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Injury and Recovery Rates of the Aging Athlete

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Injury and Recovery Rates of the Aging Athlete

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ABSTRACT

Injury and Recovery Rates of the Aging Athlete

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The precise rates of injury and recovery of the masters athlete are not yet well known. Considering that older athletes are participating at greater rates now than ever before, and that these athletes are routinely setting age-specific records, there is greater incentive to illustrate the responses related to exercise and competition as it pertains to injury and recovery. The majority of the literature focuses on younger athletes, which may be due to the amount of attention this group of individual's commands because of their physical capabilities and performance figures, but also due to their greater incidence of acute injury such as catastrophic failure of ligaments in the knee. This literature review therefore aims to elucidate some of the factors that may contribute to an older athletes seemingly different propensity for overuse injuries, as well as uncovering the precise rates of acute and chronic injury that the masters athlete suffers.

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INTRODUCTION

In athletics, masters athletes have been steadily setting new world records in their respective age classifications, while the younger population has remained relatively stable (Akkari et al., 2015). Perhaps one of the more significant reasons why this is occurring is because of the rapid growth in participation rates, such as that is seen in the marathon (Jokl et al., 2003) and triathlon (Stiefel et al., 2014).

Considering that peak performance usually occurs at a young age and then steadily declines (Young & Starkes, 2005), it is unlikely that the older athlete will be breaking overall world records anytime soon. Despite this seemingly inevitable downward trend, athletes and non-athletes alike are demonstrating a zeal for competition and are recognizing the health benefits of physical activity into the latter years of their lifespans. However, in many regards, some aspects of aging are not avoidable. Yet, that premise fails to consider the possible effects of frequency. There is a paucity of research that has specifically considered the effects of frequency rate (i.e., how often one is injured) especially amongst swimming and track and field athletes (Medic et al., 2009).

Aging and Sport Performance

Advancing age is associated with a greater incidence of degenerative joint disease, osteoporosis, sarcopenia, skeletal muscle weakness, bone fractures, various injuries and other maladies. Osteoporosis, for example, predisposes the skeleton to trauma preceded by impact or athletic activities (Prescott et al., 2012). A review by Maharam and colleagues (1999) mentioned that even though some physiological functions cannot be stopped, they can be slowed down through routine exercise. However, due to physiological decline, especially in regards to the quality of tendons, ligaments, and other tissues, it does suggest that aging predisposes an athlete to a greater risk of injury (Chen et al., 2005). Whether or not participation in exercise and sport is predisposing the older athlete to greater rate of injury is yet to be made clear. Therefore, the purpose of this review is to investigate the response and recovery to exercise as well as the risk of injury of the masters athlete. Unique to previous research, this investigation will focus on the frequency rate as a primary variable of interest.

Physiological Changes Associated with Aging & Sports

There are multiple physiological changes that occur during the process of aging. This review focuses on joints, tendons, ligaments, and skeletal muscle. Specifically, it will cover changes that occur to those tissues with advancing age and the effect those changes may have on injury and recovery.

Joints

A joint is thought to experience aging when its motion becomes more restricted, flexibility decreases, and there is a greater rate of inflammation and arthritis (Luria & Chu, 2014). Some of the changes seen in aging cartilage include a greater number of crosslinks between collagen fibers, fewer chondrocytes and reduced functional activity of those that do exist, and others, which contribute to stiffness and a compromised ability to heal. Even though the physiological changes that occur are important in regards to susceptibility to injury, the purpose of this review, however, is not to elucidate what those mechanisms are, but instead to disclose that those changes do indeed occur and are important in the context of injury and recovery. For a more comprehensive look into the changes of articular cartilage in older athletes, see Luria & Chu (2013).

It may seem that the older athlete is at a greater risk for degeneration and subsequently injury, yet this is not necessarily the case. For example, habitual, moderate exercisers are not at greater risk of osteoarthritis (OA) (Buckwalter & Lane, 1997). When the loading becomes excessive, whether it's through repetitive loading or torsional strain, there is an increase in risk of OA. Other risk factors for OA include abnormal joint anatomy, excessive body weight, previous injury, and muscular weakness. These factors can contribute to greater rates of degeneration of cartilage.

Vingard and colleagues (1993) discovered that with a higher volume of sports participation, there is a greater risk of osteoarthritis, particularly amongst those that involve repetitive motions and loading such as track and field and racket sports. Effectively, the changes associated with aging, such as stiffness and reduced healing; there is greater opportunity for damage, as well as an accumulation of damage. If the individual does not demonstrate the classic signs of aging, outcomes may appear to be different. For example, Jackson & Rouse (1982) state that patients that underwent arthroscopic meniscectomy following traumatic injury demonstrated incredibly positive outcomes if they did not show signs of degeneration. However, for some of the patients who did show degeneration, it took them longer to recover. This is important for older athletes because this may significantly affect the amount of time it takes to return to sport.

