7

Aging in Women Athletes

Monica C. Serra, Shawna L. McMillin and Alice S. Ryan*
VA Research Service, Department of Medicine, Division of Gerontology and Geriatric Medicine, University of Maryland School of Medicine, Baltimore VA Medical Center Geriatric Research, Education and Clinical Center (GRECC), VA Maryland Health Care System, Baltimore, USA

1. Introduction

Since instating Title IX of the Education Amendments of 1972, there has been a significant increase in sports participation and athletic opportunities among women (1). While it is still more common for younger than older women to engage in athletic competition, the participation of older women is growing, with over 50 countries sponsoring master athletes events (2). While aging is associated with a decrease in metabolic and physiologic function, competitive athletic women may experience more gradual declines. These declines can be slowed further, by combining adequate dietary intake with proper exercise training. Therefore, this chapter will 1) discuss how aging influences physiologic and metabolic adaptations of highly trained women athletes and 2) explore how nutrition recommendations may change with exercise and the possible benefit of supplementation of micronutrients to improve athletic performance.

2. Aging and physiological adaptations of women athletes

2.1 Endurance performance

Many master athletes are capable of performances equal to those of non-elite young athletes (3). Nevertheless, age-related alteration to functional and physiological capacities are inescapable and as a result these age-related alteration lead to a decline in performances. It is widely accepted that aerobic capacity decreases with age. The rate of decline in maximal oxygen consumption (VO_2max) varies between 5-9% per decade starting at the age of ~35 years in healthy sedentary adults (4, 5, 6). Several studies report a greater rate of decline with age in endurance-trained men and women (7, 8). Running performances decrease in a curvilinear fashion with the greatest decline after 60 years of age with women demonstrating a threefold greater decrease in performance compared to men (8, 9). Marcell et al. (10) provided evidence that a decline in VO_2max is the best predictor of age-related changes in endurance performances in female athletes. Elite endurance performances are attributed to three primary determinants: aerobic capacity, lactate threshold, and exercise economy.

* Corresponding Author

2.2 Aerobic capacity

A high VO_2max is an identifiable marker for a successful endurance athlete. Observed VO_2max in elite male endurance athletes can measure between 75 and 85 ml/kg/min; whereas; VO_2max is approximately 10% lower in elite women athletes (11). VO_2max is higher in athletes at any age than sedentary women (8, 7, 11). Endurance performance and aerobic capacity are strongly related across varying age groups of competitive athletes (9). Aerobic capacity, as measured by VO_2max is determined by cardiac output and arteriole-venous oxygen difference (12). Both cardiac output and arteriole-venous oxygen difference decrease with age in endurance athletes (5). Cardiac output is the product of heart rate and stroke volume and accounts for approximately 50% of oxygen consumption during exercise (12). Heart rate is the primary factor for increases in cardiac output during exercise; whereas stroke volume peaks at ~50% of max exercise then levels off or slightly decreases (12). The age-related loss in maximal heart rate is between 0.5-1 beat per year (13). Several studies have exhibited that habitual exercise status has no effect on the age-associated reductions in maximal heart rate (7, 14, 4). With maximal heart rates similar between athletes and non-athletes, the principle difference in cardiac output is stroke volume (11). Ogawa et al. (5) observed a greater rate of decline in stroke volume in female athletes compared to that observed in sedentary controls. The decrease in maximal heart rate, stroke volume, and arteriole-venous oxygen difference contributes to the decline in master athletes' endurance performances.

2.3 Lactate threshold

Lactate threshold is the fraction of VO_2max where there is a significant increase in blood lactate accumulation (12). Lactate threshold is a primary factor in determining endurance performances of both men and women (11). In sedentary subjects there is typically a rise in blood lactate concentration to ~60% VO_2max. In trained athletes this value can be 75–90% of VO_2max (14). A study by Evans et al. (7), showed that lactate threshold as a percentage of VO_2max did not change with age in female distance runners. This evidence coupled with similar findings in male distance runners (15) suggests that a reduction in VO_2max rather than a reduction in lactate threshold contribute the most to the decline in performance with age.

2.4 Exercise economy

Exercise economy is the oxygen cost of an endurance performance at a given velocity and can vary up to ~ 30-40% among individuals (11). Exercise economy is a predictor of performance in a population with similar VO_2max (11). Results in male runners suggest that exercise economy does not change with age in highly trained endurance runners (15). Older female runners have demonstrated a slight change in economy at submax speeds and yet displayed no relationship between age and economy at a 10K race pace (7). Therefore, exercise economy is unlikely to contribute to the age-related decline in endurance performances.

2.5 Physiological and training mechanisms for aging declines in VO_2 max

Both central (cardiac output and blood volume) and peripheral (muscle mass and oxygen delivery/utilization) factors contribute to the high VO_2max demonstrated in elite athletes (11). At present, it is still unclear as to the exact cause(s) of the age-related decrease in VO_2max in master athletes compared to young athletes. Stroke volume is responsible for the higher cardiac output in athletes versus healthy sedentary individuals (11). Determinates of stroke volume are cardiac preload, left-ventricular end-diastolic volume, and myocardial contractility. Blood volume plays an important role in stroke volume and decreases with normal aging in healthy sedentary females. However, total blood volume is maintained in older endurance trained female athletes (16). Master athletes demonstrate a larger left ventricular mass and left ventricular end-diastolic volume compared to healthy sedentary adults (17). Given the benefits of habitual endurance training, it is uncertain how advanced age alters stroke volume which would consequently result in a similar decrease in VO_2max in aging athletes compared to sedentary women. Peripheral adaptations with aging have also been suggested to contribute to reductions in VO_2max through changes in both oxygen delivery and utilization to active skeletal muscles (9). Arteriole-venous oxygen difference decreases slightly with age in trained athletes (5). It has been observed that enzyme activity and capillarization (expressed per muscle fiber) of skeletal muscle are preserved in older male athletes (18). Though muscle characteristics have not been examined in older female athletes, the reduced VO_2max per kilogram muscle in female athletes is similar to male athletes (19). Therefore, it is likely that the age-associated reductions in VO_2max are a result of oxygen delivery and/or muscle mass.

