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Analysis of ipsilateral and bilateral ratios in male amateur golfers

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The number of injuries that force golfers to quit is also increasing. In particular, the upper body injuries are concerns for amateur golfers. This study was conducted not only to investigate muscular balance, such as ipsilateral and bilateral ratios of the upper body, but to also evaluate the possible problems of muscular joints in amateur golfers. Male golfers (n=10) and a healthy control group (n=10) were recruited for the assessment of muscular function in the upper body, which was measured by an isokinetic dynamometer at 60°/sec. The tested parts were trunk, wrist, forearm, elbow, and shoulder joints. Mann–Whitney *U*-test was used to evaluate the significance of the differences between groups. The ipsilateral ratios of peak torque or work per repetition (WR) of trunk flexor and extensor in the golfers were not significantly different compared to those of the control group. These results were similar to the shoulder horizontal abductor and adductor. However, there were significant differences in the ipsilateral and bilateral ratios of the wrist, forearm, and elbow joints. Especially, the WR of the wrist flexor, forearm pronator, and elbow flexor on the left side of amateur golfers showed imbalances in bilateral ratios. Moreover, the WR of the wrist and elbow flexors on the left side of amateur golfers were lower than those of the wrist and elbow extensors. Therefore, amateur golfers should strive to prevent injuries of the wrist, forearm, and elbow joints and to reinforce the endurance on those parts of the left side.

Keywords: Amateur golfer, Ipsilateral ratio, Bilateral ratio, Wrist, Forearm, Elbow

INTRODUCTION

In the early 1990s when the number of newly established golf courses was at its peak, new golf course visitors grew by 1 million every year. It was the golf industry in particular that experienced significant growth in visitors as well as the number of international tournaments. Moreover, higher income and increased leisure time as a result of the 5-day workweek policy in Korea allowed for more active participation in golf. Golf has now become an activity enjoyed by all people regardless of age, gender, social position, or financial status (Gluck et al., 2008; Lee and Jee, 2013). The number of golfers was estimated to be greater than 25 million in the United States (Hosea and Gatt Jr, 1996) and 55 million players have played on over 30,000 golf courses around world (Farrally et al., 2003). The number of leisure time golfers is ever increasing. However, the number of injuries that force golfers to quit the sport is also increasing. Injuries are a concern, especially for amateur golfers striving to become better players. As a result, there has been growing interest in studying and preventing such injuries.

Golf injuries occur during the swing phase. A golf swing is a high-torque and high lateral bending movement, for which the anatomy is poorly suited (Lee and Jee, 2013; Parziale and Mallon, 2006). Further complicating this problem is the tendency for many amateur golfers to use maladaptive swing techniques that adversely affect kinetic forces on the trunk, shoulders, and legs. A study of 30 novice golfers demonstrated a high prevalence of body

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weight shift to the incorrect foot at the top of the backswing (Koslow, 1994; Parziale and Mallon, 2006). Moreover, most golf injuries occur during the downward swinging phase, when the club head hits the ball, while lifting or moving equipment, or moving from one place to another (McCarroll and Gioe, 1982; Parziale and Mallon, 2006). The speed of the club-head just prior to hitting the ball is 160 km/hr which occurs within 0.2 sec. Since the ball hitting movements are repeated on an average of 50 times during a field rounding and 300 times during a practice session, serious injuries can easily occur to an amateur golfer. Batt (1993) reported that 32% of 193 amateur golfers reported injuries from playing golf. Recently, Gosheger et al. (2003) also represented a higher number of injuries (2.07 per player) in amateur players than did comparable previous studies by Batt (1992) and McCarroll et al. (1990). It seemed to be reported that the reasons for the high injury rate was due to the intense training and to the more frequent training period. The causes of golf injuries also may be caused by swing laterality, continuous impact, and overuse of a specific body part.