If performing certain activities elicits microdamage to cartilage, for example, with adequate recovery time, the tissue can heal. However, if the damage is not given time to heal, this tissue has the potential to accumulate even more damage, which can then predispose it to failure or degeneration. The results of the investigation by Jackson & Rouse (1982) highlight the importance of physical activity participation that is within the physiological capabilities of the individual.

Tendons & Ligaments

In tendons, aging is associated with an increase in crosslinks, decreased water content (Cook et al., 2002), increased glycosaminoglycans, increased collagen concentration (Longo et al 2009a), reduced vascularization (Tuite et al., 1997), decreased cellularity, a reduction in fiber organization (Magnan et al., 2014), reduced tensile strength and strain to failure (So & Pollard, 1997). The older tendon, as a result, is less elastic and more prone to injury, because of the reduced elasticity forces the associated muscle to exert more force (Magnan et al., 2014), predisposing it to injury as well. However, new evidence shows that aging is not associated with a decline in cellularity (Thorpe et al., 2015) and that moderate exercise can mitigate some of the ill effects of aging on the tendon stem/progenitor cells (Zhang & Wang, 2015). Even though cellular synthetic activity may not be compromised in the older tendon, there are still numerous factors that can contribute to an increased susceptibility to injury.

In regards to traumatic injuries of tendons, such as an achilles tendon rupture, there are often preceded by overuse, which leads to microtearing of the tendon and subsequently predisposes the tendon to catastrophic failure (Hess, 2010). In such cases, it is difficult to determine the exact reason why the injury occurred. Sports-related achilles tendon ruptures occur at increasingly greater frequency up until the 4th decade, after which the rates drop (Leppilahti & Orava, 1998). This drop in injuries during middle age can simply be a reflection of lower participatory rates in physical activity and sports.

Skeletal Muscle

With advancing age, there are noticeable changes that occur to skeletal muscle, such as atrophy, reduced flexibility and ability to produce force, decrease in mitochondrial volume, and an increase in collagen content (Chen et al., 2005). Per cross-sectional area, older mice are capable of producing the same amount of isometric and concentric force as younger mice (Brooks & Faulkner, 1994). This suggests that the intrinsic, force-generating capabilities of the muscle are not altered with age, instead, the drop in strength correlates with a reduction in muscle mass, among non-human animals

Older people also demonstrate a reduction in type II muscle fibers (Larrson, 1978). The cross-sectional area of type II fibers decreases, but not type I, and the proportion of type II fibers also decrease (i.e., greater type I to type II ratio). This reduction in muscle is associated with a reduced ability to produce force (Brooks & Faulkner, 1994). The reason this may be the case is because of stunted muscle protein synthesis (MPS) rates.

In sedentary, elderly individuals, they demonstrate a reduction in the synthesis rates of myosin heavy chain (MHC) and mixed muscle protein, but following a weight training intervention, the rates are not different to young adults (Yarasheski, 2003). Balagopal et al (1997) found that MHC synthesis rates declined with age, but not sarcoplasmic proteins. It appears as though aging does not have an effect on global protein synthesis rates but rather on specific proteins (Nair, 2004).

Another reason why there is a reduction in muscle mass is because of alpha motor neuron loss, reductions in size and quantity of muscle fibers (Tarnopolsky, 2008) with particular discrimination against type II fibers (Larson, 1978), and a reduction in the synthetic rates of certain proteins such as myosin heavy chain (MHC) (Balagopal et al., 1997) and mixed muscle protein synthesis rates (Schulte & Yarasheski, 2001). As a person gets older, he or she also experiences reduced insulin sensitivity which may have a potential effect on muscle protein synthesis rates as well (Nair, 2004). However, following resistance training, the synthetic rates are similar between the young and the elderly (Yarasheski, 2003). Also, these are just acute synthetic rates, which have not been found to correlate with long-term hypertrophy (Mitchell et al., 2014). Simply put this means that younger men, versus older, are better able to augment skeletal muscle mass (Petrella et al., 2006). This phenomenon has been explained by the fact that younger men had greater levels of IGF-1 and testosterone, which may have allowed them to build more muscle.

Older people also have reduced ATP availability, which can hinder the remodeling process (Nair, 2004), as well as a slower recovery of oxygenated and deoxygenated hemoglobin following exercise (Kutsuzawa et al., 200). Since ATP an oxygenation provide energy and assist with recovery, this difference across the lifespan is worth mentioning. Beyond ATP, Moller et al., (1980) noted that older men and women had less energy-rich compound concentrations, such as ADP, total adenine nucleotides, phosphocreatine, and ratio of phosphocreatine to total creatine. There was, however, a greater amount of creatine in the older subjects, thus refuting the idea that older adults cannot build muscle.