Changes in body weight/composition may be a second mechanism for the decline in performance with age in athletes. Regardless of age, a decrease in lean body mass and an increase in percent body fat may contribute to a decrease in VO_2max (6, 19). Endurance trained women did not demonstrate the expected relationship between changes in body composition and age-related changes in VO_2max (4). Male endurance runners who maintained their lean body mass also maintained their relative VO_2max, whereas the female runners who maintained their relative VO_2max had the greatest decrease in lean body mass (4). This finding suggests that other factors, including the maintenance of training and/or estrogen rather than body composition have a greater affect on the female age-related decline of VO_2max (4).

The training stimulus may also play a role in the performance decline with age. With advanced age there seems to be a reduction in overall exercise "stimulus" (i.e. intensity, duration, and frequency) (5, 9, 14). VO_2max is positively associated with training volume and as such, the age-related decrease in VO_2max is associated with a reduction in training volume (14). However, female endurance athletes between the ages 34-78 years who maintained or increased their training volume with age, exhibited a similar change in VO_2max compared to healthy sedentary adults (14). Training stimulus appears to be a key determinant in the decline in aerobic capacity with age. Whether the decline in training is a result of the aging-process, injury, time, or motivation, has yet to be determined.

Despite the health benefits achieved through a lifetime of participating in physical activity, it seems that diminished performances are an inevitable aspect of aging. The exact mechanism(s) for the reduction in performance with age has yet to be determined. The finding that women demonstrate a greater rate of decline in performances compared to men could be a result of fewer women participating in competitive events as they age (3). However, given that more women have been encouraged to participate in sporting events since the induction of Title IX, it will be interesting to see whether the gender difference is maintained in the future.

3. Aging and metabolic adaptations in women athletes

3.1 Body composition

Normal aging results in significant changes in body composition with increases in abdominal fat and losses of muscle mass. The increase in obesity alters the risks for type 2 diabetes, cardiovascular disease, and hypertension, whereas the decline in fat-free mass (FFM) may alter energy expenditure and resting metabolic rate. It is interesting to question whether the increase in visceral fat and decrease in FFM can be prevented in women athletes. Our study of highly trained competitive women athletes aged 18 – 69 years indicates that percent body fat by DXA (dual energy x-ray absorptiometry) was lowest in 30 – 39 year old women athletes (~16% body fat) but was not different in 18 – 69 yr, 40 – 49 yr, and >50 yr old athletes (20). Total body fat was low and averaged 21 – 23% in these groups and considerably lower than normal BMI age-matched controls who were approximately 30 - 36% fat. To address whether central fat was different with age in women athletes, we measured visceral fat and subcutaneous fat by CT (computed tomography) scans. Visceral fat was significantly lower in the youngest athletes (18 – 29 yrs vs. 30 – 39 yrs) and significantly lower in the middle-aged than older athletes (Figure 1). Thus, despite the finding that athletes prevented gains in total body fat with aging, visceral fat increased with age in women athletes. However, putting the central obesity in context, it is remarkable that the oldest athletes have similar visceral fat and lower subcutaneous abdominal fat than normal BMI control women who were one-third their age. Lastly, FFM was not significantly different among the women athlete groups suggesting that muscle mass was maintained with aging and may be, in part, explained by the competitive training of these women.

