side prevents the runner from overcompensating on that side to match the work done on the dominant, stronger side (Patrick, 2020).

Another exercise method that rids of muscular imbalances and offers multiple other benefits to runners is retro running, or running backwards (Ivan, 2013). Retro running is an effective approach that, although may look peculiar, is worth consideration. According to Manchester Metropolitan University, retro running has amazing benefits that translate into running forwards (*Could running backwards be the key to getting faster going forwards?* 2019). Shantelle Gaston-Hird is an ultra-marathon, marathon, middle distance triathlon competitor as well as a world record holder for finishing a backwards half marathon at the quickest time recorded in history for a female. After six years of training retro running, Gaston-Hird decreased her triathlon completion time by over thirty minutes (*Could running backwards be the key to getting faster going forwards?,* 2019). Not only does she accredit her ability to run faster forwards to retro running, she also has seen fewer injures and better overall running mechanics since including retro running into her training regime. Manchester Metropolitan University worked with Gaston-Hird by testing her with electromyography and collecting data on her oxygen use as she ran forwards and backwards. Afterwards, they concluded that she used roughly 30% more oxygen running backwards than she did forwards (*Could running backwards be the key to getting faster going forwards?,* 2019). Researchers also found that running backwards requires more energy expenditure than running forwards, which means that the muscles used for running forwards are able to produce more force for longer periods of time.

This conclusion is extremely advantageous for runners of any kind to enhance their performance and endurance capabilities. Although western culture and many other parts of the world have not adapted retro running as a popular activity like running forwards, Retro running and walking have been practiced for thousands of years in China, dating back to ancient times (Singh, 2019). Today, it is common in Chinese culture to walk backwards in public spaces, such as in parks. According to an old phrase with Chinese orientation, "100 steps backwards are worth a thousand steps forwards," (Singh, 2019). The Chinese claimed that walking backwards helps with certain diseases, such as arthritis (Singh, 2019). Moreover, humans are actively using the right side of the brain and working their peripheral and side visions while walking backwards. So, not only is it a new way to stimulate the physical senses, but the mental senses as well (Ivan, 2013). This cognitive benefit of retro running is important is rehabilitating injury of runners as it challenges brain stimulation, trains coordination, and reintroduces the runner to proper mechanics (Ivan, 2013). This also helps enhance performance as running forward on a track will seem easier when one is used to training running backwards and being required to use their senses at a higher level (Ivan, 2013). Based on these benefits, it is likely that within the next few decades, retro running will be a common and culturally normal activity.

Another study highlighting the benefits of backwards running was performed in 2016 and investigated the effects of retro running on forwards running in eight exceedingly skilled male runners (Ordway et al, 2016). The eight male runners ran backwards on a treadmill for 10 weeks (Ordway et al, 2016). The study concluded that just after 5 weeks, the runners had an average improvement of running economy, or ability to take in less oxygen for a specific running velocity, by 2.54% (Ordway et al, 2016). Furthermore, the authors concluded that backwards running can

be used to rehabilitate stroke victims or individuals with lower leg injuries. The authors also concluded that backwards running, in comparison to forwards running, has a greater amount of muscle activity and cardiopulmonary response (Ordway et al, 2016). These conclusions are positive news for stroke victims, who may have previously enjoyed running pre-stroke, as well as those who would benefit from increased cardiopulmonary function. Ordway et al and their findings sustain running backwards as an efficient and worthwhile method to help runners reach peak performance. (Ordway et al, 2016).

Another great benefit of backwards walking is its scalability to accommodate almost any skill level. Common regressions could include walking backwards at a slow pace or using support to remove body weight and reduce risk of falling. An individual could also progress the exercise and sprint backwards or pull a weighted sled. Because of this, backwards locomotion can be suited for an elite Olympic runner or even an elderly individual looking to improve his/her running. A study investigating some different progressions of backwards walking divided sixty subjects suffering from chronic knee osteoarthritis into three groups of twenty individuals (Khilwani et al, 2019). One group performed reverse treadmill walking with no incline, one group performed inclined reverse treadmill walking, and a control group performed no treadmill walking (Khilwani et al, 2019). The study concluded that out of these three options, for individuals with chronic knee osteoarthritis, the incline reverse treadmill walking was best for improving the quality of life and decreasing these patients' pain and inflexibility. (Khilwani et al, 2019). Since knee pain has been established as the most prevalent running injury, backwards walking on a treadmill is yet again proven beneficial for runners. Furthermore, it is typical for a cycle ergometer to be used to reintroduce motion back into the legs of runners after knee injury

