Static and Dynamic Balance Control in Older Golfers

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Running title: Golfing improves balance control

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Abstract

**Purpose.** To examine whether older golfers had better static and dynamic balance control than older but non-golfing healthy adults.

**Methods.** Eleven golfers and twelve control subjects (all male; 66.2±6.8 and 71.3±6.6 years old, respectively) were recruited. Duration of static single-leg stance was timed. Control of body sway was assessed in single-leg stance during forward and backward platform perturbations. The lunge distance normalized with respect to each subject’s height was used to compare the two groups in a forward lunge test.

**Results.** Golfers maintained significantly longer duration in static single-leg stance. They achieved less anteroposterior body sway in perturbed single-leg stance and lunged significantly farther than did control subjects.

**Conclusions.** The better static and dynamic balance control exhibited by older golfers possibly reflect the effects of weight transfers from repeated golf swings during weight shift from 2-leg to predominantly 1-leg stance and from walking on uneven fairways.

**Key Words:** Aging; Golfing; Balance control.
Introduction

Falls have been identified as one of the major causes of morbidity and mortality in older adults (Carter, Kannus, & Khan, 2001; Tinetti, Gordon, Sogolow, Lapin, & Bradley, 2006). In Western countries, 32% of community-dwelling older subjects over the age of 75 were reported to have fallen at least once in the previous year (Tinetti, Speechley, & Ginter, 1988). In Hong Kong, Ho and colleagues (1996) conducted a similar cross-sectional study among Chinese aged 70 years and above, to estimate the occurrence of falls. Eighteen percent of the 1,947 subjects who could walk either independently or with aids reported at least 1 fall in the previous 12 months. Among these, 40% were multiple fallers. About one-third of the falls resulted in soft tissue injuries, with 4.6% of the falls in men and 8.5% in women resulting in fractures. In the United States, the cost of hip fractures in the older population attributable to falls was reported to be about $10 billion in 2001 (Carter, Kannus, & Khan, 2001). The risk of bone fractures due to falls could become a major financial burden to society.

Among the various intrinsic and extrinsic causes of falls, impaired postural control has been identified as a major intrinsic factor in older adults (Berg & Kairy, 2002; Carter, Kannus, & Khan, 2001; Lin & Woollacott, 2002; Shumway-Cook, Ciol, Gruber, & Robinson, 2005). Golf is a postural challenging sport that is popular among older people. A complete golf swing takes less than 2 seconds (Selicki & Segall, 1996). Hitting the ball in the right direction and to an accurate location requires golfers to develop a highly precise and efficient swing motion. With repeated practice, golfers aspire to be able to execute accurate shots in a reproducible and consistent manner. It is believed that poor trunk motion will affect the golf swing, shoulder turn, and weight shift, leading to
inaccurate shots (Draovitch, Pete and Westcott, Wayne, 99). In other words, golf demands sensory, motor and dynamic postural control with precise trunk motion and appropriate weight shifting from both legs to predominantly 1 leg during end-swing (Okuda, Armstrong, Tsunezumi, & Yoshiike, 2002).

In a previous study, we showed that older golfers (mean age, 66.2 years) had significantly better knee joint proprioception and limits of stability during double-leg stance than control subjects similar in age, gender (male), and physical activity level. Of particular interest were our results showing that the acuity of their knee joint proprioception, as well as the maximum excursion and the directional control of their normalized center of pressure during weight shifting within their base of support, were comparable to those of younger subjects (mean age, 20.3 years) (Tsang & Hui-Chan, 2004a).