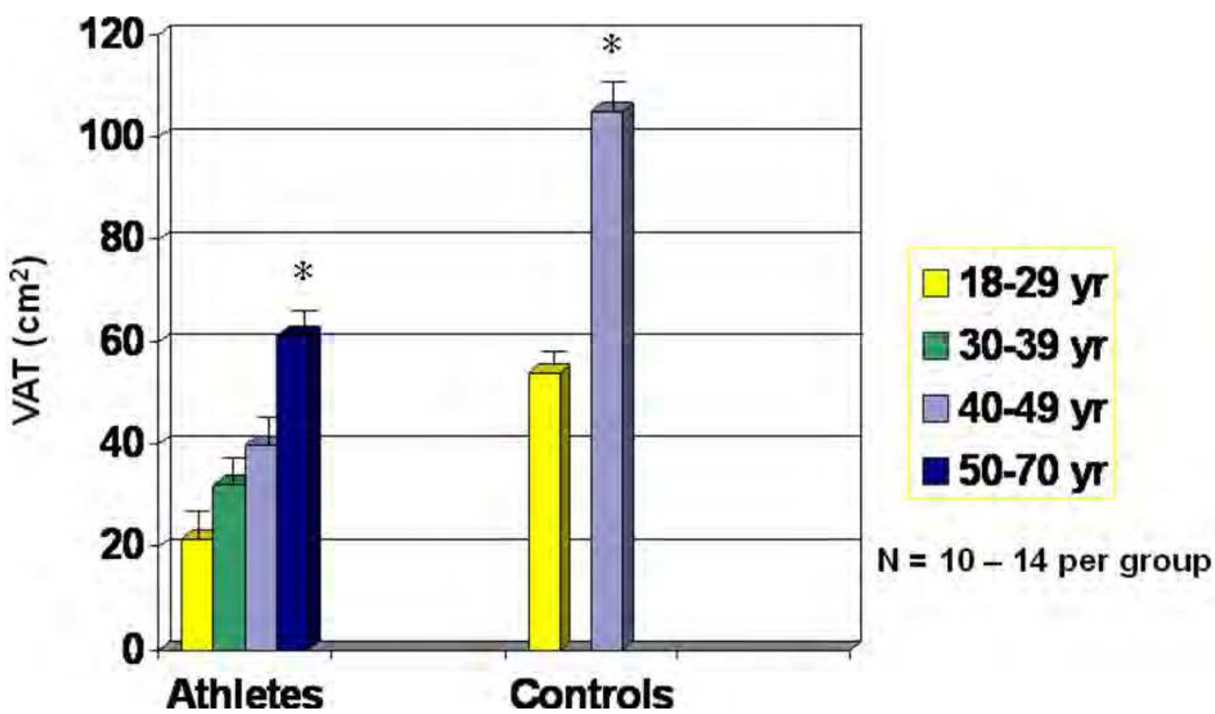


Fig. 1. Visceral adipose tissue (VAT) of women athletes and controls. Values are means ± SE. * P< 0.01

There are only a few other studies besides our own that have examined body composition in older women athletes. In agreement with our study, FFM did not differ between pre- and post-menopausal women runners (21). However, in contrast to our results, postmenopausal women athletes had higher % body fat and fat mass than the premenopausal athletes (21) but these differences were modest. More specifically, the difference was less than half that of the comparison between the healthy sedentary premenopausal and postmenopausal women. In comparison to sedentary controls, the athletes had lower % body fat, fat mass, waist circumference and trunk fat. Their results suggest that women who engage in vigorous exercise have a much smaller increase in total adiposity with advancing age (21). Two more studies (7, 22) provide some contrast as to whether age-related changes in body fat occur in women athletes. When female runners are divided into three age groups (e.g. 23-35, 37-47, 49-56 years), percent body fat by hydrostatic weighing did not differ by age and averaged 15, 14, and 18%, respectively (7). Across a continuum of age (40-77 years), body fat measured by hydrostatic weighing increased with age in women athletes, the majority of whom (90%) competed in running events (22). Thus, athletes have less total and central body fat than sedentary women (21, 23) and the vigorous training of master athletes may prevent an increase in total adiposity (7, 21).

Menstrual dysfunction in athletes could potentially alter body composition in young women. Young rowers with menstrual disorders have less subcutaneous and visceral fat by MRI compared to young controls (23). We are unaware of any studies in women athletes in the perimenopausal state. Further investigation is necessary to investigate whether the changes in hormonal status as women athletes age and go through menopause, influence body composition.

3.2 Glucose metabolism

There are two studies examining glucose metabolism in women athletes (24, 25) with one in older women athletes. We utilized a sequential clamp procedure which allowed the assessment of both ß-cell sensitivity to glucose and peripheral tissue sensitivity to insulin in a single session in young, middle-aged and older female athletes (25). Plasma insulin responses during the hyperglycemic clamp were reduced in older athletes vs. older controls and ß-cell sensitivity was maintained across the age span. First and second phase insulin response was positively correlated with body fat and negatively with VO_2max suggesting that high levels of training and low body fat in women athletes across the age span predict insulin action. Rates of utilization (Rd) of glucose during the euglycemic portion of the clamp were significantly higher in athletes than controls and were not different across the age groups of athletes (Figure 2). Although some studies show a difference in insulin clearance rate with age (26), we showed that insulin clearance rate was similar across the age of 18 to 70 years in women athletes. Thus, older sedentary women had a 70% greater first-phase and 103% greater second-phase insulin response during hyperglycemia than the athletes. Moreover, older athletes utilized on average 31% more glucose than similarly aged sedentary women, suggesting an increase in insulin sensitivity due to the effects of training.

Investigators have examined the relationships between insulin sensitivity, body composition, fitness, and muscle and metabolic predictors. In younger women athletes (age 29 yrs), insulin sensitivity determined by the frequently sampled intravenous glucose tolerance test (FSIGT) was weakly correlated with VO_2max and proportion of type 1 muscle fibers but not with percent body fat, fasting respiratory exchange ratio (RER) or RER during exercise, energy intake, macronutrient composition, and muscle triglyceride and glycogen content (24). In women athletes aged 18-69 years, we showed that percent body fat is associated with first-phase insulin release, whereas visceral fat and total body percent fat predict second-phase insulin release during hyperglycemic clamps (25). In addition, glucose uptake during the last hour of a hyperinsulinemic-euglycemic clamp was positively associated with FFM and VO_2max, negatively associated with total fat mass, visceral fat, and subcutaneous abdominal fat (25). Thus, greater physical fitness and muscle mass and lower total and abdominal fat contribute to the enhanced tissue sensitivity observed in female athletes.