(Mulla et al, 2017). A cycle ergometer has many benefits because it is low impact and non-weight bearing, but in comparison to walking backwards, it is not as effective as building back endurance after an injury (Mulla et al, 2017). A study that proved walking backwards for knee pain to be better than cycle ergometry was performed in 2017 and involved twenty individuals with chronic knee arthritis (Mulla et al, 2017). Ten of these subjects used a cycle ergometer and ten walked backwards on a treadmill. After some time, the study concluded that backwards walking on a treadmill was proven better at increasing exercise endurance and tolerance in injured runners than the cycle ergometer. (Mulla et al, 2017).

Amazingly, knee pain isn't the only running related issue that retro walking/running can fix. Retro running has brought about positive results in cases of upper extremity injury, shin splints, issues with the Achilles tendon, ankle sprains, and hip pain/injury. (Ivan, 2013). Dr. Myklebust, a physical therapist and author of, "The ACL solution: prevention and recovery for sports' most devastating knee injury", suggests that every athlete should include running backwards in his or her warmup routine because it helps to prevent injuries during play and to prepare the athlete for the kinematics of running (Boyle et al, 2012).

The Knobloch study also showed that overuse injury was more common than acute injury in elite running population (Knobloch, et al, 2008). This relates to a key factor mentioned by Jin, that most injuries experienced during running are due to the repetitive activity of running versus a single traumatic injury (Jin, 2014). Although this was the case for non-ball sport runners, such as participants in long distance or track style running, ball sport athletes could be at a higher risk of single traumatic injury occurrences due to the nature of the sport. For example, ball sport athletes, such as those who participate in football, basketball, or lacrosse, have an increased risk

of collision with another player as well as higher demands for changing speed and direction during running. Because of these factors, it is understandable why non-ball sport runners experience a higher risk of repetitive injury than do ball sport athletes. This deduction is significant because straight line runners, whose sport does not involve multi-directional changes, can focus on preventing injuries that surface with repetitive motion, not a single traumatic event.

The supposition that the straight line and the multi-directional runner populations experience different causes of injury raises the question of if specific populations within these categories are at more risk of injury than others during running. Besides runners who have previously experienced injury, beginner runners and women with lower levels of bone density are at a higher risk of becoming injured from running (Jin, 2014). Other populations at higher risk include people who run regularly over long distances, which is defined as over forty miles a week (Jin, 2014). Individuals who do not increase the intensity of their running routine gradually and increase it suddenly are also at greater risk of injury because their bodies may not be physically capable of this fast-paced progression (Jin, 2014). Older and elderly adults are also at greater risk of injury (Jin, 2014). In relation of gender and injury frequency while running, women suffer from more running injuries than men, although both genders share the top three frequent anatomical sites of running injuries (Francis et al, 2019). These sites, listed from greatest to least prevalence, are the knee, the ankle/foot, and the shank region, which is the area over the tibia bone. Men experienced a higher frequency of injury to the ankle/foot and shank region (Francis et al, 2019). Kakuris et al agrees with these findings, reporting that males exhibit a greater proportion of injuries to the ankle in comparison to female runners (Kakouris et al, 2021). Because of this, it

should be taken into account that male runners perhaps need more strengthening exercises for the ankle region than women, especially the Achilles since it is the most commonly injured anatomical site within the ankle (Kakouris et al, 2021).