In order to achieve optimal golf performance, many golfers require a great amount of practice. However, such an intensive amount of practice may be harmful to the body parts of amateur golfers. In other words, amateur golfers with low technical proficiency may swing beyond their capacity in an effort to obtain a better score. Amateur golfers may also swing with their back, waist, and abdomen with less rotation of the trunk than required due to lower technical proficiency and physical fitness levels compared to professional golfers (Cohn et al., 2013; Fradkin et al., 2005; McCarroll, 2001). Such movements intensify muscle fatigue to trigger muscle imbalances that result in injury. This is presumed to result in the asymmetry of the functional application of the upper body muscles of the aiming or non-aiming side. Moreover, few objective and credible studies have been conducted on Korean amateur golfers. Therefore, this study was not only to investigate muscular balance, such as ipsilateral and bilateral ratios of the upper body, but to also evaluate the possible problems of muscular joints in amateur golfers. The goal of the present study may help to prevent further injuries or possible imbalances in the upper body of amateur golfers.

MATERIALS AND METHODS

Subjects

Twenty male subjects (mean age, 27.10±5.92 yr) were recruited from Korea University and Hanseo University in South Korea. Male golfers (n=10) and a healthy control group (n=10) were recruited for the assessment of muscular function of the upper body. Prior to the experiment, the body composition for all of the subjects was tested. The inclusion criteria for the golf group were amateur or recreational golfers with a playing career of over 12 months. Those with prior operations or dysfunction in the upper body, cerebral disorders, and cardiovascular problems were excluded. The principal investigator explained all the procedures to the subjects in detail. Complete subject characteristics are detailed in Table 1.

Table 2 showed the results of golfers' performance assessment consisted of potential factors related to golf injury such as driving distance, carry, launch angle, ball speed, back spin, and head speed

Table 1. Physical characteristics of the subjects

Group	Age (yr)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Muscle mass (kg)	Fat mass (kg)	Golf carrier (mo)
Golf (n=10)	27.00±4.47	174.80±5.75	73.99±6.03	25.20±3.91	35.82±4.79	14.44±7.38	63.30±43.07
Control (n=10)	27.20±7.36	173.10±5.84	71.58±6.07	23.31±1.89	33.83±3.41	11.56±4.26	-
Z[a]	-0.571	-0.381	-1.134	-1.362	-1.324	-1.400	-
P-value	0.568	0.739	0.28	0.19	0.19	0.165	-

Values are presented as mean±standard deviation.
BMI, body mass Index.
[a]Nonparametric Mann–Whitney test.

Table 2. The swinging analysis using 3 golf clubs in amateur golfers

Golf club	Distance (m)	Carry (m)	Launch angle (°)	Ball speed (m/sec)	Back spin (rpm)	Head speed (m/sec)
Driver	220.96±19.97	207.59±20.16	11.06±4.32	62.53±4.63	3,033.56±474.43	46.32±3.25
Iron 7	115.61±29.01	105.55±29.43	18.95±4.25	40.89±7.71	3,936.15±1,225.06	28.41±5.58
Pitching	90.95±22.66	86.49±22.61	33.48±4.83	35.85±6.69	6,031.09±1,106.92	24.69±5.02

Values are presented as mean±standard deviation.

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(Lee and Jee, 2013). These measurements were obtained by Golfzon Vision (Golfzon Co., Seoul, Korea). All of the participants performed 10 warm-up swings and 10 test swings prior to each performance assessment by using driver, iron 7, and pitching clubs.

Experimental design and measurement methods

All of the subjects were required to read and sign an informed consent form on the first day of experiment. On the same day, they were asked to complete a self-assessed questionnaire designed to identify subjects and to measure the body composition in the laboratory. The following day, each subject returned to the laboratory to complete isokinetic torque tests during the week.