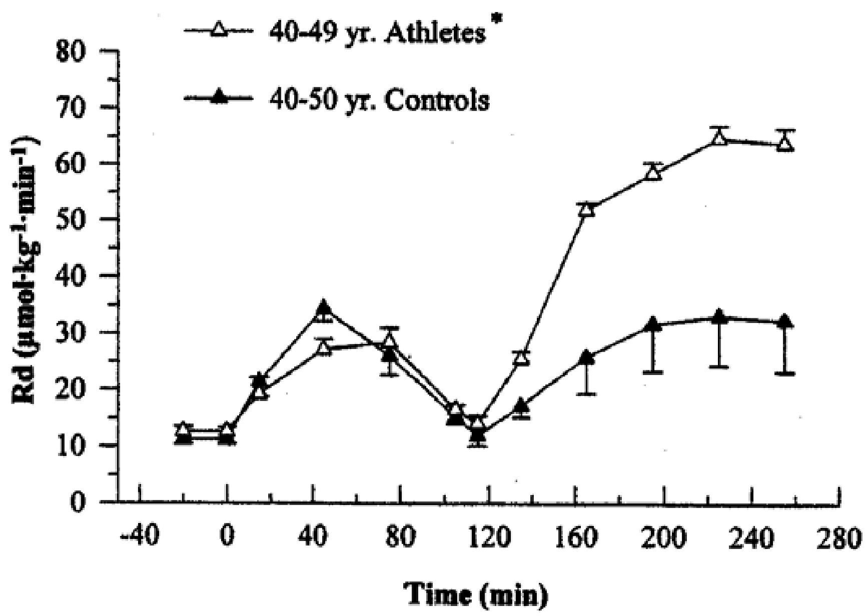


Fig. 2. Rate of utilization (Rd) of glucose during the 3-step clamp in 40- to 50 yr-old athletes and controls. Values are means ± SE. * P< 0.005

3.3 Cardiovascular risk factors

Lipid profiles are generally better in endurance trained athletes than sedentary individuals (27, 28). What occurs with aging in athletes with respect to lipid levels? We showed that total cholesterol, LDL-C (low density lipoprotein cholesterol) and triglyceride levels increased with age in women athletes (27). These relationships persisted even after adjusting for age-related declines in VO_2max and increases in visceral fat. HDL-C (high density lipoprotein cholesterol) was higher in athletes than controls and LDL-C was lower in athletes than sedentary women. Regarding the lipoprotein subfractions, we also demonstrated that LDL3-C (larger LDL-C subfraction) was lower in athletes than untrained women and there was a tendency for a higher HDL5-C (the largest HDL-C subfraction) which would suggest a protective effect. Middle-aged women (n =147) who were grouped into active ex-athletes, sedentary ex-athletes, recreational exercisers, and non-exercisers did not differ in TG (triglycerides) and HDL-C (29). In another study, HDL-C was higher in master athletes than older sedentary women but LDL-C did not differ (28). These lipid differences suggest that women athletes would have a lower risk of coronary heart disease.

Intensity or the level of exercise may influence lipoprotein lipid levels. Williams (30) utilized a national survey of ~1800 female recreational runners to examine the dose-response relationship between exercise levels and HDL-C and CVD risk factors. The women were divided into groups based on weekly running mileage and were on average 40 years of age. Lipid levels were obtained from medical records. The results of the survey indicated that women who ran more than 64 km/week had significantly higher HDL-C levels than women who ran less than 48 km/week. Further analysis revealed that plasma HDL-C was 0.133 mg/dl higher for every additional kilometer run per week. The results suggest that women who exercise at greater levels have significantly greater increases in HDL-C which in turn reduced their risk for CVD (30).

Other cardiovascular risk and metabolic parameters have been examined in older athletes. Women athletes (n=94) between 13 and 77 years of age showed some cardiovascular risk factors, including hypertension that were prevalent in athletes over the age of 35 (31). In a small sample of women master athletes (n=6), coronary artery calcium which is linked to endothelial dysfunction (32) was not significantly different than age-matched sedentary women (28). In another study that also contained only six females, older endurance trained athletes with pre-hypertension had lower arterial stiffness than sedentary controls and longer travel time of pressure waves (33). In addition, the greater augmented pressure in the athletes which disappeared after controlling for resting heart rate may have contributed to the lack of difference in carotid SBP (systolic blood pressure) and carotid intima-media thickness. The authors suggest that the vascular stiffening with pre-hypertension can be modified by chronic exercise training but that chronic training is unable to compensate for age-associated increases in pressure from wave reflections (33).

4. Nutrition recommendations in women athletes

4.1 Energy and macronutrients

Most athletes strive to achieve energy balance where energy intake = energy expenditure during exercise training. Energy expenditure (EE) consists of 3 components: basal metabolic rate, thermic effect of activity, and the thermic effect of food. These generally account for 60-70%, 25-35%, and 5-10%, respectively, of total daily energy expenditure, but can be greatly altered by the type, intensity, and duration of exercise.

Typically, energy requirements decline with age; however, debate exists whether these declines are due only to decreases in physical activity patterns or if there is also an accompanying decline in basal metabolic rate. This information is difficult to obtain because environmental factors, such as work schedules and family obligations, often make maintaining vigorous intensity training difficult for older athletes. However, in older adults, matched for exercise volume, compared to younger adults, RMR is not different (34). This one study would suggest that the decline in RMR does not occur in older adults who maintain their exercise volume. Lean mass is the greatest determinant of basal metabolic rate, accounting for up to 75-80% of energy expenditure. In our study of women athletes, age and FFM were independent predictors of the decline in RMR where the oldest athletes expended approximated 965 kJ/day less than the youngest athletes (20). In middle aged women with similar BMI and fat-free mass, habitual exercisers (9 hours per week of physical activity for 10 or more years) have greater RMR than their sedentary counterparts (35).

