16 Training and Nutritional Needs of the Masters Sprint Athlete

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CONTENTS

16.1 INTRODUCTION

Over the past decades, there have been increasing numbers of middle-aged and older people taking part in masters (>35 years) track and field competitions. Sprint running, especially the 100-m, has been a very popular competitive event from the beginning of the first international master athletics championships in the 1970s. With large numbers of serious competitive masters athletes, the current standard of sprint running is extremely high in many countries. Although the achievement of success at the highest level is largely dependent on superior genetic endowment, training-related adaptations in various attributes of sprinting ability are of considerable importance [1]. In order to reach their full potential, the training of ageing athletes must be regarded as a long-term systematic process where biomechanical, physiological and nutritional characteristics are developed together.

This chapter will review the research examining the effects of ageing on short sprint running performance (60 and 100 m) and its determinants in highly competitive male runners with special emphasis on practical aspects of training and nutrition. Because data in many areas are very limited, the literature is supplemented with information found in young sprinters and older non-athletes.

16.2 CHANGES IN SPRINT PERFORMANCE WITH AGEING

16.2.1 Competition Performance Times

Athletic records provide the basis for understanding the effect of ageing on the ability to run fast. The current world records for the men's 100-m sprint suggest that the peak performance occurs between the ages of 20 to 30 years (see Figure 16.1 [2,3]). Thereafter, the age-based record performances (in m/s) decrease almost linearly at a rate about 0.6% per year until approximately 80 years of age. However, the determination of the effects of ageing on record performances in sprinting is complicated by cohort differences and may produce a different pattern of change than longitudinal trends. In a retrospective study, Conzelmann [4] examined the best German male runners with repeated participation in sprinting competition over many years. The average rate of longitudinal decline in 100-m performance from age 20–25 to ages 70–75 years was approximately 0.3%–0.4%/year and smaller than the cross-sectional decline (~0.6%/year) of the 10 highest-ranked all time

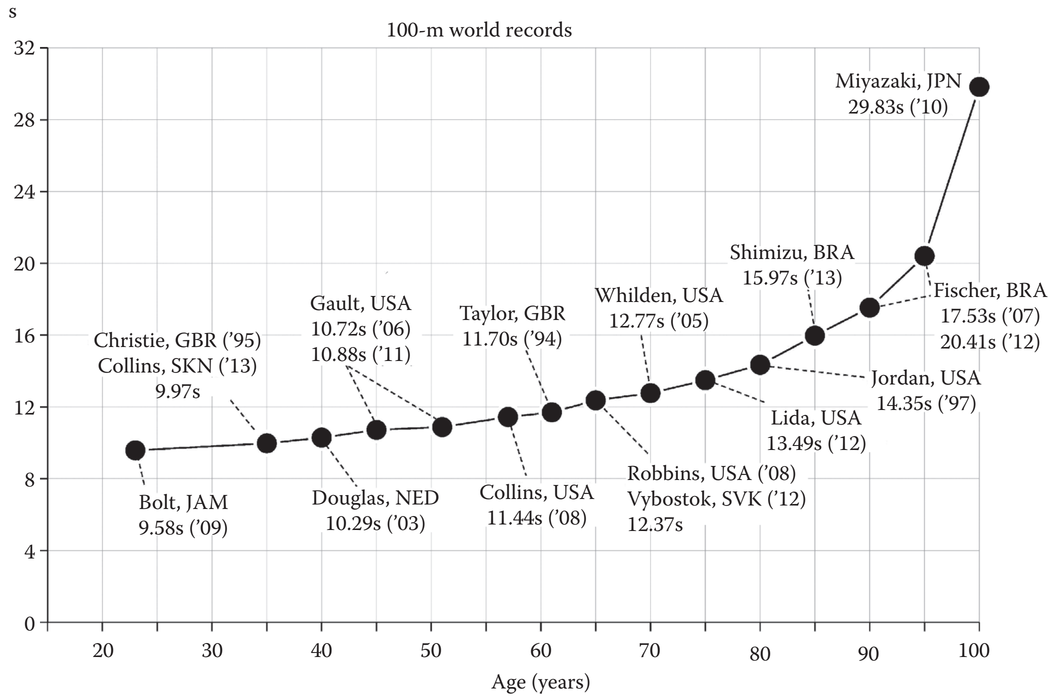


FIGURE 16.1 The official 100-m world records (year 2013) in open and each 5-year (>35 years) classes in men. The year when the record was made is in brackets. (From World Masters Athletics, Records. Available at http://www.world-masters-athletics.org/records, accessed 30 January 2014; IAAF Athletics, Senior Indoor Records. Available at http://www.iaaf.org/statistics/records, accessed 30 January 2014.)

national performances [4]. However, it is probable that longitudinal change in sprinting ability may be influenced by changes in training practices and competitive status.

In systematically trained runners who have reached their full athletic potential during adulthood, the rate and magnitude of sprint performance decline could be greater than in those with a lower-level training and performance at young adult age. Merlene Ottey presents a unique example of an athlete who has been able to continue her career as an elite-level international sprinter until her early 50s. Her personal best 100-m times have over 16 years declined from 10.74 seconds (36 years) to 11.82 seconds (52 years) corresponding to a decline in running velocity of about 0.57%/year. Given that she is at a stable, optimal level of training (still trying to qualify for major championships), the decrement in sprint running performance may reflect the smallest possible rate of change in sprint performance due to biological ageing *per se*.

16.2.2 Velocity Curve

Success in sprint running events requires not only high maximum velocity but also an efficient starting action, running acceleration and speed endurance. The 100-m competitive sprint running performance of young elite athletes has frequently been evaluated by a velocity curve [5–8] which describes acceleration from a resting position to maximum velocity and deceleration at the end of the run. During the European Veterans Athletics Championships in 2000, we investigated for the first time the velocity curve characteristics of the 100-m races in master sprinters using video analysis. In male finalists (40–89 years, $n = 37$) the age-associated differences in velocity were similar—approximately 5%–6% per decade in early acceleration (0–10 m), maximum velocity and deceleration (90–100 m) phases. One apparent difference between runners of different ages was the length of the acceleration phase. In the oldest runners (80–89 years) it took only about 25 m to reach the maximum velocity of 6.7 m/s whereas the athletes in the youngest age group (40–49 years) attained their maximum velocity of 10.2 m/s at around 45 m. Reports from major championships have shown that young elite athletes achieve very steep initial acceleration and could continue to accelerate up to about 60–70 m to increase speed to a maximum of ~11.8–12.0 m/s during a competitive sprint run performance [5–8]. Another major finding in our competition analysis was that the relative loss in velocity from the peak velocity sequence to the end of the race became greater with age (from 5.4% at age 40–49 years to 10.6% at age 80–89 years). These values were somewhat greater when compared to the decreases of about 2%–7% in velocity in young elite sprint runners [5–8]. On the other hand, in older sprint runners, maximum speed is achieved earlier so there is greater potential to decelerate towards end of the race.

16.2.3 Stride Parameters

At the first level of mechanical analysis, running velocity is determined by a product of stride rate and stride length. In the competition analyses above, the effect of age on the stride variables was examined during different phases of the 100-m race [9]. The results showed age-related declines in both acceleration and maximum velocity were primarily related to a reduction in stride length. In maximum velocity phase, stride length declined from about 2.19 m in the 40–49-year-old runners to 1.60 m in runners over 80 years (Table 16.1). Stride rate showed a small age-related decline from 4.66 to 4.23 steps per second and was explained by a progressive increase in contact time while flight time did not show any significant decrease until the oldest age group.

The same trends for stride characteristics during maximum speed phase were observed earlier by Hamilton et al. [10] who studied 83 elite-level male sprinters aged 30–94 years in competition conditions. They also found age-related decreases in range of motion in both the hip and knee joints, while leg swing time remained virtually unchanged with age. Similarly, Roberts and co-workers [11] reported that 60–65-year-old male runners had decreased range of motion and angular velocities at lower limb joints but comparable swing duration to that observed in 20–22-year-old runners.

TABLE 16.1
Step Parameters during Maximum Velocity Phase of the 100-m Race Measured on World-Class Young Adult and Master Male Sprinters

	Velocity (m/s)	Step Length (m)	Step Rate (Hz)	Flight Time (s)	Contact Time (s)
Young	12.55	2.70	4.63	0.128	0.087
40–49 years	10.20	2.19	4.66	0.121	0.098
50–59 years	9.32	2.02	4.64	0.121	0.102
60–69 years	8.90	1.96	4.54	0.116	0.109
70–79 years	7.89	1.79	4.42	0.111	0.118
80–89 years	6.74	1.60	4.23	0.097	0.141

Sources: Based on data from Mann, R., *The Mechanics of Sprinting and Hurdling*, Create Space, Lexington, KY, 2011 (young athletes); Korhonen, M.T. et al., *Med. Sci. Sports Exerc.* 41(4), 844–856, 2009 (masters athletes).

However, the authors suggested that the age-related decline in swing limb kinetics is not necessarily due to reduction in force generating potential, but rather reflect a strategy to match the swing limb timing to the reduced stride length and increased contact time.

16.2.4 GROUND REACTION FORCES

Ground-leg interaction is the major factor in sprint running because it is during the contact phase of the step cycle that segmental forces can act on and thus influence horizontal speed. Therefore, the measurement of ground reaction forces (GRF) can provide valuable information about the effect of age on performance. However, to our knowledge, the effects of age on GRF have only been examined once. In a laboratory-based study on Finnish sprint runners ranging in age from 17 to 82 years, force production during maximum velocity sprinting was described using average net resultant GRF (i.e. combination of horizontal and vertical force) as a specific force indicator [12]. The magnitude of both the braking and push-off forces declined progressively with age and was reflected in changes in step length, contact time and consequently in maximum velocity. Along with the 27% age-related decline in sprint running velocity (from 9.7 to 7.1 m/s), braking force and push-off forces decreased by 20% and 32%, respectively. In addition to decreased force production, the mean angle of push-off resultant force became more vertically oriented that may impair the acceleration of the body in the optimal horizontal direction and thus affecting stride length. A notable finding was also greater age-related increase in contact time in braking than push-off phase (Figure 16.2). It could be hypothesized that high eccentric impact loads are less well tolerated in older ages resulting in a longer braking phase and this could impair elastic energy/force potentiation during concentric phase of the contact [13].

Mechanical stiffness during contact (eccentric phase) is thought to be an important determinant of optimal reactive force production in sprint running. In the study on ageing Finnish sprint runners, stiffness regulation of whole body and contact leg was predicted by spring-mass models (ratio of peak GRF to vertical length change of the centre of mass or to leg length) [12]. It was found that vertical stiffness and leg stiffness decreased by 41% and 21%, respectively, from the 17–33-year-old runners to runners over 70 years. In addition, stiffness values were strongly related to braking phase contact time, suggesting that high stiffness is a prerequisite for tolerating higher impact loads and can lead to faster transition from the braking to the push-off phase.

