ARTICLE

Potential Benefits of Warm-up for Neuromuscular Performance of Older Athletes

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VANDERVOORT, A.A. Potential benefits of warm-up for neuromuscular performance of older athletes. *Exerc. Sport Sci. Rev.*, Vol. 37, No. 2, pp. 00–00, 2009. *Demographic trends project increasing numbers of older people to engage in exercise programs and sports. Sustained participation depends on both perceived health outcomes and avoidance of debilitating injuries. This review explores the potential benefits of physiologically based warm-up strategies to alleviate some key age-related decreases in the biomechanical capacity for skilled sport movements.* **Key Words:** physical activity, aging, senior golfer, motor performance, swing biomechanics, musculoskeletal injury

INTRODUCTION

Promotion of a physically active lifestyle for the older adult segment of our population has become a major focus for both governments and the research community (23,25). Such activities can take many forms, ranging from household chores to highly competitive sports for seniors. Ironically, the obvious need for physical interventions has a negative counterinfluence arising from the fact that the aging process itself results in declining capacity for skilled motor function. These declines stem from reductions in strength, flexibility, balance ability, neural coordination of sequenced muscle activations, and overall cardiorespiratory endurance (1,2,27,29). However, the hypothesis of this review is that a properly conducted warm-up session for older adults undertaken for a few minutes before sport participation can serve as a simple but highly beneficial mechanism to offset some of the negative aging effects, thereby enhancing performance of the senior athlete (1,7,30).

A warm-up strategy of some kind is usually incorporated into preparation for any sport and athletic competitions, and thus in most situations, it would be viewed as deficient to just start playing at an intense level without any pre-game routine. Guidelines for exercise such as those published by the American College of Sports Medicine (1) advocate that such approaches to the warm-up session should start with 5 to 10 min of whole-body aerobic activity at a light intensity level (*e.g.*, walking, jogging, cycling, etc) that prepares the skeletal muscles, heart, and lungs for the more intense activity to come (Fig. 1). The particularly important benefit to muscle tissue of such warm-up, with regard to the theme of this review, is that the initial exercise period raises internal temperature, thereby increasing its contractile speed and also affecting the power-velocity relationship (4,6). F1

Next, a stretching routine is also recommended as part of a typical warm-up strategy and helps to release some of the connective tissue bonds that exist in resting musculotendinous units (22). These cross-linkages can be a limiting factor for the desirable range of motion for a given joint (however, it is noted that the actual benefits of extensive passive stretching on performance and rate of injury are somewhat controversial, as per Fields *et al.* (8)). Finally, it is common practice to rehearse the specific patterns of coordinated movement involved in the sport, for example, shooting at the net, sprinting out of the starting blocks, swinging a baseball bat or golf club. This is also an opportunity for athletes to use visualization techniques from sport psychology to focus mental concentration on a positive motor outcome (26).

EFFECTS OF AGING ON THE MUSCULOSKELETAL SYSTEM

Muscle Strength

Most tissues and systems of the body experience an age-related loss of physiological capacity, and muscle strength is

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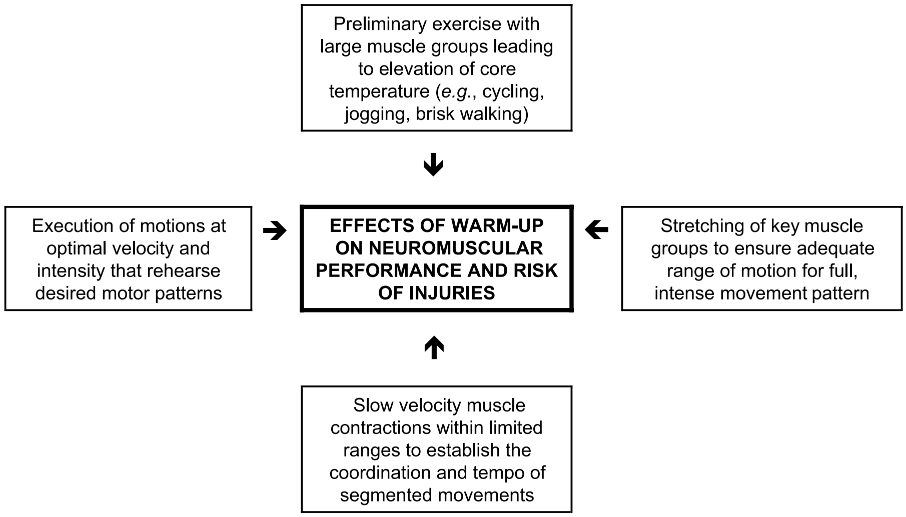