In women athletes, decreased energy intake can result in declines in body weight, muscle mass and bone density, as well as increased menstrual dysfunction, fatigue, injury and illness. Maintaining or gaining body weight is often difficult for athletes performing large volumes of physical activity. A popular trend is for athletes to consume only extra protein which may promote greater WL, (weight loss) by increasing EE through thermogenesis (36). Ideally, extra energy should come from a combination of all three macronutrients. Caloric intake recommendations are often based upon prediction equations, which multiply a predicted resting metabolic rate by a physical activity factor, and the athlete’s goal to maintain, gain, or lose weight.

While numerous studies exist examining the macronutrient requirement of athletes, a variety of variables (i.e. sport type, training status) affect nutritional requirements, resulting in broad recommendations. Current recommendations for a trained women include 45-65% (5-7 g/kg/d for general training, 7-10 g/kg/d for endurance athletes, and 11+g/kg/d for ultraendurance athletes) of energy from carbohydrates, 20-35% (~1 g/d) from fat, for general training, and 10-35% (1.2-1.4 g/kg/d for endurance trained and 1.6-1.7 g/kg/d for strength trained athletes) from protein (37). For all athletes, carbohydrates are recommended to make up the majority of energy intake, with an emphasis on whole grains, fruits, and vegetables. A diet high in carbohydrates typically results in adequate total protein intake, but may be lacking some of the essential amino acids, as well as intake of essential fatty acids and fat soluble vitamins and minerals.

Meal timing and nutrient composition recommendations surrounding athletic competition recommendations are based upon substrate utilization. Exercise intensity and duration drive these recommendations. For lower intensity activities (performed at ~25% of VO_{2max}), circulating fat provides the majority of energy during exercise. At moderate intensity (performed at ~65% VO_{2max}), fat oxidation contributes less and energy is mainly supplied from intramuscular stores of fat and glycogen. During high intensity exercise (performed at ~85% VO_{2max}), glycogen is the major energy source. At lower intensities where fat oxidation is providing the dominate source of energy, exercise can be sustained for up to a few hours; however, as intensity increases and requirements switch to glycogen, the ability to perform physical activities decline without carbohydrate repletion. Few studies have examined how macronutrient needs of women are altered by age; therefore, current macronutrient recommendations are similar between older and younger women athletes. During endurance based activities, depletion of plasma and muscle glycogen results in reduced exercise performance and fatigue. Prior to endurance exercise, it is recommended that 1 g/kg of carbohydrates be consumed for each hour prior to exercise (i.e. 1 g/kg if 1 hour prior and 4 g/kg if 4 hours prior) (37). Also, the meal should be low in fat and fiber and moderate in protein to facilitate gastric emptying and minimize gastrointestinal distress. During exercise, 30-60 g should be consumed every hour. If longer than 90 minutes, 6-20 g of protein should also be consumed during exercise and 1.5 g/kg carbohydrates with a small amount of protein immediately following exercise, with an additional 1.5 g/kg of carbohydrates consumed 2 hours later (37). Ensuring adequate fat intake during aerobic training is important since fat oxidation results in sparing of glycogen. Very low fat diets reduce intramuscular fat stores, impeding endurance. For strength based activities, protein intake has been suggested to maximize muscle synthesis by enhance amino acid uptake into skeletal muscle, providing substrate for hypertrophy if consumed immediate after the strength training bout. However, protein intake greater than 1.7-1.8 g/kg/d results in oxidation of the excess amino acids and is not incorporation into greater muscle mass, even when coupled with vigorous resistance training (38).

4.2 Micronutrients

Exercise and micronutrient activity work synergistically to ensure maximal performance of the body; therefore, if micronutrient deficiencies exist, there is a subsequent risk for declines in metabolic and physical function. Studies of dietary intake in women endurance athletes shown low intakes of calcium, vitamin D, vitamin E and zinc (39, 40). However, numerous other nutrients should be monitored for insufficient intake in women master athletes, including B_{12}, folate, riboflavin, pyridoxine, and magnesium (41). Additionally, the Dietary Reference Intakes (DRIs) acknowledge a decreased need for iron in older women (http://www.iom.edu/Activities/Nutrition/ SummaryDRIs.pdf). Because specific recommendation regarding micronutrient intake for older women have not been established, women athletes should consume at least the recommended dietary allowance (RDA) for all micronutrients to avoid nutrient deficiencies. In female master athletes partaking in nutritional supplementation, the supplemented group had significantly greater intakes of calcium, magnesium, vitamin C, and vitamin E than non supplemented women, indicating that female master athletes may rely on supplements to assist achieving micronutrient intake goals (40). If women consume a variety of foods in their diets and meet caloric requirements, vitamin and mineral supplementation typically is not necessary. Women greater than 60 years of age may want to consider a synthetic form of vitamin D and B_{12} because of altered absorption and nutrient action occurring with age. If a nutrient-balanced diet is not consumed, athletes should consider taking a multivitamin and mineral supplement. Too little data exists to recommend micronutrient supplementation above the RDA to improve athletic performance.

Free radicals produce oxidative damage during aging, as well as following strenuous exercise. During an intense endurance competition, master athletes experience elevations in reactive oxygen metabolites and biological antioxidant potentials, which continue at least 48 hours after completion of competition (43). Antioxidant supplementation may improve athletic performance, recovery time, and overall health by reducing oxidative damage. In endurance trained master athletes supplemented with antioxidants 21 days prior to intense cycling, antioxidant supplementation resulted in improved cycling efficiency (44). Unfortunately, most over the counter antioxidant supplements are not regulated by the FDA, and are not subject to thorough safety and effectiveness tests. One should heed caution not to consume vitamin intakes beyond the recommended upper limit (i.e. 2,000 mg for vitamin C and 1,000 mg for vitamin E).