The exact process by which stiffness during running is regulated is not fully understood, but may reflect a complex interaction of centrally programmed prelanding activation and reflex potentiation after the impact phase [14], stiffness of tendons and other connective tissues [15], and muscle force-generating capacity. A 20-week training program emphasising maximum strength and explosive strength training exercises increased sprint running leg stiffness by 14% in a group of elite masters

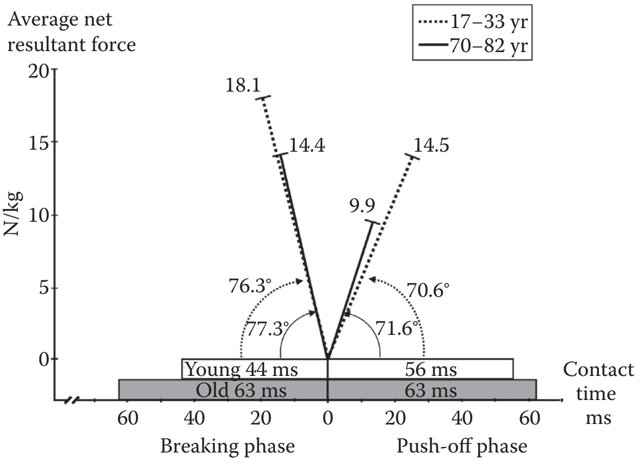


FIGURE 16.2 Resultant force production characteristics of maximum speed running in the youngest and oldest athlete groups. There was a greater relative age-group difference in push-off than braking forces as well as greater age-related increase in braking than push-off ground contact time. Further, the mean angle of push-off force increased with age. (From Korhonen, M.T., *Effects of Aging and Training on Sprint Performance, Muscle Structure and Contractile Function in Athletes*, Ph.D. thesis, Studies in Sport, Physical Education and Health, No. 137, University of Jyväskylä, Finland, 2009.)

male sprint runners (52–78 years) with limited or no prior strength training experience [16]. Thus, it might be hypothesised that muscle force-generating capacity is an important factor determining age-related declines in stiffness and reactive force production during sprint running. However, a limitation of the vertical and leg stiffness calculations are that they do not provide information about joint-specificity and the interaction of muscle and tendon function. Studies in young athletes have suggested that stiffness in the ankle joint rather than knee joint determines ground contact time in sprinting [17].

16.3 LIMITING FACTORS IN SPRINT PERFORMANCE WITH AGEING

16.3.1 Maximal and Explosive Muscle Strength

Several studies in young adult athletes have reported significant correlations between sprint running ability and explosive muscle strength/power defined by various jumping tests and isometric rate of force development [18–20]. In addition, many investigations have shown positive relationships between measures of sprint running performance and maximum strength [18,19,21]. The advantage of higher maximum strength is likely to be connected to its influence on power production (power = force × velocity). For stronger runners, the inertia of body weight represents a smaller percentage of maximum strength and it is thus easier to accelerate. Masters sprint and strength/power athletes have been found to experience progressive age-related reductions in both maximal and explosive strength characteristics, the decrease being somewhat larger for rapid force production capacity [22–24]. We have previously observed that in sprinters between 17 and 82 years of age the maximum load that can be lifted one time (1-RM) using concentric half squat exercise reduced from approximately 2.5 to 1.6 times body weight (BW) (–36%) while counter-movement jump height declined from 52 to 23 cm (–56%) [12]. With regard to sprint performance, the squat 1-RM and vertical jump heights measured in our study correlated positively with both sprinting speed and stride frequency, and negatively with contact time of maximum velocity phase. The squat 1-RM was positively associated with vertical and leg stiffness [12].

In an ongoing study we have tried to identify the importance of different lower extremity muscles in the age-related decline in maximum sprinting speed. Muscle moments and powers at the ankle, knee and hip joints were evaluated during maximum-speed phase at 30–40 m in young (26 ± 6 years), upper middle-aged (61 ± 5 years) and old (78 ± 4 years) male sprinters (n = 13 in each group). The preliminary data indicate that a significant age-related decline in muscular output occurred at the level of hip and ankle joints, but surprisingly, not at knee joint level. In regression analysis, power generation of the ankle plantarflexors explained 80% of the total variance, with knee power absorption being other factor (5%) to appear in the model. Although the decline in overall sprinting performance (start, acceleration, maximum-speed phase) with age is probably linked to the function of multiple muscle groups, the ankle plantarflexors may become the important weak link in the force production chain during the maximum-speed phase. This should be taken into consideration for the design of sprint training programs for masters sprinters.

16.3.2 MUSCLE MASS AND CONTRACTILITY

A major factor affecting rapid-force production capacity is the inherited muscle fibre composition. Analyses of muscle fibre contractile properties have shown that shortening velocity and power of fast type IIA and IIB muscle fibres is ~4- and ~10-fold higher, respectively, than that of slow type I fibres [25,26] in young and middle-aged untrained men. In successful young sprint runners, fast fibres (IIA+B) have been found to account for about 60% (range 50%–75%) of the fibres in the vastus lateralis thigh muscle [27]. However, in young sprinters the proportion of the total muscle cross-sectional area occupied by fast fibres is likely to be greater because the training-induced muscle fibre enlargement (hypertrophy) is typically much more pronounced in the fast compared to slow fibres [28,29]. Another factor that could influence contractile velocity is muscle fibre length and pennation angle (the angle at which fibres insert into the aponeurosis) [30]. A greater fibre length (more sarcomeres in series) enhances to contraction velocity, whereas increased pennation angle and muscle thickness (more sarcomeres in parallel) enhances the contractile force potential.

In our study, various muscle characteristics were examined in 18- to 84-year-old sprint runners [28]. The results implied that the decline in contractile force and velocity potential of quadriceps muscle with age were mainly attributable to reductions in muscle thickness (mass) and size of fast-contracting type II fibres, because the muscle fibre distribution, fascicle length as well as single-fibre contractile force and velocity remained largely unchanged with ageing. The percentage decline in cross-sectional area of fast type II fibres was 6.9% per decade, while type I fibre area remained unaltered (Figure 16.3). Our findings of selective atrophy of fast fibres agree with the results of master sprint runners and jumpers [31,32] and ageing endurance-trained athletes [33–35]. However, the size of fast fibres appears to be far above the age norms in masters athletes exposed to long-term strength training [32–34], suggesting that resistance training in masters sprinters be encouraged.

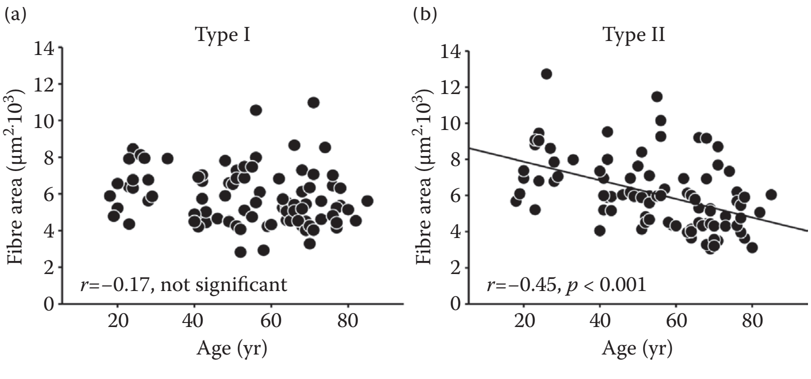


FIGURE 16.3 Association between age and mean fibre cross-sectional area of type I (a) and type II muscle fibres (b) of the vastus lateralis muscle. (Adapted from Korhonen, M.T. et al., *J. Appl. Physiol.* 101[3], 906–917, 2006.)

In addition to muscle fibre atrophy, the major factor underlying the ageing-related decrease in muscle mass is a loss of muscle fibre number due to the age-related reduction in number of functioning motor units. In human vastus lateralis muscle, the decrease in fibre number has been reported to be about 50%, from 650,000 to 325,000 fibres between age 20 and 80 years [37]. Whether the loss of motor units and fibres can be slowed or prevented by systematic exercise is one of the most important unanswered questions relating to deterioration in muscle function in older ages.

There is preliminary evidence from masters endurance runners that exercise may counteract muscle from motor unit loss. Power and co-workers [38] measured the number of functioning motor units (MUs) in lower leg tibialis anterior muscle and found that MU number was higher in habitually trained 65-year-old male runners (140 ± 53 MU) than age-matched controls (91 ± 22 MU) but similar to those of 25-year-old recreationally active controls (150 ± 43 MU). Their recent subsequent study [39] showed that the number of functioning MU was lower in the upper limb biceps muscles in both endurance-trained (185 ± 69 MU) and untrained (133 ± 69 MU) older men compared with the young men (354 ± 113 MU) suggesting that the life-long exercise might provide neuroprotective effects only in muscle groups that are directly over-loaded by exercise.

As regards to relationships between muscle structural properties and sprint running performance, we found that combined knee extensor and plantar flexor muscle thickness was significantly associated with maximum running speed and 60-m running times in runners aged between 17 and 82 years [12]. Moreover, the muscle thickness correlated with both leg and vertical stiffness and, in a regression analysis, muscle thickness was the strongest predictor of GRF during the braking phase. In other words, it seems that the larger the leg muscles, the higher the stiffness and ability to produce/tolerate high eccentric forces. These findings appear to be in line with Weyand et al. [40] who estimated the vertical force requirement for different velocities in young runners and concluded that the greater body masses of faster sprint runners are directly associated with the greater ground support forces required to reach faster running speeds. Figure 16.4 presents a simplified model of

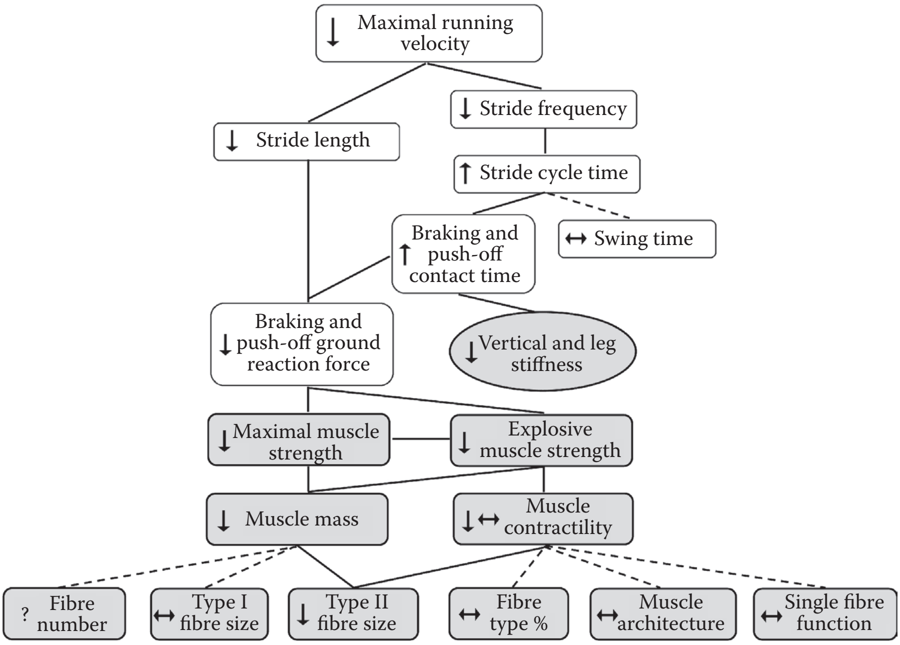


FIGURE 16.4 Schematic diagram of the skeletal muscle and biomechanical factors that may determine age-related decline in sprint running performance. Arrows denote significant decrease (↓), increase (↑) and no alteration (↔). (Adapted from Korhonen, M.T. et al., *Med. Sci. Sports Exerc.* 41[4], 844–856, 2009.)

some of the structural and functional changes in skeletal muscle with age that may be connected to decline in sprinting performance.

