REVIEW ARTICLE

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A Review of Injury Characteristics, Aging Factors and Prevention Programmes for the Older Golfer

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Contents

Abstract

Participation in the sport of golf has risen considerably, particularly amongst senior players whose age is categorised as 50 years or more. However, golf presents both potential health benefits and risks for this older group of players. The health risks are compounded by the fact that the musculoskeletal and cardiovascular systems of senior players may not be as efficient at withstanding the strains and stress of this type of repetitive exercise. It was the purpose of this review paper to investigate the age-related health issues facing senior golfers and to discuss appropriate intervention strategies to help minimise these detrimental effects. The literature search identified only a minimal amount of epidemiological information pertaining specifically to the older golfer. A number of case reports were found which described a variety of musculoskeletal and cardiovascular incidents involving senior players. There was evidence from the literature that many of the age-related changes affecting older players' risk profiles were preventable or treatable through exercise. It was the conclusion of the authors of this review that conditioning programmes were highly recommended for all older players irrespective of their level of participation. Not only could the programmes prevent injury, they also had the potential to improve performance. Such programmes should incorporate flexibility, strength, endurance, speed and balance exercises specifically tailored to the demands of golf in order to be effective. Exercise equipment did not need to be elaborate and home-based programmes incorporating bodyweight, weighted clubs or elastic tubing resistance could be utilised. Future research needs to focus more specifically on injury incidence and mechanisms amongst groups of senior golfers whose participation rates vary. Randomised controlled trials are also recommended to investigate the efficacy of specific golf-related exercise regimens in this segment of the older population.

The popularity of golf has risen considerably in recent years. The most notable increase in participation has been individuals between the ages of 50 and 59 years.[1] Statistics from the National Golf Foundation[2] indicated that in 1996 there were over 6 million seniors (aged over 50 years) playing golf in the US. This group accounted for approximately 25% of the golfing population but played 50% of the total number of annual rounds.[3] The popularity of the sport in those aged over 50 is further reflected by the escalating growth of the Senior Professional Golf Association Tours. Overall, it seems likely the senior golf market will continue to grow, especially in light of the advancing age of the 'baby boomer' segment of the population.

The popularity of golf amongst older persons is likely due to a variety of reasons such as increased leisure time and disposable income.[3] Thériault et al.,[4] reporting on a survey of 600 amateur golfers, found that health benefits was one of the main reasons identified for taking up the sport. The walking associated with a game of golf represents a moderate intensity, long duration, interval form of exercise that can maintain or increase aerobic capacity amongst older people.[5-7] While golf may be associated with health and fitness benefits, it is not without certain injury risks. As mentioned, the frequency of play tends to increase with age. This is contrary to most sports, where athletes' participation levels decrease with age. Also, the musculoskeletal system of senior players may not be as efficient in dealing with the physical stress associated with repetitively swinging a golf club.

Although there are numerous studies addressing injuries in older athletes and age-related changes to the musculoskeletal system, there is little published information addressing the physical problems affecting senior golfers. The authors of this review are aware of only 9 original articles, published between 1990 and 1999, that focused on the aging player.[4,8-15] Only 5 of these specifically investigated conditioning and injury issues in older golfers.[2,11,12,14,15] It was the purpose of this review paper to investigate the age-related health issues facing senior golfers and to discuss appropriate prevention and rehabilitation strategies to help minimise these detrimental effects.

1. Physical Demands of Golf

It has been suggested that golf places low physical demands on the body and therefore is well suited to the older population.[16,17] While the demands of playing golf may not be obvious, unique musculoskeletal and cardiovascular stresses do exist and have the potential to cause problems.

1.1 Cardiovascular Demands

The cardiovascular challenges arising from golf are not intense but are worth identifying, especially when dealing with players over the age of 50 years. Murase et al.[5] found the mean heart rate of 5 healthy, middle-aged men who played 18 holes to be 108 beats/minute. This corresponded to 35 to 41% of maximal oxygen uptake ($\dot{V}O_{2max}$) resulting in an energy consumption of 5.9 kcal/min. Magnusson[7] monitored 10 middle-aged men and 9 women over 3 specially selected golf holes. Results showed that women tended to reach a peak of about 80% of their maximum heart rate while walking some of the uphill fairways. For men the peak was approximately 70% of their maximum heart rate. The total energy expenditure of playing golf was estimated to fall between 622 and 960kcal per 18 holes, depending on the terrain of the golf course.[5,7,18] Carrying golf clubs was shown to cause a 15% increase in oxygen consumption, a 2.5% rise in minute ventilation and a 10% increase in kcal/min expended compared with normal walking.[18,19]

1.2 Musculoskeletal Demands

In addition to cardiovascular demands, the musculoskeletal system is also subjected to considerable stress. The golf swing is a very complex dynamic movement involving powerful muscle contractions. Touring professionals often repeat these powerful movements 300 times or more per practice session, resulting in considerable stresses being generated and dissipated during each of these swings.[1]