Even though muscle can increase in size across the lifespan, hypertrophy is greater among younger men. One of the key factors that regulate skeletal muscle hypertrophy and recovery is satellite cell content and activation. As mice aged, there were less satellite cells, both relative to the number of myonuclei and the absolute number of cells (Gibson & Schultz, 1983). The reduction in number of satellite cells is evident in humans as well (Hunter et al., 2004). This is potentially another reason why the young men in the in the study demonstrated greater hypertrophy (Petrella et al., 2006).

Another competing argument is that we are less active as we age. Chen et al (2005) argues that the effects of aging may be more due to a sedentary lifestyle than anything else. When one takes into consideration that the older individual still has a profound capability to augment skeletal muscle (Peterson et al., 2011), the age-associated muscle mass and strength loss very well may be due to disuse. However, when you look at the performance of competitive Olympic weight lifters, for example, there is decline of 1-1.5% per year up until the age of 70, after which the rate increases significantly (Meltzer, 1994). Many masters track and field world records follow a similar decline, where the 100m record drops at a rate of 0.6% and the shot put drops at a rate of 1.4% per year (Gava et al., 2015).

It may not be that older muscle *per se* is affected by age, but rather the environment that the muscle is in that affects it. In non-human animals, Carlson & Faulkner (1988) demonstrated that you can successfully graft muscle from one rat to another. The muscle from old rat that was grafted to young rat generated greater mass than muscle grafted to old rats (Carlson & Faulkner, 1989). When muscle from young rat was grafted into the older rat, the response was the same as older muscle grafted to older rat.

Exercise-Induced Muscle Damage

Eccentric exercise has been shown to be particularly effective at inducing skeletal muscle damage (Friden et al., 1983), especially when compared to other types of contractions (Clarkson & Sayers, 1999). The damage induced by exercise increases as one ages. This is even evident in very young men less than 20 years old, where adolescent boys (14.3 years old) demonstrated more damage than pre-adolescent (9.4 years old) but not as much as post-adolescent (22.6 years old) men (Chen et al., 2014).

When active, older women (67.4 years old) are compared to college-aged women (23.6 years old), following eccentric exercise, the older women had not recovered their strength by the fifth day while the younger women did (Dedrick & Clarkson, 1990). When old men (64 years old) were compared to young men (25 years old), the response was similar, where older men recovered strength significantly more slowly than younger men (Chapman et al., 2008) and demonstrated greater skeletal muscle damage after the initial bout (Manfredi et al., 1991).

Even though older men and women appear to be affected more by eccentric exercise, the differences are minimized with the subsequent bout where there are no differences between younger and older women (Clarkson & Dedrick, 1988) and few differences between younger and older men (Lavender & Nosaka, 2006). Also, sedentary old women who underwent a 12-week-long resistance-training program responded similarly to a bout of eccentric exercise as untrained young women (Ploutz-Snyder et al., 2001).

Among exercise protocols that were not focused purely on eccentric contractions, the outcome looks different. Active young and older men were electrically stimulated to fatigue, where both groups demonstrated similar loss in force (Klein et al., 1988). However, the older men were slower to recover, where the rate of relaxation was slower and the half-relaxation time was greater. Following a 55-kilometer trail running competition, where both master and younger athletes had had suffered similar levels of muscle damage but the young athletes had recovered quicker in terms of contractile characteristics (e.g., peak twitch and contraction time) (Easthope et al., 2010).

Following a heavy resistance training protocol, older sedentary men did not demonstrate any differences in regards to muscle fiber damage to young men before and after the protocol (Roth et al., 1999). The same group of researchers performed the same protocol on young and old women. (Roth et al., 2000), where the older women demonstrated greater muscle damage.

The data for masters athletes is clearly limited. However, a few studies did utilize physically active participants (Clarkson & Dedrick, 198; Chapman et al., 2008: Klein et al., 1988; Dedrick & Clarkson, 1990). The majority of them demonstrate that older, active men and women show a compromised ability to recover as quickly as their younger counterparts. It has to be mentioned that many of the studies suffered from a small sample size (Clarkson & Dedrick, 1988; Dedrick & Clarkson, 1990; Chapman et al., 2008; Klein et al., 1988).

