International Journal of Golf Science, 2012, 1, 54-69

Golf is a Physical Activity for a Lifetime

Anthony A. Vandervoort
University of Western Ontario

David M. Lindsay
University of Calgary

Scott K. Lynn and Guillermo J. Noffal
California State University, Fullerton

Participation in the sport of golf involves regular walking activity that promotes physical fitness for all ages, including the rapidly growing population of retired men and women in the baby boomer generation. Golf professionals and health experts can therefore benefit from having a working knowledge about the aging process and how this will affect the older golfer's performance and participation level. This information also needs to include the potential for injury such as musculoskeletal problems arising from overly vigorous swings, faulty body mechanics or improper equipment. Literature is reviewed that is pertinent to the key performance and health issues that need to be considered when describing and promoting golf participation for the older population. Further research is still required on how best to disseminate such information widely to the large population of older people who could enjoy this activity as part of their lifelong strategy for successful aging.

Keywords*:* senior golfer, physical activity, sport, exercise, injury prevention

The sport of golf is potentially an ideal physical activity for healthy and enjoyable participation throughout most of the lifespan into very old age, thereby being an important option for motivating the older population to maintain their physical capacities (Baker, Deakin, Horton, & Pearce, 2007; Lindsay, Horton, & Vandervoort, 2000; Nelson, et al., 2007; Reid & Fielding, 2012). Indeed, a remarkable observation from Sweden is that dedicated golfers who play regularly may be accruing health benefits that increase their longevity by several years (Farahmand, Broman, de Faire, Vagero, & Ahlbohm, 2009). Therefore our paper advocates for increasing

Vandervoort is with the School of Physical Therapy and Kinesiology, University of Western Ontario, London, Ontario, Canada. Lindsay is with the Sports Medicine Center, University of Calgary, Calgary, Alberta, Canada. Lynn and Noffal are with the Department of Kinesiology, California State University, Fullerton, CA.

the numbers of "Senior" golfers, and it is notable that while some analyses have concluded that older adults aged 65 or more years comprise only about 25% of the overall population who play golf, they already account for a much higher proportion of the total rounds played each year (Morehouse, 1990; World Golf Foundation, 2012). Furthermore, the current demographic pattern for those countries where golf is popular means there will be an increasing number of potential senior golfers in the future, as the "baby boom" generation moves steadily forward into the last third of their lifespan. While stories of octogenerians (e.g., the entertainer Bob Hope) still happily playing golf are readily available in local newspapers across the country, the sport does make considerable physical demands on the body—stresses that interact with the effects of aging.

This literature review therefore includes information about both how health benefits can accrue from walking golf courses, and what are some of the injury risks and barriers to lifelong participation. It is also important to realize that there are strategies for aging players to use when managing chronic diseases such as arthritis, hypertension and type 2 late-onset diabetes. A concerted effort among various golf organizations, businesses, teaching professionals, associations for seniors, and researchers is needed to promote golf for this rapidly expanding segment of the world's population.

In comparison with other sports, golf is considered to be a relatively benign activity of just moderate exercise intensity level (Spirduso, Francis, & MacRae, 2005; Taylor & Johnson, 2008; Wallace & Reilly, 1993), yet survey studies have shown a surprising overall musculoskeletal injury rate at between 1.19 and 2.07 incidents per each amateur's golf history, and as high as 3.06 in professionals' careers. Furthermore, McCarroll (1996) found that injuries in professionals limited their ability to play for an average of five weeks per injury. Thus, proper injury management is especially critical for those who depend on full active golf participation for their livelihood, and some professional careers are now extended considerably by the presence of various Seniors' tournaments, combined with attention to the sport's fitness requirements.

Walking a golf course creates 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 (Wilmore, Costill, & Kenney, 2008; Wallace & Reilly, 1993). Notable however, is that as the golfer ages and his or her cardiorespiratory capacity undergoes a normal decline over time, the relative intensity of any such exercise will increase (Nelson, et al., 2007; Taylor & Johnson, 2008). An additional advantage of golf for older people is that each shot is initiated with a stationary ball (unlike typical racquet sports or soccer that require good peripheral vision), and best begun with the body "set-up" in an athletic and stable postural stance that requires adequate muscle strength, joint flexibility and balance control (Figure 1).

Fatigue can also be a factor influencing performance because sufficient cardiorespiratory endurance is required to sustain the golfer throughout the event, especially while walking the entire course (and perhaps actively transporting the bag of clubs too in some manner). Indeed, when heart rates were monitored in a study of adult recreational golfers, the women participants tended to reach a peak of about 80% of their maximum heart rate while walking some of the uphill fairways (Broman, Johnsson, & Kaijser, 2004). For the men in this sample, the peak intensity

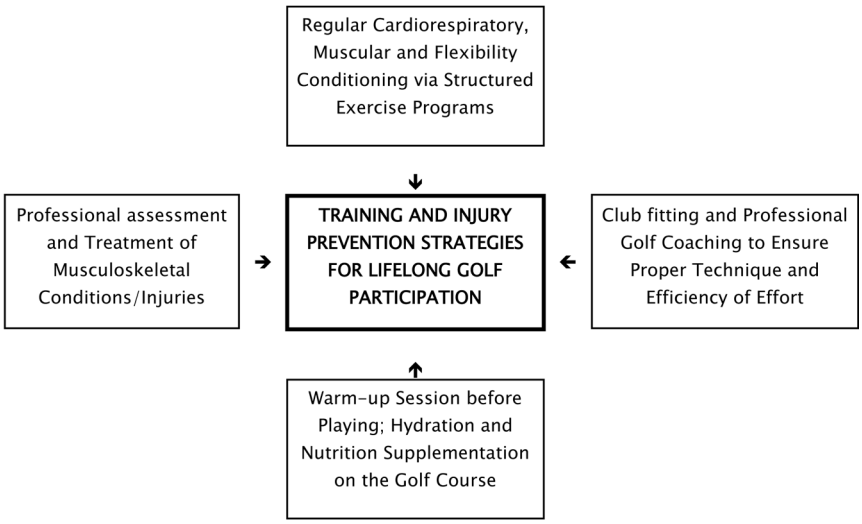

Figure 1 — The stable and athletic posture of an effective golf swing: starting position for a right-handed golfer.