In terms of spinal stress, the golf swing produces a complex loading pattern involving shear, compression and axial torsional loads with rapid changes in the direction of these forces. Hosea et al.[20] found the average peak shear load for amateurs and professionals to be 596 and 329N, respectively. Peak shear loads in the spine in male rowers have been calculated to be approximately 848N.[20] The compression loads equaled approximately 8 times bodyweight in both amateurs (6100N) and professionals (7584N) golfers. In comparison, running produces spinal compression forces equal to approximately 3 times bodyweight.[20,21] Additional loading on the spine has also been attributed to the postural strain associated with putting and compressive loading from walking and carrying clubs.[19]

Previous studies have also examined hip and knee stress during a golf swing. Stover et al.[22] calculated that the lead hip experienced a much greater rotational torque than the trail hip during the downswing. These findings may partly explain the asymmetrical hip deterioration of golf superstar Jack Nicklaus. Nicklaus recently underwent total joint arthroplasty on his lead hip. Gatt et al.[23] found the magnitude of forces on the knee during a golf swing were at least equal to those generated from running or side-cutting motions. The lead knee was subjected more to an internal rotation, posterior and varus force on the downswing, while the trail side experienced an external rotation, anterior and valgus stress.

Muscle function during the golf swing has also been studied. Pink et al.[24] analysed muscle activity in 8 shoulder muscles of both the right and left arms during the golf swing using electromyography (EMG). These authors concluded that golf was not a strenuous arm activity but did require high synchronous activity of the rotator cuff muscles in order to protect the glenohumeral complex. The authors noted that all of the right handed golfers seen at their clinic for shoulder problems had left sided rotator cuff problems.

Kao et al.[25] examined the role of the scapular muscles (levator scapulae, rhomboid, trapezius, serratus anterior) during the golf swing. They concluded that the upper, middle and lower trapezius all work together to help retract the scapula during different parts of the swing. Activity in the trailing arm primarily occurred during takeaway, whereas activity in the leading arm occurred during acceleration. The lead side levator scapulae and rhomboid muscles also helped elevate and retract the scapula on the downswing.

The activity patterns of the trunk muscles (erector spinae and abdominal obliques) in amateur golfers was investigated by Pink et al.[26] Results demonstrated relatively high and constant activity in

TABLE I HERE

the oblique muscles throughout most parts of the swing. The authors did not distinguish between external or internal abdominal oblique muscles. In a similar study of professional golfers, Watkins et al.[27] measured muscle activity in the erector spinae, gluteus maximus, abdominal oblique, and rectus abdominis. These authors established that all trunk muscles were relatively active during the acceleration phase of the golf swing. The trail side abdominal oblique muscles showed the highest relative activity

Belcher et al.[28] studied the activity patterns of the gluteus maximus, gluteus medius, adductor magnus, biceps femoris, semimembranosus and vastus lateralis muscles in competitive golfers. The authors concluded the extensors and abductors of the trail hip, in conjunction with the lead adductor magnus, contract powerfully to initiate pelvic rotation during the down swing. The lead vastus lateralis and the hamstrings acted to stabilise the knee joints during this pelvic rotation.

2. Epidemiology and Aetiology of Golf Injuries

Several studies have investigated the frequency of golf injuries among amateur and professional players.[4,15,29-33] These results are summarised in table I.

Although some of these studies include senior golfers within the sample size, the wide range of ages of the study participants (e.g. 15 to 86 years[30]) prevents the determination of age-specific injury characteristics. Only the study by Sugaya et al.[15] included epidemiological data from different age categories. The most common injury in senior Japanese professional golfers was to the lumbar region (see table II).

Injury has been identified as the second most common barrier to sport participation in the older age group.[34] McCarroll and Mallon[35] found a statistically significant difference ($p < 0.05$) in the injury rates of amateur golfers aged 50 years and younger and those older than 50 years. They found that 58% of the 528 younger golfers included in their study had experienced a golf-related injury. In com-

Table I. Injury distribution by site,[a] showing number of reports (when given) and percentages (in parenthesis)