Figure 1. Major components of an effective warm-up before sports participation.

one of the more obvious physical parameters influenced by age. Maximum muscle strength normally increases through the growth and maturation phase of the life span until one's early 20s, has a general plateau phase until the fifth decade, and then decreases by about 10% per decade thereafter (29). The decline in strength is primarily the result of decreased muscle mass (age-related sarcopenia). Total muscle cross-sectional area declines slightly by 10% between ages 24 and 50 yr, then drops another 30% between ages 50 and 80 yr and beyond. Equal amounts of both Type 1 (slow twitch) and Type 2 (fast twitch) muscle fibers are lost with old age. However, in addition to overall fiber loss, Type 2 fibers also undergo a much greater decrease in size compared with their Type 1 counterparts (27).

The resultant pattern of the sarcopenic strength loss is such that a middle-aged athlete would not be expected to have any significant decrease in maximum isometric or concentric strength compared with a younger adult, but an 80-yr-old person would have only about half the overall F2 strength level of the young adult (Fig. 2). The forces generated by muscles while being lengthened under external loads also follow a similar curvilinear pattern with regard to age-related differences, but with a less steep decline. Possible mechanisms for this difference arise from the prolonged contraction times of older muscle fibers, in combination with greater passive resistance from the elastic tissue structures (22,29).

Flexibility

A common complaint of older people is generalized stiffness in several key joints involved in most sport movements (*e.g.*, shoulders, wrists, hips, and knees). From a physiological standpoint, much of this stiffness relates to connective tissue changes within the body caused by the significant water loss with age that contributes to a reduction in this tissue's plasticity (22,27). Functionally, age-related changes in connective tissue are manifested by losses in flexibility. For example, one study comparing spinal motion during the golf swings of players aged between 18 and 21 yr and senior players (aged 50+ yr) showed that maximum trunk side bending range of motion was 25% less in the older group (21). Another investigation by Mitchell *et al.* (20) compared maximum shoulder ranges of motion in the golf swing of groups between 18 and 24 yr with those between 50 and 86 yr and found that the older players used about 15% less shoulder elevation and 30% less shoulder external rotation when swinging the club.

Cardiovascular and Muscular Endurance

In terms of age-related changes to cardiovascular performance, cardiac output decreases by about 30% between ages 30 and 70 yr (2,23,27). During physical activity, this decrease in endurance may cause premature mental and physical fatigue leading to performance inconsistencies, particularly toward the end of a prolonged period of exercise. When walking, running, cycling, or skiing outdoors, the effect of limited cardiovascular capacity on performance may further be compounded by localized muscle fatigue that can occur during ambulation up steep hills. Given that the overall

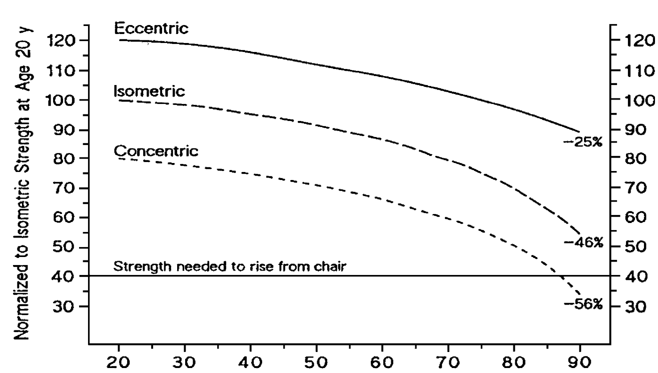

Figure 2. An illustration of how the relationship between strength and age varies with the type of muscle contraction. The general shape and height of the schematic curves are based on the author's gerontology research and vary according to the testing procedure: isometric, concentric (activated muscle allowed to shorten), or eccentric movements (actively resisting muscle is lengthened by external load). Note the extent of concentric muscle weakness predicted for a very old person and eventual crossing of threshold for rising unassisted from an armless chair.

ability of older adults to carry an absolute load over time is reduced compared with younger adults, a common mechanism of many sports injuries — fatigue and associated neuromuscular incoordination — is a likely contributing risk factor for older exercisers. Finally, overall reductions in the body's ability to maintain cardiovascular and muscular homeostasis also indicate that older athletes need to pay close attention to maintaining adequate hydration, nutritional supplementation, and blood electrolytes during their sport activities, particularly in hotter climates.

In summary, the aging athlete has muscles that have a slower speed of contraction under baseline resting conditions, a tendency toward tightness in the connective tissues, reduced motor coordination ability, and a general decline in the total capacity and initial responsiveness of the cardiorespiratory system at the start of exercise. Hence, the potential benefits can be seen for shifting these age-related effects to a more favorable state of movement readiness via a strategic warm-up routine.