reached was about 70% of their maximum heart rate, depending on whether the terrain was level or uphill, and also the age of the golfer. Another investigation by Dobrosielski, et al. (2002) confirmed that the metabolic demand during nine-holes of golf for 20 male golfers aged 49–78 years was on average about 4.1 (±0.1) 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 and intensity of exercise for improving cardiovascular fitness (Nelson, et al., 2007; Taylor & Johnson, 2008). Notable then is that Parkkari, et al. (2000) found increased aerobic performance (measured during a walking treadmill test), as well as improved body composition and HDL serum cholesterol levels in a previously sedentary group of 55 healthy Finnish male subjects aged 48–64 years who participated in a golf program 2–3 times per week over a 20 week season. Finally with regard to implications for body weight management, it has also been calculated that the average male golfer burns about 900 calories per typical round of walking an 18-hole course, while females metabolize about 700 calories. And carrying clubs with shoulder straps adds about another 10–15% to these numbers (Wallace & Reilly, 1993). Studies have shown walking during a round of golf consistently provides over 11,000–12,000 steps of exercise (Kobriger, Smith, Hollman, & Smith, 2006; Peterson, 2012), which surpasses common healthy living guidelines of attempting to achieve at least 10,000 steps per day. Furthermore, playing golf also has the potential to improve knee joint proprioception and the limits of postural stability in older people—important components of balance that have been shown to correlate with risk of falls in the elderly (Girardi, Konrad, Amin, & Hughes, 2001; Tsang & Hui-Chan, 2010).

Biomechanics of the Golf Swing and Injuries

Given the large momentum developed at the point of ball impact by the various body segments' rotational patterns, it can be a challenge for the player to have a smooth follow-through while still maintaining postural stability. Indeed golf teaching and rehabilitation professionals pay close attention to where the final positions and weight transfer end up, due to the implications for both efficiency and musculoskeletal damage. As reported in several epidemiological surveys, the large majority of injuries for golfers are in effect self-induced because they occur at some point in their golf swing (Fradkin, Windley, Myers, Sell, & Lephart, 2007; Lindsay & Vandervoort, 2010; McHardy, Pollard, & Luo, 2006). The motions that allow elite players to generate hand movements and clubhead speeds in excess of 125 miles/hr are highly ballistic in some parts of the swing, because the club acceleration phase before striking the ball can be as brief as 0.2 s (Lindsay & Horton, 2002; Okuda & Armstrong, 2002). Unskilled recreational golfers attempting to imitate professionals may induce muscle sprains 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 (Lindsay, Horton & Paley, 2002; Mitchell, Banks, Morgan, & Sugaya, 2003). The importance of an athletic posture in the set-up (see Figure 1), and maintenance of spine angle and balance throughout are key elements of both skilled performance and injury prevention.

Playing Golf with an Aging Body

The typical pattern of aging decreases the body's reserve capacity and reduces the ability of the individual to adapt effectively to stress (Lindsay, et al., 2000; Spirduso, et al., 2005; Taylor & Johnson, 2008). Not only does this reduction lead to an increased risk of injury, but the severity of injury and consequent rehabilitation time required may also be heightened in the older athlete. Epidemiological surveys have indicated some trends that older golfers may be more prone to injury that young adults, but as noted above the etiological picture involves a complex mix of player characteristics, frequency of participation, and environmental conditions (Gosheger, Liem, Ludwig, Greshake, & Winklemann, 2003; Palmer, Young, Fox, Lindsay, & Vandervoort, 2003; Suguya, Tsuchiya, Moriya, Morgan, & Banks, 1999). In our survey of injuries and orthopedic problems among senior recreational players, half of the 100 respondents reported having musculoskeletal conditions in the last three years that affected their golf game—46% of these conditions affecting the upper extremity and 34% involving the spine (Palmer, et al., 2003). Furthermore, approximately one-third had on occasion experienced notable discomfort in the lumbar region after playing. Low back pain is a concern for older professional golfers as well, a problem that was identified in the results of Suguya, et al., (1999).

The human shoulder joint has complex anatomical structures that allow extraordinary range of motions, but at the expense of strong stability. For shoulder problems among golfers the injury typically takes place in the lead side (i.e., left shoulder for a right-handed golfer), via the high eccentric load that is applied to the shoulder muscles during the transition between the back and down-swing. Another

mechanism of injury identified in surveys (Kim, Millett, Warner, & Jobe, 2004; McNicholas, Neilsen, & Knill-Jones, 1999) was "hitting heavy" (i.e., taking a deep divot) or inadvertently striking a buried object (e.g., a tree root). The vulnerability of the shoulder to injury in aging athletic populations has been reported by other authors too, and may lead to long-term rotator cuff problems, as well as chronic arthritis of the glenohumeral joint in about 3% of patients seen in orthopedic clinics (Kim, et al., 2004). Many older golfers with joint problems are determined to keep playing though via technique modifications that can include: shortening the back-swing, keeping the elbows in-close to the trunk during the back-swing, and finishing with the hands low and the club shaft horizontal on the follow-through. Keeping the elbows in and hands low helps promote a slightly flatter swing plane and reduces the chance of impinging the rotator cuff. It is thus recommended that rotator cuff and scapular stabilizer strengthening programs should be a regular component of any senior golfer's rehabilitation or training program.