16.3.3 TENDON PROPERTIES

Tendons can play an important role as power amplifiers during sprint running. Some recent studies have examined the association of tendon compliance (elongation of tendon and aponeurosis at given tendon force in isometric contractions) on sprint performance in young runners [41,42]. These studies suggest that the stiffness of the tendon that is optimal for performance is dependent on the specific joint/muscle group. For example, Stafilidis and Arampatzis [41] and Kubo et al. [42] have found more compliant tendon structures at the knee extensors were related to better 100-m sprint times. A major suggested advantage of increased tendon compliance at the knee extensor muscles for sprinters is that it allows muscle fibres to generate force at lower shortening velocities that augment the muscle force potential as a result of the force-velocity relation (the faster a muscle shortens the less force it can produce). However, the compliance of tendon structures at the calf muscle was not associated with sprint run performance [42] and sprinters showed considerably higher stiffness compared to endurance-trained and untrained subjects [43].

Earlier studies have shown that in sprint running, minimum contact time is determined, at least in young runners, by stiffness of the ankle joint [17]. Therefore, one could assume that stiffer tendon structures at plantar flexors are best suited for the fast contact pattern. It has been suggested that age-related changes in tendon properties (e.g. loss of Achilles tendon stiffness) play a role in the age-related decline in sprint running performance by compromising the rate of force development and elastic storage capacity [44]. However, the currently available scientific data on muscle-tendon behaviour is from untrained people using isometric contractions. Therefore, to verify the assumptions above, studies in physically highly active masters sprinters during actual sprint running conditions are warranted.

16.3.4 FLEXIBILITY

Training of flexibility is commonly recommended for sprint athletes for reducing the risk of injury [45]. In addition, good flexibility is thought to be an important prerequisite to perform technically correct sprint running stride and is an especially important issue in sprint hurdling [45,46]. Ageing is associated with a degeneration and hardening of soft tissue leading to functional loss of joint flexibility [47]. The age-related changes in flexibility are evident for both untrained and athletic people and can start in the 20s. In a study on amateur soccer players of three different age levels of competition (19–44 years, $n = 24$), McHugh et al. [48] found that players over 30 years of age had less lumbar flexion and hip rotation static flexibility than players in their thirties (19–29 years). In our studies, we have measured static range of motion (ROM) in the hip, knee and ankle goniometrically (with modified Thomas test [49,50]) to estimate the flexibility of quadriceps and iliopsoas hamstrings (straight leg raise) and calf muscles in 68 male sprinters ranging in age from 17 to 82 years (unpublished data). There was a progressive age-related decline in flexibility values for hamstrings (r with age = –0.33, $p < 0.01$) and quadriceps ($r = –0.40$, $p < 0.001$), but no significant age effect was found in iliopsoas and calf muscle flexibility. The difference in average range of motion between the youngest (17–29 years) and oldest group (70–82 years) was 11.6° (95.4° vs. 83.8°) for hamstring flexibility and 16.0° (66.9° vs. 50.9°) for quadriceps flexibility.

The association between flexibility and sprint performance measures was analysed in a pooled sample using partial correlation analysis, controlling for age ($n = 52$). Interestingly, the flexibility of the hamstring muscles was inversely related to running speed ($r = –0.36$, $p < 0.05$) and stride frequency ($r = –0.50$, $p < 0.001$) of maximum speed phase (30–40 m) and showed a strong trend for direct association with 60-m sprint running times ($r = 0.26$, $p = 0.059$). These findings suggest possible performance benefits in runners with lower compliance of the hamstring muscle group.

Although the above data should be interpreted cautiously due to non-sport-specific static flexibility measurements, they raise questions as to what is an optimal flexibility from a sprint running performance standpoint. There are some theories that if muscles and tendons become easily lengthened and stretched this could lead to suboptimal stiffness and decreased rate of force development that is a critical factor for sprint run performance [51]. Therefore, some researchers have suggested that the focus on the development of flexibility in athletes might not be to exceed but rather to maintain normal physiological range of motion that allow good body positions to perform an effective movement pattern [52]. In addition, it is recommended that because acute stretching can decrease force output, pre-event stretching should be limited to stretching within available ROM and performed at least 45–60 minutes before an event [52]. Nevertheless, it is plausible that soft tissue may become more injury-prone with ageing [53] and thus the importance of flexibility and stretching from an injury prevention point of view may increase in masters athletes. Clearly, more scientific evidence is needed about the effects of flexibility and stretching on injury rates and sprint performance in ageing athletes.

16.3.5 ENERGY METABOLISM

In sprint running, the ability to produce force over a long period of time is affected by adenosine triphosphate (ATP) supply to the muscles. Due to the requirement for rapid production of energy, the major ATP contribution to sprinting comes from anaerobic processes of phosphocreatine (PCr) breakdown and degradation of glycogen to lactate (anaerobic glycolysis). Intramuscular PCr is a very rapid energy source but is limited in quantity and reduced considerably during the first 5 seconds of maximal sprinting [54]. Anaerobic glycolysis, which is also activated at the beginning of exercise, reaches a maximal rate by about 5 seconds of maximal sprinting but can be maintained for a longer time [54]. It has been estimated that in world-class 100-m performance (10 s) the energy production is 50% from both PCr and anaerobic glycolysis, whereas in the 400 m, the relative energy contribution is about 62.5% from anaerobic glycolysis, 12.5% from PCr and 25% from aerobic processes [55]. Increased anaerobic glycolytic stress with increasing sprint distance is reflected in peak post-exercise blood lactate concentrations, $[La]_{b\ peak}$. In young high-performance male sprinters $[La]_{b\ peak}$ following 100-, 200- and 400-m sprint races have been found to be about 12–14 mmol/l, 17–20 mmol/l and 20–25 mmol/l, respectively [56–59].

Muscle fatigue is a complex performance-limiting phenomenon in sprinting. A muscle biopsy study in seven young male sprint runners (100-m records: 10.60–10.99 s) has suggested that PCr depletion is the main factor for the loss of speed towards the end of the 100 m sprint, because the energy transfer from glycogen may not be fast enough to maintain the high rates of ATP utilisation needed for sprinting [54]. Fatigue in sprinting may also be related to the lactic acid-induced accumulation of H^+ ions (fall in pH) that may impair contractile function either directly (inhibition of cross-bridge kinetics) or indirectly (via glycolytic inhibition) [60]. Some investigations have connected fatigue to other components of the metabolism, such as increased inorganic phosphate from PCr breakdown and potassium ion concentrations [61]. Nevertheless, the exact mechanism of fatigue during sprint running remains unclear.

Our current understanding of the effects of age on energy production during sprinting is restricted to $[La]_{b\ peak}$ measurements that provide a rough indirect measure about anaerobic glycolytic energy production. We studied $[La]_{b\ peak}$ in competition conditions in 81 male sprint runners aged 40 to 88 years [62]. The results showed an age-associated decline in $[La]_{b\ peak}$ following 100-m (from 14.6 to 10.9 mmol/l), 200-m (17.4 to 15.4 mmol/l) and 400-m (17.0 to 14.1 mmol/l) events, the age-group differences becoming significant after 70 years of age. Moreover, the decline in $[La]_{b\ peak}$ with age was related to increases in running times and thus slowing of sprint run performance. These data support the view that reduced energy production via anaerobic glycolysis in older ages may be a factor in the curvilinear deterioration in overall sprint run performance [63]. Our results also agree with the recent study by Benelli et al. [64] who studied blood lactate response to competitive swimming in 52 male swimmers (40–79 years) using the same analytical method. They found an age-related decline in $[\mathrm{La}]_{\mathrm{b\ peak}}$ following competitive 50–400-m events (from 14.2 to 8.2 mmol/l) with the age-related difference becoming most salient after 70 years of age. However, Reaburn and Mackinnon [65] reported no significant age differences in the capillary $[\mathrm{La}]_{\mathrm{b\ peak}}$ following a 100-m freestyle swimming test when comparing groups of male swimmers aged 25–35, 36–45, 46–55, and 56+ years ($n = 4$ in each group), but their differing findings may relate to the small number of elderly athletes.

The exact causative factors explaining age-related decline in $[\mathrm{La}]_{\mathrm{b\ peak}}$ have not been distinguished, but some hypotheses could be suggested. Total lactic acid production is highly correlated with both the contractile muscle mass [66,67] and the size and number of fast fibres [68,69]. Therefore the age-related reduction in muscle mass via preferential atrophy and loss of fast fibres could play a major role in the observed age-related decreases in $[\mathrm{La}]_{\mathrm{b\ peak}}$. It is also known that high-intensity sprint training increases both muscle [70,71] and blood lactate accumulation [72] together with increases in glycolytic enzyme activities [70,71]. Because older sprinters in general exhibit an age-related reduction in the volume of high-intensity exercise they undertake [62], this could in part contribute to an age-related decline in anaerobic metabolic capacity. In addition, on the basis of studies on untrained people, other factors such as preferential reliance on oxidative metabolism during exercise [73] could potentially play a role in reduced lactate production. However, a problem when interpreting the findings of general ageing population is that the physiological changes may reflect sedentary lifestyle and decreased physical activity rather than ageing process *per se*.

16.4 TRAINING METHODS TO IMPROVE SPRINT PERFORMANCE

To improve sprint performance both hard and persistent physical training over a long period is required. Optimisation of training is therefore highly desirable, but little is known about how to best train older sprint athletes. Many masters sprint runners have adopted their training methods through personal experience rather than application of research-based practices. The purpose of this section is to provide scientific and practical knowledge of sprint running that will help the design of effective training programs. Examples of training practices employed by successful master sprinter will be given.