Falls seldom occur during double-leg stance when the center of mass is well within the base of support. Often they happen during walking, turning, ascending or descending stairs (Nevitt, Cummings, & Hudes, 1991). Thus, any evaluation of balance control confined to double-leg stance alone may not reflect the functional performance required of older people in certain activities of daily living. A round of golf (18 holes) usually involves 8 km of walking and takes approximately 4 hours to play (Parkkari, Natri, Kannus, Mänttäri, Laukkanen, Haapasalo et al., 2000; Stauch, Liu, Giesler, & Lehmann, 1999). Since walking consists of double-leg as well as single-leg support phases, walking on the uneven golf fairway may enhance balance performance in single-leg stance.
In a review study, Horak et al. (1997) reported that 35% of falls among older persons could be due to inadequate responses to perturbations caused by external displacements of the body’s center of mass. They noted that balance control in response to environmental perturbations is important, as part of effective postural control during functional activities. Indeed, the support surface is not always stationary when one conducts daily activities such as stepping onto a moving escalator or walking in a moving bus. Such daily activities will demand greater balance control and could pose particular problems to older adults. Weight-shifting from 2 legs to predominantly 1 leg while moving the trunk and arms in a precise golf swing is an activity which would demand a high level of balance control. Extrinsic causes such as uneven ground and obstacles in the environment, combined with intrinsic causes of poorer balance in the older adults may precipitate them to fall (Li, Keegan, Sternfeld, Sidney, Quesenberry, & Kelsev, 2007). Also, activities of daily living demand multi-dimensional complex tasks which require multi-joint co-ordination, lower limb muscle strength, and single-leg stance control. Golfing 18 holes often involves walking with double- and single-leg support up and down hills and sometimes through bunkers (Parkkari, Natri, Kannus, Mänttäri, Laukkanen, Haapasalo et al., 2000; Stauch, Liu, Giesler, & Lehmann, 1999), activities which may promote balance control in both static and perturbed single-leg stance, as well as multi-dimensional balance tests. Therefore, the objective of the present study was to compare balance control between older golfers and healthy controls.

**Methods**
Participants

Eleven subjects with a mean age of 70.8 years (± standard deviation, 4.0 years) were recruited in a pilot study to examine test-retest reliability. Of the 23 main study participants, 11 male golfers (mean age, 66.2 ± 6.8 years) were recruited from local golf clubs and had practiced golf for a minimum of 1.5 hours a week for at least 3 years (mean golf experience, 15.2 ± 13.4 years). The remaining 12 healthy male subjects (mean age, 71.3 ± 6.6 years) were recruited from community centers and who had no previous experience in golf, though some took morning walks or did stretching exercises. All participants were independent in their activities of daily living and none required walking aids. They were able to communicate and follow the testing procedures. Candidates with poorly controlled hypertension, those showing severe cognitive impairment (Mini-Mental Status Examination score < 24, see below) or diagnosed with metastatic cancer, Parkinson’s disease, stroke or any other neurologic disorder were excluded. Also excluded were people diagnosed with cardiovascular diseases, symptomatic orthostatic hypotension, peripheral neuropathy of the lower extremities, or disabling arthritis which prevented them from completing the balance tests in the study. In addition, subjects who reported a history of fall in the past 12 months, either injurious or non-injurious, were excluded.

Candidates were first interviewed using a general health questionnaire and a physical activity questionnaire. The validated Chinese version of the Mini-Mental Status Examination of Folstein et al. was then administered (Chiu, Lee, Chung, & Kwong, 1994), with a scale ranging from 0 to 30. A score below 24 was considered indicative of cognitive dysfunction, and such subjects were excluded from the study. A modified
version of the Minnesota Leisure Time Physical Activity Questionnaire (Tsang, Wong, Fu, & Hui-Chan, 2004; Tsang & Hui-Chan, 2003; Tsang & Hui-Chan, 2004a) was used to compare the physical activity levels of the golfers with those of the control subjects. This instrument evaluated the energy expended in leisure-time physical activities and household tasks (Van Heuvelen, Kempen, Ormel, & Rispens, 1998). The activities were categorized according to their metabolic equivalent (MET) status as either light (intensity ≤ 4.0 METs), moderate (4.0 METs < intensity ≤ 5.5 METs), or heavy activities (intensity > 5.5 METs). This project was approved by the Ethics Committee of The xxx University, and written informed consent was obtained from all subjects before study commenced.