With increasing age, osteoarthritis (OA) becomes a common problem facing older golfers, given the high prevalence of significant osteoarthritic changes in even middle-aged persons (Lindsay, et al., 2000; Spirduso, et al., 2005; Taylor & Johnson, 2008). Areas of special concern in golfers include the first metacarpal phalangeal joint of the top hand (left hand for a right-handed golfer), the facets of the lumbar and cervical spines, and the hip and knee joints. Those with significant foot pain or deformities will also experience limitations to completing the arching motion onto the ball of the foot during the follow-through phase of the swing. However, it is encouraging to note that having to resort to arthoplastic procedures for treating these joints does not preclude future participation in golf, and can indeed lead to substantial improvement in performance when range of motion and strength are restored. The orthopedic history of well-known professional golfers such as Jack Nicklaus and Tom Watson, who returned to successful competitive golf after a hip joint replacement, serves as inspiration for those players with advanced osteoarthritic degeneration. The latter player in fact thrilled older golfers around the globe in 2009 when he came within one shot of winning The Open major championship in Muirfield, Scotland—at the amazing age of 59 years old.

Another example of swing accommodation involves the position of the foot at set-up. It has been recommended by Ben Hogan, in his famous golf instruction book (Hogan & Wind, 1957), that the optimal golf set-up places the lead foot into a toe-out position (although a clear biomechanical rationale remains to be provided for why this is a desirable technique). Of related interest, however, is the observation that people with symptomatic knee OA tend to adopt a toe-out style gait pattern and this strategy has been shown to help in unloading the diseased medial compartment of the knee—where most knee arthritis occurs (Hurwitz, Ryals, Case, Block, & Andriacchi, 2002; Lynn & Noffal, 2010; Wang, Kuo, Andriacchi, & Galante, 1990). Further research with golfers who have play with chronic osteoarthritis will help to illuminate the possible application of this finding to their particular situation.

Considering the important biomechanical stress factors created in a golf swing (Bulbulian, Ball, & Seaman, 2001; Hosea, Gatt, Galli, Langrana, & Zawadsky, 1990; Hosea & Gatt, 1996; Lim & Chow, 2000; Lindsay & Vandervoort, 2010) in conjunction with the known degenerative changes that the spine and peripheral joints go through while aging, specific swing strategies need to be implemented when dealing with some senior golfers. Firstly, it has been reported that golfers who perform a

pregame warm up routine greater than 10 minutes experienced less than half the injuries per player than those who warm up for 10 minutes or less (Gosheger, et al., 2003). Therefore, a substantial warm-up period appears to be good advice for incorporation into the golfer's normal pregame routine. Secondly, as depicted in Figure 1—a proper setup needs to be achieved with the spine in a straight position (e.g., reminding recreational players to flex at the hips, rather than the low back). Thirdly, use of a shorter backswing has been shown to reduce muscle activation in the trunk muscles while maintaining clubhead velocity (Bulbulian, et al., 2001). This would indicate that using an abbreviated backswing has the potential to reduce the chance of back and shoulder injury or pain while maintaining performance, a strategy which can be optimal 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 (Vad, et al., 2003). The authors speculated that as the body pivots onto the lead leg during the swing, the decreased amount of hip rotation might cause an increased force to be transmitted to the lumbar spine resulting in low back pain. By changing the lead foot's starting position to a more open stance (i.e., toed out toward the target), this adaptation should reduce the internal rotation force translating up into the spine. Furthermore, avoiding an excessive posture of extension (inverted C position) on follow-through will help to reduce excessive forces on the lumbar spine at the end of the swing. In summary, it is a good sign when the golfer can easily maintain his or her balance from start to finish!

Some additional practical recommendations for older golfers are to avoid carrying their clubs over the shoulder for extended time periods as this has been shown to cause significant shrinkage and decreased shock absorption of the intervertebral discs (Wallace & Reilly, 1993). Low back pain can also be caused or aggravated by repetitive forward bending, so considering that each golf hole involves several bending motions to place the tee in ground, pick up the ball from hole, and fix divots, golfers with low back concerns should consider using some of the helpful extension tools on the golf market to aid with this task. Finally, we note that although Gosheger et al., (2003) found chronic back pain to be a major source of pregolf injuries, 80.5% of these affected golfers did not report that playing the game made their back pain worse. Therefore, the preexistence of common back pain should not necessarily be considered an absolute contraindication for playing golf.

Recommendations for Physical Conditioning Programs

Gerontology research has provided evidence that most tissues and systems of the body will experience an age-related loss of physiological capacity, and some of these changes affecting performance of the senior golfer are summarized in Table 1. Muscular strength is one of the more obvious physical parameters influenced by age: it increases via growth and maturation up to one's early 20's, has a general plateau phase until the fifth decade, and then decreases by about 10% per decade thereafter, albeit retaining marvelous plasticity for training effects into very old age (Baker, Atlantis, & Fiatarone Singh, 2007; Spirduso, et al., 2005; Taylor & Johnson, 2008; Vandervoort, 2002). The decline in strength is primarily the result of decreased muscle mass (age-related sarcopenia). Total muscle cross sectional area declines by 10% between the ages 24–50 years, then drops another 30% between

Table 1 Contrasting Effects of Aging and Regular Exercise on Physical Capacity.