The Sport of Golf as a Specific Example

Particular focus is now given to the sport of golf in this review because of its high potential to be a valuable physical activity for older adults who are trying to maintain a healthy lifestyle. Indeed, it has the highest participation rate among the few sports that seniors regularly play (22,30), and older golfers with increased leisure time account for a substantial proportion of the total annual number of golf outings in countries where the activity is popular. Furthermore, the major current demographic trend of aging of the baby boomers generation leads to a prediction of increasing number of senior golfers in the future. Unfortunately, however, survey studies have also shown a surprising overall musculoskeletal injury rate of between 1.19 and 2.07 incidents for each amateur's golf history, and as high as 3.06 in professionals' careers, although the sport is considered to be a nonviolent sporting activity of just moderate exercise intensity level (see later). McCarroll (19) also noted that injuries in professionals limited their ability to play for an average of 5 wk per injury. Part of the explanation for these surprising prevalence rates stems from the ballistic nature of the high biomechanical forces created during the full golf swing, sometimes in combination with repetitive strain problems arising from extensive practice (10,11,13). Thus, just as with other sports, there is a clear injury-prevention rationale for a proper warm-up session before playing golf.

Fitness Requirements

Golf can be viewed as a valuable exercise opportunity for senior players conducted over a period of several hours involving intermittent bursts of walking activity at a moderate intensity level that does not usually induce breathlessness. Notable, however, is that as the golfer ages and his or her physiological capacity undergoes a normal decline over time, the relative intensity of any such exercise will tend to increase (27). Dobrosielski *et al.* (5) reported that the metabolic demand during nine holes of golf for 20 male golfers aged 49 to 78 yr was on average about four times the resting metabolic rate. Interestingly, these golfers all had a previous history of heart disease, and the recorded exercise intensity of approximately 57% of their peak functional capacity was indicative that they were performing adequate amounts of moderate-intensity exercise for improving cardiovascular fitness.

GOLF SWING MECHANICS

As depicted in Figure 3, each shot is best begun with the body set up in an athletic and stable upright postural stance, with a slight flex at the hips and knees (but sometimes, the ability to assume this posture may be limited by either the golfer's physical characteristics or the environmental circumstances of the stance). The illustration provides a view of the left arm (*i.e.*, leading toward the target for a right-handed golfer) that hangs down freely without tension in the shoulders, thereby encouraging a smooth relaxed start to the swing. In addition, one of the important advantages of participation in this particular sport for the older athlete is that the ball is at rest for the beginning of each swing, thereby decreasing demands for peripheral vision and movement timing that exist in other activities such as tennis, soccer, or baseball. However, adequate flexibility, muscle strength, and balance are still needed to assume the initial body position, and then maintain stability during and after forceful acceleration of the club through the ball impact zone.

A biomechanically appropriate set-up not only increases the effectiveness of key golf muscles, such as the abdominals and hip muscles, but also reduces the risk of injury to the lower back.

- During the set-up, the spine needs to be held in a relatively straight line. The trunk still has to tilt forward 25-30 degrees when setting up to swing at the ball, but this flexion movement should come mostly from the hip joints.
- In order to facilitate powerful and comfortable hip rotation through the backswing and follow-through, BOTH feet can be turned outwards about 25-30 degrees at set-up.
- A knee bend of about 25-30 degrees is also recommended to bring the clubhead down to the ball without excessive spine flexion. This athletic stance also aids stability.

Figure 3. Biomechanically efficient posture at the start of the golf swing.

The typical breakdown of the golf swing into phases "Set-Up," "Take Away," "Return to Impact," and "Follow-through" allows insight for how the skilled golfer is able to rotate the club away from the start position in a large arc, and then return it to an impact position in such a way that optimal launch conditions are achieved for the distance and accuracy requirements of the planned shot. The various body segments' sequential rotational patterns generate tremendous momentum that ideally is timed to create maximum club-head speed at the point of ball strike (13,26,30). Precisely positioning the hands so that the middle of the clubface strikes the ball is another key challenge for the skillful movement, along with an application of sufficient braking efforts during the follow-through to maintain postural stability (and golfers certainly do occasionally lose balance completely!). Indeed, teaching professionals pay close attention to where the final positions and weight transfer end up for the player because of the implications for both efficiency and musculoskeletal damage.