16.4.1 Basic Training Principles

The basic principles of training include progressive overload, training specificity, accommodation and individuality [74]. Progressive overload suggests that in order to allow physiological systems to systematically adapt to physical training, the intensity and duration of that training should increase progressively over time. Compared to younger exercisers, the older athletes may need more time to recover after hard training sessions [75]. Therefore, the frequency of high-intensity or high-volume training bouts may need to be reduced to avoid overtraining and/or injury. Training specificity refers to the concept that adaptation to exercise is specific to the type of loading. In the case of enhancing sprint performance, the training practices should reflect the physiological and biomechanical demands (e.g. energy systems, muscle groups, force production characteristics) of the competitive event. In practical terms, this means that a mixture of sprint, strength and plyometric exercises should be employed when training for sprint running. If the same exercise with the same training load is used over an extended period of time, the adaptation occurs only during the early part of training. In other words the response to a constant stimulus decreases over time, which is referred to as accommodation. Therefore, the intensity and volume of the training sessions should be progressively increased and the types of exercises varied to maximise adaptation. Periodisation of training into different training cycles (weekly, monthly and yearly cycles) ensures variation in overall training load and optimises adaptation before major competitions. According to the principle of individuality, athletes may respond differently to training stimuli, partly due to the genetic differences [76]. For example, the volume of training that is optimal for one athlete can lead to overtraining in others. Coaches should be aware of the individual differences and plan training considering characteristics, such as the age, training years, strengths and weaknesses, health status and recovery rate of the individual athlete.

16.4.2 SPEED TRAINING

Many successful master sprinters apply only speed exercises during training. Their success is proof of the effectiveness of the event-specific training in maintenance of sprinting ability with ageing. Sprint exercises form the basis for developing explosive power and anaerobic energy production. In addition, fast cyclical sprint movements require a high level of neuromuscular coordination/skill, which can be achieved only by regular sprinting. For speed development, the training sessions with short sprints should be done in a fully recovered state. In maximal speed efforts, psychological factors such as willpower and concentration are thought to be essential to achieve an optimal training response especially in terms of recruiting maximum number of fast motor units [77].

The intensity of the sprint training remains high throughout the training year while the distances in running drills increase as the competition season approximates (Figure 16.5). This principle is referred to as the short to long approach and it is widely used in speed training for short sprint events (100–200 m, short sprint hurdles). When it comes to long sprints (400-m flat and hurdles) typically a long to short approach is utilised simultaneously. In this approach the speed of the training sessions is increased and the length of running distances decreased gradually as the training year progresses towards the competition season.

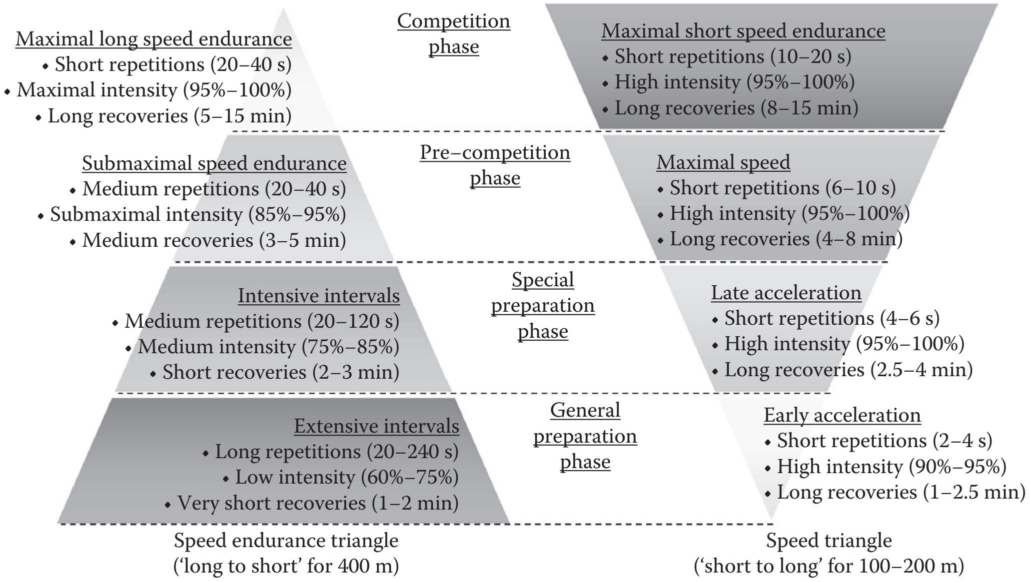


FIGURE 16.5 Schematic illustration of how to develop speed in short-sprint events (100 m, 200 m, short sprint hurdles) in different parts of the training year according to the 'short to long' approach, accompanied by the principles of simultaneous speed endurance development in long sprints (400-m flat and hurdles) according to the 'long to short' approach.

16.4.3 STRENGTH TRAINING

Both running and plyometric (jumping) exercises are essential to develop anaerobic metabolic properties of skeletal muscles, sprint-specific neuromuscular coordination, and both tendon strength and elastic properties. However, training regimens consisting solely of running and plyometric exercise are ineffective to increase muscle mass and strength that are essential attributes for a good sprinting ability. Therefore, optimal training regimens to enhance sprint performance in master sprinters also require high-intensity weight training. One of the most significant impacts of strength training in master sprint athletes could be an effective overload of the fast-contracting type II fibres that are known to be particularly at risk of age-related atrophy [28,78].

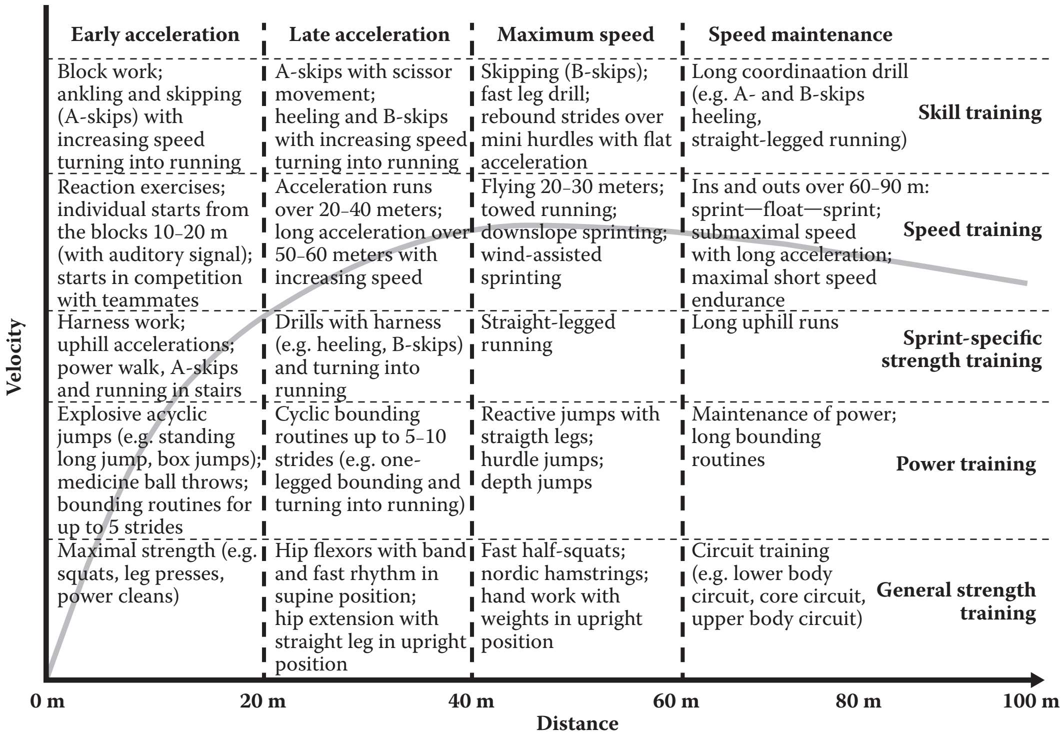
The success of strength training to optimise sprint performance in masters sprinters is indicated by a number of studies. For example, Cristea et al. [16] examined the effects of combined strength and speed training (4×/week) in world-class male sprinters (52–78 years, $n = 7$ and 4 controls) who had limited or no previous experience in weight training. The 20-week periodised training program increased type II fibre size by 17%–20%. This was accompanied by significant improvements in maximal (21%–40%) and explosive (4%–29%) strength, maximum speed (4%) and 60-m sprint times (2%). Running mechanics were also altered with significant increases in propulsive ground reaction forces (8%), rate of force development (12%–14%), stride length (3%) and a decrease in ground contact time (5%–9%). Reaburn and co-workers [79,80] found that an 8-week combined sprint (2×/week) and hypertrophic strength (3×/week) training program in male sprinters (55 ± 6 years, $n = 6$ and 4 controls) resulted not only in an increased maximal leg strength (10%–25%) but also improvements in 100-m (4%) and 300-m (2%) sprint performances. Taken together, these studies strongly suggest that combined resistance and sprint training is clearly more effective than sprint training alone.

In sprint events one can distinguish a start, acceleration, maximum speed and speed maintenance phase. Each of these phases places different demands on strength and power-generating capacities of the various muscle groups. The acceleration phase requires particularly a high maximum and explosive force production in the hip extensor muscles, while the maximum speed phase depends especially on the ability to produce high reactive power by the plantar and knee flexors and hip extensors. Figure 16.6 shows an example of sprint and strength exercises that are planned using the information on force production and technique requirements of a 100-m sprint run event.

16.4.4 STRUCTURE OF THE TRAINING PROGRAMS

To avoid overtraining and to reach maximum performance during important competitions, the annual planning based on short- and long-term objectives is an important aspect of training for the athlete [81]. Most young and masters sprinters concentrate on both indoor and outdoor competitions and thus an annual training program with double-peak periodisation models could be optimal. Tables 16.2 through 16.4 show this approach developed and employed by a successful male masters sprinter (100–200 m) with a long-term personal experience in coaching of young elite athletes. The indoor season represents the phase I and the outdoor season phase II with general and pre-competition phases in both. The type of exercises and rhythm (hard/easy) are fundamentally similar in both indoor and outdoor seasons, with deviations in the length of the training phases. The training program contains a mixture of aerobic, speed endurance, acceleration and maximum speed and strength exercises. The aim is to preserve sprint performance at a relatively high level throughout the year. Within weeks, there are two–three developing heavy training sessions and two–three maintenance or recovery sessions. The muscle conditioning, daily flexibility practices and injury prevention strategies are also central elements in training of this successful sprinter.

