Physiology and Performance in Masters Athletics

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Introduction

The level of voluntary physical activity usually begins to decline soon after people reach physical maturity and regular voluntary participation in strenuous physical activity is not observed in most ageing laboratory animals. Thus, older men and women who choose to exercise exhaustively do not follow natural human or animal behaviour patterns. Nevertheless, the number of people who train for and participate in competitive sport into middle age and later in life has increased dramatically over the past 30 years and this has led to great interest in the effects on both health and quality of life.

Opportunities are now available for older athletes to compete in almost all sports disciplines, including athletics. Termed Masters by the IAAF and other governing bodies, many of these athletes engage in competition for fun, general recreation, and fitness but others train with the same enthusiasm and intensity as younger competitors. The successes achieved and the performance records established by some Masters athletes are phenomenal. However, although they exhibit strength and endurance capacities that are far greater than those of untrained people their age, even the most highly trained Masters athlete experiences a decline in performance after the fourth or fifth decade of life (KENNEY, WILMORE & COSTILL, 2012).

The provision of Masters-level competition, which started out as isolated events in individual sports, has evolved into a very sophisticated element of the sport sector with a comprehensive organisational structure attending to issues ranging from determining world records to policing doping infractions among participants (WEIR, BAKER & HORTON, 2010).

The aim of this article is to provide background for further discussion and study of Masters athletics based on the current literature. It addresses the following topic areas:

- Physiological aspects of ageing
- Responses to exercise and training
- Notes on Masters athletics performances

It concludes with a short history of the organisation of Masters athletics.

Physiological Aspects of Ageing

Physical stature

As humans age, they tend to lose height and gain weight. The reduction in height generally starts at about 35–40 years of age and is primarily attributable to compression of the intervertebral disks and poor posture early in life. At about 40–50 years in women, and 50–60 years in men, osteopenia (a reduction in bone mineral density below normal) and osteoporosis (a severe loss of bone mass with deterioration of the microarchitecture of bone) become a factor.

A gain in weight typically occurs between the ages of 25 and 45. Beyond 45, weight stabilises for about 10–15 years and then decreases as the body loses bone calcium and muscle mass. Weight gain in early maturity is linked with a tendency to gain fat that begins at about 20. This is largely attributable to three factors: diet, physical inactivity, and reduced ability to mobilise fat stores. The body fat content of physically active older people, including older athletes, is significantly lower than that of age-matched sedentary people. In addition, with primary ageing there tends to be a shift in the location where body fat is stored, from the periphery toward the centre of the body around the organs. This centralised adiposity is associated with cardiovascular and metabolic diseases. Although physical activity cannot fully counteract the age-related gain in fat mass, in active men and women there is less of a shift of the fat stores with ageing, which reduces the risk of disease.

Strength and neuromuscular function

In general, maximal muscle strength is achieved between the ages of 25 and 35 and then decreases steadily with ageing. There is almost no decline in muscle mass until about age 40, at which time the rate of sarcopenia (muscle loss related to ageing) increases, the decline being greater in men than women. The loss of both muscle and bone mass mentioned above is at least partially attributable to decreased physical activity, especially a lack of weight-bearing exercise. Of course, as with other measurements of human performance, individual strength performances vary considerably. Some individuals, for example, exhibit greater strength at age 60 than people half their age (KENNEY, WILMORE & COSTILL, 2012).

Cross-sectional studies of the entire vastus lateralis (quadriceps) muscle in 15–83 year-old subjects, post-mortem, have suggested that muscle fibre type remains unchanged throughout life. However, numerous investigations have shown a decrease in both the number and the size of muscle fibres with ageing. One study reported a loss of approximately 10% of the total number of muscle fibres per decade after age 50 (LEXELL, TAYLOR & SJÖSTRÖM, 1988).