Experimental Procedures

Three tests were conducted, namely 1) static single-leg stance; 2) single-leg stance in response to external perturbations; and 3) a forward lunge test which was more multi-dimensional than traditional balance tests and incorporated multi-joint coordination and muscle strength.

*Single-leg stance.* Timed single-leg stance has frequently been employed as a clinical tool for assessing balance control in patients with balance disorders. In a cross-sectional study, Hurvitz and colleagues (2000) found that subjects (mean age = 69.8 years) who had a history of falls showed significantly poorer results in timed single-leg stance when compared with slightly younger subjects (mean age = 63.2 years) without a history of falls. In this study, subjects performed a single-leg stance test on their dominant leg by standing on a force platform (Kistler, model 9286AA, Switzerland) with their eyes open and arms by their side. The leg used to kick a ball was defined as the dominant leg (found
to be the trailing leg of all golfers participated in this study). Subjects were instructed to keep their non-dominant leg off the ground and flexed 90° at the knee, with the hip in a neutral position for a maximum of 30 seconds (Bohannon, 2006). A second force platform was used to record the duration of single-leg stance on the dominant leg (in seconds) by timing the moment when the non-dominant leg landed on it. After familiarization, 3 trials were recorded. The mean standing duration was used to compare the balance control of single-leg stance between the two groups.

**Perturbed single-leg stance.** The test procedure has been detailed in our previous paper (Tsang & Hui-Chan, 2005), and is therefore only highlighted here. Wearing a security harness, with their feet at shoulder width, subjects stood without shoes on a computerized dynamic posturography machine with a movable platform (NeuroCom International Inc., type Smart EquiTest®, Portland). They were asked to stand still, with the same instructions as those in the static single-leg stance test. They were told that the perturbation could start any time as soon as they flexed the non-dominant knee. Subjects were then perturbed with forward and backward platform translations in a random order. To minimize their anticipation, perturbations were initiated after a random delay of 2 to 7 seconds. The computerized dynamic posturography equipment scaled the platform translation amplitudes according to the subject’s height, to give a maximum anteroposterior body sway angle of 3.2° (NeuroCom, 2002). Translation lasted for 400 ms. The center of pressure (COP) was measured by 4 sensors mounted on the support surface. This was used to estimate the actual anteroposterior (AP) body sway angle of the subjects during perturbations. The average of the maximum AP body sway angles
recorded over 3 trials was used to compare the balance control of the 2 groups for each perturbation direction (Tsang & Hui-Chan, 2005).

**Forward lunge test.** The forward lunge test has been frequently used to assess athletes’ fitness (Alkjær, Simonsen, Magnusson, Aagaard, & Dyhre-Poulsen, 2002). The test involves lunging one step forward using either the dominant or non-dominant leg, to evaluate subject’s balance performance and lower limb co-ordination and joint stabilization as reflected by agonist-antagonist co-contraction (Mattacola, Jacobs, Rund, & Johnson, 2004). Subjects were instructed to stand in an upright position on a rectangular force platform that consisted of 2 9-inch by 60-inch foot-plates (NeuroCom International Inc., type Smart EquiTest®, Portland). They were instructed to perform a forward lunge by taking 1 step forward as far and as fast as they could. After landing on the force platform, subjects flexed the knee of the lunged leg. They then extended that knee to move it back to the starting position as fast as possible (NeuroCom, 2002). Their arms were by the side of their body in the starting position, and free to move to maintain balance if necessary during test. Practice trials were given to familiarize the subjects with the testing procedure. Afterwards, 3 trials were given for each leg, and the average distance of the forward lunge, expressed as a percentage of body height and termed the **normalized lunge distance**, was computed for comparison between the 2 groups (NeuroCom, 2002).
Data Recording and Analysis