The injury rate for master athletes is higher than younger athletes, making a balanced dietary intake especially important to support tissue healing (45). Ensuring adequate protein intake is important during all phases of tissue repair. Insufficient protein intake can inhibit wound healing and increase inflammation (46). It appears that several amino acids, including leucine, arginine, and glutamine, play a role in tissue repair mainly through amelioration of muscle atrophy (47) and/or stimulation of collagen formation (48). Current recommendations do not include supplementing with a specific amino acid as limited research exists research exists. While it is possible to consume all essential amino acids from plant based sources, it is easier to consume the essential amino acids from animal based protein sources. Omega-3 fatty acids modulate inflammation, resulting in reduced wound healing time (49). Unless the athlete encounters excessive inflammation following an injury, supplementation is not necessary. A diet high in omega-3 rich foods, such as salmon, walnuts, and flaxseeds would be effective. Several micronutrients also act to enhance tissue healing. For example, vitamin A is required for epithelial and bone formation, cellular differentiation, and immune function, vitamin C for collagen formation, proper immune function, and as a tissue antioxidant. Vitamin E is the major lipid-soluble antioxidant in the skin (50). Although not enough information exists to warrant supplementation to promote wound healing above RDA recommendations, nutritional intake should be assessed to ensure recommended dietary intake of all micronutrients.

4.3 Fluid

Dehydration can have serious health consequences to all athletes, but older athletes are more susceptible than younger ones. During periods of heat stress, older individuals typically respond with attenuated sweat gland output, decreased skin blood flow, reduced cardiac outputs, and smaller distribution of blood flow from the splanchnic and renal circulation (51). Kenney et al. (52) compared the effects of fluid restriction while exercising under different environmental stimuli in older versus younger women. They found that the percent decrease in sweat rate and plasma volume is greater in older versus younger women, indicating that older women have a greater propensity to develop dehydration associated with lack of fluid replacement. Additionally, older individuals are more likely to have altered thirst and kidney function placing them at increased risk for consequences of dehydration. However, if older women athletes are well conditioned and acclimatized to exercising in warm environments, a tolerance to heat stress can be developed. Athletes should drink 16 oz of fluid 30-40 minutes prior to exercise to ensure enough time to optimize hydration status and excrete excess fluid (37). During exercise, athletes should attempt to match their sweat rate with fluids following the guideline to consume 6-12 fl oz every 15-20 minutes (37). Sports drinks containing 6% to 8% carbohydrates and electrolytes are recommended for events lasting greater than 1 hour (41). One needs to compare post exercise weight to pre exercise weight and replace 16-24 fl oz of a fluid for every 0.5 kg of weight lost during exercise. This should supply ample fluid for rehydration following exercise (41). Additionally, consuming foods with high water content will aid rehydration following exercise.

Prior to and during exercise, nutrition intake should be aimed at maintaining hydration, while providing carbohydrates to maintain blood glucose concentrations during exercise. After exercise, meals should provide adequate fluids, electrolytes, energy, protein, and carbohydrates to replace nutrients lost during exercise and promote recovery. More research is needed before nutritional supplementation to improve performance, promote tissue healing, and optimize aging are recommended to women master athletes. However, encouraging a varied diet with balanced energy intake will help to ensure adequate macro- and micronutrient intakes.

5. Summary

Competitive athletic women may experience successful aging. Older trained women athletes can have a 30-50% higher VO_2max than sedentary women but may have a greater age-related decline per decade than the normal population. Factors such as a decrease in cardiac output due to a decrease in maximal heart rate and stroke volume, altered pulmonary function, changes in arteriole compliance, and a decrease and change in skeletal muscle fibers may play a role in the age associated decrease in aerobic capacity in the normal population as well as in athletes. Women athletes also confer a favorable body composition coincident with enhanced glucose and lipid metabolism. Highly trained women athletes maintain a low percentage of total and central body fat compared to healthy sedentary women. The reduced body fat and maintenance of muscle mass may contribute to enhanced glucose uptake and insulin action observed in highly trained women athletes. Proper nutrition is essential for maximizing athletic performance and general health in older women athletes. Specific needs are highly individualized and depend upon the athlete's mode of exercise, stage of training, and recovery time, as well as the intensity, duration, and frequency of each exercise session. Athletes may want to consider taking a multivitamin and mineral supplement, pay attention to fluid requirements and consume a nutrient-balanced diet.

6. Acknowledgements

This research was supported by VA Research Career Scientist Award, Veterans Affairs Merit Award, the Baltimore Veterans Affairs Medical Center Geriatric Research, Education and Clinical Center (GRECC), T32-AG-00219, NIH grant RO1 AG030075, NORC of Maryland (DK072488), and the University of Maryland Claude D. Pepper Center (P30-AG-12583).

7. References

[1] Kaestner R, Xin, X 2010 Title IX, girls' sports participation, and adult female physical activity and weight. Eval Rev 34:52-78.