SYSTEM	CHANGES WITH AGING	EFFECTS OF EXERCISE
Muscle	- max strength 25–50 years, then decline of 1.5% / year after sixty - ↓ number of motor units - ↓ number of muscle fibers - ↓ the size of Type II fibers - some lean muscle replaced with fat & connective tissue	- plays a key role in maintenance of muscle mass - over-load training ↑ muscular strength - early strength gains primarily by neurological adaptation, then some hypertrophy is also possible
Nervous System	- muscle atrophy is contributed to by neurological changes - 37% ↓ # of spinal cord axons - 10% ↓ nerve conduction velocity in older adults - ↓ sensory & proprioception - ↓ reflex speed to respond to stimuli	- activity allows rapid response time to remain relatively unchanged in older adults - balance can be improved with specific strengthening exercises and postural maneuvers, including those in golf swing
Skeletal	- after third & fourth decade ↓ bone mineralization of 0.3–0.5% / year - over full lifetime: 35% of cortical and 50% of trabecular bone is lost - men only lose 2/3 the bone mass which females lose - other factors: diet and hormonal changes	- gravitational loading and muscular traction found to effect: thickness, strength, calcium concentration - physical activity such as walking found to partially counteract the demineralization with aging
Connective Tissue	- altered proportions & properties of connective components - ↑ stability of cross-links in collagen, ↑ strength, become nonadaptive - ↓ water and ↓ plasticity - becomes nonpliable, brittle, weak - predisposition to tendon & ligament injury - ability to return to original length when injured–affects stress/strain properties	- physical activity known to increase turnover rate of collagen - ↑ pliability and ↓ formation nonadaptive connective tissue - connective tissue needs the regular stimulus of being stretched by movements in walking and golf swing
Cartilage	- atrophies with age - proteoglycan subunits smaller - ↓ cartilage water content - ↓ lubrication of joint - vulnerability to injury	- weight bearing activity thickens cartilage and facilitates diffusion of fluid into joint space - joints need to move regularly through their range of motion

(continued)

Table 1 *(continued)*

SYSTEM	CHANGES WITH AGING	EFFECTS OF EXERCISE
Respiratory	- ↓ vital capacity and FEV1.0 - Residual volume +30% by 50 years - ↑ residual vol. vs. total lung capacity = less efficient air exchange) - ↓lung tissue & chest wall elasticity	- endurance training effect from walking improves elasticity - increased sensitivity of ventilatory response to exercise, and less sense of breathlessness
Cardiovascular	- maximum oxygen uptake↓ ~10%/decade - maximum HR ↓ decreases approx. 1 beat/year - ↓ stroke volume due to changes in contractility and total peripheral resistance - therefore, decreased total Cardiac Output	- maximal HR appears unchanged with activity, but maintenance of maximal stroke volume possible with regular walking exercise - maximal oxygen uptake improves due to↑ arterio-venous difference

↑ = increase in variable; ↓ = decrease. Gerontological information in Table is based on research conducted by the authors and others from reviews cited in the Reference List.

ages 50–80 years and beyond (Lexell, Taylor, & Sjostrom, 1988). Equal amounts of both type 1 (slow twitch) and type 2 (fast twitch) muscle fiber numbers are thought to be 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 (Porter, Vandervoort, & Lexell, 1995).

A curvilinear relationship between age and strength infers somewhat of a good news or bad news story, depending on where a person locates on the curve. For example, the pattern of strength loss is such that a middle-aged golfer would not be expected to have any large decrease in maximum torque generation compared with a young player, but an 80-year old would have only about half the overall strength level of the young adult. It is quite interesting to note that golf performance tends to follow the same pattern, as evidenced by comparisons of average golf "handicaps" versus age. Recreational golfers tend to reach their prime in the third decade and then begin to experience some loss of performance after their forties. However, they can still continue to play well and even compete with other age groups via the handicap system for the rest of their lives (Lindsay, et al., 2000; Spirduso, et al., 2005). For example, Lockwood (1999) observed in his survey that the average handicap of recreational golfers in England was about 19 for adolescents, dropped to 13 for young adults aged 20–39 years, and then increased by about one stroke per decade thereafter to again reach 19 for players in the 70–79-year-old age. Thus the older golfer's "net" score can be adjusted statistically to compare expected performance on a more equal basis, especially if players are willing to use an appropriate tee box for their typical skill level.

Of particular importance is the fact that the aging muscular system remains quite adaptable to exercise programming (Baker, et al., 2007; Nelson et al., 2007; Vandervoort, 2002) and so there are definite benefits for senior golfers who decide to take up a properly designed periodized resistance training program that can help

to optimize the motor system's ability to generate effective muscle forces for the golf swing. Furthermore, our recent research has shown that older individuals can take advantage of the muscle strengthening benefits of eccentric overload resistance training principles, and that this mode of exercise also causes less cardiovascular stress compared with concentric exercises (Bellew, Symons, & Vandervoort, 2005; Overend, Thompson, Versteegh, Birmingham, & Vandervoort, 2000). Finally, it is useful to optimize any motor learning associated with the training exercises, especially those involving coordinated ballistic movements among several muscles that directly simulate motions of the golf swing (Gabriel, Kamen, & Frost, 2006).

Another effect of the typical aging process is generalized stiffness in several of the key joints involved in the golf swing. From a physiological standpoint, much of reduced flexibility relates to connective tissue changes within the body, due to the significant water loss with age that contributes to a reduction in this tissue's plasticity (Nelson et al., 2007; Taylor & Johnson, 2008). Clinically, age-related changes in connective tissue are manifested by losses in maximal range of joint movement. One study comparing spinal motion during the golf swings of players aged between 18–21 years and senior players (age 50+ years), showed that maximum trunk side bending range of motion was 25% less in the older group (Morgan, Cook, Banks, Sugaya, & Moriya, 1999). Another investigation by Mitchell, et al. (2003) compared maximum golf swing shoulder ranges of motion between golfers aged between 18–24 years and those between 50–86 years, and found that the older players used about 15% less shoulder elevation and 30% less shoulder external rotation when swinging the club. Not surprisingly then, Brown, Best, Ball, & Dowlan (2002) have documented that swing velocity also typically decreases as the golfer ages.