**Perturbed single-leg stance.** The COP, as measured by the 4 sensors attached to the force platform, was recorded and used to calculate the amount of body sway, termed *body sway angle*, during the perturbed single-leg stance (Tsang & Hui-Chan, 2005). The latter was used in this study to compare the control of body sway between the 2 groups. Similar to our previous studies (Tsang, Wong, Fu, & Hui-Chan, 2004; Tsang & Hui-Chan, 2004b; Tsang & Hui-Chan, 2004a; Tsang & Hui-Chan, 2005) each subject’s body sway was first recorded for 2 seconds before any platform translation. The average value of the body sway angle during these 2 seconds was computed and served as the baseline value. The maximum body sway angle during perturbation was then estimated, and the difference from the baseline value, termed the *perturbed body sway angle*, was calculated. A total of 3 trials were performed for each perturbation direction, and the average value was used to compare the 2 groups. If any subject fell during the platform perturbation, the theoretical anteroposterior sway stability limit of 12.5° was treated as the perturbed body sway angle (NeuroCom, 2002). A “fall” in the perturbed single-leg stance test was recorded when the subject began to fall and touched the visual surround for support, or gained support by using the non-dominant leg (NeuroCom, 2002).

Statistical Analysis

Age, weight and height were compared between the 2 groups using independent t-tests. Because of the categorical nature of physical activity levels, a chi-square test was used for between-group comparison. An intraclass correlation coefficient was applied to assess the test-retest reliability of single-leg stance duration, body sway angle during
perturbed single-leg stance, and normalized lunge distance in the forward lunge test. The ICC model 3, denoted by ICC(3,3) was used for assessing intra-rater reliability, with the latter “3” denoting the number of trials used in the balance tests. As shown in Table 1, the golfers were 5.1 years younger on average than control subjects ($p = 0.079$). Although this difference was not statistically significant, age was treated as a covariate in the analysis of all balance tests. A univariate test with age as covariate was employed to compare the duration of single-leg stance between the older golfers and the control subjects. Multivariate analysis of co-variance was used to compare the perturbed single-leg stance and forward lunge test results between the 2 groups. If statistically significant differences were found in the overall multivariate tests, a univariate test was conducted for each of the measures. A significance level ($\alpha$) of 0.05 was chosen for statistical comparisons.

**Results**

**Participants**

Independent t-tests showed that there was no statistically significant difference in age, height, or weight between the golfers and control subjects ($p > 0.05$; Table 1). A chi-square test also found no statistically significant difference between the 2 groups in physical activity level ($p = 0.269$; Table 1). The golfers and control subjects were thus similar with respect to age, height, weight, gender, and physical activity levels.

**Test-retest Reliability of Single-leg Stance, Perturbed Single-leg Stance and Forward Lunge Test Results**
The balance control tests were re-administered to subjects in the pilot study 1 week after the first assessment. For single-leg stance, the ICC(3,3) value for stance duration was 0.99 (confidence intervals or CI 0.94–0.99). For perturbed single-leg stance, the ICC(3,3) values for the maximum AP body sway angles in forward translation and backward translation were respectively, 0.81 (CI 0.51–0.93) and 0.74 (CI 0.35–0.90). The ICC(3,3) values for the lunge test in stepping forward onto their dominant and non-dominant legs were, respectively, 0.90 (CI 0.58–0.97) and 0.93 (CI 0.73–0.98). The ICC values found in this study ranged from 0.74 to 0.99. Therefore, all the tests used in this study have produced reliable measures. However, the confidence intervals for backward translation of the perturbed single-leg stance test was large (CI 0.35–0.90). This might be due to the small sample size in the reliability test (n = 11).