Injury Rate

Between 1999 and 2008, there were over 6.6 million knee injuries in the United States (Gage et al., 2012). Those that were 15 to 24 years old had the highest rate of knee injury, while those in the 45-64 and over 65 years old groups had the third and second lowest rate of knee injury, respectively. Interestingly, the oldest group was more likely to visit the ER for bruising and abrasions than sprains, suggesting that they're big babies. More importantly, the vast majority of knee injuries sustained by those 25 years old or older were unrelated to sports or exercise.

In Germany between 1997 and 1999, 3.1% of people surveyed said that they had sustained some type of sport-related injury during the past year (Schneider et al., 2006). This corresponds to an annual injury rate of 5.6%. The vast majority of sports injuries (60%) were sprains, strains, tears, and dislocations. The incidence of injury did decline as age progressed.

Even though the masters athlete may seem like he or she is more prone to injury due to the changes associated with aging, there are benefits to lifelong sport participation. For example, older athletes have a much greater bone mineral density than their inactive counterparts (Kettunen et al., 2010), which can help stave off fractures to later ages (Kettunen et al., 2010, Nordstrom et al., 2005). There are many potential reasons why former athletes may be less susceptible to fractures, which can be attributed to a reduction in falls because of increased strength, balance, and coordination (Karlsson, 2004).

Acute & Overuse Injury Risk

Older individuals appear to be at greater risk of injury overall (Taimela et al., 1990). As the athlete ages, he or she will experience a greater amount of inflammatory problems commonly associated with overuse, such as tendinitis and bursitis (DeHaven et al., 1986). Within this age group, 85% of the injuries reported by older people were overuse (Matheson et al., 1989). A similar findings was confirmed by Chen et al (2005), where 70% of veteran athletes suffered overuse injuries. Yet the research is not equivocal, as The research is equivocal, for example, Kallinen & Alen (1994) found that in those that 70-81 year old athletes were much more likely (62% more) to sustain acute injuries. This is doubtful because older individuals are less likely to participate in activities that would expose them to greater risk of acute trauma (Menard et al., 1989).

Masters football players from New Zealand demonstrated that the most common areas injured were in the lower limb, specifically the lower leg, ankle, hamstring, knee, and achilles tendon (Newsham-West et al., 2009). Football players are more likely to get injured as they get older, independent of previous injury (Arnason et al., 2004). Gabbe and colleagues (2006) found that Australian football players over 25 years of age were at greater risk of hamstring injury than those 20 years old or younger. Yet among Swedish footballers, age was not a risk factor for injury, instead previous injury was the most prominent predictor (Hagglund et al., 2006). Opar et al (2015) found that greater eccentric hamstring strength is associated with lower incidence of hamstring injury, even in older age, suggesting that some of the injuries can be mitigated with strength training.

A similar injury trend was witnessed during the 2012 London Paralympic games, where the older age group (26-34 years old) had a higher injury rate than those that were younger (Willick et al., 2013). Alonso et al (2011) found that during the 2011 IAAF Championships, older athletes (> 30 years old) were more likely to get injured during the event. Edouard et al (2014) found a similar outcome where older, male athletes were at greater risk of injury during the 2012 European Athletics Championships.

Over the span of 3 years of the Penn Relays, it was found that male and masters athletes were more likely to sustain injuries during this event (Opar et al., 2015). During the 2012 European Veteran Athletics Championships, older athletes were not any more likely to get injured than younger ones (Ganse et al., 2014). It has to be mentioned that the Veterans Championships have a minimum age of 35 years old. Although it may seem that the athlete is at greater risk of injury up until age 35 or that injury rates become more stable after the 3rd decade.

Masters runners appear to be at greater risk of injury than younger runners, where 49% reported having suffered an injury in the past year, compared to 45% for those that are younger (McKean et al., 2006). The masters runner was more likely to suffer multiple injuries as well as incurring greater rate of injury to the hamstring, calf, and achilles. Masters runners were more likely to run more in terms of distance, weekly frequency, and years practiced, which may have contributed to their greater incidence. It was also found that the masters runner is at greater risk of suffering an overuse injury rather than an acute one, with achilles tendinopathy as the most common issue, followed by knee anterior knee pain and shin splints (Knobloch et al., 2008). The authors mention that the more experienced runners (i.e., more than 10 years of running experience) had a greater risk of achilles tendinopathy, further implicating excessive physical activity as the culprit behind the greater overuse injury rates.

The risk of injury is greater for the older athlete but one has to take into consideration that many of the studies mentioned did not use veteran athletes above 40 years of age. Additionally, the longer an individual participates in highly competitive sport that mandates a large amount of physical activity, this places the competitor in a situation where it may only be a matter of time before an injury occurs.