In light of these evolutionary past studies, there are new, contemporary approaches to treating knee pain emerging, such as the novel case study of Ben Patrick. As an overcomer of chronic knee problems, Ben Patrick has not only accomplished what many doctors would say is an impossible recovery, but he has pushed research on runner performance like only few have done. His research and story have allowed him to help thousands of others, ranging from individuals who like running as a hobby to NBA and Olympic athletes (Morales,2022). By the time Ben turned eighteen years old, he had endured three surgical knee alterations that left him in tremendous pain when running (Morales, 2022). Rather than giving up, he devoted his life to studying rehabilitation methods, exercise techniques, and athletes with world class knee health to program a set of exercises to help individuals of any running level, regardless of injury history, to restore their knee health. Notably, his journey allowed him to rid himself of his knee pain and achieve a forty-two inch vertical after only ever having a personal best of nineteen inches (*Ben Patrick,2019.)* His impact on the exercise science community and contributions to the world of running performance signify a new wave of research and athletic potential that is being made available to athletes of all levels who seek to improve running mechanics (Morales, 2022). Not surprisingly, Ben Patrick also endorses walking backwards, specifically, for just 10 minutes a day to improve knee pain (Patrick,2020).

One of Ben's main principles to overcoming knee pain, that has also been backed up by several other studies, is performing exercises in which the knees travel over the toes. This belief

is so revolutionary because this is an idea that was long thought to cause knee pain and destruction, mainly due to a study performed at Duke University in 1978 titled, “Kinetics of the parallel squat,” (McLaughlin et al 1978). Researchers found in this particular study that the further past vertical the knees go when squatting, the more shear forces and pressures are exerted onto the knee (McLaughlin et al 1978). This pressure was labeled detrimental and harmful to the knees, and thus, the universal advice was created to not let your knees go past your toes when squatting or performing exercises. Coaching cues began to develop to maintain a vertical shin or to only squat to a certain depth. Though, the interpretation of this study was likely wrong. Applying pressure onto a muscle is how it becomes stronger, and injury or detrimental effects only occur if the load is too strong for what the muscle can yet handle (Kraemer and Ratamess, 2004). Again, pressure and stress are not a bad thing in the correct amount. Therefore, the study that could have led humans to understanding how to build resilient knees in 1978 more than likely regressed us in our understanding of knee health (McLaughlin et al 1978). To entertain the idea of maintaining a vertical shin and minimizing the distance the knee travels over the toe, the effects these mechanics have on other joints and anatomical positions on the body must be deliberated. A study performed at the University of Memphis shows that, although not allowing the knees to go far over the toes during squats decreased the amount of pressure on the knees, it increased force and pressure on the lower back and hips dramatically- almost 28% greater that of a squat that didn’t restrict knee position (Fry et al, 2003). With this information, it can be concluded that the stronger the knee is over the toe in its full range of motion, the more resilient the athlete becomes and the less he or she risks injury to other areas of the body. It would be beneficial to add squats into a training program for

runners in which the knees go through their full range of motion, over the toes, and the hips surpass 90-degree flexion. But, regardless of the proven benefits to runners of working through the entire range of motion of a squat, it is arguably just as important to consider the risks of injury. As previously mentioned, pressure on specific muscles and joints is ok, but only if it does not exceed what the muscles can handle. To make the full range exercises for runners as safe as possible, regression to an individual's specific strength and current skill level will create an optimal environment for resiliency and rehabilitation while balancing maximal gains and low injury risk (Kraemer and Ratamess, 2004). Additionally, this will allow the athlete to focus on pain free, reconstructive exercises that allow for proper reconstruction of injured muscles. Kraemer and Ratamess suggest that, when progressing any exercise, the individual should do so gradually (Kraemer and Ratamess, 2004). For example, for a runner attempting to squat, he or she should progress gradually from an assisted squat holding bands to alleviate the pull of gravity, to bodyweight, to eventually adding load (Kraemer and Ratamess, 2004). Ben Patrick's research agrees with this advice, stating in his articles that the conclusions of numerous studies conducted on full knee bend exercising are that gradual progression builds thicker tendons and stronger muscles in the knees throughout a larger range of motion (Patrick, 2020). This information is extremely advantageous for a runner struggling to overcome knee pain or looking to enhance his or her athletic capabilities.