**Balance Tests**

Univariate analysis test of single-leg stance results indicated that the golfers achieved significantly longer stance duration (average, 28.1 ± 3.6 seconds) than the control subjects (average, 17.1 ± 11.9 seconds; \( p = 0.020 \); Figure 1a). Multivariate test results of the perturbed single-leg stance indicated an overall statistically significant effect across the 2 measures between golfers and control subjects (\( p = 0.023 \)). Univariate tests showed that golfers had smaller body sway angles during forward platform translation (mean, 6.0 ± 2.7°) than control subjects (mean, 9.5 ± 3.1°; \( p = 0.005 \); Figure 1b), as well as during backward platform translation (means, 6.1 ± 2.3° and 9.0 ± 3.4°, respectively; \( p = 0.041 \)).
Multivariate tests of the forward lunge results indicated an overall statistically significant difference across the 2 measures between golfers and control subjects \( (p = 0.032) \). Univariate tests showed that the golfers performed larger normalized lunge distance onto both dominant \( (\text{average} = 54.1 \pm 4.5\%) \) and non-dominant legs \( (\text{average}, 53.8 \pm 4.8\%) \) when compared with control subjects \( (46.0 \pm 9.1\%; \ p = 0.014 \) and \( 46.7\% \pm 10.0\%; \ p = 0.043 \), respectively; Figure 1c).

**Discussion**

**Golf and Health Benefits**

Shatil and Garland (2000) prescribed a therapeutic golf program for patients suffering from stroke. The authors suggested that therapeutic effects of golf training could include midline postural alignment, trunk rotation with large shoulder girdle movement, weight shifting and eye-hand coordination. However, they produced no data to demonstrate the effectiveness of such a program. Our previous findings showed that older golfers manifested greater limits of stability during double-leg stance, when they were instructed to shift their weight to 1 of the 8 target positions, pre-selected in a random order, as quickly and smoothly as possible without moving their feet (Tsang & Hui-Chan, 2004a). In a well-executed golf swing, golfers must maintain good balance during weight-shift between the 2 legs and precise control of the posture of the head-and-body in relation to space and to the limbs, as well as timely coordination of their muscle activities. These requirements might have promoted balance control with repeated golf practice over time \( \text{(mean golf experience, 15.2 years)} \) (Tsang & Hui-Chan, 2004a). In the present study, older golfers demonstrated significantly longer duration in single-leg stance, achieved less body sway in single-leg stance under perturbation, and lunged
farther in the forward lunge test than did the control subjects (all $p < 0.05$; Figure 1). A question may arise as to why golfers had better balance performance during single-leg stance when golf practice mainly involves double-leg stance.

**Golf and Balance Control**

Parkkari and colleagues (2000) studied the health benefits of golf by recruiting 55 healthy male golfers, aged 48 to 64y, who stopped golfing for 7 months prior to the investigation. During the 20-week study period, these golfers played golf an average of 10 hours per week. The investigators found that the golfers improved significantly in treadmill walking time and static back extension time when compared with age-matched sedentary controls without any intervention. They attributed the improvement observed in golfers to the regular walking on the golf course, estimated to be 20 km per week. Note that a usual gait cycle involves approximately 20-25% double-leg support for older adults, while the remainder of the cycle is spent on single-leg support (Oatis, 2004). Thus, walking could facilitate balance control on 1 leg and weight transfer to the other (Hurvitz, Richardson, Werner, Ruhl, & Dixon, 2000). Consequently, prolonged walking especially on uneven or hilly golf courses could enhance balance control during single-leg stance. In this study, golfers achieved 64% longer single-leg stance duration than control subjects (Figure 1a). Since older fallers (average age, 69.8y) had significantly shorter single-leg stance duration (mean, 9.6 seconds) than non-fallers (Hurvitz, Richardson, Werner, Ruhl, & Dixon, 2000), our findings imply that the improved single-leg stance in experienced golfers may reduce their risk for fall. Moreover, falls resulting from perturbations caused by external displacements of the body’s center of mass are not uncommon (Horak, Henry,
& Shumway-Cook, 1997). In the present study, golfers demonstrated significantly less body sway than control subjects in response to both forward (37% less, \( p = 0.005 \); Figure 1b) and backward platform translations (32% less, \( p = 0.041 \)). Therefore, older golfers who are better able to maintain balance control in the face of perturbations could be expected to experience fewer falls. If so, golf could be a good balance training approach for older adults.