The annual training hours of 438 (8.4 hours/week) and training sessions of 222 (4.3 sessions/week) is lower than that normally observed in young sprint athletes. This may be attributable to



Early acceleration	Late acceleration	Maximum speed	Speed maintenance	
Block work; ankling and skipping (A-skips) with increasing speed turning into running	A-skips with scissor movement; heeling and B-skips with increasing speed turning into running	Skipping (B-skips); fast leg drill; rebound strides over mini hurdles with flat acceleration	Long coordinaation drill (e.g. A- and B-skips heeling, straight-legged running)	**Skill training**
Reaction exercises; individual starts from the blocks 10–20 m (with auditory signal); starts in competition with teammates	Acceleration runs over 20–40 meters; long acceleration over 50–60 meters with increasing speed	Flying 20–30 meters; towed running; downslope sprinting; wind-assisted sprinting	Ins and outs over 60–90 m: sprint—float—sprint; submaximal speed with long acceleration; maximal short speed endurance	**Speed training**
Harness work; uphill accelerations; power walk, A-skips and running in stairs	Drills with harness (e.g. heeling, B-skips) and turning into running	Straight-legged running	Long uphill runs	**Sprint-specific strength training**
Explosive acyclic jumps (e.g. standing long jump, box jumps); medicine ball throws; bounding routines for up to 5 strides	Cyclic bounding routines up to 5–10 strides (e.g. one-legged bounding and turning into running)	Reactive jumps with straigth legs; hurdle jumps; depth jumps	Maintenance of power; long bounding routines	**Power training**
Maximal strength (e.g. squats, leg presses, power cleans)	Hip flexors with band and fast rhythm in supine position; hip extension with straight leg in upright position	Fast half-squats; nordic hamstrings; hand work with weights in upright position	Circuit training (e.g. lower body circuit, core circuit, upper body circuit)	**General strength training**

FIGURE 16.6 The different sections of a sprint running event (100 m in this example) and how these sections are emphasised in selection of skill, speed, sprint-specific strength, power and general strength-training exercises. The grey line represents a typical velocity curve of an elite master sprinter.

differences in recovery potential, which reduces the optimal training frequency and consequently the training volume in masters versus younger sprinters. There is some evidence that highly trained masters sprinters are susceptible to fatigue and/or overtraining. For example, Heazlewood [82] studied training and performance characteristics of 40–60-year-old elite Australian masters male sprinters who used a traditional single-peak periodisation model. Many of the sprinters reported chronic fatigue after the competition phase and hence needed a rest period before resumption of training. The generalised fatigue and overtraining in masters sprinters could partially be related to age-related changes in circulating hormones, which could affect also the rapidity and magnitude of the training response [75].

16.5 NUTRITION FOR THE MASTERS SPRINT RUNNER

16.5.1 Energy Needs

Dietary energy and the intakes of macro- and micronutrients and fluids can have an important influence on both health and performance characteristics. The first important consideration is an energy balance that depends on energy intake and expenditure. In all athletes, total energy intake should be raised to meet the increased energy expended during training and to maintain body weight. Insufficient amount of energy intake can result in illness and/or the onset of physical and psychological symptoms of overtraining. However, the energy expenditure can vary considerably in different sports as discussed at length in Chapter 3.

As a general rule it can be said that energy expenditure is higher in submaximal endurance training than in strength, speed or skill-based athletic training and this is reflected in nutritional intake

TABLE 16.2
Structure of Training Program of World-Champion Male Sprinter Aged 65 years[a]

Type of Training	General Preparation I 15.10–31.12 11 Weeks	Competition Preparation I 1.1–31.1 4 Weeks	Indoor Competitions 1.2–28.2 4 Weeks	General Preparation II 1.3–30.4 8 Weeks	Competition Preparation II 1.5–30.6 8 Weeks	Outdoor Competitions 1.7–31.8 8 Weeks
Aerobic work	Steady state jogging and light interval runs, and cross-country skiing can be an alternative form at wintertime.					
(50%–70% of maximum heart rate)	Aerobic work is also incorporated into warming-up and cooling-down exercises and coordination drills.					
Speed endurance						
• Sprint drills (length of runs)	100–300 m	60–200 m	60–150 m	200–400 m	60–300 m	60–150 m
• Range of speeds (% max)	70%–75%	80%–85%	85%–90%	65%–70%	75%–80%	85%–95%
• Weekly volume	800 m	1000 m	800 m	1000 m	800 m	600 m
Speed						
• Start/acceleration/max speed	30–60 m	30–80 m	30–60 m	30–60 m	30–150 m	30–150 m
• Range of speeds (% max)	90%–95%	90%–98%	90%–100%	90%–95%	95%–103%	90%–100%
• Weekly volume	200–300 m	400–500 m	300–400 m	200–300m	400–500 m	200–300 m
Technique	Starting practice and general technique drills as a part of speed exercise.					
Maximum, explosive and hypertrophy weight training	5–10 exercises, 4–6 sets of 1–10 reps at 60–100% maximum load (often with pyramid method)					
Sprint-specific explosive strength	Hill sprints, vertical and horizontal forward jumps and hops, sled pulls, weight throws					
% of total amount of strength training	50%	70%	90%	50%	70%	90%
Muscle conditioning and flexibility	Aerobic circuit, stretching	Aerobic circuit, stretching	Aerobic circuit, stretching	Aerobic circuit, stretching	Aerobic circuit, stretching	Aerobic circuit, stretching

Notes: Weight training exercises

1. One- and two-leg squats (with barbell and Smith machine)
2. One- and two-leg lying leg (knee) curls
3. One- and two-leg (knee) extensions
4. Gluteus exercise
5. Pull-up (without and with extra weights up to 30 kg)
6. Standing and seated calf raise (varied foot positions/angles)
7. Bent-knee sit-ups
8. Back extensions

[a] 100-m record 12.50 seconds at age 65 years.

TABLE 16.3
Structure of Training Program of World-Champion Male Sprinter Aged 65 Years

	General Preparation I 15.10–31.12 11 Weeks	**Competition Preparation I 1.1–31.1 4 Weeks**	**Indoor Competitions 1.2–28.2 4 Weeks**	**General Preparation II 1.3–30.4 8 Weeks**	**Competition Preparation II 1.5–30.6 8 Weeks**	**Outdoor Competitions 1.7–31.8 8 Weeks**
Number of competitions	0	1–2	1–2	0	5–6	5–6
Times of exercise	55	20	18	40	36	28
Type of training						
• Aerobic work	11	2	2	10	4	4
• Speed endurance	11	4	4	6	8	8
• Speed/technique	11	6	6	6	12	10
• Weight training	11	2	2	10	4	2
• Sport-specific explosive strength	11	6	4	8	8	4
• Muscle conditioning and flexibility	Daily	Daily	Daily	Daily	Daily	Daily
Rhythm (hard/easy)	2:1	Based on training (recovery)	Based on competition schedule	2:1	Based on training (recovery)	Based on competition schedule
Performance tests	Sprint 20, 30, 60 m (flying starts). Stride length and frequency. Standing long and triple jumps	Sprint 20, 30, 60 m (flying starts). Stride length and frequency. Standing long and triple jumps	Sprint 20, 30, 60 m (flying starts). Stride length and frequency. Standing long jump	Sprint 20, 30, 60 m (flying starts). Stride length and frequency. Standing long jump	Sprint 20, 30, 60 m (flying starts). Stride length and frequency. Standing long jump	Sprint 20, 30, 60 m (flying starts). Stride length and frequency. Standing long jump
Injury prevention strategies	Sports massage and physiotherapy (1 time/3 weeks)	Sports massage and physiotherapy (1 time/2 weeks)	Sports massage and physiotherapy (if needed)	Sports massage and physiotherapy (1 time/3 weeks)	Sports massage and physiotherapy (1 time/10 days)	Sports massage and physiotherapy (if needed)

TABLE 16.4
Summary of Yearly Training Volume of World-Champion Male Sprinter Aged 65 Years

Type of Training	Training Sessions	Training Hours	Percentage of Total
Aerobic work	33	41	9
Speed endurance	41	62	14
Speed/technique+	51	114	26
Competitions/starts	25		
Maximum, explosive and hypertrophy weight training	31	47	11
Sport-specific explosive strength	41	62	14
Muscle conditioning and flexibility	(225)	112	26
Total	222	438	100

of athletes [83,84]. One study assessed the dietary intake by 3-d food records of 62 elite young adult Japanese track and field athletes [83]. It was found that the mean daily energy intake was 2653 kcal (40.0 kcal/kg) for male sprinters and 3628 kcal (59.9 kcal/kg) for male long-distance runners. These findings are in line with those obtained in young adult Finnish track and field athletes [85]. After examining 5-d food records in this study, Mero and co-workers found that male sprinters and hurdlers ($n = 15$) consumed an average 2848 kcal/day (38.4 kcal/kg) while male endurance runners ($n = 5$) averaged 3578 kcal (53.6 kcal/kg). Mero has recommended a daily energy intake of about 2000–3000 kcal (25–45 kcal/kg) for young adult sprint and power athletes, 2500–4000 kcal (35–55 kcal/kg) for ball sports athletes and 3000–6000 kcal (45–70 kcal/kg) for endurance athletes during training season depending on the energy expenditure of an individual [86].

The research of dietary patterns of ageing athletes has focused on endurance-trained athletes [87–89] while the information for masters sprint runners or strength athletes [90] is very limited. As a part of our larger veteran athlete project, Malmberg [91] evaluated dietary intake of 54 male sprinters, 40–85 years of age, during their winter training season (Table 16.5 [92]). The absolute daily energy intake declined ~15% ($p < 0.05$) from 2430 kcal/day in the youngest to 2070 kcal/day in the oldest athlete group. However, when energy intake was expressed as kcal/kg/day, the groups were similar. Although the values for masters sprint runners were about 10% higher than in age-matched general population [93], they were well below those reported for masters endurance runners [87–89] and young adult sprinters [83,84]. Compared to young sprint athletes, the masters sprinters may need lower absolute amount of energy for body weight maintenance due to decreasing lean body mass which is the main determinant of energy expenditure [94]. Moreover, the lower training volumes observed in older athletes in general is likely to decrease the need for energy in masters athletes. However, it should be emphasised that food diaries are characterised by underreporting [95] and that the true energy requirements of masters sprinters may perhaps be somewhat higher than our results indicate. However, this should be verified with more accurate assessments of energy intake and expenditure in future studies.