Injuries During Training

Examination of injuries during training opposed to during the competition revealed unique age comparisons. State prison and county jail inmates (20 – 35 years old) underwent exercise training that was either 1, 3, or 5 days a week or went for 15, 30, or 45 minutes per session, to see if there was any difference in injury incidence (Pollock et al., 1977). Pollock and colleagues found that the injury rates for the 1, 3, or 5 days per week intervention was 0%, 12% and 39%, respectively. For the duration portion of the study, the injury rate was 22%, 24%, and 54% for the 15, 30, or 45 minute-long sessions, respectively.

A walk/jog exercise intervention was provided for sedentary elderly (70-79 years old), that was either aerobic or resistance training, where 19.3% suffered injuries during strength testing, 8.6% of subjects were injured during training in the resistance training group, and 42.9% of subjects were injured during training in the aerobic group (Pollock et al., 1991). The author's mention that incidence of injury increased when the training program shifted from walking to jogging. A similar study incorporated walk training for the elderly (60-79 years old), where 14% suffered injuries (Carroll et al., 1992). Community-dwellers (69 years old) were asked to recall their injury incidence in the preceding 12-months, where 16% reported injury (Stathokastas et al., 2012). Another group of community-dwelling seniors were prospectively evaluated, where 14% sustained injuries (Little et al., 2013).

Hootman et al (2001) found that for those that were between 40-60 years old, men had an injury rate of 71.1% and women had 67.7%. For those older than 60, for men the injury rate was 15.9% and for women 12.0%. In a second study, (Hootman et al., 2002) found that for those that are 40-60 years old, physical activity-related injuries for men and women were 22.1% and 22.0%, respectively. For men and women older than 60, the rates were 16.4% and 15.4%, respectively. They also found that those that were more physically active had a greater injury rate for both men and women. Both of these studies were longitudinal that utilized surveys to retrospectively assess injury rates. Another survey-based study found that during recreational activities and sport, the injury rate was lower the older the population got (Mummery et al., 1998). They found an injury rate of 8.3%, 5.7%, 2.2%, and 0% for ages 35-44, 45-54, 55-64, and 65+, respectively.

The studies mentioned illustrate a very interesting point; the reduction in injuries amongst the elderly in regards to physical activity or sport may simply be a reflection of reduced participation. When older subjects took on exercise programs, especially when the volume and/or intensity was manipulated, the authors of those studies found that injury rate increased.

Tendon & Ligament Injuries

Clayton & Court-Brown (2008) found that the annual incidence rate for tendinous and ligamentous injuries was 106.2 per 100,000. Men are more likely than women to sustain such injuries (166.6/100,000 vs 52.1/100,000), although this gap narrows with increasing age. The mean age for men was 33.1 and for women 43.6 years old, suggesting older women are at greater risk of injury. The most common injuries found were meniscal tears, injury to the hand/forearm extensor tendon, acromioclavicular joint, achilles tendon rupture, mallet finger, and ACL. These injuries accounted for 80.4% of all the soft tissue injuries witnessed between 1996 and 2000 in a Scottish orthopaedic trauma unit. ACL injuries occur more frequently in those that are younger and start to decline after the second decade. Achilles tendon rupture incidence increases steadily for both men and women until the fourth decade and decreases thereafter. Injury to the quadriceps tendon begins to rise after the third decade for men and drops off after the sixth decade whereas for women, it's very low up until the sixth decade.

In terms of sports-related injuries, achilles tendon injuries are one of the most common sports injuries, which include acute injuries such as tears and ruptures and chronic, overuse injuries such as paratenonitis, tendinosis, bursitis, and tendinitis (Schepsis et al., 2002). Overuse injuries of the achilles predominate (Cook et al., 2002), which is especially evident in track and field, soccer, volleyball, and raquet sports (Longo et al., 2009a). For the masters Track athlete, age didn't appear to be associated with greater incidence of achilles tendinopathy during the 2006 European Veterans Athletics Championships (Longo et al., 2009b). It is also not a risk factor for patellar tendinopathy, either (Longo et al., 2011). This was not a surprise considering that tendinopathy of tendons is not associated with aging (Cook et al., 2002).

Knee Injuries

Knee injuries pose a particularly unique problem to athletes both young and old and as such, is one of the most studied forms of injury. Often, they can be season and career ending. Older patients are less likely to continue participating in their pre-knee-injury (i.e., ACL reconstruction) sport (Ardern et al., 2012; Ardern et al., 2014); after osteochondral allograft transplantation (Krych et al., 2012), after articular cartilage repair (Mithoefer & Della Villa, 2012), and after microfracture treatment of the knee (Mithoefer et al., 2010).