The golfers’ balance performance in perturbed single leg stance in this study was comparable to that of older Tai Chi practitioners (average age, 69.3 years) reported in our previous study (Tsang & Hui-Chan, 2005). The Tai Chi subjects in that study underwent the same assessment protocol and had average body sway angles of 7.2° and 6.2° in response to forward and backward perturbations. Their performance was also significantly better than that of control subjects similar in age and physical activity level. Note that Tai Chi requires constant weight shifting between double-leg and single-leg stances. Also, the execution of various arm and leg movements in a coordinated manner during single-leg stance demands a high degree of balance control (Tsang & Hui-Chan, 2005). A round of golf usually involves 8 km of walking, often over uneven ground, up and down a hilly course, and sometimes through bunkers. These activities would also provide good balance training for older people. In a previous study (Tsang & Hui-Chan, 2005), we demonstrated that body sway during single-leg stance in older subjects subjected to forward and backward platform perturbations was negatively correlated with their balance confidence as measured by the Activities-Specific Balance Confidence Scale. The better balance control in response to standing perturbations shown by the
golfers may have given them better balance confidence. This might help them maintain their physical activity level and reduce the risk of their falling as they age further.

In this study, golfers could lunge significantly farther than control subjects, both when lunging onto their dominant leg (18% farther, \( p = 0.014 \); Figure 1c) and non-dominant leg (15% farther, \( p = 0.043 \)). Lunging is commonly used in the sports field to assess lower extremity flexibility, muscle strength and balance, because the ability to quickly finish a lunge and return to a standing posture is important for success in sports such as squash, fencing and basketball. Alkjaer et al. (2002) conducted a study to determine the differences in movement pattern during a forward lunge as a result of anterior cruciate ligament deficiency (average age, 29.4 years) using kinematic, kinetic and electromyographic recordings. They found that the lunging knee reached an average of 80° flexion, followed by its extension being controlled by eccentric and concentric contractions of the quadriceps. The hamstrings were shown to be active during the lunging process both in the patients who could cope with their sporting activities and in healthy control subjects. In contrast, the contraction of the hamstrings was significantly lower in those who could not participate in sports. The authors attributed the stability of the lunging knee joint to better co-contraction of the hamstrings.

What is the role of the support leg during the test? In this connection, Pijnappels et al. (2005) investigated the contribution made by the support leg muscles in maintaining postural control after tripping (Pijnappels, Bobbert, & van Dieën, 2005), one of the main causes of falls (Nevitt, Cummings, & Hudes, 1991). Older adults and young subjects were asked to walk over a platform and the investigators tripped their swinging leg using an obstacle at different points in their gait cycle. They found that the magnitude and rate
of development of muscle activity in the support leg were significantly lower in older subjects, leading to inadequate recovery responses and falls. The better lunging performance of golfers may indicate better strength and motor control of both the lunging and support legs. However, further research is needed.

Golfing requires coordinated trunk and arm movements and controlled weight shifting from 2 legs to predominantly 1 leg during precise golf swings, as well as prolonged walking comprising single- and double-leg support over uneven ground (Selicki & Segall, 1996). Okuda et al. (2002) conducted a biomechanical analysis of swing of a professional golfer. Using the force platforms, the investigators found that the weight distribution were similar, with 49% and 51% of body weight of the leading and trailing legs respectively, at the starting position (address phase) of golf swing. The weight varied from 21% to 142% of body weight from top of swing to impact phases for leading leg, whereas values ranged from 85% to 32% from back swing to follow through phases of the trailing leg (Okuda, Armstrong, Tsunezumi, & Yoshiike, 2002). All these requirements may contribute to the better single-leg stance performance found in our present study. Rather than using a cart, older golf players should be encouraged to walk on the golf course, as it may enhance their balance control, as well as their cardiovascular system and muscle strength. With urbanization, older adults who reside in a city may no longer have much chance to walk on uneven and hilly ground. Golfing may provide an opportunity for people to exercise, not just in terms of the golf swing, but also to walk on the uneven terrain of the fairway, carrying bag, pulling or pushing bag cart. Since the metabolic demands of golfing activity are moderate (Ainsworth, Haskell, Leon, Jacobs,
Montoye, Sallis et al., 1993), it may provide an attractive outdoor exercise option for older people.