16.5.2 MACRONUTRIENTS

Carbohydrates are the major energy source of muscle during physical activity and are critical for proper function of the brain and nervous system. In typical sprint training, the reliance on carbohydrate utilisation (blood glucose, muscle and liver glycogen) is high. However, since the overall effective training volume is relatively low, the availability of carbohydrates is not as critical as that in longer-duration aerobic exercise as discussed in Chapter 14. The guidelines for young athletes suggest that in sprint runners, carbohydrates should provide approximately 50%–60% of the daily energy intake to meet the needs of activity and recovery from training. When adjusted to body mass the carbohydrate intake of 3–7 g/kg/day is suggested to be sufficient when training 1–2 hours daily

TABLE 16.5
Anthropometric Characteristics and Average Daily Dietary Intake of Male Masters Sprinters and Basic Recommendations for Male Sprint and Strength Athletes

		Age				
		40–49 ($n = 10$)	**50–59 ($n = 13$)**	**60–69 ($n = 19$)**	**70–84 ($n = 12$)**	**Recommendations**
Height	cm	183 ± 8	174 ± 4	172 ± 4	171 ± 5	
Body mass	kg	84 ± 8	74 ± 6	72 ± 6	70 ± 10	
Body fat	%	21 ± 3	20 ± 3	21 ± 4	23 ± 5	
LBM	kg	67 ± 6	58 ± 4	57 ± 4	54 ± 5	
Energy	kcal	2430 ± 390	2230 ± 410	2370 ± 290	2070 ± 210	2000–3000
	Kcal/kg	29.8 ± 4.2	31.2 ± 6.0	32.6 ± 5.2	29.6 ± 4.1	25–45
Protein	E%	15.9 ± 2.9	17.6 ± 1.6	17.1 ± 2.5	16.1 ± 2.0	15–20
	g/kg	1.14 ± 0.18	1.34 ± 0.29	1.43 ± 0.30	1.20 ± 0.22	1.2–1.8
Carbohydrates	E%	50.0 ± 3.2	50.4 ± 6.2	51.7 ± 8.4	51.0 ± 5.4	40–60
	g/kg	3.61 ± 0.65	3.88 ± 1.09	4.31 ± 0.93	3.83 ± 0.72	5–6
Total fat	E%	30.9 ± 4.7	29.3 ± 4.8	28.6 ± 5.3	31.6 ± 5.8	25–35
	g/kg	0.99 ± 0.20	0.99 ± 0.25	1.06 ± 0.27	1.04 ± 0.18	
Saturated fat	E%	12.0 ± 2.9	11.2 ± 2.7	11.0 ± 2.9	12.2 ± 3.0	<10
Monounsaturated fat	E%	10.5 ± 1.6	10.1 ± 2.3	9.4 ± 2.2	10.6 ± 2.2	10–15
Polyunsaturated fat	E%	4.7 ± 0.6	4.6 ± 1.1	4.9 ± 1.6	4.9 ± 1.2	5–10
Alcohol	E%	1.8 ± 1.2	2.3 ± 2.1	2.9 ± 4.0	1.0 ± 0.7	
	g	10.8 ± 7.0	13.0 ± 14.0	18.4 ± 25.0	5.1 ± 3.7	
Cholesterol	mg	304 ± 106	284 ± 111	318 ± 118	252 ± 76	<300
Dietary fibre	g	29 ± 11	32 ± 10	34 ± 10	25 ± 7	25–35
Water	L	2.5 ± 0.7	2.4 ± 0.6	2.2 ± 0.4	2.2 ± 0.6	>2

Sources: Modified from Malmberg, K., *Dietary Patterns of Masters Sprinters Aged 40 to 85 Years*, unpublished thesis (in Finnish), University of Jyväskylä, Finland, 2003; Mero, A., Nutrition coaching, in *Sport Coaching* (in Finnish), A. Mero, A. Nummela, K. Keskinen and K. Häkkinen, eds., VK Kustannus Oy, Lahti, Finland, 2004, pp. 179–209; Borg, P., Fogelholm, M. and Hiilloskorpi, H., *Nutrition for Exerciser* (in Finnish), Edita Publishing, Helsinki, Finland, 2004.

Notes: Values are means ± SD. Statistical significance of the trend in the data was examined using analysis of variance. Group effect was significant for body height, body mass, and LBM (all $p < 0.001$) and absolute energy intake ($p < 0.05$). LBM, lean body mass; n, number of subjects.

[96]. In our research [91], masters sprinters consumed an average 4.0 ± 0.9 g/kg/day (51% ± 6%) carbohydrate that could adequately meet the need given that they were undertaking run-based training of about 1 hour per day (Table 16.5) [12].

The timing of carbohydrate intakes is important to consider since the glycogen-depleted state might have negative effects on both muscle strength and short-term high-intensity exercise [97]. A carbohydrate-containing meal approximately 3–4 hours before exercise should elevate muscle and liver glycogen levels to enable maximum intensity training. Consuming small amounts of carbohydrate (sports drinks) during exercise could help to maintain blood glucose concentration but may be needed only in the intensive training sessions lasting more than 1 hour. If rapid recovery is needed from training or events during a competition, carbohydrate feeding should start immediately after exercise since the speed of muscle glycogen synthesis is maximal during the first 2 hours of recovery [98]. Carbohydrates with moderate to high glycaemic index (i.e. sports drinks, white bread, potatoes) induce fast muscle glycogen synthesis and could hasten carbohydrate replenishment and thus recovery for the next event or training bout [99]. However, in masters sprinters there is typically one training session per day and immediate recovery is not critical. Therefore, for these athletes, post-exercise and other dietary carbohydrate should come primarily from healthy low-glycaemic carbohydrate foods (i.e. fruits, vegetables, whole grain bread, brown rice) that provide also important micronutrients and dietary fibre for health. The carbohydrate needs of masters athletes are discussed in detail in Chapter 4.

The recommended dietary allowance for protein intake is 0.8 g/kg/day. However, based on the findings of maintenance of muscle mass (instead of nitrogen balance), a higher protein intake of about 1.1 g/kg/day may be needed to prevent sarcopenia [100]. Protein recommendations for masters athletes are higher than for non-athletes but could vary somewhat depending on the nature of the sport. Older endurance athletes are advised to consume 1.2–1.4 g/kg/day while in strength-trained athletes the need for protein intake may be as high as 1.5–1.7 g/kg/day [101]. In strength-trained athletes the increased protein (amino acid) intake can be a prerequisite for tissue repair and hypertrophy whereas in endurance athletes long duration of exercise may also increase the use of amino acids for energy production. The development of muscle mass is also a significant training focus in older sprint athletes and during periods of hard training it may be important to increase and target protein intake at 1.5–1.7 g/kg/day for maximum benefit (Table 16.5). Consuming protein at these levels may not increase the risk for metabolic, cardiac, renal, bone or liver diseases in healthy individuals [102].

The quality of protein in food, as determined by its essential amino acid content, is thought to be an important factor for training-induced anabolic response of muscle [103,104]. Consuming protein from animal sources may optimise the growth or maintenance of muscle mass, a view also supported by a large prospective cohort study in older community-dwelling adults [100]. Lean pork and beef, poultry, fish, eggs and dairy products are good examples of high-quality protein sources containing all essential amino acids and in amounts adequate to sustain protein synthesis. Of the different amino acids, the branched-chain amino acid leucine is thought to be particularly important for muscle protein synthesis [103,104]. Recent studies suggest that whey protein (component of milk) that has a high rate of absorption and is rich in branched-chain amino acids (including leucine) may provide a good protective effect against age-related muscle atrophy [105–107]. Therefore, it has been suggested that older athletes could benefit from consuming dietary supplements with whey protein. Casein (major component of milk) has also been widely promoted to strength trainers especially due to its slow absorption qualities being optimal between meals or before bed [103].

The influence of timing of protein intake to stimulate resistance exercise-induced muscle anabolism has been studied extensively in recent years. Although not all studies agree [108,109], a number of investigations suggest that the anabolic effect of protein intake (with or without carbohydrate stimulates) is increased when taken before or immediately after exercise than at other times of the day [103,110,111]. During and within the first 2 hours following exercise, the physiological state of the body appears to be more suitable for rapid protein resynthesis than in a delayed condition (3 hours), possibly because of increases in muscle blood flow, insulin sensitivity and delivery of amino acids to muscle [112].

Of potential importance for older athletes are studies demonstrating that with ageing muscle may become less sensitive to lower doses of amino acids and thus may require a higher quantity of protein to obtain a similar anabolic response to that of young muscle. It has been found that, while in the young, exercise-induced rate of muscle protein synthesis plateaus with ingestion of 20 g of high-quality protein, elderly may require 40 g of protein to achieve maximal stimulation of protein synthesis after exercise [113]. Thus it has been suggested that to optimise muscle anabolism, older exercisers should eat a sufficient amount of high-quality, leucine-rich protein preferably with three or more daily meals [114]. The protein needs of masters athletes are discussed in detail in Chapter 6.

A commonly overlooked issue is that the recovery and trainability of athletes may be influenced by fatty acids. A low-fat diet has found to be associated with reduced testosterone in men [115,116] and a reduction in oestrogen levels in women [117]. Testosterone is known to be a strong mediator of acute and long-term responses and adaptations to physical training and it is possible that too little fat intake may have indirect negative influence on trainability. Evidence from our masters sprinters study [118] and research on untrained elderly individuals [119,120] suggests that of the different fat subtypes, it is saturated fat that may increase biologically active testosterone concentrations, probably by affecting serum sex hormone-binding globulin (SHBG) concentrations. In the masters sprint runners in our study, the relative fat intake was an average 30% with saturated fat contributing 11.5% (Table 16.5). Based on a national survey [121], the diet of the general population (35–74 years) in Finland is quite similar in the total fat intake (32.4%) and saturated fat intake (12.5%) to that of the masters sprinters in our study.

According to some dietary guidelines, this level of fat intake could be of nutritional concern. However, a number of large research studies have failed to substantiate the view that consuming fat at this level is detrimental to health. For example, a recent population-based, prospective cohort study showed that receiving more than 30% of daily energy from fat and more than 10% from saturated fat did not increase all-cause mortality [122]. Indeed, men in the highest quartile of total fat intake, receiving 48% of their total energy intake from fat, had the lowest cardiovascular mortality. Nevertheless, the use of mono- and polyunsaturated fats should be recommended due to their numerous beneficial health effects such as lowered cholesterol and triglyceride levels in blood. For a more detailed discussion on the fat needs of masters athletes and the importance of nutrients for health and chronic disease prevention, see Chapters 5 and 12, respectively.