Study	Spine (%)			Upper limb (%)				Lower limb (%)				Other (%)
	cervical (neck)	thoracic	lumbar	shoulder	elbow	wrist	hand	hip/groin	knee	ankle	feet	
Thériault et al.[4] n = 528 A; age range = 12-70y	(40)			(42)				(18)				
Sugaya et al.[15] n = 281 P; mean age (age range) = 35 (21-54) y	93 (20)		154 (34)	44 (10)	45 (10)	42 (9)	7 (2)		26 (6)	20 (4)	6 (3)	14 (3)
McCarroll & Gioe[29] n = 393 P; mean age (age range) = 30 (23-72) y	12 (3)	8 (2)	93 (24)	37 (9)	26 (7)	106 (27)	41 (10)	9 (2)	26 (7)	8 (2)	13 (3)	14 (4)
McCarroll et al.[30] n = 708 A; mean age (age range) = 52 (15-86) y	28 (3)		244 (27)	84 (9)	234 (26)	144 (16)		22 (2)	66 (7)	18 (2)	12 (1)	34 (4)
Batt[31] n = 53 A; mean age (age range) = 49.5 (17-85) y	2 (4)	13 (25)		2 (4)	4 (8)	15 (28)	2 (4)		4 (8)	3 (6)	2 (4)	(11)
Finch et al.[32] n = 34 A; median age (age range) = 40.5 (24-65) y	(15)		(24)	(6)	(18)		(6)		(18)			(13)
McNicholas et al.[33] n = 286 A and P; age range = 0-70+y		(21)		(45)					(13)	(4)	(4)	(13)

a Percentages are represented as a proportion of all reported injuries.

A = amateur; **P** = professional.

Table II. Injury distribution by site seniors

	Neck/high back	Lumbar	Shoulder	Elbow	Wrist	Knee	Ankle	Feet	Other
Sugaya et al.[15] No. of reports (%); n = 55 P; mean age (range) = 53 (50-63) y	17 (17)	28 (28)	13 (13)	17 (17)	9 (9)	8 (8)	3 (3)	0 (0)	4 (4)

P = professional; **y** = years.

parison, 65% of the 616 golfers over 50 years of age had experienced an injury.

Increased age has been identified by several authors as a risk factor for upper limb injury amongst golfers.[33,35,36] McNicholas et al.[33] reported that amongst male golfers, the 50 to 59 years age category was the most prevalent age group seeking medical intervention for upper limb injuries. For women, the 50 to 59 years age group was second after the 40 to 49 years age category. McCarroll and Mallon[35] reported that most shoulder injuries from golf occurred in older players. The injury typically occurred on the lead shoulder and was thought to be associated with the high eccentric load that is applied to the shoulder muscles during the transition between the back and down-swing. Although not specific to golf, the vulnerability of the shoulder to injury in aging athletic populations has been reported by other authors.[37,38]

Although not specific to senior players, the aetiology of golf injuries has been investigated by several authors.[4,29-31,32] Overuse through excessive practice (e.g. repetitive swings) was consistently identified as the most common cause of injury.[30,31,32] The ramifications of this are particularly important to senior golfers as their ability to recover from the microtrauma associated with repetitive motions decreases with age.[8]

2.1 Case Reports of Specific Problems in Senior Golfers

While there has not been a lot of epidemiological data in the scientific literature on injuries to senior golfers, several case reports and investigations of specific health problems have been published. Ekin and Sinaki[39] reported on a case series of 3 postmenopausal women who had experienced multiple acute vertebral compression fractures while golfing. The ages at the time of injury were 63, 58 and 66 years. All 3 were diagnosed as osteoporotic with age-corrected bone mineral density values between 1 and 3 percentiles of normal. The authors concluded that physicians should caution patients with osteoporosis about playing golf. Those who continue to golf should participate in an appropriate fitness programme and possibly utilise a thoracolumbar support while playing.

Several case studies of stress fractures of the ribs in golfers have been reported in the literature.[40-42] In fact, golf ranks fifth in terms of the frequency of reported cases amongst 19 different sports.[43] Two of the 5 cases of rib stress fractures reviewed by Orava et al.[40] occurred in players over the age of 50 years. Lord et al.[42] reported on a case series involving 19 golfers whose average age was 39 years. Two cases involved individuals over the age of 50 years. The lead side was involved in almost 80% of cases in both studies. Most fractures occurred in the mid axilla line of ribs 6 and 7 in the study by Orava et al.,[40] while Lord et al.[42] found the posterolateral portions of ribs 4 to 6 to be the most susceptible region. Weakness and fatigue of the serratus anterior muscle was proposed as a key risk factor for developing rib stress fracture from golf.

Cardiovascular problems amongst senior golfers have also been reported in the literature. Ragosta et al.[44] found that 19 individuals died suddenly while playing golf in Rhode Island between 1975 and 1982. This represented the highest number of deaths compared to all other types of recreational exercise. The mean age of these individuals was 59 years and atherosclerotic coronary heart disease was prevalent in the majority of the cases (88%). In a related study, Fujiwara et al.[45] investigated 30 patients (27 males, 3 females) experiencing acute myocardial infarction during sport. Twelve of the 30 patients experienced myocardial infarction while playing golf. Pre-existing coronary heart disease was again identified as the mitigating factor leading to the infarct.