Ageing is accompanied by substantial changes in the nervous system's capacity to process information and activate muscles. Specifically, ageing affects the ability to detect a stimulus and process the information to produce a response. Simple and complex movements are slowed with ageing, although people who remain physically active are only slightly slower than younger, active individuals. Motor unit activation is lower in aged adults. For example, one study showed that older men (-80 years) had lower firing rates and longer twitch contraction durations, whereas younger men (-20 years) had relatively higher firing rates and shorter contraction times (CONNELLY et al., 1999). However, others have shown that older individuals retain their ability to maximally recruit skeletal muscle, suggesting that reduced strength is due to local muscle rather than neural factors (DOHERTY et al., 1993).

Cardiovascular and lung function

Similar to muscle function, cardiovascular function declines with age. One of the most notable changes that accompanies ageing is a decrease in maximal heart rate (HRmax). Whereas children's values usually range between 195 and 215 beats/min, the average 60-year-old has a HRmax of approximately 166 beats/min. HR is estimated to decrease slightly less than one beat/min per year as we age. Traditionally, the average HRmax for any age has been estimated from the equation HRmax = 220 – age. However, HRmax = [208 – (0.7 X age), which is applicable to all people and is not influenced by sex or activity levels is seen as more accurate (TANAKA, MONAHAN & SEALS, 2001).

Lung function changes considerably with ageing in sedentary people. Both vital capacity (VC) and forced expiratory volume in 1 second (FEV1.0) decrease linearly with age, starting at age 20–30. However, residual volume (RV) increases, and the total lung capacity (TLC) remains essentially unchanged. As a result, the ratio of the residual volume to total lung capacity (RV/TLC) increases, meaning that less air can be exchanged.

These changes are matched by changes in maximal ventilatory capacity during exhaustive exercise. Maximal expiratory ventilation (VEmax) increases during growth until people achieve physical maturity, and then it decreases with age. VEmax values average about 40 L/min for 4–6-year-old boys, increase to 110–140 L/ min for fully mature men, and then decrease to 70–90 L/min for 60–70-year-old men. Girls and women follow the same general pattern, although their absolute values are considerably lower at each age, primarily because of smaller body size.

Responses to Exercise and Training

Strength and neuromuscular function

Neuromuscular changes with ageing are at least partially responsible for decreased strength and endurance, but active participation in exercise and sport tends to lessen the impact of ageing on performance (KENNEY, WILMORE & COSTILL, 2012). Despite the loss of muscle mass in active ageing men, the structural and biochemical properties of the remaining muscle mass are well maintained. The number of capillaries per unit area is similar in young and old endurance runners. Oxidative enzyme activities in the muscles of endurance-trained older athletes are only 10–15% lower than in endurance-trained young athletes (SALTIN, 1986). Thus, the oxidative capacity of skeletal muscle of endurance-trained older runners is only slightly less than that of young elite runners, which suggests that ageing has little effect on skeletal muscle's adaptability to endurance training.

Results from longitudinal studies conducted over a 20-year period indicate that the amount or intensity of activity, perhaps both, might play an important role in muscle fibre type distribution with ageing. Muscle biopsy samples from the gastrocnemius (calf) muscles of a group of previously elite distance runners, obtained from 1970 through 1974 and again in 1992, demonstrated that runners who had decreased their activity (fitness trained) or become sedentary (untrained) had a significantly greater proportion of type I fibres than when they were 18–22 years younger. Those who remained highly trained had no change. Although some of the elite runners who still competed in distance running (highly trained) showed a small increase in the percentage of type I fibres, on average these highly trained runners showed no change in their calf muscle fibre composition over the 18–22 year span of the study (TRAPPE et al., 1995 & 1996).