Another interesting and beneficial aspect of training with the knees over the toes is its relationship with running kinematics itself. When studying the specific mechanics of running, there are several points in the running stride that the knees of a runner are over the toes and force must be produced in this position. Some instances include a sprinter taking off from the

starting line or a cross country runner midstride pushing off of his or her back leg. As he or she hikes the front leg up and forwards, the knee goes over the toes as the athlete pushes his or her foot into the ground to accelerate forwards. This motion is then repeated throughout the entire running cycle, which again, is why the repetitive nature of running can be so detrimental to the body (Jin, 2014). If the muscles aren't strong throughout the entire range of motion, including the range where the knee must travel over the toe, peak performance cannot be reached and a weak link will continue to exist. If the muscles surrounding and supporting the knee in this position are weakened, the athlete will perform sub-optimally and be more prone to injury (Patrick, 2020).

Because the two most common running injuries are to the knee and Achilles, it is logical to review the muscles that are important to keep these areas protected and the exercises that allow for this. The Tibialis Anterior, Soleus, hip flexors, hamstrings, Piriformis, and the Achilles itself are the muscles and tendon that, when strengthened, are associated with increased knee and Achilles ability (Patrick, 2020; Kenhub, 2022). The Tibialis Anterior muscle inverts and dorsiflexes the ankle (Kenhub, 2022). While running, the Tibialis Anterior is important in deceleration as well as helping to keep the foot off the ground as the leg swings during stride (Patrick, 2020). For runners who must travel up or downhill, this muscle is especially important to train because keeps the foot off the ground while stabilizing the ankle, knee, and lower leg (Patrick,2020). Weakness in this muscle makes the athlete susceptible to injury in all of these areas and can cause an increased risk of inversion sprain, injury to the Achilles due to overcompensation, and shin splints as the Tibialis is anatomically positioned over the shins (Bennett, 2019). Therefore, runners experiencing Achilles issues should exercise this muscle, and

a great way to do that is by performing Tibialis raises and gradually increasing the difficulty (Patrick, 2020; Bennett, 2019). A last interesting thought on the Tibialis Anterior is its role in running endurance. The Tibialis Anterior muscle fired above the fatigue threshold for 85% of the time during a 1993 study testing muscles and their relation to the fatigue threshold while running (Reber et al, 1993). There are a high number of fatigue related Tibialis Anterior injuries, so the more resilient and durable this muscle is, the more fatigue resistant the athlete will become (Reber et al, 1993).

Strengthening the Tibialis Anterior does protect the Achilles, but the Achilles can also be strengthened itself through direct and specific exercises (Kenhub, 2022). Although this tendon is the strongest tendon in the human body, it is the highest frequently occurring running-related tendinopathy (Knobloch, et al, 2008). Perhaps this could be because it has not been trained properly within its full range of motion, causing it to be more susceptible to injury under the stretch and load of running. The Achilles works to plantarflex the foot and stabilize the entire ankle, making it extremely important during the running motion (Kenhub,2022). Athletes with stronger Achilles can use these tendons to transmit greater force from the lower leg into the foot to strike the ground, allowing for a strong, spring like movement when running (Kenhub,2022). The Achilles can be targeted efficiently by a bent knee calf raise, which can be gradually progressed as strength increases (Patrick, 2020). The Achilles tendon attaches two muscles of the posterior leg, the Gastrocnemius and the Soleus muscles, to the calcaneal bone of the foot (Kenhub, 2022). Although the Achilles attaches to both muscles, Ben Patrick suggests that working the Soleus muscle will help strengthen the Achilles more effectively as it also plantarflexes the foot. Because it also plantarflexes the foot, this muscle is important in running

because it enables the athlete to push the foot into the ground and produce a spring like motion with their ankle. Furthermore, the stronger this muscle is, the more load it takes off of the Achilles to solely perform plantarflexion. The Soleus muscle is most active during the midstance phase of running, and it can also be exercised effectively by the seated calf raise (Reber et al, 1993; Patrick, 2020).