However, an important and encouraging study for older golfers was conducted by Thompson & Osness (2004) who examined muscle strength and flexibility in male recreational players (mean age = 65.1 years), and determined that both resistance training and flexibility exercises emphasizing trunk rotation generated improvements in clubhead speed. Similar findings came from Hetu, Christie, & Faigenbaum (1998) in their study of fitness and performance measures that improved among mature golfers (average age 52.4 years) after an 8-week conditioning program that increased trunk rotation flexibility by 47%, and also produced a 6% gain in maximum clubhead speed. For golfers looking for an alternative to heavy weight-lifting, Jones (1999) has also shown that using an 8-week Proprioceptive Neuromuscular Facilitation (PNF) program of stretching agonist muscles against their opposite (antagonist) group also had a positive impact on increasing clubhead speed. The PNF stretches were aimed at improving the flexibility of hip flexion and extension, shoulder abduction and external rotation and trunk rotation. Therefore, the older golfer can be encouraged to set reasonable goals for managing these age-related physiological changes—utilizing approaches that involve the optimization of their existing physical capacity and attempts to maintain performance as much as possible (Newton, 2007; Reid & Fielding, 2012).

Activated muscles that are used to walk the golf course and swing clubs need a steady supply of oxygen and nutrients via the cardiorespiratory system, but cardiac output decreases by about 30% between the ages of 30–70 years (Bellew et al., 2005; Shepherd, 1997; Taylor & Johnson, 2008). In golfers, this decrease in endurance may cause premature mental and physical fatigue leading to performance inconsistencies, particularly toward the end of a round (Palank, 1994). 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 ability of older adults to carry an absolute load over time is reduced compared with younger adults (Bemben, 1998; Wilmore, et al., 2008), a common mechanism of many sports injuries—fatigue and associated neuromuscular incoordination—is a likely contributing risk factor for Senior players. However, fatigue resistance can be also built up with appropriate exercise strategies. Senior golfers can be encouraged to participate in continuing training programs throughout the year that include cardiovascular endurance (i.e., if additional physiological stimulation is necessary beyond the effects of walking the course). Overall reductions in the body's ability to maintain cardiovascular and muscular homeostasis in stressful environmental conditions also indicate that older players need to pay close attention to maintaining adequate hydration, nutritional supplementation and blood electrolytes during their round, particularly in hotter climates (Smith, 2007).

The Benefits of an Effective Warm-up Strategy. Although it seems remarkably simple, yet another important strategy to be recommended when working with golfers of all ages is implementation of a proper warm-up routine (Gosheger, et al., 2003; Page, 2012; Smith, 2007). 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, such warm-up seems particularly valuable for this age group. Therefore, it was of interest to discover whether the example of dedication to pregame routines from the professional ranks was duplicated by recreational players (Palmer et al., 2003). We conducted a survey of the usual warm-up habits of a sample of male and female golfers aged 50 years or older (n = 100, mean age = 69.9 years). The large majority of this group of recreational players used just a short warm-up period of less than five minutes (75%), while others spent even less than one minute in preround preparation, i.e., simply doing a few preround stretches and practice swings at the first tee. And there was also a group of players who devoted no time at all to getting ready to play! Similar observations were reported by Fradkin, Cameron, & Gabbe (2007) in their study of Australian amateur golfers, and this lack of preparation before playing is rather perplexing when one realizes that both performance and injury prevention strategies are easily enhanced by an adequate warm-up before commencing the round of golf.

Additional motivation to take the extra time for a warm-up comes from another study by Fradkin, Sherman, & Finch (2004) who demonstrated that performing a brief warm-up routine of approximately 10 min duration before swinging a 5-iron improved clubhead speed of a group of male recreational golfers (mean age of 39.6 years) by 3–6m/s (12.8% change). They also found that performing this warm-up routine for five weeks, five times per week either before practice, before an actual round or even at home improved clubhead speed by 7–10 m/s (24% difference) compared with the control group. The warm-up routine consisted of three parts: first were windmill and trunk rotations along with two other vigorous exercises performed for 15 s each. These were used in an effort to increase body temperature. Secondly, stretches were performed with the main golf muscles, including three shoulder stretches, lateral trunk/torso, hamstring/lower back, two for the wrist, and one for the forearm. Each of these stretches were held at the end range of the stretch for duration of at least five seconds and repeated twice on each side. Finally 30 s of

air swings with a golf club were performed with gradual increasing range of motion and vigor. Subsequently, Versteegh, Vandervoort, Overend, Birmingham, & Jones (2011) have demonstrated that senior recreational golfers over the age of 65 years can also benefit from this type of brief warm-up strategy. It should be motivating for older player to realize they can take advantage of the simple fact that an increase of just a few percentage points in swing speed will translate into several more yards of distance on long golf shots! In addition, equipment recommendations by golf professionals for senior players could also include the use of properly fitted and lighter clubs with more flexible graphite shafts that tend to enhance swing speed as well as reduce vibrational forces (Stover & Stoltz, 1996).

Finally, it is important to note the value of collaborative approaches to golf coaching and injury management that bring several disciplines together—e.g., golf teaching professional, physician, rehabilitation expert, sport psychologist and exercise specialist as needed. They can focus and bring special knowledge onto the four key concepts involved: clinical rehabilitation of the injury itself, education on swing mechanics, specific warm up practices, and appropriate fitness conditioning (Figure 2). This type of multidisciplinary approach has been shown to result in a high rate of return to getting both recreational and professional players back to participating fully in the sport of golf (Parziale, 2002). Thus, the inherent physical activity and socialization associated with a lifetime of golf means this sport can be another important option for keeping even very old people from entering the downward progressive spiral toward a sedentary lifestyle and frailty (Baker, Atlantis, & Fiatarone Singh, 2007; Nelson, et al., 2007; Theou, et al., 2011).