Body composition

To measure body composition, including body weight and muscle mass of the subjects, the bioelectrical impedance analysis method (BIA) was used. The BIA was assessed by the InBody 320 Body Composition Analyzer (BioSpace, Seoul, Korea) and height was measured using BMS 330 anthropometer (BioSpace). The Body Composition Analyzer is a segmental impedance device measuring the voltage drop in the upper and lower body. The electrodes were made of stainless steel and the electrical interfaces were created as the subject stood upright while gripping hand electrodes and stepping onto foot electrodes. Eight tactile electrodes were placed in contact with the surfaces of both hands and feet: thumb, palm and fingers, front sole, and rear sole (Cha et al., 2014; Choi et al., 2011).

Isokinetic torque tests

All subjects were submitted to a stretching program and a warm up program before the tests. An isokinetic dynamometer (HUMAC/NORM Testing & Rehabilitation System, CSMI, MA, US) was used for this study. The isokinetic torque tests were composed of trunk flexion/extension, wrist flexion/extension, forearm pronation/supination, elbow flexion/extension, and shoulder horizontal abduction/adduction which were similar motions with golf swing. All of the subjects performed four maximal warm-up repetitions and five maximal test repetitions at 60°/sec. All tests were supervised by one trained researcher. The measured results of isokinetic torques at 60°/sec has been analyzed by peak torque (PT) and work per repetition (WR) on the right and left sides in the assessed body parts, respectively. The bilateral deficit ratio between right and left sides was developed by using PT and WR. The ipsilateral ratio between agonist and antagonist was developed by using PT and WR. Detailed explanations are outlined below.

Trunk flexion/extension test

Subjects were placed on the trunk flexion/extension modular component in a standing position. The axis of rotation was set at the intersection point of the midaxillary line and the lumbosacral junction, which was approximately 3.5 cm below the top of the iliac crest. After subjects had been transferred to the footplate of the trunk flexion/extension modular component, their heels were placed against the footplate heel cups. To align the patient's vertical axis with the Humac Norm unit dynamometer axis, footplate height was adjusted via the footplate switch until the rubber alignment pointer was approximately 3.5 cm below the top of the iliac crest. The pelvic belt was loosely fastened across the top of the anterior superior iliac spines. The popliteal pad height was adjusted to a position directly behind the patellae at the popliteal space. After the popliteal pad had been aligned, the tight pad was positioned directly above the patellae and the locking lever was secured. After the thigh pad, the tibial pad was secured just below the patellae. The lower body was stabilized in a slightly bent-knee position (15° of knee flexion) by the tibial, popliteal, and thigh pads. The subjects leaned against the sacral pad and were moved forward or back via the fore-aft alignment wheel until the rubber alignment pointer was centered approximately at the axis of rotation. The pelvic belt was then tightened. The scapular pad was positioned across the center of the scapulae and locked in place. The chest pad was properly placed in a position that was parallel to the scapular pad and secured. The range of motion of trunk flexion/extension was approximately -15° to 95°.

Wrist flexion/extension test

Each subject was placed in the equipment's adjustable seat. The tested wrist was placed and fixed with a Velcro strap on a support over the forearm muscle and the wrist joint was positioned at 180° of extension. The axis alignment is critical and somewhat difficult in the pattern. The axis of rotation is slightly oblique passing through the wrist just distal to the tubercle of the radius and the head of the ulna. The accessories of this assessment included thigh/forearm stabilizer tube, forearm stabilizer v-pad, wrist/shoulder adapter, and lumbar cushion. The range of motion of wrist flexion/extension was from 80° to 70° respectively (Fig. 1).

Forearm pronation/supination test

Each subject was placed in the equipment's adjustable seat. The tested wrist was placed and fixed with a Velcro strap on a support over the forearm muscle and the wrist joint was positioned at 180° of extension. The axis of rotation bisects the head of the ulna

Fig. 1. Wrist flexion/extension test.