Individual case reports have identified other cardiovascular problems affecting senior golfers. Calligaro et al.[46] reported on a 77-year-old man who experienced a femoral artery pseudoaneurysm following acute torsion of the trunk and hips while golfing. Flugelman et al.[47] described a 72-year-old man who experienced 2 episodes of syncope while playing golf. One incident occurred after completing a drive, and the other while turning his head when distracted while putting. In both episodes there was a sudden rotational motion of the head relative to the body immediately prior to the loss of consciousness.

Another problem facing senior golfers relates to exposure to ultraviolet radiation. Hanke et al.[48] evaluated 51 female professional golfers and 142 female amateur golfers for skin cancer and skin cancer risk. The average age of the professional golfers was 28.4 years compared to 54.5 years for the amateurs. Four professionals and 11 amateurs had developed basal cell carcinoma. Redheads and blue-eyed, fair-skinned Caucasians were identified as most at risk for developing skin cancer. The authors stressed the need to educate golfers about the dangers of excessive sun exposure as well as the importance of ultraviolet skin protection.

3. Age-Related Changes Affecting Senior Golfers

There are many different risk factors associated with golf injuries, such as aptitude, frequency of play and experience.[49] The senior golfer is susceptible to additional factors (see table III) related to declines in strength, flexibility, and coordination as well as increased body fat.[3,38] Aging decreases the body's reserve capacity and reduces the ability of the individual to adapt effectively to stress.[52-54] Not only does this lead to an increased risk of injury, but the severity of injury and consequent rehabilitation time required may also be increased in older athletes.[55] The following section summarises how age-related changes can affect the senior golfer.

3.1 Strength Changes Affecting Senior Golfers

Of much current interest in the fields of exercise science and gerontology is the age-related reduction in muscle strength that occurs near the end of the adult life span.[3,50,56] Strength has been defined as the maximum force a muscle can produce during a single effort.[57] The loss of muscle mass and function in this age group has been recently termed 'sarcopenia', reflecting a process which has minimal changes through middle age, but accelerates after the sixth decade to cause increasing problems for older adults.[58] It stems from both a reduction in the total number of motor units and also an atrophy of the type II, fast-twitch fibres. While it is generally thought that the former process affecting whole motor units is probably part of the normal genetic programme of aging,[59] the latter process of type II atrophy may well be related to the more sedentary lifestyle of older persons that seldom requires the forceful activation of these fibres.

The resultant pattern of strength loss is thus curvilinear, such that the middle-aged golfer would not be expected to have any significant decrease in maximum isometric or concentric (muscle shortens during contraction) strength, but an 80-year-old would have only about half that of a young adult.[60,61] Therefore, compared with young adults, aged persons need to recruit a larger percentage of a smaller muscle mass to achieve a given isometric or concentric force, and this can lead to earlier fatigue during exercise.[62,63]

However, further research in the 1990s has shown that an important distinction must be made between the effect of aging on the 3 possible types of muscle contraction. As compared to isometric and concentric tests, when muscles are activated in the eccentric condition of lengthening (i.e. while attempting to resist a very heavy load) older adults can perform surprisingly well and the age-related deficit in strength is minimised.[64,65] This differential effect of aging

Table III. Age-related changes in physical function affecting the senior golfer[a]

System	Changes with aging	Effects of activity
Muscle	Maximum strength 25-50 years, then decline of approximately 1.5% per year after 60 years Decreased number of motor units Decreased number of muscle fibres Decreased size of type II fibres Total CSA decreased approximately 10% per decade after 50 years Some lean muscle replaced with fat and connective tissue	Plays a key role in maintenance of muscle mass Over-load training stimulus increases muscular strength CSA maintained with training Early strength gains primarily by neurological adaptation, then limited hypertrophy possible
Nervous system	Muscle atrophy contributed to by neurological changes Approximately 35% decreased number of spinal cord axons 10% decrease in nerve conduction velocity in older adults Sensory and proprioception decreased Decreased reaction speed to stimuli	Activity allows rapid response time to remain relatively unchanged in older adults Balance can be improved with specific strengthening exercises and postural manoeuvres
Skeletal	After third and fourth decade decreased mineralisation of 0.3 to 0.5% per year Over lifetime: 35% cortical and 50% trabecular lost Men only lose 2/3 the bone mass that females lose Influential factors: diet, exercise and hormonal changes	Gravitational loading and muscular traction found to affect thickness, strength, calcium concentration Physical activity found to partially counteract the demineralisation
Connective tissue	Altered proportions and properties of connective components Increased stability of cross-links in collagen, increased strength, become non-adaptive Decreased water content and plasticity Becomes non-pliable, brittle, weak with predisposition to tendon and ligament injury Decreased ability to return to original length when injured, affects stress/strain properties	Physical activity known to increase turnover rate of collagen With a shortened collagen lifespan, improved pliability and less formation of non-adaptive connective tissue
Cartilage	Atrophies with age Proteoglycan subunits smaller Decreased cartilage water content Decreased lubrication of joint Vulnerability to injury	Weight-bearing activity thickens cartilage and facilitates diffusion of fluid into joint space
Cardiovascular	$\dot{V}O_{2max}$ decreases approximately 10% per decade HR_{max} decreases approximately 1 beat per year Decreased stroke $volume_{max}$ due to changes in contractility and total peripheral resistance Therefore, decreased cardiac output	HR_{max} appears unchanged with activity Maintenance of stroke $volume_{max}$ with continued activity $\dot{V}O_{2max}$ improves due to arterio-venous O_2 difference with exercise
Respiratory	Decreased vital capacity and FEV_1 Residual volume +30% by 50 years Increased residual volume *vs* total lung capacity = less efficient air exchange Decreased lung tissue and chest wall elasticity	Endurance training reduces loss of elasticity Increased sensitivity of ventilatory response to exercise, and less sense of breathlessness