As reported in several epidemiological surveys, the swing itself is thus the most common cause of injury for golfers (10,11,15,19). The primary injury risk associated with the golf swing derives from the repetitious nature of the motions involved, motions that allow elite players to generate clubhead speeds in excess of 125 mph. These movements are also highly ballistic in some parts of the swing because the club acceleration phase from end of take-away to striking the ball can be as brief as 0.2 s (13,16). The golf swing can also present acute muscle strain issues for unskilled recreational golfers versus professionals because their less efficient swing styles are typically compensated for by greater muscular exertions and poor postures. For example, both the spine and the shoulder are typically taken near to but not quite to the maximum range of all available joint motion by skilled golfers in a full swing with the driver, and slightly less with a more controlled 7-iron swing (13,20,21). An athletic posture in the set-up (Fig. 3) and maintenance of spine angle and balance throughout are thus key elements of both performance and injury prevention. Therefore, the warm-up session — as opposed to the first shot of the competition — is the ideal time to check on the golfer's swing path, especially if they need to make adjustments for preexisting musculoskeletal conditions.

Accommodation of Musculoskeletal Injuries in Golf: Two Examples

Biomechanical analyses have shown that the full golf swing at maximum speed generates compression loads on the lower spine with magnitudes of up to seven to eight times the body weight. For example, taking a full swing with a 5-iron produced peak shear forces of 560 N and 329 N in amateurs and professionals, respectively, whereas similar measurements with the driver club produced up to 882 N of shear force (12,14). It may be surprising for some readers to learn that this latter level of stress on the low back is comparable to forces produced in other sports that would normally be viewed as being of much higher muscular intensity, such as rowing and whole-body weight lifting movements. When reconsidering the magnitude of these forces, it is no wonder that low back pain is consistently reported to be one of the most common injuries reported in the sport of golf.

Given the known degenerative changes of the normal aging spine, plus loss of overall body strength and flexibility, specific swing strategies need to be used when dealing with some senior golfers. Getting into a proper setup at the beginning of each swing is accomplished by holding the spine in as neutral a posture as possible (*i.e.*, flexion toward the ball is achieved by bending forward at the hips rather than curving the low back). Second, use of a shortened backswing has been shown to reduce muscle activation in the trunk muscles while still permitting the golfer to generate substantial club head velocity during the downswing (3). This in turn reduces the chance of back injury or pain for the senior golfer. In another study, players who had a history of low back pain demonstrated a significant restriction of lead side hip internal hip rotation as well as lumbar extension compared with the asymptomatic golfers. The authors speculated that as the body pivots onto the lead leg during the full swing, the problem of limitations to hip rotation might cause an increased force to be transmitted to the lumbar spine, resulting in low back pain (28). By changing the lead foot address position to a more open position, that is, toed out toward the target, this alteration can also reduce the internal rotation force translating up into the spine (16). Furthermore, avoiding the tendency to assume an inverted C position of the spine during the follow-through (caused by a high angular momentum) helps to reduce excessive extension forces on the lumbar area.

A second interesting example of swing modification to accommodate problems with arthritic joints also involves this aspect of how the lead foot is initially positioned during the golf swing. Anecdotal observation that people with symptomatic osteoarthritis of the knee tend to adopt a toe-out style gait pattern over time led to a laboratory biomechanical study of whether this apparent strategy to alter their knee joint forces (17) could potentially also help to unload affected compartments of the joint during the golf swing. Indeed, Lynn *et al.* (18) found that by externally rotating the lead foot by about 20 degrees — versus the condition of toes pointing perpendicular to the swing path — a significant decrease in the external adduction (varus) moment was generated on the left knee just after ball contact (*i.e.*, during the swing of right-handed golfers). Further research with golfers who have chronic osteoarthritis and altered swing mechanics will help illuminate the possible application of this finding to their particular situation.

ENHANCING GOLF PERFORMANCE WITH EFFECTIVE WARM-UP

The benefits of a warm-up session before competition for the older athlete are summarized in the Table. Most striking T1
perhaps is the rather simple concept that the slowed speed of muscle contraction and power generation in older adults can be altered just by increasing temperature with the initial low-intensity exercise phase. Then additional benefits would accrue from ensuring that the connective tissue in muscles and tendons is supple enough from stretching to support an

TABLE. Interaction between age-related changes in physical function and effects of warm-up.