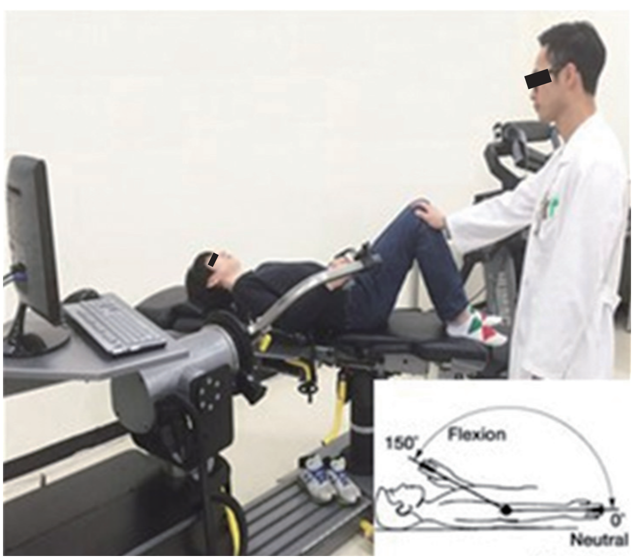

Fig. 2. Elbow flexion/extension test.

distally and the head of the radius proximally. It is established by placing the forearm directly in line with the dot on the dynamometer input tube at approximately the level of the ring finger. The accessories of this assessment included thigh/forearm stabilizer tube, forearm stabilizer v-pad, wrist/shoulder adapter, lumbar cushion, and counterbalance weight. The range of motion of forearm pronation/supination was from 80° to 80° respectively.

Elbow flexion/extension test

Each subject was placed in the supine position with the knee placed in full extension, while the tested limb was placed and

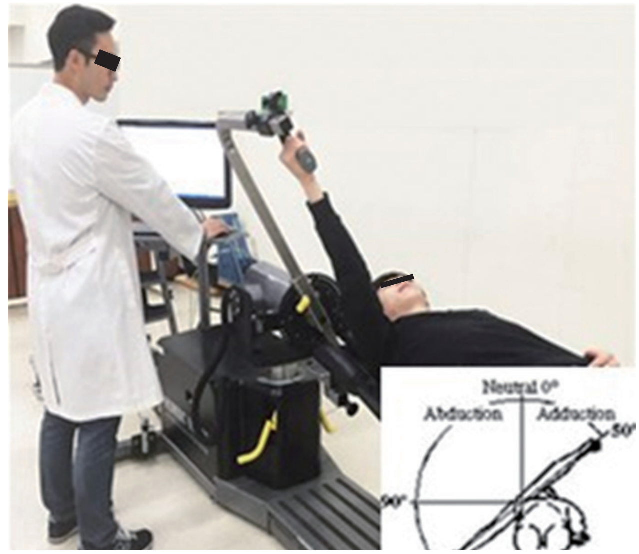

Fig. 3. Shoulder horizontal abduction/adduction test.

fixed with an elbow strap. The tested elbow was placed and fixed with a Velcro strap on a support over the bicep muscle and the elbow joint was positioned at 180° of extension. The axis of rotation is immediately distal to the lateral epicondyle and moves only slightly anteriorly as flexion increases. The accessories of this assessment included elbow/shoulder adapter, footrest, and lumbar cushion. The range of motion of elbow flexion/extension was from 150° to 0° respectively (Fig. 2).

Shoulder horizontal abduction/adduction test

Each subject was placed in the supine position with the knee placed in full extension, while the tested limb was placed and fixed with an elbow strap. The tested elbow was placed and fixed with a Velcro strap on a support over the bicep muscle and the elbow joint was positioned at 180° of extension. The instantaneous axis of rotation changes throughout the movement. The compromise axis is medial to the acromion process when the limb is at 90° horizontal abduction. The accessories of this assessment included an elbow/shoulder adapter, footrest, and torso belt. The range of motion of shoulder horizontal abduction/adduction was from 50° to 130°respectively (Fig. 3).

Statistical analysis

Statistical analysis was conducted with the SPSS ver. 15.0 (SPSS Inc., Chicago, IL, USA). All data are reported as mean±standard deviation. Prior to the comparison of measurements, including the body composition and isokinetic torque variables, the Kolmogorov–Smirnov test was used to determine the normality of distribu-

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tion for the examined variables. Mann–Whitney U-test was used to evaluate the significance of the differences between groups. The between-group factor was the study groups (i.e., golfer vs. control). The significance level for all analyses was set a priori at $P \leq 0.05$.