a The information in this table on age-related changes in physical function and the reported benefits of habitual physical activity programmes for older people is based on the gerontology research of the authors and others (see American College of Sports Medicine,[6] Vandervoort[50] and Krishnathasan and Vandervoort[51] for recent reviews of the literature).

CSA = cross-sectional area; **FEV_1** = forced expiratory volume in 1 second; **HR_{max}** = maximal heart rate; **$\dot{V}O_{2max}$** = maximal oxygen uptake.

stems from the slowing in muscle fibre type composition and also connective tissue stiffening that occurs in older adults,[50,58,62] and also illustrates that weakness in old age is partly dependent on the context of how strength is measured.

3.2 Strength Training as a Form of Prevention/Rehabilitation

A few articles dealing with general conditioning programmes for senior golfers have been published which cover such areas as warming up, strengthening and stretching.[8,10,11] However, the information in these articles is quite general and not based on a rigorous controlled scientific research design. It is clear that there are very few studies in the published literature investigating the effects of strength training in senior golfers. Westcott and Parziale[11] used a combination of resistance training exercises and stretching in an 8-week programme for recreational golfers over 50 years of age. They observed large gains in leg muscle strength (approximately 50%), along with a significant increase in the maximal clubhead velocity achieved during post-tests of the golf swing. This increased velocity at ball contact would result in several more yards of driving distance.

Hetu et al.[12] also investigated the effects of 8 weeks of a general strength and flexibility training programme on clubhead speed in 17 recreational golfers (mean age 52.4 years). They also reported significant increases in strength (measured by 1 repetition maximum (RM) leg extension, 1RM chest press, and grip strength) and clubhead speed. However, as with the studies of Westcott and Parziale,[11] the research design did not include a control group.

While strength training benefits can thus be demonstrated for the golf swing, there has been a popular notion in the past among many golfers to refrain from such training because it might have a negative effect on golf performance (there are myths that training might possibly reduce their range of movement, increase bodyweight, increase blood pressure, increase arthritic and low back discomfort, and decrease swinging speed). There can be little doubt now that strength training is advantageous for golfers of all ages, but especially for seniors. Older adults who remain active exhibit only moderate losses in skeletal muscle mass and strength compared with sedentary controls.[62,66]

Porter et al.[63] reported in their review that high intensity training (>70% 1RM) leads to greater strength gains in older persons than low intensity training, although even the latter type of programme can have value in a very old, sedentary population.[67] Recent research on eccentric loading seems to indicate that this form of exercise may be particularly useful for prescribing high intensity workouts for older people. As noted above, as a person ages some of the changes in the neuromuscular system such as muscle slowing and stiffening may actually facilitate eccentric type movements. Therefore the mechanical overload which can be produced in the eccentric phase of muscle movement is considerably higher than during shortening, and could be a large stimulus for muscle hypertrophy (see Vandervoort[50]). Use of animal models with a stretch overload stimulus similar to eccentric loading in humans shows it has a powerful effect on muscle protein synthesis and growth, possibly due to a mechanism known as muscular supercompensation.[68]

Also of relevance to senior golfers is the issue of whether strength training can help to improve motor control of actions related to the golf swing. The possible mechanisms are first to achieve a greater ability to activate high threshold motor units and then learn possible adaptations in the firing rates of these activated motor units.[69] This learning can occur fairly quickly in a programme; increased peak torque production after just 2 weeks of isokinetic training at high velocities was observed by Connelly and Vandervoort[70] in their study of ankle muscles of older adults, and the augmentation was linked to greater surface EMG recordings over the primary muscle mover. A final note is that this type of eccentric isokinetic loading appears to elicit a relatively lower cardiovascular stress as compared to concentric exercises, both in terms of heart rate increases and elevation of blood pressure.[71]

Since there is evidence that motor learning does indeed occur during resistance training with skilled high velocity movements, it would seem logical to design exercises which simulate the golf swing, thereby stimulating adaptation within the appropriate musculature and neural pathways. Analysis of the pattern of the modern golf swing demonstrates a highly effective use of the stretch-shortening cycle of muscle contraction[72] for optimal power generation. During the slow backswing, key muscles of the target side trunk and upper limb are being lengthened in a controlled manner, and thus primed to contract powerfully on the downswing. The timing of this cycle is critical to execute the stretch-shortening manoeuvre effectively: the pause in the transition phase has to be kept very brief. Hence, exercises which mimic this pattern and strengthen in both a concentric and eccentric mode are advisable.