System	Changes With Aging	Effects of Warm-up
Muscle	- Maximum strength 25–50 yr, then decline of 1.5%/year after 60 yr - ↓ No. motor units - ↓ No. muscle fibers - ↓ The size of Type II fibers - Some lean muscle replaced with fat and connective tissue	- General body warm-up increases blood flow and body temperature, which speeds up muscle contraction - Static and dynamic stretching alter the biomechanical length-tension relationship of shortened tight muscles
Nervous system	- Muscle atrophy contributed to by neurological changes - 37% ↓ No. spinal cord axons - 10% ↓ Nerve conduction velocity in older adults - ↓ Sensory and proprioception function - ↓ Reflex speed when responding to stimuli	- General body warm-up increases blood flow to the brain, which enhances alertness and cognitive function ("getting into the zone") - Dynamic stretching and specific motor rehearsal enhance coordination of muscle activation sequences, plus postural control
Skeletal	- After third and fourth decade ↓ mineralization of 0.3%–0.5%/year - Over lifetime: 35% of cortical and 50% of trabecular bone is lost - Men only lose two thirds the bone mass that females lose; notable menopause effect	- General body warm-up plus static and dynamic stretching gradually increase range of motion for stiffened joints (*e.g.*, shoulders and wrists) to maximum levels needed for full swing
Connective tissue	- Altered proportions and properties of connective components - ↑ Stability of cross-links in collagen, ↑ Strength, become nonadaptive - ↓ Water and ↓ plasticity - Becomes nonpliable, brittle, weak - Predisposition to tendon and ligament injury	- General body warm-up increases blood flow and body temperature, facilitates elongation of connective tissue - Static and dynamic stretching increases the flexibility of the muscle-tendon units, allowing golfer to obtain desired biomechanical positions for swing
Cartilage	- Atrophies with age - Proteoglycan subunits smaller - ↓ Cartilage water content - ↓ Lubrication of joint - Vulnerability to injury	- Weight bearing activity throughout the warm-up facilitates diffusion of lubricating fluid into joint space (but need to avoid excessive stresses)

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↑, increase in variable; ↓, decrease in variable. Gerontological information in Table is based on research summarized in Bellew *et al.* (2), Nelson *et al.* (23), Paterson *et al.* (25), Taylor and Johnson (27), and Vandervoort (29).

adequate range of joint motion for full swings. Finally, there is the facilitation of coordinated motor pathways that occurs from rehearsal of the specific swings that will be used on the course. In particular, the first shot on most golf courses tends to encourage golfers to take their longest club (the driver) and swing as hard as possible for maximum distance; therefore, it is valuable to have already rehearsed the desired movements and incorporated any adjustments to accommodate painful or stiff joints.

As noted in several recent articles, implementation of a proper warm-up routine is recommended as an important strategy for both enhancing performance and injury prevention when working with golfers of all ages (10,11,26). Specific evidence for such benefits on swing biomechanics comes from a study of middle-aged men who participated in a randomized controlled trial conducted in Australia by Fradkin *et al.* (9). They demonstrated that performing a brief warm-up routine of approximately 10-min duration before swinging a 5-iron immediately improved an individual's clubhead speed by 3 to 6 m/s (12.8% change). They also found that performing this warm-up routine for 5 wk, five times per week either before practicing, playing, or even at home further improved clubhead speed by 7 to 10 m/s (24% difference) compared with the control group. The warm-up routine used consisted of three parts. First, windmill and trunk rotation types of whole-body exercises performed for 15 s each. These were used to increase body temperature. Second, static stretches were performed on the main golf muscles, including three shoulder stretches, lateral trunk/torso, the hamstring/lower back, two for the wrist, and one for the forearm. Each of these stretches was held at the end range of the stretch for a duration of at least 5 s and repeated twice on each side. Finally, 30 s of air swings with a golf club were performed with a gradually increasing range of motion and vigor. Unfortunately for older athletes, the question of whether the beneficial results of the above investigation would have been even more pronounced in a sample of senior golfers with greater age-related limitations to their swings remains to be answered.

CONCLUSIONS

In summary, it has been argued that there are worthwhile benefits of an appropriate warm-up routine for older athletes preparing to engage in skilled movement patterns for their sport. Golf was used as a specific application of this hypothesis because of its relative popularity and health implications among the physical activity choices that seniors have. Given the age-related changes in the motor and skeletal systems that tend to inhibit the ability of senior golfers to make a full repeatable swing with optimal tempo and rhythm, an adequate warm-up session before playing seems particularly valuable for this age group. However, when we conducted a survey of the usual warm-up habits of a sample of male and female recreational golfers 50 yr or older (n = 100; mean age, 69.9 yr), the large majority only used a very short warm-up period of less than 5 min (75%), whereas others spent even less than 1 min in precompetition preparation (24). Similar observations were reported by Fradkin *et al.* (9) in their study of Australian amateur golfers, and these findings are rather perplexing when one realizes that both performance and injury-prevention strategies can be enhanced by properly designed warm-up routines before commencing sport activities. Inadequate facilities at some public golf courses for warm-up activities and general lack of health knowledge among the senior population may be contributing factors.

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