While endurance training (such as distance running) has little impact on the decline in muscle mass with ageing, strength training reduces muscle atrophy in ageing adults and can, in fact, cause older individuals to increase their muscle cross-sectional area. Although it is difficult to compare the adaptations to resistance training in younger and older people, ageing appears to neither impair the ability to improve muscle strength nor prevent muscle hypertrophy. For example, older men (ages 60–72) who resistance trained for 12 weeks at 80% of their one-repetition maximum (1RM), for extension and flexion of both knees, saw their extension strength increase by 107% and flexion strength increase by 227% (FRONTERA et al., 1988). These improvements were attributed to muscle hypertrophy as determined from mid-thigh CT scans. Biopsies of the vastus lateralis muscle (in the quadriceps) revealed that the cross-sectional area of type I fibres increased by 34% and that of type II fibres by 28%. In another study of older untrained men (aged 64 years), a 16-week resistance training programme resulted in major increases in strength (50% for leg extension strength, 72% for leg press strength, and 83% for half-squat strength) and an increase in the mean cross-sectional area of all major muscle fibre types (HAAGERMAN et al., 2000; HIKIDA et al., 2000).

Older resistance-trained athletes tend to have higher muscle mass, are generally leaner, and are approximately 30–50% stronger than their sedentary peers. Furthermore, compared to age-matched aerobic exercise trained subjects, resistance trained athletes have more total muscle mass, have higher bone mineral densities, and maintain greater muscle strength and power. Although not to the same extent as older athletes, older sedentary individuals also experience significant strength gains from resistance training, which greatly improves their abilities to perform activities of daily living and helps to prevent falling (CHODZKO-ZAJKO et al. 2009).

Cardiovascular and lung function

The reduction in HRmax with ageing appears to be similar for sedentary and well-trained adults. At age 50, for example, normally active men have the same HRmax as former and still-active distance runners of the same age.

Maximal stroke volume (SVmax) is modestly reduced in highly trained older adults. This is primarily attributable to decreased heart rate and to a lesser extent to a decrease in stroke volume. Studies of endurance runners have shown that the lower VO_2max values observed in older athletes result from a reduction in maximal cardiac output, despite the fact that heart volumes of older athletes are similar to those of young athletes, confirming that a decreased maximal heart rate is the primary cause of reduced VO_2max. In untrained men and women, a number of studies have demonstrated a clear decrease in maximal stroke volume with ageing (KENNEY, WILMORE & COSTILL, 2012).

Peripheral blood flow, i.e. to the limbs, decreases with ageing, even though capillary density in the muscles is unchanged. Studies reveal a 10–15% reduction in blood flow to the exercising leg muscles in middle-aged athletes at any given work rate when compared with well-trained young athletes (SALTIN, 1986). But the reduced blood flow to the legs of these middle-aged and older endurance runners during submaximal exercise was apparently compensated for by a greater arterial-mixed venous oxygen difference, or O_2 difference (more oxygen is extracted by the muscles). As a result, although the blood flow is lower, oxygen uptake by the exercising muscles is similar at a given submaximal work intensity in the older age-group.

It is hard to determine the extent to which the age-related changes in stroke volume, cardiac output, and peripheral blood flow result from the ageing process alone, and the extent to which they are attributable to the cardiovascular deconditioning that accompanies reduced activity. Studies suggest that both are involved, but the relative contribution of each is unknown. However, even the older athlete generally trains at a lower volume and intensity than the 20-year-old athlete. Ageing alone might decrease cardiovascular function and endurance less than the deconditioning that accompanies inactivity, decreased activity, or decreased intensity of training. These declines in cardiovascular function with ageing are largely responsible for the declines observed in VO_2 max (KENNEY, WILMORE & COSTILL, 2012).

During strenuous exercise, both normally active older people and athletes can maintain near-maximal arterial oxygen saturation. Thus, neither changes in the lungs nor in the blood's oxygen-carrying capacity appear to be responsible for the observed decrease in VO_2max reported in older athletes. Rather, the primary limitation is apparently linked with oxygen transport to the muscles, that is, cardiovascular changes. As mentioned above, ageing decreases maximum heart rate, which lowers maximal cardiac output and blood flow to the exercising muscles. Submaximal (a-v) O_2 difference is maintained in older exercisers, suggesting that O_2 extraction is well preserved with ageing (KENNEY, WILMORE & COSTILL, 2012).