Discussion

In summary, golf is an activity that can be enjoyed from a young age throughout the rest of the lifespan. It is appealing for older adults because they can continue to perform well if they maintain their conditioning and participation level. Golf activity also presents both potential benefits from walking exercise and risks to the health of the senior player, whether professional or amateur. The health risks are influenced by the fact that older adults' musculoskeletal systems may not be as efficient at withstanding the strains and stress of the type of repetitive movement found in a golf swing. However, there is encouraging evidence from the literature that many of the age-related changes affecting older players, as well as the injuries they might experience, can be managed with appropriate prevention or rehabilitation strategies implemented by a multidisciplinary team.

It is recommended that older golfers access professional teaching and coaching provided by knowledgeable personnel who can help them to prevent reoccurrence of injuries resulting from poor swing mechanics or improper equipment. Education should also be given concerning adequate warm up practices and key principles of healthy living. Finally, the utilization of a targeted conditioning program for golf, emphasizing the key body structures involved, also helps to optimize performance and prevent further injury. Future research is needed regarding how to best promote golf as a valuable physical activity for older people, along with effective educational strategies for injury management so that they can keep playing into very old age.

- Stability of the golf posture is important for older players. A proper stance facilitates the motions of the key golf muscles, such as the abdominals and hip muscles, and also reduces the risk of strain and injury to the lower back.

- Note how the spine angle is kept relatively straight and that the trunk tilts forward about 25-30 degrees when setting up to hit the ball. This amount of flex should occur mostly via the hip joints.

- The arms should hang freely from the shoulders, and an athletic knee bend of about 25-30 degrees is necessary to allow the clubhead to reach to the ball without excess spine flexion.

- A useful option for older golfers to facilitate powerful but comfortable hip rotation through the backswing and follow-through is to turn both feet outwards approximately 25-30 degrees in the starting posture

Figure 2 — Strategies for maintaining lifelong participation and enjoyment of the sport of golf.

References

Baker, J., Deakin, J., Horton, S., & Pearce, J.W. (2007). Maintenance of skilled performance with age: a descriptive examination of professional golfers. *Journal of Aging and Physical Activity, 15,* 300–317. PubMed

Baker, M.K., Atlantis, E., & Fiatarone Singh, M.A. (2007). Multi-modal exercise programs for older adults. *Age and Ageing, 36,* 375–381. PubMed doi:10.1093/ageing/afm054

Bellew, J.W., Symons, T.B., & Vandervoort, A.A. (2005). Geriatric fitness: effects of aging and recommendations for exercise in older adults. *Cardiopulmonary Physical Therapy Journal, 16,* 21–32.

Bemben, M.G. (1998). Age-related alterations in muscular endurance. *Sports Medicine (Auckland, N.Z.), 25,* 259–268. PubMed doi:10.2165/00007256-199825040-00004

Broman, G., Johnsson, L., & Kaijser, L. (2004). Golf: a high intensity interval activity for elderly men. *Aging Clinical and Experimental Research, 16,* 375–381. PubMed

Brown, D., Best, R., Ball, K., & Dowlan, S. (2002). Age, center of pressure and clubhead speed I n golf. Biomechanical analysis of professional golfer's swing. In: *Science and Golf IV: Proceedings of the World Scientific Congress of Golf,* Thain, E. (Ed.), London: Routledge, London, 28-34.

Bulbulian, R., Ball, K., & Seaman, D. (2001). The short golf backswing: effects on performance and spinal health implications. *Journal of Manipulative and Physiological Therapeutics, 24,* 569–575. PubMed doi:10.1067/mmt.2001.118982

Dobrosielski, D.A., Brubaker, P.H., Berry, M.J., Ayabe, M., & Miller, H.S. (2002). The metabolic demand of golf in patients with heart disease and in healthy adults. *Journal of Cardiopulmonary Rehabilitation, 22,* 96–104. PubMed doi:10.1097/00008483-200203000-00008

Farahmand, B., Broman, G., de Faire, U., Vagero, D., & Ahlbohm, A. (2009). Golf: a game of life and death – reduced mortality in Swedish golf players. *Scandinavian Journal of Medicine & Science in Sports, 19,* 419–424. PubMed doi:10.1111/j.1600-0838.2008.00814.x

Fradkin, A.J., Sherman, C.A., & Finch, C.F. (2004). Improving golf performance with a warm up conditioning programme. *British Journal of Sports Medicine, 38,* 762–765. PubMed doi:10.1136/bjsm.2003.009399

Fradkin, A.J., Cameron, P.A., & Gabbe, B.J. (2007). Is there an association between self-reported warm-up behaviour and golf related injury in female golfers? *Journal of Science and Medicine in Sport, 10,* 66–71. PubMed doi:10.1016/j.jsams.2006.04.001

Fradkin, A.J., Windley, T.C., Myers, J.B., Sell, T.C., & Lephart, S.M. (2007). Describing the epidemiology and associated age, gender and handicap comparisons among golfing injuries. *International Journal of Injury Control and Safety Promotion, 14,* 264–266. PubMed doi:10.1080/17457300701722585

Gabriel, D.A., Kamen, G., & Frost, G. (2006). Neural adaptations to resistive exercise: mechanisms and recommendations for training practices. *Sports Medicine (Auckland, N.Z.), 36,* 133–149. PubMed doi:10.2165/00007256-200636020-00004

Girardi, M., Konrad, H.R., Amin, M., & Hughes, L.F. (2001). Predicting fall risks in an elderly population: computer dynamic posturography versus electronystagmography test results. *The Laryngoscope, 111,* 1528–1532. PubMed doi:10.1097/00005537-200109000-00008

Gosheger, G., Liem, D., Ludwig, K., Greshake, O., & Winkelmann, W. (2003). Injuries and overuse syndromes in golf. *American Journal of Sports Medicine, 31,* 438–443. PubMed

Hetu, F.E., Christie, C.A., & Faigenbaum, A.D. (1998). Effects of conditioning on physical fitness and club head speed in mature golfers. *Perceptual and Motor Skills, 86,* 811–815. PubMed doi:10.2466/pms.1998.86.3.811

Hogan, B., & Wind, H.W. (1957). *The Modern Fundamentals of Golf*. London: Kaye & Ward.