Perhaps one of the reasons this is so is because of prolonged recovery time. Younger patients recovered faster following arthroscopic meniscectomy (Kim et al., 2013) and had a lower incidence of patellofemoral pain 12-months after ACL reconstruction (Culvenor et al., 2015). However, following unicompartmental knee arthroplasty to treat OA, age was not a factor for time to return to sport or work (Jahromi et al., 2004). Another reason may be the fear of re-injury. This may be entirely unfounded because following an ACL injury that required surgery, older patients (> 25 years of age) were less likely to sustain a re-injury to the same, repaired knee or non-injured knee (Shelbourne et al., 2009).

The risk of knee injury increases in recreational and sporting activities when compared to commuting (e.g., walking, cycling, etc.) and lifestyle (e.g., gardening, hunting, etc.) activities (Haapasalo et al., 2007). In commuting, recreational, and competitive sports, there was a decreasing risk of injury with age whereas with lifestyle activities, there was an increasing trend. Once again, these findings may be due to declining activity rates common among the elderly, especially away from sports and recreational activities that have a higher risk of injury.

Muscular Injuries

Age is a risk factor for recurring hamstring injuries (DeWitt & Vidale, 2014), hamstring and calf strains in Australian footballers (Orchard, 2001), hamstring strains in Australian footballers (Verrall et al., 2001), and hamstring injuries in English footballers (Woods et al 2004, Henderson et al 2010). They also occur at greater rates when there is a past history of strain(s) (Verrall et al., 2001). Verrall and colleagues pointed out that even when past history is excluded, age is still a significant predictor. For masters footballers, hamstring injuries are some of the most common injuries to the skeletal musculature (Newsham-West et al., 2009). Age, however, is not a risk factor for quadriceps strains in Australian footballers (Orchard, 2001) and recovery (i.e., recovery of isokinetic strength) following hamstring avulsion (Birmingham et al., 2011).

Rotator Cuff Injuries

In the general population, rotator cuff injuries are very common. A village in Japan was assessed for full-thickness tears and found that 22.1% had tears (Minagawa et al., 2013). This study looked at over 600 individuals that were 20 years or older. The group that had the greatest frequency were those in their 80's or older (36.6%), while those 20-40 years old had no rotator cuff injuries. Interestingly, 65.3% of those who had tears were asymptomatic.

In people who do not report of any pain or discomfort to their shoulders, 23% had rotator cuff tears (Tempelhof et al., 1999). Much like the previous study, they found that with greater age, tears were more common. In the youngest group (50-59 years of age), 13% had tears while the oldest group (> 80 years of age) had 51%. Fehringer et al (2008) found that those over 65 had a full-thickness tear prevalence rate of 22%. Sonnery-Cottet et al (2002) suggested that full-thickness tears are uncommon in athletes under the age of 35 and that the frequency of this complication increases in those older than 50.

Yamaguchi and colleagues (2006) found that the average age of those studied with single tears was 58.7 years and those with tears in both shoulders was 67.8 years. This study looked at 588 consecutive ultrasounds of the shoulder in those that had pain or known abnormality of the shoulder. One review looked at the all the studies that measured the frequency of rotator cuff tears in cadavers and those that utilized ultrasound and MRI, finding that 11.75% had full-thickness tears and 18.49% had partial-thickness tears (Reilly et al., 2006).

In regards to athletes, Maharam et al (1999) mentions that injuries to the rotator cuff, including tears, are much more common in those that are 40 years of age or older. It is not clear whether or not these athletes sustain injuries at a greater rate than the general population or that an injury to the rotator cuff is something that just happens with age. Ozaki et al (1988) comments that the overarching theme behind all of these rotator cuff injuries is degeneration associated with age, which predisposes it to rupture when exposed to trauma.

Surprisingly, there was only one study that looked at masters athletes and their prevalence of rotator cuff injuries. During one Senior Olympics, 141 athletes older than 60 had their dominant shoulder ultrasound, finding that 21.3% had full-thickness tears and 48.2% had partial thickness tears (McMahon et al., 2014).

There are two limitations, one of which the authors admit to, which is that the participants that they had may have not been a good representative of the Senior Olympics. The other limitation was that they only studied the dominant shoulder. In any case, these athletes exhibited a greater incidence than the general population.

Following surgical intervention, 17% of repaired rotator cuffs were re-torn after 6 months (Le et al., 2014). 27% occurred in full-thickness tears and only 5% of partial-thickness. The average age for this group was 57.6 years and those that had a re-torn rotator cuff was 65.7 years. The authors do state that age was a significant predictor of re-tear. Another study found that the re-tear rate was 5% for small to medium tears while large or massive tears had a 40% re-tear rate (Sugaya et al.,2007), confirming the results by Le et al (2014). 21 overhead throwing athletes (58.9 years old) had rotator cuff repair, where 5 experienced a re-tear (23.8%) (Liem et al., 2008). The re-tear rate here was not different than those not participating in overhead sports or any other sport for that matter.