Prior training offers little advantage to endurance capacity in later life unless a person continues to engage in some form of vigorous activity. However, due to their high initial values, these individuals have a large functional reserve, and this large decrease in aerobic capacity has little effect on their ability to carry out activities of daily living. In addition, there are large individual differences in the rate of decline in VO_2max with ageing, and genetics is a major contributor.

In the early 2000s, a 25-year follow-up study re-examined highly competitive, older male distance runners. These men were initially tested at 18–25 years of age. During the interval between testing sessions, the runners trained at about the same relative intensity as they had when they were younger. As a consequence, their VO_2max values (L/min) declined only 3.6%. Although their maximal oxygen uptake decreased from 69.0 to 64.3 ml/kg/min, this is a decrease of only 0.19 ml/kg/min per year or 0.3% per year, and most of that change was attributable to a 2.1 kj (4.6 lb) increase in body weight (TRAPPE et al., 1995 & 1996). This rate of decrease in VO_2max values is significantly less than that of either sedentary people or those who fitness train at levels and intensities below those of these older runners.

Although intense training reduces the normal ageing-related decline in VO_2max, aerobic capacity still declines. Thus, it appears that highly intense training has a slowing effect on the rate of loss in aerobic capacity during the early and middle years of adult life (e.g., 30–50 years) but less effect after 50 years of age. However, new findings show that when older subjects train at relatively high intensities they have the ability to increase their endurance capacity and strength. Whereas much of the improvement in VO_2max seen in younger subjects is associated with an increase in maximal cardiac output, older subjects show significantly greater gains in muscle oxidative enzyme activities, which suggests that peripheral factors in older subjects' muscles might play a greater role in aerobic adaptations to training than in younger subjects (KENNEY, WILMORE & COSTILL, 2012).

Lactate threshold

Lactate threshold, expressed as a percentage of (LT-% VO_2max), provides the best marker relative to endurance running performance in individuals with similar VO_2max values. Interestingly, LT-% VO_2max does not differ between men and women, but it increases with age. A recent longitudinal study with Masters athletes reports that the change in lactate threshold over a six-year follow-up is not predictive of running performance when it is expressed as a percent of VO_2max (MARCELL et al., 2003). Another study reports similar results in 152 untrained men and 146 untrained women (MEREDITH et al., 1989). However, in both studies VO_2max was lower in the older groups, which helps explain the increase in LT-% VO_2max. When the LT at the absolute VO_2 is compared between age-groups, LT declines with age.

Risk of injury or death

As people get older they are at a greater risk for injuries involving tendons, cartilage, and bone. The most common orthopaedic injuries for Masters athletes include rotator cuff tears, quadriceps tendon ruptures, Achilles tendon ruptures, degenerative meniscus tears, focal articular cartilage defects and injuries, and stress fractures. Furthermore, when injuries occur, the healing process is usually prolonged and complete recovery can take up to a full year.

The risk of death during exercise appears to be no higher in older athletes compared with younger and middle-aged athletes. However, the risk of death from many chronic diseases is lower in older people leading an active lifestyle (KENNEY, WILMORE & COSTILL, 2012).

Notes on Masters Athletics Performances

Sprinting

World records for 100m decrease by about 1% per year from age 25 to 60. Beyond age 60, however, the records for men slow by nearly 2% per year. A sprint-running test of 560 women between ages 30 and 70 revealed a steady decrease in maximal running velocity of 8.5%

per decade (0.85% per year) (MEREDITH et al., 1989). The three main contributors to the reduction in maximal running velocity seem to be: 1) The reduced maximum strength of lower limb muscles, 2) the slower rate of force development and transmission, and 3) the reduction in elastic energy storage and recovery in tendons.

In 2011, a group of European researchers reviewed 34 papers that had examined the effects of age on the speed of muscle contractions and tendon elasticity in both rats and humans, including non-athletes, endurance runners, and sprinters. They concluded that Masters sprinters preserve their stride frequency but appear to reduce their stride length as they age. Moreover, the researchers concluded that this reduced stride length appears due to reduced propulsive ground reaction forces and the reduced rate of development of this force, i.e., the ability to push off the ground quickly.