The next muscle important in protecting runners from injury is actually a group of muscles, namely the hip flexors. These muscles are a part of the core, which is also important for stabilizing the swinging motion and stride during running (Patrick, 2020). The main role of the hip flexors is to lift the leg up when running or walking (Kenhub,2022). The hip flexors are arguably the most underrated muscles that runners should train for several key reasons. Patrick highlights this in his research, even going so far as to claim that ordinary humans and elite athletes are separated physically by one factor: the hip flexors (Patrick, 2020). A study that further highlighted the prominence of hip flexor strength was conducted in 2005 and tested thirteen men and eleven women on various field running tests (Dean et al, 2005). Thirteen men and eleven women served as controls, and hip flexor strength was measured for each participant before the test was conducted (Dean et al, 2005). After putting the participants through an eight week hip flexor strengthening program, the field tests, which included a timed forty yard dash and a timed 4.3 meter and 5.8 meter shuttle run, were evaluated once again. The results showed decreased running times in the group that trained hip flexors, but not in the control group (Dean et al, 2005). Specifically, the trained group increased their hip flexion strength by an average of about 12% and decreased their forty yard dash and shuttle run times by an average of about 4% and 9.0%, correspondingly. The conclusions of this study therefore support that, to enhance the

performance and speed of runners, it is beneficial to train the hip flexors (Dean et al, 2005). This most likely has to do with increased strength when driving the front leg forward during a running stride. Another study, performed in 2016, proved that hip flexor strength can be increased by almost 17% with elastic bands over a span of just 6 weeks when the exercises are done just ten minutes, three times per week (Thorborg et al, 2016). About half of the thirty- three participants in this study were male and the other half was female. This shows that the positive effects of hip flexor strength on running is not gender biased (Thorborg et al, 2016). Furthermore, the participants gradually increased the resistance of the band over the eight weeks from a fifteen repetition maximum to an eight repetition maximum (Thorborg et al, 2016). This once again highlights the benefits of gradual progression.

Although new studies and emerging exercise science professionals promoting the training of the hip flexors makes this seem like a novel idea, this muscle has been associated with increased running speed for quite some time. A study dating back to 1993 found that stronger hip flexors allow for a faster athlete (Guskiewicz et al, 1993). A muscular assessment using a Cybex II isokinetic technology was performed on forty-one intercollegiate athletes. The athletes then performed a forty yard dash, and the conclusion of the study showed a strong correlation between hip flexion strength and sprint speed (Guskiewicz et al, 1993).

Research also shows that, regardless of running speed, training the hip flexors is beneficial to either sprinters or long distance runners. Usain Bolt, eight time Olympic gold medalist and world renown sprinter, has hip flexors three times larger in size than the average human (Patrick 2020; *Faster Out of the Gate: How to Improve Speed and Explosiveness,2016*). His routine is very anaerobic and of high intensity, and he also trains his hip flexors regularly (*Faster*

Out of the Gate: How to Improve Speed and Explosiveness,2016). Although genetics play a large role in Bolt's success as a runner, it is logical for runners to follow the training style of such a successful athlete. Furthermore, if an individual's training style matches more with a long distance runner, a study done over twelve weeks by Yamanaka et al showed that training the main hip flexor, the Psoas Major, for this entirety of time increased all eight subjects' cross sectional area of the muscle and increased all eight subjects' duration times for a constant velocity running test (Yamanaka et al, 2021). This proves that training the hip flexor not only helps in short distance scenarios that require speed but also in long distance endurance scenarios (Yamanaka et al,2021).

Furthermore, tightness in the hip flexors can also lead to knee pain (Patrick, 2020). The Rectus Femoris, a major hip flexor, inserts onto the patella via the patellar ligament (Kenhub,2022). If the hip flexors are too tight, the muscles on the front of the thigh will pull the kneecap up, putting stress onto the patella and consequently causing patellar tendonitis or knee pain. Therefore, ensuring this muscle is not tight or weak should be equally important to runners (Patrick, 2020). The hip flexors are the antagonists to the hamstrings and gluteal muscles, so it is of much importance to ensure that one group is not stronger or tighter than the other since running relies so heavily on both hip flexion and extension (Patrick, 2020). This relates back to the importance of balancing antagonist and agonist muscle groups mentioned earlier (Patrick, 2020). Hip extensors are the main muscles that work to propel the entire mass of the body, which can be done in any direction (Guskiewicz et al, 1993). The Gluteus Maximus is the largest of the gluteal muscles and plays its main role in extension (Kenhub,2022). The hamstrings work to flex the knee and extend the thigh, both of which motions are used during running mechanics