RESULTS

Differences of ipsilateral ratio in trunk flexor/extensor PT and WR

Table 3 displays the PT of trunk flexor and extensor between golf and control groups. It also displays the ipsilateral ratios on the PT of the trunk flexor and extensor in the lumbosacral joint. In Table 3, the ipsilateral ratios of PT and WR in the golf group were not significantly different compared to those of the control group.

Differences of ipsilateral and bilateral ratios in wrist flexor/extensor PT and WR

In Table 4, the PT ipsilateral ratios of the wrist flexor/extensor in both the right ($P=0.247$) and left ($P=0.796$) sides were not significantly different between groups. Moreover, the PT bilateral ratios of the wrist flexor ($P=0.218$) and extensor ($P=0.123$) were not significantly different between groups.

As a result, the PT bilateral ratio (21.10% ± 10.98%) of the wrist flexor in the golf group means 'probably abnormal' whereas the PT bilateral ratio (16.20% ± 12.87%) of the wrist extensor in the golf group means 'possibly abnormal' as suggested in a study by Kannus (1994). Although the WR bilateral ratio of the wrist extensor was significantly different ($P=0.029$), that of the wrist flexor was not significantly different ($P=0.280$) between groups (Table 4). In the aspect of the WR ipsilateral ratio of the wrist extensor and flexor, that of the right wrist was not significantly different ($P=0.143$), whereas that of the left wrist was significantly different ($P=0.035$) between groups. In other words, it means that the extensor WR of the left wrist in the golf group was lower (≈6%) than that of the control group. As a result, the WR bilateral ratio (20.40% ± 15.45%) of the wrist flexor in the golf group

Table 3. Differences of ipsilateral ratios in trunk flexor/extensor peak torque and work per repetition

Item	Peak torque (Nm)		Work per repetition (Nm)	
	Golf	Control	Golf	Control
Flexor	206.80 ± 49.76	171.30 ± 31.54	291.40 ± 67.02	253.00 ± 60.24
Extensor	218.10 ± 61.37	186.10 ± 37.37	266.10 ± 72.72	254.90 ± 51.38
Ipsilateral ratio	99.30 ± 24.05	92.60 ± 10.82	112.70 ± 19.97	98.90 ± 10.07
Z* (P-value)	-0.379 (0.739)		-1.817 (0.075)	

Values are presented as mean ± standard deviation.
*Statistical differences in ipsilateral and bilateral ratios by Mann–Whitney U-test.

Table 4. Differences of ipsilateral and bilateral ratios in wrist flexor/extensor peak torque and work per repetition

Item	Right		Left		Bilateral ratios		Z*	P-value
	Golf	Control	Golf	Control	Golf	Control		
Peak torque (Nm)								
Flexor	14.80 ± 3.05	13.40 ± 3.27	12.60 ± 3.63	12.90 ± 4.82	21.10 ± 10.98	16.90 ± 5.72	-1.253	0.218
Extensor	15.30 ± 4.99	15.30 ± 1.57	14.50 ± 3.95	15.10 ± 2.08	16.20 ± 12.87	6.40 ± 3.84	-1.615	0.123
Ipsilateral ratios	102.90 ± 27.44	119.60 ± 28.08	119.50 ± 26.36	127.50 ± 39.79				
Z*	-1.175		-0.265					
P-value	0.247		0.796					
Work per repetition (Nm)								
Flexor	17.80 ± 4.54	15.30 ± 4.52	14.30 ± 4.08	14.10 ± 3.96	20.40 ± 15.45	17.30 ± 14.63	-1.141	0.280
Extensor	18.50 ± 6.06	18.90 ± 2.33	17.50 ± 4.25	18.60 ± 2.46	14.80 ± 12.01	4.70 ± 4.27	-2.231	0.029
Ipsilateral ratios	103.00 ± 26.95	129.90 ± 34.31	129.20 ± 30.20	180.90 ± 56.95				
Z*	-1.519		-2.080					
P-value	0.143		0.035					

Values are presented as mean ± standard deviation.
*Statistical differences in ipsilateral and bilateral ratios by Mann–Whitney U-test.