Although the tendons of different muscle-tendon units in the lower limbs seem to have different effects depending on the contribution of the different joints to running mechanics, it is clear that the loss of muscle mass and the deterioration of muscle contractile properties are the main factors slowing down old sprinters. Fortunately, the plasticity of the neuromuscular and musculoskeletal systems allows the adaptability of neuromuscular performance parameters with highly specific training and a partial reduction in the rate of decline of the physiological characteristics associated with ageing (ARAMPATZIS, DEGENS, BALTZOPOULOS, & RITTWEGER, 2011).

According to REABURN (2013), the rate of decline in sprinting ability may be reduced in the following ways:

1. By ensuring hypertrophy (muscle enlargement) resistance training becomes part of a veteran sprinters training regime, especially in the off- and pre-season. This will help build or at least maintain muscle mass and thus strength.
2. Through power training, including plyometrics (bounds, hops, and jumps) and gym work (e.g. jump squats), as a part of all training programmes. This type of training develops the rate of force development and elastic energy stored in tendons and the tissue surrounding muscle fibres.
3. Through flexibility training, particularly of the hip and ankle joint. In general, developing muscle size and then converting that muscle to power by doing plyometrics are keys to slowing the decline in sprint speed. Increasing the range of motion about the key sprinting joints is also critical for veteran sprinters.

Hurdles

Speed is essential in hurdles, of course, but also key is adapting to the event's demands for rhythm and flexibility. Ageing makes it harder to bend and stretch muscles and limbs to their limits. Entry-level Masters hurdles are 39 inches high, and only the best manage to maintain the "three strides" cadence between hurdles. Thus a steeply rising time slope starts at age 40. In 1998, the record for 40 year-old men was 14.24 seconds. For age 60, the record had nearly doubled to 25.5 seconds (OLSON, 2001).

Acknowledging this rapid falloff in flexibility, the hurdle heights and race distances have been eased for the older age groups. In Masters events, the men's hurdles go from 39 inches at age 40 to 36 inches at age 50. At 60, they run 33-inch hurdles. And at 70, hurdles are 30 inches high. Women's hurdles are lowered from 33 inches to 30 inches at age 40 and stay there. The 110m men's race becomes 100m at age 50 and 80m at age 70, with a corresponding decrease in the distance between hurdles (OLSON, 2001).

Endurance

In 1954, when Roger Bannister stunned the sporting world by becoming the first person to run the mile in less than four minutes (3 min 59.4), it would have seemed inconceivable that the same could be accomplished by someone over the age of 30. However, forty years later Eamonn Coghlan, did just that at the age of 41 when he ran 3:58:13. The oldest individual to record a sub-five minute mile was 65 years old.

Although older runners have achieved some exceptional records, running performance in general declines with age, and the rate of this decline appears to be independent of distance. Longitudinal studies of elite distance runners indicate that despite a high level of training, performance in events from the mile to the marathon declines at a rate of about 1.0% per year from the age of 27–47 years (TRAPPE et al., 1995 & 1996).

Jumping

Unlike the sprints and long distances, there is no severe change of jumping performances after one reaches the 65–70 years range. Based on age-record Masters performances in the high jump and long jump, the rate of decline remains constant into the 80s. At elite levels, high jump marks fall off six inches every five years, while the long jump decrease is about two feet over the same period. But the rates of decline for the average top 10 and top 50 are significantly greater (OLSON, 2001).

The pole vault, which requires a combination of flexibility, speed, upper-body strength and coordination, shows a fairly constant "decline" rate between 45 and 65 of about one foot every five years (OLSON, 2001).

Throwing

In the shot put and discus events (which rely on an explosive type of strength), a nearly flat plateau is evident at elite levels from 35–45 years. Marks pretty much stay the same. After that, based on the age records in the 16-pound shot, a steady but steep decline occurs. A decrease in distance of about one foot per year is noted. In the two-kilogram discus throw, the slope changes at age 45. It falls off at about a four-feet-per-year pace (OLSON, 2001).