(Kenhub, 2022). The hamstring muscles can be worked efficiently by the Nordic curl, which is not only endorsed by ben Patrick but also Dr. Myklebust (Boyle et al, 2012, Patrick, 2020). Because the hamstrings, which consist of three separate muscles, insert into the back of the knee, the Nordic curl can also serve to rehabilitate knee injury (Boyle et al, 2012; Kenhub, 2022). What makes Nordic curls unique is their ability to train the hamstring in the entire range of motion, helping keep runners safer as they take larger strides. (Patrick, 2020). Knee pain is commonly caused by weakness or injury to the ACL, and not only does strengthening the hamstrings help keep this injury from occurring, but it helps protect from hamstring strains (Boyle, et al, 2012).

Lastly, the Piriformis muscle can be linked to running injury due to the detrimental effects it causes when it is tight or weak (*Piriformis Syndrome*, 2019). The Piriformis muscle is an outer gluteal muscle that is important in stabilizing the pelvis from left to right as well as externally rotating the hip (Kenhub, 2022). If this muscle is weak or tight in one leg, it not only affects the runner's ability to control his or her pelvis during strides, but it can also affect his or her knees by making them tight on the lateral side. This can cause weakness in the VMO muscle and is a common cause of knee pain (Patrick,2020) Tightness in the Piriformis is commonly called Piriformis syndrome, and individuals that run with this condition exacerbate their pain (*Piriformis Syndrome,* 2019)

In consideration of the extensive research listed above on enhancing running performance and injury prevention techniques, there does seem to be noticeable gaps in the current research, considerations that should have been made during the studies, and further evidence to hold these conclusions as genuine. There are many key factors that play into injury,

but a key factor that was not considered during any of the above studies nor has been adequately explored is running posture or posture during these strengthening exercises. It would be interesting to see how posture affects the results of these studies because the form that each participant performed the exercises in or ran in is not described. Certain postures and kinematics can create more or less optimal positions for the athlete and can cause intended muscle groups being trained to be worked, not worked, or over-worked depending on the form the body takes. Furthermore, unlike elite athletes, the average person may not have a professional to judge their form. Therefore, injury prevalence could be higher for average or recreational runners. So, even if recreational runners are performing rehabilitation or performance enhancing exercises, they may not be doing them correctly. This could cause the injury to linger or for their untapped running potential to not be reached. Again, this issue is most likely not as prevalent for professional athletes and those who are able to exercise under professional supervision. Furthermore, in consideration of Ben Patrick, contemporary believes are shifting from the old, and this case study is a great example of this. Credibility of his work is promising and proven in the thousands of people he has helped. It is possibly only a matter of time before his findings are published in medical journals and textbooks. Regardless, skepticism is important, especially because exercise is a science, and any idea is a theory that should be repeatedly tested for truth. Though, his method of studying elite performers who have excelled in running is genius, and this method should continue to be used to bridge the gap between the habits of extraordinary athletes and recreational runners.

In conclusion, to effectively prevent injury and enhance performance for runners, runners should train with the knee traveling over the toes. This is because it mimics running

kinetics, strengthens the knees, which the most susceptible body part to running injuries, and is proven safe when the load is handled gradually. Secondly, runners should regularly run backwards, progressing as his or her skill level improves. Backwards running is scalable to almost any fitness level, has physiological and muscular benefits for runners, and is most likely going to gain popularity withing the next fifteen years. Next, in order to protect the knee, lower leg, and ankle, which are the most common anatomical locations of injury, runners should train and strengthen the Tibialis Anterior, the Soleus, the Achilles tendon, the hip flexors, the hamstrings, the Piriformis, and glutes. And lastly, runners should recognize that exercises that prevent injury and enhance running skills are scalable, and progress can be made even if it is slow. By training in these standards, it is highly supported with evidence that, whatever level of skill or distance frequented, runners will be able to prevent common injuries and enhance the performance of his or her body.

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