Hosea, T.M., Gatt, C.J., Galli, K.M., Langrana, N.A., & Zawadsky, J.P. (1990). Biomechanical analysis of the golfer's back. *Science and Golf: Proceedings of the World Scientific Congress of Golf,* Cochrane, A.J. (Ed.), London: Chapman & Hall, 43-48.

Hosea, T.M., & Gatt, C.J. (1996). Back pain in golf. *Clinics in Sports Medicine, 15,* 37–53. PubMed

Hurwitz, D.E., Ryals, A.B., Case, J.P., Block, J.A., & Andriacchi, T.P. (2002). The knee adduction moment during gait in subjects with knee osteoarthritis is more closely correlated with static alignment than radiographic disease severity, toe out angle and pain. *Journal of Orthopaedic Research, 20,* 101–107. PubMed doi:10.1016/S0736-0266(01)00081-X

Jones, D. The effects of proprioceptive neuromuscular facilitation flexibility training on the clubhead speed of recreational golfers. (1999). In: Farrally, M.R., & Cochran, A.J., (Eds.), *Science and Golf III: Proceedings of the World Scientific Congress of Golf*, Champaign, Il: Human Kinetics, 46-50.

Kim, D.H., Millett, P.J., Warner, J.J., & Jobe, F.W. (2004). Shoulder injuries in golf. *American Journal of Sports Medicine, 32,* 1324–1330. PubMed doi:10.1177/0363546504267346

Kobriger, S.L., Smith, J., Hollman, J.H., & Smith, A.N. (2006). The contribution of golf to daily physical activity recommendations: how many steps does it take to complete a round of golf? *Mayo Clinic Proceedings, 81,* 1041–1043. PubMed doi:10.4065/81.8.1041

Lexell, J., Taylor, C.C., & Sjostrom, M. (1988). What is the cause of the ageing atrophy? *Journal of the Neurological Sciences, 84,* 275–294. PubMed doi:10.1016/0022-510X(88)90132-3

Lim, T.Y., & Chow, J.W. (2000). Estimating lumbar spinal loads during a golf swing using an EMG-assisted optimization model approach. *Proceedings of the 18th International Symposium of Biomechanics in Sports*, Hong Kong, June 25-30, 2000.

Lindsay, D.M., Horton, J.F., & Vandervoort, A.A. (2000). A review of injury characteristics, aging factors and prevention programs for the older golfer. *Sports Medicine (Auckland, N.Z.), 30,* 89–103. PubMed doi:10.2165/00007256-200030020-00003

Lindsay, D.M., & Horton, J.F. (2002). Comparison of spine motion in elite golfers with and without low back pain. *Journal of Sports Sciences, 20,* 599–605. PubMed doi:10.1080/026404102320183158

Lindsay, D.M., Horton, J.F., & Paley, R.D. (2002). Trunk motion of male professional golfers using two different golf clubs. *Journal of Applied Biomechanics, 18,* 366–373.

Lindsay, D.M., & Vandervoort, A.A. (2010). Applied biomechanics of golf. In D.J. Magee, R.C. Manske, J.E. Zachazewski, & W.S. Quillen (Eds.), *Athletic and Sport Issues in Musculoskeletal Rehabilitation* (pp. 217–233). Philadelphia: Elsevier.

Lockwood, J. (1999). A small scale local survey of age-related male golfing ability. In: *Science and Golf III: Proceedings of the World Scientific Congress of Golf*. Farrally, M.R., & Cochran, A.J. (Eds.), Champaign, Il: Human Kinetics, 112-119.

Lynn, S.K., & Noffal, G.J. (2010). Frontal plane knee moments in golf: Effect of target side foot position at address. *Journal of Sports, Science, and Medicine, 9,* 275–281.

McCarroll, J.R. (1996). The frequency of golf injuries. *Clinics in Sports Medicine, 15,* 1–7. PubMed

McHardy, A., Pollard, H., & Luo, K. (2006). Golf injuries: a review of the literature. *Sports Medicine (Auckland, N.Z.), 36,* 171–187. PubMed doi:10.2165/00007256-200636020-00006

McNicholas, M.J., Neilsen, A., & Knill-Jones, R.P. (1999). Golf injuries in Scotland. In: *Science and Golf III: Proceedings of the World Scientific Congress of Golf.* In: Farrally, M.R., & Cochran, A.J. (Eds.), Champaign, Il: Human Kinetics, 1999, 65-72.

Mitchell, K., Banks, S., Morgan, D., & Sugaya, H. (2003). Shoulder motions during the golf swing in male amateur golfers. *The Journal of Orthopaedic and Sports Physical Therapy, 33,* 196–203. PubMed

Morehouse, C.A. (1990). The super senior golfer. In: *Science and Golf: Proceedings of the World Scientific Congress of Golf*, Cochrane, A.J. (Ed). London: Chapman & Hall, 14-23.

Morgan, D., Cook, F., Banks, S., Sugaya, H., & Moriya, H. (1999). The influence of age on lumbar mechanics during the golf swing. In*: Science and Golf III: Proceedings of the World Scientific Congress of Golf,* In: Farrally, M.R., & Cochran, A.J. (Eds.), Champaign, Il: Human Kinetics, 120-126.

Nelson, M.E., Rejeski, W.J., Blair, S.N., Duncan, P.W., Judge, J.O., King, A.C., . . . Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise, 39,* 1435–1445. PubMed doi:10.1249/mss.0b013e3180616aa2

Newton, H. (2007). Effective strength training for golf: what's the right approach? *Annual Review of Golf Coaching*, 135-140.