**Limitations of Study**

There are several limitations in the present study. Because of the cross-sectional study design, a causal relation between golfing practice and balance control could not be established. Although the golfers had shown significantly better performance in static and perturbed single-leg stance and forward lunge test (all $p < 0.05$), the sample size of the present study was relatively small. Also, the participants were healthy male subjects. This will limit the generalization of the present findings to older females and unhealthy males. The physical activity levels of the golfers and control subjects were compared using a questionnaire and found to have statistically insignificant difference. However, the higher number of golfers who achieved moderate activity level (5 out of 11 subjects) as compared with control subjects (2 out of 12) might have confounded the results. This is because higher physical activity may lead to better balance control, not necessarily golfing per se. In order to control these potential confounding factors, a prospective intervention design should be adopted next. Also, such a design may differentiate the causal effect of motor actions of golf versus walking the golf course to improve balance control. The forward lunge test, commonly employed to assess subjects with sport injuries in the lower limbs, was used to assess more complex balance control involving lower limb co-ordination and muscle strength in this study. However, its relationship to more functional balance control such as gait and fall reduction has not been established. Therefore, the present findings should be interpreted with caution.
Conclusions

There have been few investigations of the effect of golf on balance control in older adults. The improvements in static and perturbed single-leg stance and in the forward lunge test, together with the improvement in knee joint proprioception and in voluntary weight shifting in experienced golfers – respectively reported in our present and previous studies (Tsang & Hui-Chan, 2004a), suggest that golfing may improve balance control in older subjects. If so, the increasingly popular sport may have the potential to become part of a falls prevention program. Towards these goals, a prospective study examining the effect of golf on balance control is warranted.

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References


Figure Legend

Figure 1. Comparison of (a) single-leg stance, (b) perturbed single-leg stance, and (c) forward lunge test results between healthy control subjects and golfers.

Values are mean ± S.D.

* Denotes significant difference at $p < 0.05$ using univariate test.

** and † Denote significant difference at $p < 0.05$ and $p < 0.01$ respectively using univariate tests, after multivariate tests showing an overall statistically significant difference at $p = 0.023$ for the perturbed single-leg stance and at $p = 0.032$ for the forward lunge test.
Table 1  Comparison of age, height, body weight, and physical activity level between healthy control subjects and older golfers

<table>
<thead>
<tr>
<th></th>
<th>Control subjects</th>
<th>Golfers</th>
<th>P</th>
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<tbody>
<tr>
<td></td>
<td>(n = 12)</td>
<td>(n = 11)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>71.3 ± 6.6</td>
<td>66.2 ± 6.8</td>
<td>.079</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160.0 ± 6.2</td>
<td>164.5 ± 7.7</td>
<td>.135</td>
</tr>
<tr>
<td>Body Weight (kg)</td>
<td>62.4 ± 8.6</td>
<td>65.7 ± 7.7</td>
<td>.349</td>
</tr>
<tr>
<td>Physical activity levels (n)</td>
<td></td>
<td></td>
<td>.269</td>
</tr>
<tr>
<td>Light ≤ 4 METs</td>
<td>10 (83.3%)</td>
<td>6 (54.5%)</td>
<td></td>
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<tr>
<td>Moderate ≤ 5.5 METs</td>
<td>2 (16.7%)</td>
<td>4 (36.4%)</td>
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<tr>
<td>Heavy &gt; 5.5 METs</td>
<td>0 (0%)</td>
<td>1 (9.1%)</td>
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NOTE: MET is metabolic equivalent.
(a) Single-leg stance

\[
P = 0.020^*\]

(b) Perturbed single-leg stance

\[
P = 0.005^{+}\]

\[
P = 0.041^{**}\]
(c) Forward lunge test

![Bar graph showing average distance of the forward step, expressed as a percent of body height](image)

**Figure 1**