3.3 Muscular Endurance Changes in the Aging Golfer

Although there has been no research conducted to date on age-related changes in muscular endurance in the aging golfer, there have been several published articles dealing with muscular endurance in older people.[73-75] A recent review article by Bemben[76] has summarised these findings with the conclusion that, on a relative basis, older adults have similar muscular endurance capacity to young adults, but also that their ability to carry an absolute load over time is reduced. He also suggested that assessment of muscular endurance, rather than absolute strength, is perhaps a more practical measure of neuromuscular function especially in the elderly. This belief seems logical when considering how infrequently maximal force is required during normal daily activities. Voss[77] has stated that the most common cause of all sports injury is poor physical condition and fatigue. Fatigue is believed to adversely influence coordination and reflexes and thus contribute to injury. Others even suggest that muscle fatigue may be a possible aetiological factor in stress fractures.[40]

Age-related changes in muscle morphology affecting muscular endurance may be related to changes in fibre type with age, changes in fibre size and number, muscle blood flow and capillarity, and changes in muscle metabolism (i.e. substrate availability and oxidative capacity).[76] Roos et al.[78] observed that older persons took significantly longer to recover from a strenuous bout of fatiguing muscular exercise than young controls. Parnianpour et al.[79] have reported that fatigued muscles were slower and took longer to accommodate to changes in load. They also found trunk rotation and lateral bending to increase as fatigue develops during repeated sagittal trunk movements against a fixed load. Suzuki and Endo[80] have shown that fatigue developed faster in the abdominal muscles than in the back muscles and the fatigability of the abdominal muscles in the patients with low back pain was significantly greater than that in the control group.

3.4 Muscular Endurance Training as a Form of Prevention/Rehabilitation

There is a lack of published research investigating the effects of muscular endurance training in older golfers. McGill[57] stated that with respect to back rehabilitation an emphasis should be placed on endurance, and this should precede strengthening efforts in a gradual, progressive exercise programme, since the few studies available suggest that endurance has a much greater prophylactic value than strength. It would appear that as long as the intensity and duration of the endurance training are adequate, elderly skeletal muscle can adapt in a fashion similar to that of young skeletal muscle.[76] Also commonly stated is that weakness and lack of endurance of the trunk muscles seem to be significant risk factors in the development and occurrence of chronic low back pain.[81-83] It is clear that there is a need for controlled research studies to investigate the most effective type of muscular endurance training for older golfers. Such research would permit development of specific training programmes for senior golfers rather than using current programmes which were developed for a younger population.

3.5 Flexibility Changes in the Older Golfer

Significant reductions in active and passive range of motion have been reported in comparisons of joint flexibility between young and older adults.[84-86] Shephard[86] noted that about 80% of a sample of men and women between 55 and 64 years of age had signs of osteoarthritis in some joint of the body. Osteoarthritis is a form of chronic arthritis chiefly found in the elderly, which is marked by degeneration and hypertrophy of the bone and cartilage and thickening of the synovial membrane. The osteoarthritic joint has a greater resistance to the movement of the bones forming the joint, and in more severe cases there is pain upon initiation of a movement.

Thériault and Lachance[1] suggested that reduced shoulder flexibility with the onset of articular degenerative processes, acromioclavicular joint arthrosis with secondary osteophytes, was a common problem for older golfers. These degenerative changes could lead to impingement syndromes and muscle imbalances around the glenohumeral joint.

Morgan et al.[14] found that trunk lateral bending range of motion measured during the golf swing of senior golfers (mean age 65 years) was 25% less than that recorded from college players (mean age 19 years). Axial rotation also decreased, although the amount was not reported. The authors commented that the decreased range of motion was partly the expected sequelae of aging and lost flexibility.

3.6 Flexibility Training as a Form of Prevention/Rehabilitation

Westcott and Parziale[11] conducted a study on 8 recreational golfers (mean age 55.7 years) who participated in an 8-week programme of flexibility exercises. The results of this study indicated that senior golfers could improve flexibility and club head speed without an increase in spinal torque. Similar findings with a similar stretching programme were also reported by Jones[87] in a group of golfers with a mean age of 58 years. Munns[88] conducted a 12-week programme of more general exercises and dance movements, with participants aged between 65 and 88 years. The range of motion of the participants was significantly increased compared with a control group in the 6 limb joints tested.