Okuda, I., & Armstrong, C.W. (2002). Biomechanical analysis of professional golfer's swing. In: *Science and Golf IV: Proceedings of the World Scientific Congress of Golf,* In: Thain, E. (Ed.), London: Routledge, 18-27.

Overend, T.J., Thompson, E., Verstegh, T.H., Birmingham, T.B., & Vandervoort, A.A. (2000). Cardiovascular stress associated with concentric and eccentric isokinetic exercise in young and older adults. *Journals of Gerontology: Biological Sciences, 55,* B177–B182. PubMed doi:10.1093/gerona/55.4.B177

Page, P. (2102). Current concepts in muscle stretching for exercise and rehabilitation. *International Journal of Sports Physical Therapy, 7*, 109-119.

Palank, E.A. (1994). The cardiovascular system. In C.N. Stover, J.R. McCarroll, & W.J. Mallon (Eds.), *Feeling Up To Par: Medicine From Tee To Green* (pp. 69–73). Philadelphia: FA Davis.

Palmer, J.L., Young, S.D., Fox, E., Lindsay, D.M., & Vandervoort, A.A. (2003). Senior recreational golfers: A survey of musculoskeletal conditions, playing characteristics and warm up patterns. *Physiotherapy Canada. Physiotherapie Canada, 55,* 79–86. doi:10.2310/6640.2003.37767

Parkkari, J., Natri, A., Kannus, P., Manttari, A., Laukkanen, R., Haapasalo, H., ... (2000). A controlled trial of the health benefits of regular walking on a golf course. *The American Journal of Medicine, 109,* 102–108. PubMed doi:10.1016/S0002-9343(00)00455-1

Parziale, J.R. (2002). Healthy swing: A golf rehabilitation model. *American Journal of Physical Medicine & Rehabilitation, 81,* 498–501. PubMed doi:10.1097/00002060-200207000-00005

Peterson, M. (2012). Physical activity parameters for walking golf participation: an analysis of volume and intensity. Information available at: http://www.golf2020.com/Reports/Walking.pdf, Accessed May 21, 2012.

Porter, M.M., Vandervoort, A.A., & Lexell, J. (1995). Aging of human muscle: structure, function and adaptability. *Scandinavian Journal of Medicine & Science in Sports, 5,* 129–142. PubMed

Reid, K.F., & Fielding, R.A. (2102). Skeletal muscle power: a critical determinant of physical functioning in older adults. *Exercise and Sports Science Reviews, 40*, 4-12.

Shepherd, R.J. (1997). *Aging, Physical Activity and Health*, Champaign, Il: Human Kinetics.

Smith M. (2007). Physical preparation for golf: strategies for optimising movement potential. *Annual Review of Golf Coaching*, 151-164.

Spirduso, W.W., Francis, K.L., & MacRae, P.G. (2005). *Physical Dimensions of Aging* (2nd ed.). Champaign, Illinois: Human Kinetics.

Stover, C., & Stoltz, J. (1996). Golf for the senior player. *Clinics in Sports Medicine, 15,* 163–178. PubMed

Sugaya, H., Tsuchiya, A., Moriya, H., Morgan, D.A., & Banks, S.A. (1999). Low back injury in elite and professional golfers: an epidemiologic and radiographic study. In: *Science and Golf III: Proceedings of the World Scientific Congress of Golf*, In: Farrally, M.R., & Cochran, A.J. (Eds.), Champaign, Il: Human Kinetics, 83-91.

Taylor, A.W., & Johnson, M.J. (2008). *Physiology of Exercise and Healthy Aging*. Champaign, IL: Human Kinetics.

Theou, O., Stathokostas, L., Roland, K., Jakobi, J.M., Patterson, C.J., Vandervoort, A.A., & Jones, G.R. (2011). The effectiveness of exercise interventions for the management of frailty: a systematic review. *Journal of Aging Research, XXX,* 1–19 10.4061/2011/569194. PubMed doi:10.4061/2011/569194

Thompson, C.J., & Osness, W.H. (2004). Effects of an 8-week multimodal exercise program on strength, flexibility, and golf performance in 55- to 79-year-old men. *Journal of Aging and Physical Activity, 12,* 144–156. PubMed

Tsang, W.W., & Hui-Chan, C.W. (2010). Effects of exercise on joint sense and balance in elderly men: Tai chi versus golf. *Journal of Aging and Physical Activity, 18,* 1–13. PubMed

Vad, V.B., Bhat, A.L., Basrai, D., Gebeh, A., Aspergren, D.D., & Andrews, J.R. (2003). Low back pain in professional golfers: the role of associated hip and low back range-of-motion deficits. *American Journal of Sports Medicine, 32,* 494–497. PubMed

Vandervoort, A.A. (2002). Aging of the human neuromuscular system. *Muscle & Nerve, 25,* 17–25. PubMed doi:10.1002/mus.1215

Versteegh, T.H., Vandervoort, A.A., Overend, T.J., Birmingham, T.B., & Jones, I.C. (2011). Effect of a dynamic warm-up on clubhead velocity in Senior golfers. *Proceedings of 16th International Congress of World Confederation for Physical Therapy*, Amsterdam, June 20-23.

Wallace, P., & Reilly, T. (1993). Spinal and metabolic loading during simulations of golf play. *Journal of Sports Sciences, 11,* 511–515. PubMed doi:10.1080/02640419308730021

Wang, J.W., Kuo, K.N., Andriacchi, T.P., & Galante, J.O. (1990). The influence of walking mechanics and time on the results of proximal tibial osteotomy. *The Journal of Bone and Joint Surgery. American Volume, 72A,* 905–909. PubMed

Wilmore, J.H., Costill, D.L., & Kenney, W.L. (2008). *Physiology of Sport and Exercise* (4th ed.). Champaign, Illinois: Human Kinetics.

World Golf Foundation. Information available at: http://www.golf2020.com, accessed May 21, 2012.