Thirty, middle-aged (43.1 years old) patients with subscapularis tears had them repaired, finding that the 18 recreational athletes included in the study had a 75% success rate at returning to pre-injury performance (Bartl et al., 2011). A review of the outcomes of superior labrum anterior-posterior (SLAP) tears seems to suggest that those older than 40 have as good or worse ability to recover from such a procedure (Erickson et al., 2015). Erickson and colleagues comment that older individuals are more likely to experience complications, stiffness, and reoperations.

Osteoarthritis

In the general population, osteoarthritis (OA) typically occurs in weight-bearing joints, such as the hip, knee, lumbar and cervical spine, and base of the thumb (Wolf & Amendola, 2005). It is a joint disease characterized by a decline in cartilage structure and function, and it is a significant contributor to a reduced quality of life and disability. Certain types of activities expose an athletes weight-bearing joints to substantial loads, which is a cause for concern that sport participation may predispose an individual to premature OA. Those that are overweight, female, and have a history of injury are at increased risk of developing OA (Wolf & Amendola, 2005).

Finnish elite athletes that participated in endurance, mixed sports such as soccer and hockey, and power sports, all had higher incidence of OA (Kujala et al., 1994). Even though the risk was significantly greater than the control group, the authors do mention that it was only a slightly increased risk, where 5.9% of athletes were admitted to hospital for OA of the hip, knee, or ankle during the 21-year follow-up, whereas only 2.6% of control was admitted. Two big limitations of the study were that the control group was not age-matched and that they did not take into account injury.

A robust study looked at 709 former elite athletes and compared them to well-matched controls, finding that risk of both hip and knee OA was higher in the former athletes (Tveit et al., 2012). The vast majority of the elite athletes had pariticipated in impact sports such as hockey, soccer, and handball (n=696) versus non-impact sports (n=96), which may have skewed the incidence of OA.

Retired football players (56.4 years old) were compared to an age- and weight-matched control group and it was found that the footballers had greater signs of hip OA, but not in the knee (Klunder et al., 1980). Soccer players and weight lifters are at greater risk of premature OA of the knee when compared to long-distance runners and shooters (Kujula et al., 1995). Veteran soccer players (40-74 years old) demonstrated more frequent signs of OA than a randomly selected population (Chantraine, 1985). In this study, 41% of players that did not have meniscectomy showed signs of OA and every soccer player that had a meniscectomy had OA. Former elite soccer players are at a greater risk of developing coxarthrosis as well (5.6% versus 2.8% in a age-matched control group) (Lindberg et al., 1993).

Former professional NFL football players were surveyed, finding that their rate of arthritis (including OA), was greater (40.6%) than the general male population (11.7%) (Golightly et al., 2009). They also found that injuries were more associated with OA than those players that did not experience injuries. Thirty-three percent of former elite tennis players demonstrated at least some OA to their dominant shoulders whereas only 11% of age-matched controls showed signs of OA (Maquirriain et al., 2006). None of the tennis players had any trauma or injuries to their shoulders. 78.3% of table tennis players had demonstrated varying amounts of OA in the knees when compared to age-matched control (36.3%; Rajabi et al., 2012). This study, however, was limited by the small sample size.

Only 4% of former elite, older runners demonstrated primary OA while 8.7% of controls showed primary OA (Puranen et al., 1975). When older (50-72 years old) long-distance runners are compared to age-matched control, no differences were found in incidence of OA (Lane et al., 1986). Former long-distance runners, bobslayers, and normal untrained men were compared, finding that high-mileage running is a significant predictor of degenerative hip disease (Marti et al., 1989).

Former elite male high jumpers were compared to age- and BMI-matched controls, finding no significant differences in risk of OA in the ankle (Schmitt et al., 2003). However, high jumping seemed to affect the hips more. Former elite javelin throwers and high jumpers were compared with age- and BMI-matched controls, 58% of throwers and 34% of high jumpers demonstrated hip arthrosis, whereas for the control group, it was 16% (Schmitt et al., 2004). The only study that looked at former elite female athletes found that they were at greater risk of OA in the hip, tibiofemoral, and patelofemoral joints (Spector et al., 1996). This study included primarily middle- and long-distance runners, with some tennis players.

Men who recently received prosthesis because of severe OA were compared to the general population, finding that those that had greater exposure to sport seemed to increase risk of developing hip OA, particularly track and field and racket sports (Vingard et al., 1993). This study had a fairly large sample size (n=535) and numerous sports. Author's comment that sports with a great deal of rapid deceleration may have contributed to knee OA. Perhaps this is why the table tennis players had such a high rate of knee complications.