3.7 Speed of Movement Changes in the Older Golfer

Spirduso[89] has reported that neuromuscular efficiency declines with age. Motor performance is not only slower but is less consistent.[3] The possible reason proposed by Spirduso[89] for this reduced speed of movement with age was less oxygenation of the brain cells causing impaired central nervous system functioning and reduced cerebral blood flow. Maximal speeds of nerve conduction velocity also decrease with age, which has a detrimental effect on motor coordination.[85] Larsson et al.[60] have reported that lower limb maximal speed of movement decreased by 7% between the third and seventh decades. Their results of muscle biopsy analysis revealed a selective loss of type II muscle fibres with a corresponding increase in type I fibres with age. In addition, these researchers noted a parallel decrease in the average cross-sectional area of type II fibres with no significant linear change in the type I fibre area. The loss of type II fibres would seem to explain the slower speed of movement which is characteristic of older individuals.

Morgan et al.[14] have also showed such a decrease in speed of movement amongst older golfers. Lumbar axial rotational velocities were calculated for college age golfers (mean age 19 years), adult golfers less than 50 years of age (mean age 36 years) and senior golfers over 50 years of age (mean age 65 years). Maximum values in degrees/second were found to be 202 ± 19, 143 ± 44 and 115 ± 50 for the 3 groups, respectively, and the difference was significant between the youngest and oldest ages.

However, it is encouraging to note that speed of movement and power development can be improved in older adults with specific training exercises.[90] Of particular interest to senior golfers are resisted movement patterns that mimic the swing, such as exercising with a specially weighted golf club, a golf trainer device that utilises a regular golf grip plus elastic tubing, and plyometric routines which emphasise arm and trunk rotational exercises.[51,91]

Finally, one sign of a properly executed golf swing is to observe powerful, yet controlled downward and follow-through movements that allow the individual to stay in balance. However, the ability to maintain proper balance may also be compromised with aging,[85,86] because of changes in the several body systems that maintain postural control: muscular, skeletal, neural and cardiovascular (in terms of regulating blood pressure during standing and also responding to sudden alterations in position). Thus, dealing with an older adult who has balance problems involves complex assessment and treatment approaches which can result in considerable enhancement of function, but are beyond the scope of this review.[92]

3.8 Bone Changes in the Aging Golfer

When considering bone changes in older individuals, golf poses a unique situation since many individuals play more frequently as they get older. Bones are highly dynamic, rigid structures that undergo a gradual loss of mineralisation with increasing age, leading to weakened bone in a natural process called osteopenia. Over a lifetime, women may lose 35% of their cortical bone and 50% of their trabecular bone,[91] with initial losses of 0.3 to 0.5% per year beginning around age 30 years. The loss of trabecular bone begins a decade earlier than cortical bone loss in both sexes, and cortical bone loss seems to be sensitive to change in menstrual status in women. Men commonly lose two-thirds of the bone that women lose over a lifespan, and may not encounter difficulties until their eighth decade. At menopause and continuing approximately 2 years thereafter, the rate of cortical bone loss in women reaches 2 to 3% per year, and then slows exponentially.[93] The main contributors to bone loss are changes in levels of bone-related hormones, dietary deficiencies and decreased daily exercise.[89]

If precautions are not taken, bone loss can lead to osteoporosis, the greatest skeletal threat facing the elderly. Its aetiology is multifactorial with genetics, hormone levels, calcium uptake and physical activity all implicated.[94] Older golfers who are unaware they have osteoporosis are particularly at risk given the amount of repetitive twisting involved with increased play and practice.[39]

3.9 Prevention of Bone Injuries

Prevention of osteoporosis is focused on development and maintenance of a large bone reservoir, which can be accomplished in part with a healthy diet and by remaining active.[89] Research has shown that gravitational loading and muscular traction have the effect of increasing thickness, strength and calcium concentration of osseous tissues while physical activity has been shown to counteract or even reverse the demineralisation of bone.[92] In an extensive review of studies on athletes that used a cross-sectional research design, Suominen[95,96] concluded that postmenopausal female athletes generally have a greater bone mass than nonathletic females. However, this difference in bone mass is less pronounced than is found between male athletes and sedentary controls. In addition, middle-aged and elderly male athletes were noted to have significantly higher bone mineral density (BMD) and content (BMC) than sedentary individuals. Long term training has been shown to result in higher calcaneal BMD and BMC in 70-year-old individuals than less active controls.[97] Increases in bone mineral content have been found at lumbar vertebral and distal radial sites in women who participate in an exercise regimen.[39] These findings strongly support the notion that exercise is a key factor in preventing age-related bone loss. Currently, most physicians prescribe weight bearing exercise, estrogen replacement therapy, and calcium and colecalciferol (vitamin D) supplementation to help prevent osteoporosis.[39] Thus, golf as a form of exercise is an excellent method of prevention for this age group provided it is started when the skeletal system is still healthy and not prone to stress fractures. However, older women with a risk profile for osteoporosis are well advised to seek medical clearance before playing.