Interestingly, recent research [123] suggests omega-3 polyunsaturated fats (found in fish oil and some plants such as flaxseed) can increase the rate of muscle protein synthesis in older men and might therefore promote muscle adaptations. Hence, to ensure an optimal anabolic environment, a moderate-fat diet with sufficient protein and energy is advisable for older sprint athletes. Overall, it appears that in most master sprinters we studied, normal dietary habits provided an adequate intake of proteins, fats and carbohydrates as also reflected by normal glucose and lipid profiles, except for relatively high cholesterol levels (Table 16.6 [124]). Moreover, in the masters athletes, total testosterone concentrations were within normal physiological range (ref.values for 51–70 years: 8–29

TABLE 16.6
Blood Biochemical Values of Male Masters Sprinters and Recommended Levels for Men

		Age				
		40–49 (*n* = 10)	**50–59 (*n* = 13)**	**60–69 (*n* = 19)**	**70–84 (*n* = 10)**	**Recommendations**
Serum total cholesterol	(mmol/L)	5.5 ± 0.8	5.6 ± 1.1	5.5 ± 1.2	5.6 ± 0.9	<5.0[a]
Serum HDL cholesterol	(mmol/L)	1.1 ± 0.3	1.3 ± 0.3	1.3 ± 0.3	1.1 ± 0.3	>1.1[a]
Fasting blood glucose	(mmol/L)	4.8 ± 0.7	4.6 ± 0.5	4.7 ± 0.4	4.7 ± 0.5	<5.5[b]
Hemoglobin	(g/L)	148 ± 5	146 ± 4	144 ± 5	148 ± 5	132–164[a]
Hematocrit	(%)	46 ± 2	45 ± 1	45 ± 1	46 ± 2	0.38–0.49[a]
Total testosterone	nmol/L	16.2 ± 7.3	14.2 ± 1.9	16.4 ± 4.3	17.1 ± 7.3	
SHBG	nmol/L	37.5 ± 12.5	35.3 ± 10.7	41.7 ± 12.3	64.4 ± 18.5	
FAI	nmol/nmol	0.43 ± 0.12	0.42 ± 0.10	0.42 ± 0.16	0.28 ± 0.12	

Sources: Modified from Malmberg, K., *Dietary Patterns of Masters Sprinters Aged 40 to 85 Years*, Unpublished thesis (in Finnish), University of Jyväskylä, Finland, 2003; Korhonen, M.T., *Effects of Aging and Training on Sprint Performance, Muscle Structure and Contractile Function in Athletes*, Ph.D. thesis, Studies in Sport, Physical Education and Health, No. 137, University of Jyväskylä, Finland, 2009.

Notes: Values are means ± SD; group effect was significant for SHBG ($p < 0.001$) and FAI ($p < 0.05$). FAI, free androgen index (total testosterone/SHBG); *n*, Number of subjects; SHBG, sex hormone-binding globulin.

[a] Borg, P., Fogelholm, M. and Hiilloskorpi, H., *Nutrition for Exerciser*, (in Finnish), Edita publishing, Helsinki, Finland, 2004.

[b] Ceriello, A. and Colagiuri, S., International Diabetes Federation guideline for management of postmeal glucose: A review of recommendations, *Diabet. Med. 25*(10), 1151–6, 2008.

nmol/L; for 70+ years: 6–25 nmol/L) and the estimated prevalence of hypogonadism was only 2%, defined as having a free androgen index (total testosterone/SHBG) below 0.153 [125].

16.5.3 MICRONUTRIENTS

In the above section we concluded that an adequate fat intake is important to realise an optimal anabolic environment. In addition to this, fats are crucial for the uptake of the fat soluble vitamins A, D, E and K. Even though the intake of macronutrients and the caloric intake appear adequate in masters athletes, a large proportion, including sprint runners, has a lower than the daily recommended intake of one or more micronutrients, among them some of the fat-soluble vitamins [83,126]. One of the most commonly observed nutritional deficiencies in older people is a vitamin D deficiency [126]. Only 20%–50% of masters sprinters exceeded 100% of the RDI of D vitamin, and 15%–50% had less than two-thirds of RDI (Table 16.7 [127]), a level associated with likelihood of inadequate intake of micronutrients [128]. Studies have suggested that inadequate vitamin D intake with age may not only increase the risk of various diseases and bone loss but could also contribute to the deterioration of muscle characteristics including loss and atrophy of fast type II fibres [129,130].

TABLE 16.7
Percent of Male Masters Sprinters Meeting ≥100% and (≥67%) of the RDAs for Vitamins and Minerals for Healthy Male Population

	Age			
	40–49 (*n* = 10)	**50–59 (*n* = 13)**	**60–69 (*n* = 19)**	**70–84 (*n* = 12)**
Vitamin A	50 (90)	54 (92)	53 (79)	75 (92)
Vitamin D	20 (50)	31 (85)	32 (63)	50 (67)
Vitamin E	30 (90)	46 (100)	58 (95)	58 (75)
Thiamin (B_1)	70 (90)	69 (100)	95 (100)	58 (100)
Riboflavin (B_2)	80 (90)	85 (100)	100	100
Niacin	100	100	100	100
Folate	70 (90)	77 (100)	68 (95)	50 (100)
Cobalamin (B_{12})	100	100	100	100
Vitamin C	60 (90)	92 (100)	68 (84)	92 (100)
Calcium	90 (100)	92 (92)	89 (95)	92 (100)
Potassium	80 (90)	100	89 (95)	75 (100)
Magnesium	80 (90)	85 (100)	89 (95)	92 (100)
Iron	90 (100)	100	100	83 (100)
Zinc	90 (100)	100	100	100
Selenium	100	100	100	100

Sources: Modified from Malmberg, K., *Dietary Patterns of Masters Sprinters Aged 40 to 85 Years*, Unpublished thesis (in Finnish), University of Jyväskylä, Finland, 2003; RDAs from Hasunen, K., Heiskanen, S., Packalén, L. et al., *Finnish Nutrition Recommendations* (in Finnish), National Nutrition Council, Ministry of Agriculture and Forestry, Edita, Helsinki, Finland, 2005.

Notes: Recommended Dietary Allowances (RDAs): Vitamin A = 900 RE; vitamin D = 7.5 μg for ages 31–60 years, 10.0 μg for ages ≥61 years; vitamin E = 10 mg α-toko; thiamin =1.4 mg for ages 31–60 years, 1.3 mg for ages 61–74 years, 1.2 mg for ages ≥75 years; riboflavin = 1.7 mg for ages 31–60 years, 1.5 mg for ages 61–74 years, 1.3 mg for ages ≥75 years; niacin = 19 mg for ages 31–60 years, 17 mg for ages 61–74 years, 15 mg for ages ≥75 years; folate = 300 μg; vitamin B12 = 2 μg; vitamin C = 75 mg; calcium = 800 mg; potassium = 3500 mg; magnesium = 350 mg; iron = 9 mg; zinc = 9 mg.

The use of vitamin and mineral supplements is common among masters athletes [131]. In a recent review, Brisswalter and Louis [132] addressed the role of vitamin supplementation on recovery, inflammation and muscle performance in athletes. There remains a lot of uncertainty regarding potential benefits of these supplements. One concern is that high-dose vitamin supplementation may prevent training-induced adaptations, perhaps by interfering reactive oxygen species (ROS)-mediated physiological processes, such as insulin signalling. Therefore, the authors argue that use of supplementations is questionable and the antioxidant micronutrients intake should follow the daily recommendations. While Chapters 7 and 8 examine the vitamin and mineral needs respectively of masters athletes, clearly further research of specific needs of highly trained masters athletes is needed.

Although not a micronutrient, maintaining an adequate hydration status is important for optimal performance during both training and competition. On the basis of studies in young adult athletes, there is greater negative effect of body water deficit (dehydration) for aerobic exercise performance than muscular strength and anaerobic (sprint) performance [133]. It has been reported that while dehydration of as little as 2% body mass due to sweat loss may be enough to cause a measurable reduction in aerobic performance, dehydration of up to 3%–5% may not impair anaerobic or strength performance [133]. To our knowledge, no investigators have documented the effect of dehydration on performance in older athletes. However, maintenance of optimal hydration status may become challenging in older athletes (see Chapter 9) since ageing could bring physiological changes such as reduced thirst sensation, less ability to concentrate urine (increase urine formation) and reduced potential to dissipate heat [134].

In addition, due to the well-observed age-related loss of muscle mass, decreases in total body water increase the susceptibility to exercise-induced dehydration and subsequent harmful influences on thermoregulation and performance [135]. Apart from acute effects on performance, long-term dehydration can cause several symptoms and health problems such as increased blood pressure, tiredness and diarrhoea. Because of these risks, older athletes should be careful to obtain enough water during the day. Fluid intake of athletes is dependent on various individual, training and environmental factors and no firm recommendation can be provided. It has been estimated that one should consume over 1–1.5 L of water a day (in addition to other fluids) and 0.4–0.8 L/hour during exercise, but thermally stressful environments and exercise intensity can increase this need. The fluid, electrolytes and hydration needs of masters athletes are discussed in detail in Chapter 9.

16.5.4 Nutrition for Sprint Racing

Unlike long-distance running, sprint running performance from 60–400 m is not limited by muscle glycogen stores [60] so there is no need for carbohydrate loading before competition. In addition, pre-race intakes of proteins or fats are unlikely to result in an acute improvement in performance. Therefore, sprinter's performance is more related to long-term dietary practices than the acute influence of nutritional intake. The major goal of the precompetition food consumption of all athletes is to stay hydrated (but avoid overdrinking), maintain adequate blood glucose levels and prevent gastrointestinal distress [136].

Caffeine could have some beneficial effect on sprint performance [136,137]. However, capsules or tablets are considered a better form of taking caffeine than strong coffee since the latter is more likely to cause gastrointestinal distress [136]. In order to avoid abdominal discomfort during the stress of competition, a common strategy is to eat 3–4 hours before events and ingest a small amount of sport drink and/or water 1–2 hours before event. Clearly, the optimal timing as well as amount and types of food and fluids for race day nutrition can vary greatly from athletes to athletes and no detailed recommendations can be provided. Fine-tuning of precompetition nutrition should be based on personal preference and food tolerance.

As discussed in Section 16.3.5, a significant proportion of the ATP supply during a sprint is derived from immediate PCr breakdown. We might therefore expect that oral creatine supplementation may enhance anaerobic performance by increasing intracellular creatine and PCr in muscle. The results of studies in young sprinters appear conflicting with some studies showing significant positive effect [138,139] and others no effect [140–142] on sprint performance following creatine supplementation. The potential benefit of creatine supplementation could be the most evident in repetitive sprint performance with not enough time for full recovery of phosphagen pool between sprints [143–145].

The use of creatine supplements is also widespread among masters athletes [131]. However, there appears to be only one study that has examined the effect of creatine loading on sprint performance in masters athletes. Wiroth et al. [146] supplemented elderly male masters cyclists (66 years, $n = 14$) with creatine for five days (3 × 5 g/day) which resulted in no improvements in anaerobic cycling test (five all-out 10-s sprints separated by 60-s passive recovery). However, improvements in performance were observed in young (26 years, $n = 14$) and elderly (70 years, $n = 14$) sedentary controls suggesting that habitual physical activity level may influence the response to creatine supplementation.

Several, but not all, studies indicate muscular benefit from creatine supplementation during strength training in young athletes [147,148] and this could have an indirect influence on sprint performance. The creatine supplementation has found to increase total training load and amplify training-induced muscle fibre growth possibly by increasing myofibrillar protein synthesis [149] and the number of satellite cells and myonuclei [150]. However, again, data on masters athletes are not available and the evidence from well-controlled studies on untrained older people is inconclusive to support the beneficial effects of creatine supplementation during strength training on muscle characteristics [151–155].