[2] Rosenbloom C, Bahns M 2006 What can we learn about diet and physical activity from master athletes? Holist Nurs Pract 20:161-166; quiz 167-168

[3] Ransdall L VJ, and Huberty J 2009 Masters athletes: an analysis of running, swimming, and cycling performance by age and gender. J Exerc Sci Fit 7:S61-S73

[4] Hawkins S, Wiswell R 2003 Rate and mechanism of maximal oxygen consumption decline with aging: implications for exercise training. Sports Med 33:877-888

[5] Ogawa T, Spina RJ, Martin WH, 3rd, Kohrt WM, Schechtman KB, Holloszy JO, Ehsani AA 1992 Effects of aging, sex, and physical training on cardiovascular responses to exercise. Circulation 86:494-503

[6] Pollock ML, Foster C, Knapp D, Rod JL, Schmidt DH 1987 Effect of age and training on aerobic capacity and body composition of master athletes. J Appl Physiol 62:725-731

[7] Evans SL, Davy KP, Stevenson ET, Seals DR 1995 Physiological determinants of 10-km performance in highly trained female runners of different ages. J Appl Physiol 78:1931-1941

[8] Tanaka H, Desouza CA, Jones PP, Stevenson ET, Davy KP, Seals DR 1997 Greater rate of decline in maximal aerobic capacity with age in physically active vs. sedentary healthy women. J Appl Physiol 83:1947-1953

[9] Tanaka H, Seals DR 2008 Endurance exercise performance in Masters athletes: age-associated changes and underlying physiological mechanisms. J Physiol 586:55-63

[10] Marcell TJ, Hawkins SA, Tarpenning KM, Hyslop DM, Wiswell RA 2003 Longitudinal analysis of lactate threshold in male and female master athletes. Med Sci Sports Exerc 35:810-817

[11] Joyner MJ, Coyle EF 2008 Endurance exercise performance: the physiology of champions. J Physiol 586:35-44

[12] Brooks G, Fahey, T., and Baldwin, K 2005 Exercise Physiology: Human Bioienergetics and its Applications: McGraw-Hill Higher Educations.

[13] Pollock ML, Mengelkoch LJ, Graves JE, Lowenthal DT, Limacher MC, Foster C, Wilmore JH 1997 Twenty-year follow-up of aerobic power and body composition of older track athletes. J Appl Physiol 82:1508-1516
[14] Eskurza I, Donato AJ, Moreau KL, Seals DR, Tanaka H 2002 Changes in maximal aerobic capacity with age in endurance-trained women: 7-yr follow-up. J Appl Physiol 92:2303-2308
[15] Allen WK, Seals DR, Hurley BF, Ehsani AA, Hagberg JM 1985 Lactate threshold and distance-running performance in young and older endurance athletes. J Appl Physiol 58:1281-1284
[16] Jones PP, Davy KP, DeSouza CA, van Pelt RE, Seals DR 1997 Absence of age-related decline in total blood volume in physically active females. Am J Physiol 272:H2534-2540
[17] Fujimoto N, Prasad A, Hastings JL, Arbab-Zadeh A, Bhella PS, Shibata S, Palmer D, Levine BD 2010 Cardiovascular effects of 1 year of progressive and vigorous exercise training in previously sedentary individuals older than 65 years of age. Circulation 122:1797-1805
[18] Proctor DN, Sinning WE, Walro JM, Sieck GC, Lemon PW 1995 Oxidative capacity of human muscle fiber types: effects of age and training status. JApplPhysiol 78:2033-2038
[19] Proctor DN, Joyner MJ 1997 Skeletal muscle mass and the reduction of VO2max in trained older subjects. J Appl Physiol 82:1411-1415
[20] Ryan AS, Nicklas BJ, Elahi D 1996 A cross-sectional study on body composition and energy expenditure in women athletes during aging. AmJPhysiol 271:E916-E921
[21] Van Pelt RE, Davy KP, Stevenson ET, Wilson TM, Jones PP, Desouza CA, Seals DR 1998 Smaller differences in total and regional adiposity with age in women who regularly perform endurance exercise. Am J Physiol 275:E626-634
[22] Wiswell RA, Hawkins SA, Jaque SV, Hyslop D, Constantino N, Tarpenning K, Marcell T, Schroeder ET 2001 Relationship between physiological loss, performance decrement, and age in master athletes. J Gerontol A Biol Sci Med Sci 56:M618-626
[23] Frisch RE, Snow RC, Johnson LA, Gerard B, Barbieri R, Rosen B 1993 Magnetic resonance imaging of overall and regional body fat, estrogen metabolism, and ovulation of athletes compared to controls. J Clin Endocrinol Metab 77:471-477
[24] Goedecke JH, Levitt NS, St Clair Gibson A, Grobler L, Noakes TD, Lambert EV 2001 Insulin sensitivity measured by the minimal model: no associations with fasting respiratory exchange ratio in trained athletes. Metabolism 50:1286-1293
[25] Ryan AS, Muller DC, Elahi D 2001 Sequential hyperglycemic-euglycemic clamp to assess beta-cell and peripheral tissue: studies in female athletes. JApplPhysiol 91:872-881
[26] Rowe JW, Minaker KL, Pallotta JA 1983 Characterization of the insulin resistance of aging. J Clin Invest 71:1581-1587
[27] Nicklas BJ, Ryan AS, Katzel LI 1999 Lipoprotein subfractions in women athletes: effects of age, visceral obesity and aerobic fitness. Int J Obes Relat Metab Disord 23:41-47