Gouttebarge and colleagues (2015) performed a review of OA in former elite athletes, mentioning that the cause of OA in elite athletes is complex and involves numerous biological, mechanical, and biochemical factors. They found that incidence of OA occurred at widely different rates for both the knee and hip joints. In the end, they conclude that former elite athletes suffer from OA at a greater rate than the general population. It has to be mentioned that some of the articles Gouttebarge et al (2015) utilized for their review were not controlled.

Elite athletes are predisposing themselves to greater rates of OA because of injuries, as well as with the amount and level of activity. For example, long-distance skiers were more likely to develop OA the more active and competitive (i.e., participating in more races) they were (Michaelsson et al., 2011). Another factor that may contribute to incidence of OA in athletes is damage that goes untreated or unnoticed. Nineteen high-level athletes from various disciplines, experienced ACL rupture and followed a conservative treatment route (i.e., without surgery), where 95% of them eventually developed severe OA

(Nebelung & Wuschech, 2005). It should be mentioned that despite not having an intact ACL, they continued to compete.

DISCUSSION

Every day, we are learning more about why certain individuals are more susceptible to injury. Interestingly enough, researchers are beginning to establish links between genetics and injury risk (Goodlin et al., 2015). For now, though, the focus is on the older athlete and his or her response to exercise, as well as how prone he is to becoming injured. The older athlete may very well be at greater risk of injury than his younger counterpart. However, the data on masters athlete is lacking, but that doesn't mean we cannot apply existing knowledge of the way the human body ages and the responses witnessed by the general population.

It appears as though changes associated with aging are unavoidable (Chen et al., 2005; Maharam et al., 1999). The older athlete ought to be cognizant of his limitations and the fact that his body does not respond the same way to exercise as he once did. For some athletes, activity rates are still very high, sometimes higher than those younger (McKean et al., 2006). Perhaps endurance activities such as marathon running and triathlons provide a false-sense of security where the preconception may be that the more dynamic and explosive team sports, such as soccer or basketball, will expose him to a greater risk of injury. In endurance sports, loading rates to joints can be substantially lower, which is one of the reasons why runners are less susceptible to traumatic injuries (Knobloch et al., 2008).

Endurance athletes between the ages of 15-35 had a 5.2-fold increased risk of overuse injury if they only had 2 rest days during the training season (Ristolainen et al., 2014). Those that trained for more than 700 hours during a year had a 2.1-fold increase in risk. It is evidence like this that shines a light onto the overuse problems that often plague the older athlete. It is not known just how much greater the risk of overuse injury is for the masters athlete, but evidence from younger participants illustrate that when adequate recovery is not administered, he or she is at greater risk of overuse injury.

Certain physiological changes that occur places the masters athlete at a disadvantage when it comes to being able to recover. Older individuals and athletes are more prone to suffering skeletal muscle damage following eccentric exercise and exercise in general, they have reduced blood flow to tendons, ligaments, and articular cartilage, and demonstrate structural changes to those same tissues (e.g., increased collagen content).

It is for these reasons and others that have not been explored that the older athlete should acknowledge before taking on strenuous exercise and training programs. This does not mean that he or she should completely refrain from exercise, either. Even those that have arthritis can still participate in vigorous exercise without risking further damage or exacerbating symptoms (Coleman et al 1996). As it was previously stressed by Chen et al (2005), perhaps the reason why the older individual experiences loss in muscle mass, strength, and performance is simply because of disuse.

The aging person is particularly susceptible to a decrease in number and size of fast-twitch, type II muscle fiber. This is worrisome for someone with advanced age because these fibers are capable of producing more force than type I and so a greater amount or larger sized type II fiber is advantageous. Those that are stronger appear to be at lower risk of falls and fractures and programming exercise for older individuals ought to incorporate some strength- and power-oriented training.

In conclusion, it does appear that the older individual, particularly the older athlete, is at a greater risk of injury across a number of different sports. This is particularly evident for overuse injuries and traumatic injuries that may arise because of overuse, such as rotator cuff tears. For many individuals, the effects of aging are unavoidable but this shouldn't dissuade him or her from participating in sport or other forms of physical activity because of the numerous benefits to physical activity, particularly into later stages of life. The older athlete has to be more aware of their reduced capability to recover so a reduction in total volume of work may be a prudent course to take. It is not clear how the older athlete responds to a more diverse training program, one that incorporates multiple facets of athleticism such as strength, endurance, power, flexibility, balance, and coordination, which is something that deserves to be explored by future research.

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