4. Changes in the Cardiorespiratory System in the Aging Golfer

Cardiac output declines on average about 30% in the aging individual between 30 and 70 years of age, due to decreases in heart muscle mass and contractility.[3,6] These changes result in a decrease in stroke volume of the heart in the aged, which is 15 to 20% less than in the young. Blood pressure increases of 10 to 15mm Hg in systolic pressure and of 5 to 10mm Hg in diastolic pressure may also be present because of increased peripheral resistance to blood flow related to a stiffening of the walls of the arteries and/or fatty deposits forming on the walls of the blood vessels. Similar deterioration takes

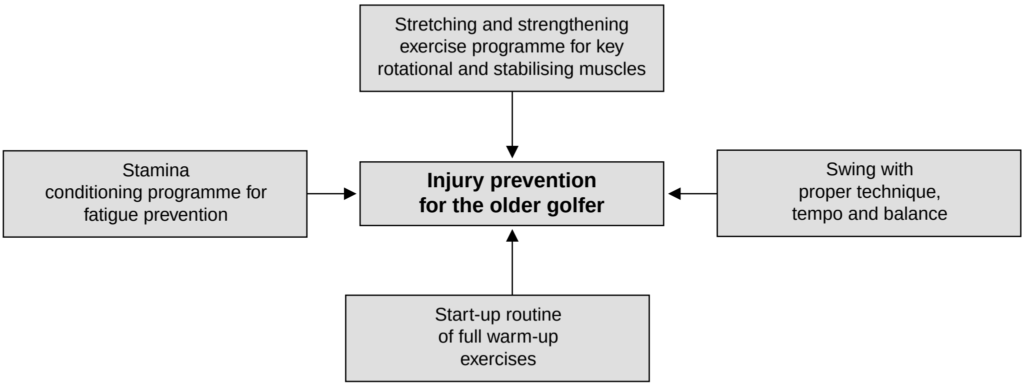

Fig.1. The 'foursome' of injury prevention for strategies for the older golfer.

place in the sedentary older person's respiratory system, due to reductions in the lung elasticity and increased resistance to flow in the airways. These conditions may have a pronounced effect on the senior's golf game, especially in the final holes of an 18-hole round.

4.1 Cardiorespiratory Conditioning

American College of Sports Medicine (ACSM) guidelines suggest that individuals should perform aerobic exercise for 20 to 30 minutes a day, 3 times per week at 60 to 80% $\dot{V}O_{2max}$, to improve cardiovascular function.[5,6] Although the cardiovascular demands of playing golf estimated by Murase et al.[5] are not quite as intense as the preferred recommendations by the ACSM, recent studies have demonstrated that mild to moderate exercise such as walking or cycling can be effective in increasing aerobic capacity, especially in elderly persons, and can also be beneficial in lowering blood pressure in hypertensive patients.[6]

Research has shown that regular physical activity is associated with a decreased incidence of coronary heart disease and increased longevity.[22,97,98] One mechanism of prevention is the altering of plasma lipid and lipoprotein levels towards a more favourable profile; high-density lipoprotein cholesterol has been shown to have an inverse effect on the development of coronary heart disease.[22,99] Palank[100] reported on the effect of walking the golf course in 28 previously sedentary male golfers (aged 48 to 80 years, median age 61 years), comparing them with 16 older men who did not engage in any regular exercise. The study results suggested that the walking exercise during golf participation appeared to significantly reduce low-density lipoprotein cholesterol levels and improved the ratio of total cholesterol to high-density lipoprotein cholesterol. Finally, it is important to note that these types of health benefits would be negated by riding in a power cart, and it is highly recommended that older golfers find and be given opportunities to play where they can comfortably and safely walk the entire course.

5. Conclusion

The literature shows that golf presents both potential health benefits and risks for senior players. The health risks are compounded by the fact that the musculoskeletal and cardiovascular systems of senior players may not be as efficient as they were at a younger age. Fortunately, the literature also suggests many of the age-related changes affecting older players are preventable or treatable through exercise. Therefore, conditioning programmes based on a 'foursome' of prevention strategies – including stretching and strengthening of muscles, starting a golf game with a full warm-up, swinging with a proper technique, and having sufficient stamina for a full round (fig. 1) – are highly recommended for older persons who wish to play golf. Not only can the programmes prevent injury, they also have the potential to improve performance. Programmes which incorporate flexibility, strength, endurance, speed and balance exercises that are specifically tailored to the demands of golf are likely to be the most effective. While expensive gym machines and other devices are available, equipment does not always need to be elaborate. Home-based programmes incorporating bodyweight, weighted clubs or elastic tubing resistance can be utilised. Future research needs to focus more specifically on injury incidence and mechanisms amongst senior golfers as well as using randomised controlled trial designs to investigate the efficacy of specific golf-related exercise regimens in this population.

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