Some data suggest that the response to creatine supplementation is high in individuals with faster fibre type profile and greater muscle mass [156] and thus ageing-related decreases in type II muscle fibre number and size could reduce the effectiveness of creatine supplementation. On the other hand, older masters sprinters have demonstrated considerably larger size of fast fibres than untrained people [28] and may theoretically possess favourable physiological profile to respond the supplementation. To clarify this issue, new research with assessment of intramuscular creatine stores among masters sprinters is warranted. Finally, it is noteworthy that in some persons creatine supplementation may lead to weight gain (~1%–3%) due to water retention [144,157] that may have small negative effect on mass-dependent sprint running performance. Another important consideration is that although there typically are no adverse effects on health, a number of studies have linked creatine supplementation to muscle cramping, dehydration, diarrhoea and dizziness [158].

During sprint running, acidification of both the blood and muscles (decrease in pH) take place that can compromise contractile function leading to muscular fatigue. Extra- and intracellular buffering agents such as sodium bicarbonate and carnosine may enhance sprint performance by attenuating this acidification [136,159]. The consumption of sodium bicarbonate is known to increase pH and bicarbonate concentrations in the blood that increases the rate of H+ and lactate ions efflux from active muscles [159]. Theoretically this would keep the muscle pH within normal levels to maintain contractile capacity and delay the onset of fatigue during long-term anaerobic performance such as 400-m sprint runs. In support of this assumption, several, but not all, studies have found positive effect of bicarbonate loading (200–300 mg/kg, 1–2 hours before exercise) on longer sprint and middle-distance performances lasting 1–7 minutes (i.e. 400 m–3 km) [159]. However, the predominance of research indicates that bicarbonate loading has no beneficial effects for shorter efforts (30–40 seconds or less) [159].

While sodium bicarbonate helps maintain pH outside the cell, carnosine can act as an intracellular buffer slowing the drop in pH. Inside the muscle cells, carnosine is synthesised from beta-alanine and histidine with the help of enzyme carnosine synthethase. However, of these two amino acids it is beta-alanine that drives carnosine synthesis. Supplementation with beta-alanine for 4 and 10 weeks has been shown to elevate carnosine levels by about 60% and 80%, respectively, in physically active young men [160]. As to performance benefits, a recent meta-analysis of studies showed that beta-alanine supplementation (mean daily dose 5.12 g/day) may produce improvement in maximal performance lasting 60–240 seconds and over 240 seconds [161]. However, no significant benefit of beta-alanine was found for exercise lasting less than 60 seconds. There could be some mild acute side effects with both sodium bicarbonate (gastrointestinal discomfort) and beta-alanine (skin irritation and prickly sensation) ingestion and no information exists about the effects of long-term use of beta-alanine on health. We are not aware of any studies examining the influence of sodium bicarbonate or beta-alanine/carnosine in masters athletes and it is questionable whether the same effects exist in this cohort. The use and efficacy of both supplements and ergogenic aids in masters athletes are discussed in detail in Chapters 10 and 11.

16.6 CONCLUSIONS

Sprint running ability is determined by multiple biomechanical and neuromuscular factors. In this chapter we have presented some of the major biomechanical and physiological changes that may be associated with decline in sprint performance with age in male runners. In addition, we have provided information about fundamental principles of training applied to ageing sprinters. In order to maximise sprinting potential, athletes of all ages should adhere to training practices in which demands of the sport and athlete's individual strength and weaknesses are carefully considered.

Because age-related loss of muscle mass seems to be primarily responsible for the changes in sprint running ability, care must be taken to design exercises which promote muscle growth with special emphasis to increase the size of fast-contracting type II fibres. Therefore, heterogeneous training program containing components of high-intensity strength training together with run-based training is essential for optimal maintenance of sprinting ability in masters athletes. Furthermore, older age can lead to impaired recovery and may require modifications in short- and long-term periodisation of training (variation of volume, intensity and exercise selection) to optimise adaptation and peak performance before important competitions.

Nutritional factors are also important for effective training. Masters sprinters may not be concerned about adequate energy intake from carbohydrates due to relatively low energy requirements of sprint training. However, combined sprint and strength training may increase protein needs and older sprinters should pay attention to quality protein consumption to aid in muscle recovery.

16.7 IMPLICATIONS FOR MASTERS ATHLETES AND COACHES

- Although success in sprinting is largely affected by inherited physiological characteristics such as muscle fibre type composition, the determinants of sprint performance can be improved significantly by proper training in athletes of all ages.
- Age-related slowing of maximum running speed is associated with reduction in stride length and an increase in contact time, while stride frequency shows a minor decline and swing time remains unaffected. The changes in stride length and contact times are directly related to decreased ability to produce high-magnitude ground reaction forces.
- Sprint running is a complex neuromuscular skill that must be constantly rehearsed. Only with frequent practices and many repetitions can correct movement pattern remain effective and stable. Accordingly, the best way to maintain sprinting ability is to sprint. In short-sprint events (60–100 m) all speed phases are critical for overall performance and need to be focused on in training. Optimal sprint technique can be impaired by insufficient flexibility. Inclusion of flexibility exercises in the training schedule is necessary.
- Strength is a critical element of sprint running and the importance of weight training for masters runners cannot be overstated. Improved strength levels will enable the ability to generate a higher magnitude of ground reaction force more quickly, resulting in increased stride length and frequency. Weight training is the only exercise mode for effective maintenance of muscle mass and fast fibre size that plays a critical role in sprint running performance with age. Consider doing strength training at least two times per week throughout the year including both maximal and explosive strength and plyometric (jump) exercises.

- Advancing age is known to be associated with a slower rate of recovery from exercise. To optimise recovery-adaptation there is need for modifications in intensity and volume of training within weeks and months.
- All athletes must consume an adequate amount of calories to meet the increased energy demands of exercise. Insufficient energy intake reduces the benefits of training and can lead to weight loss and a higher risk of illness and overtraining. The diet for sprint athletes should provide approximately 10%–20% (1.2–1.7 g/kg) of daily energy intake from protein, about 50%–60% from carbohydrates (3–7 g/kg) and the remaining 30% should be provided by fat.
- Protein is essential for repair and building of new muscle tissue in response to training and during periods of hard training it may be important to target protein intake at 1.5–1.7 g/kg/day for maximum benefit. Consuming high-protein before, during and immediately after training rather than other times of day may enhance protein metabolism and muscle growth.
- There is published and anecdotal evidence that some masters sprinters use sports supplements such as creatine, beta-alanine and sodium bicarbonate to enhance sprinting performance. However, based on the few available studies in older and younger athletes, the ergogenic effect of sports supplements for older sprint runners can be questioned. In addition, since the supplementation may induce some adverse health effects, the use any nutritional aids should be done under the guidance of a qualified nutrition or health professional. Verify that any types of supplements or pharmaceuticals you are planning to take are not on a banned list.

16.8 IMPLICATIONS FOR SPORTS MEDICINE PROFESSIONALS AND CLINICIANS

- Whereas athletes and coaches are largely interested in improving the performance, sports medicine professionals and clinicians are primarily concerned about the health and secondarily in maintaining the performance of the masters athlete. In many cases the recommendations that improve performance are equally beneficial for the health of the athlete and the advice above for athletes and coaches thus also applies to the sports medicine practitioner.
- Masters athletes are more prone to various types of injuries than young athletes. It is therefore particularly important to monitor any impact of demanding resistance and run/jump training on the integrity of the trained muscles, tendons, cartilage and bones and impact on blood pressure that rises considerably during particular weight lifting exercises. For masters athletes having structural problems (e.g. knee and lower back), certain typical sprint-training exercises such as intensive jumping, bounding and deep squat exercises should be avoided.
- Consider that recovery from training bouts is slower and longer in the older athlete and pay special attention to recovery from injuries or tissue damage incurred during training; if no special heed is given to this advice the older athlete may suffer from lasting fatigue and overtraining consequences.
- Although many masters sprint athletes appear to have quite healthy food behaviours, they need more information about the most appropriate energy and nutrient intake to sustain the specific demands of training. Annual monitoring of dietary intake is useful to ensure that diet contains an adequate amount of energy and nutrients. In addition, regular assessment of blood profiles may be advisable to detect as early as possible any mineral and vitamin deficiencies.
- The use of legal nutritional supplements should be closely supervised with a particular emphasis on the specific complications that may arise from the use of particular nutritional aids. It must be recognised that some medications and even pharmaceuticals sold without

prescription (e.g. prohormones) are classified as performance-enhancing drugs and their use is banned by anti-doping committees around the world. See Chapters 10 and 13 for a more detailed discussion these areas.

16.9 FUTURE RESEARCH DIRECTIONS

- Most previous studies on the effect of age on sprint performance are based on cross-sectional design that is limited in its ability in determining causality between performance/physiological changes and ageing. To define the true effect of ageing on sprint performance and its determinants, there is need for more longitudinal studies where athletes are followed for several years.
- Perhaps the most fundamental impact of ageing on physical performance is the progressive loss of muscle fibres, especially fast type II fibres. Although this change is commonly thought to be inevitable, recent studies have suggested that the muscle fibre loss can be prevented or slowed by regular endurance exercise. This issue clearly warrants further exploration in masters athletes from various sports.
- Studies should be conducted to evaluate muscle-tendon behaviour and elastic energy utilisation in ageing athletes. Due to exercise-type and intensity specificity, the muscle-tendon interaction should be measured *in vivo* during the contact phase of fast running. In addition, because older sprinters show variability in foot strike pattern (forefoot, midfoot, rearfoot), we need also to know how the landing strategy affect the spring-like bouncing mechanism.
- To date, the studies on the effect of ageing on anaerobic metabolic characteristics such as muscle enzyme activities and ATP, PCr and lactate concentrations have focused on non-athletes. However, well-trained masters sprinters may have very different metabolic capabilities than normal age-matched individuals. More research on muscle metabolism and its role in age-related differences in sprint performance in masters sprint athletes is needed.
- Decreased ability to tolerate heavy training may be a key factor for age-related performance losses. However, the physiological bases of diminishing trainability with age is still unclear. More studies on the possible effects of anabolic hormonal and nutrition factors on trainability in masters athletes should be undertaken.
- Although the values for various performance and musculoskeletal properties in masters sprint athletes are maintained far above the age norms, the available evidence for potential training-related risks are still very limited. New information about the benefits and risks of demanding strength-, run- and jump-based exercises is needed not only to counsel the masters athletes themselves but also to develop modified training programs for non-athletes in whom the improvement of rapid force and musculoskeletal characteristics with age has good potential to enhance functional well-being.
- With very few exceptions, most of the studies on the effects of ageing on sprint performance have used male participants. More research is needed to learn how the physiological factors related to sprint performance are affected by gender.

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