History of Masters Athletics

At the beginning of the 20th century, there were hardly any middle or older age athletes who continued to compete at a national level. However, since at least the early 1930s, middle-aged athletes in Europe, Australia, and New Zealand have competed with younger athletes, especially in cross-country and road races. Some of these were active into their 50s.

One of the most famous was the American runner Clarence DeMar, who won his seventh Boston Marathon at age 42, placed 7th at age 50, and was 78th in a field of 153 runners at age 65. In all, he ran more than 1,000 distance races, including at least 100 marathons between 1909 and 1957. His performances at the Boston Marathon alone spanned 48 years, from age 20 to 68. DeMar's last race in 1957, at age 68, was over 15km, which he ran despite advanced intestinal cancer and a colostomy. His best time for the Boston Marathon was 2:29:42 at age 36 and thereafter his time gradually slowed to 3:58:37 at age 66 (KENNEY; WILMORE & COSTILL, 2012).

At the time of DeMar, there was no organised system of Masters sports. Although it is difficult to identify the specific 'birthdate' of Masters sports, it is generally accepted that its origins were in the mid-1960s. Interest in New Zealand's early veterans runners movement was imported to the USA, leading to the formation of the USA Masters Track and Field Team after 1965. International Veteran Track and Field meetings followed. In 1966, David Pain, an attorney from San Diego, created the first 'Masters Mile.' The minimum age for participation was set at 40. Pain and others soon launched the U.S. National Masters Championships, where everyone 40 and over competed together. The inaugural event, at San Diego's Balboa Stadium, in July 1968, attracted 186 competitors. In the same year, the "Interessen-Gemeinschaft Älterer Langstreckenläufer" (IGÄL = Partnership of Older Long Distance Runners) was formed in Germany.

In 1972, Pain and his wife took 152 mainly U.S. and Canadian Masters athletes to London, Helsinki, Stockholm, Gothenburg and Cologne for age-group athletics meetings and distance races – thus jump-starting the worldwide Masters athletics movement. The following year, they travelled together with 51 athletes to the South Pacific and Oceania for more age-group competitions.

The first World Masters Athletics Championships were held in August 1985, in Toronto, Ontario. More than 1,400 competitors from 32 nations took part. A meeting at the University of Toronto saw the election of a steering committee to plan an international governing body for Masters athletics. Two years later, at the second World Masters Athletics Championships in Gothenburg, Sweden, the World Association of Veteran Athletes (WAVA) was founded. Under its auspices, World Masters Championships have been held every two years ever since, and a biennial World Masters Indoor Championships debuted in March 2004 in Sindelfingen, Germany. The WAVA later changed its name to World Masters Athletics (WMA) and continues to be the sport's governing body. It provides a global standard of rule modifications (based upon the international rules for the sport created by the IAAF) for athletes of a certain age. Each individual country governs its own affairs through a body that is an affiliate to the WMA.

Among its key tasks, the WMA has been working to coordinate its outdoor championship schedule with the International Masters Games Association (IMGA), which stages the multi-sport World Masters Games (WMG) every four years. The first World Masters Games (WMG) in Toronto in 1985 included 8,305 participants representing 61 countries and participating in 22 sports. Since this first event, participation in the WMG has increased considerably: 1985: 8,305; 1994 (3rd WMG, Brisbane): 24,500; 2002 (5th WMG, Melbourne): 24,886; 2009 (7th WMG, Sydney): 28,676 (WEIR, BAKER & HORTON, 2010).

The IMGA, a non-profit organisation constituted under the laws of Switzerland, was founded on 25 October 1995 as the successor to the earlier body formed by the organisers of the first and second World Masters Games. It controls the exclusive rights to the Games and its main purpose is to represent Masters sport and 'promote lifelong competition, friendship, and understanding between mature sportspeople, regardless of age, gender, race, religion, or sport status.' The organisation is made up of members from individual sporting associations and the International Olympic Committee.

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