[28] Wilund KR, Tomayko EJ, Evans EM, Kim K, Ishaque MR, Fernhall B 2008 Physical activity, coronary artery calcium, and bone mineral density in elderly men and women: a preliminary investigation. Metabolism 57:584-591
[29] Pihl E, Jurimae T, Kaasik T 1998 Coronary heart disease risk factors in middle-aged former top-level athletes. Scand J Med Sci Sports 8:229-235
[30] Williams PT 1996 High-density lipoprotein cholesterol and other risk factors for coronary heart disease in female runners. N Engl J Med 334:1298-1303
[31] LD DEM, Caldeira ND, Perlingeiro PD, Dos Santos IL, Negrao CE, Azevedo LF 2011 Cardiovascular Risk and Clinical Factors in Athletes: 10 Years of Evaluation. Med Sci Sports Exerc 43:943-950
[32] Ghiadoni L, Cupisti A, Huang Y, Mattei P, Cardinal H, Favilla S, Rindi P, Barsotti G, Taddei S, Salvetti A 2004 Endothelial dysfunction and oxidative stress in chronic renal failure. J Nephrol 17:512-519
[33] Heffernan KS, Jae SY, Tomayko E, Ishaque MR, Fernhall B, Wilund KR 2009 Influence of arterial wave reflection on carotid blood pressure and intima-media thickness in older endurance trained men and women with pre-hypertension. Clin Physiol Funct Imaging 29:193-200
[34] van Pelt RE, Dinneno FA, Seals DR, Jones PP 2001 Age-related decline in RMR in physically active men: relation to exercise volume and energy intake. Am J Physiol Endocrinol Metab 281:E633-639
[35] Gilliat-Wimberly M, Manore MM, Woolf K, Swan PD, Carroll SS 2001 Effects of habitual physical activity on the resting metabolic rates and body compositions of women aged 35 to 50 years. J Am Diet Assoc 101:1181-1188
[36] Weigle DS, Breen PA, Matthys CC, Callahan HS, Meeuws KE, Burden VR, Purnell JQ 2005 A high-protein diet induces sustained reductions in appetite, ad libitum caloric intake, and body weight despite compensatory changes in diurnal plasma leptin and ghrelin concentrations. Am J Clin Nutr 82:41-48
[37] Sports, Cardiovascular, and Wellness Nutritionists Dietetic Practice Group 2006 Sports nutrition: a practice manual for professionals Diana Faulhaber
[38] Tipton KD, Wolfe RR 2004 Protein and amino acids for athletes. J Sports Sci 22:65-79
[39] Nieman DC, Butler JV, Pollett LM, Dietrich SJ, Lutz RD 1989 Nutrient intake of marathon runners. J Am Diet Assoc 89:1273-1278
[40] Beshgetoor D, Nichols JF 2003 Dietary intake and supplement use in female master cyclists and runners. Int J Sport Nutr Exerc Metab 13:166-172
[41] Rodriguez NR, Di Marco NM, Langley S 2009 American College of Sports Medicine position stand. Nutrition and athletic performance. Med Sci Sports Exerc 41:709-731
[42] Amati F, Dube JJ, Coen PM, Stefanovic-Racic M, Toledo FG, Goodpaster BH 2009 Physical inactivity and obesity underlie the insulin resistance of aging. Diabetes Care 32:1547-1549
[43] Martarelli D, Pompei P 2009 Oxidative stress and antioxidant changes during a 24-hours mountain bike endurance exercise in master athletes. J Sports Med Phys Fitness 49:122-127

[44] Louis J, Hausswirth C, Bieuzen F, Brisswalter J 2010 Vitamin and mineral supplementation effect on muscular activity and cycling efficiency in master athletes. Appl Physiol Nutr Metab 35:251-260

[45] McKean KA, Manson NA, Stanish WD 2006 Musculoskeletal injury in the masters runners. Clin J Sport Med 16:149-154

[46] Demling RH 2009 Nutrition, anabolism, and the wound healing process: an overview. Eplasty 9:e9

[47] Tipton KD 2010 Nutrition for acute exercise-induced injuries. Ann Nutr Metab 57 Suppl 2:43-53

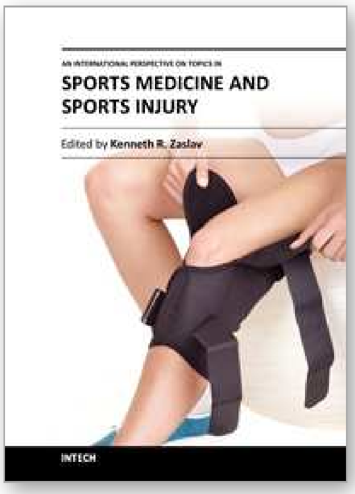
[48] Stechmiller JK 2010 Understanding the role of nutrition and wound healing. Nutr Clin Pract 25:61-68

[49] McDaniel JC, Belury M, Ahijevych K, Blakely W 2008 Omega-3 fatty acids effect on wound healing. Wound Repair Regen 16:337-345

[50] MacKay D, Miller AL 2003 Nutritional support for wound healing. Altern Med Rev 8:359-377

[51] Kenney WL, Munce TA 2003 Invited review: aging and human temperature regulation. J Appl Physiol 95:2598-2603

[52] Kenney WL, Anderson RK 1988 Responses of older and younger women to exercise in dry and humid heat without fluid replacement. Med Sci Sports Exerc 20:155-160



An International Perspective on Topics in Sports Medicine and Sports Injury
Edited by Dr. Kenneth R. Zaslav

ISBN 978-953-51-0005-8
Hard cover, 534 pages
Publisher InTech
Published online 17, February, 2012
Published in print edition February, 2012

For the past two decades, Sports Medicine has been a burgeoning science in the USA and Western Europe. Great strides have been made in understanding the basic physiology of exercise, energy consumption and the mechanisms of sports injury. Additionally, through advances in minimally invasive surgical treatment and physical rehabilitation, athletes have been returning to sports quicker and at higher levels after injury. This book contains new information from basic scientists on the physiology of exercise and sports performance, updates on medical diseases treated in athletes and excellent summaries of treatment options for common sports-related injuries to the skeletal system.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821