Table 5. Differences of ipsilateral and bilateral ratios in forearm supinator/pronator peak torque and work per repetition

Item	Right		Left		Bilateral ratios		Z*	*P*-value
	Golf	Control	Golf	Control	Golf	Control		
Peak torque (Nm)								
Supinator	6.60±1.51	5.60±1.51	5.30±0.95	5.80±2.44	19.70±7.45	11.10±16.74	-0.270	-0.796
Pronator	7.30±1.64	6.10±2.38	6.50±1.65	5.90±1.91	13.40±12.08	13.40±13.66	0.001	1.000
Ipsilateral ratios	91.20±19.57	97.80±26.92	94.50±41.90	98.30±36.40				
Z*	-0.5		-0.304					
P-value	0.631		0.796					
Work per repetition (Nm)								
Supinator	11.20±3.55	10.60±2.91	8.20±1.23	9.60±4.72	30.60±12.93	14.40±15.66	-0.798	0.436
Pronator	11.80±3.85	10.20±4.05	11.50±3.34	12.00±4.06	21.00±13.19	8.40±6.80	-2.162	0.029
Ipsilateral ratios	103.80±35.97	113.60±44.96	79.50±33.44	82.50±29.55				
Z*	-0.454		-0.265					
P-value	0.684		0.796					

Values are presented as mean±standard deviation.
*Statistical differences in ipsilateral and bilateral ratios by Mann–Whitney *U*-test.

Table 6. Differences of ipsilateral and bilateral ratios in elbow flexor/extensor peak torque and work per repetition

Item	Right		Left		Bilateral ratios		Z*	*P*-value
	Golf	Control	Golf	Control	Golf	Control		
Peak torque (Nm)								
Flexor	32.10±5.20	30.90±5.69	30.90±7.26	30.10±6.67	14.30±11.10	9.20±9.57	-1.213	0.247
Extensor	40.00±9.63	34.90±9.87	37.20±8.84	36.80±12.50	9.60±10.89	13.00±7.85	-1.705	0.089
Ipsilateral ratios	82.70±12.77	91.10±12.16	83.50±9.68	85.00±13.11				
Z*	-1.406		-0.568					
P-value	0.165		0.579					
Work per repetition (Nm)								
Flexor	55.40±12.08	50.20±11.10	49.40±9.28	46.70±11.90	16.40±10.29	9.50±11.03	-1.971	0.050
Extensor	67.50±13.48	60.10±17.38	63.70±11.42	61.40±19.78	10.60±8.32	13.10±11.09	-0.341	0.739
Ipsilateral ratios	82.40±9.59	85.00±10.21	77.60±7.40	77.70±11.67				
Z*	-0.568		-0.114					
P-value	0.579		0.912					

Values are presented as mean±standard deviation.
*Statistical differences in ipsilateral and bilateral ratios by Mann–Whitney *U*-test.

means 'probably abnormal', whereas the WR bilateral ratio (14.80%±12.01%) of the wrist extensor in a golf group means 'possibly abnormal'.

Differences of ipsilateral and bilateral ratios in forearm supinator/pronator PT and WR

In Table 5, the PT bilateral ratios of the forearm pronator ($P=1.000$) and supinator ($P=-0.796$) were not significantly different between groups. Moreover, the PT ipsilateral ratios of the forearm pronator and supinator for both the right ($P=0.631$) and left ($P=0.796$) sides were not significantly different between groups.

Although the WR bilateral ratio of the forearm supinator was not significantly different ($P=0.436$), that of the forearm pronator was significantly different ($P=0.029$) between groups (Table 5). There were no significant differences between groups for the WR ipsilateral ratio of the forearm pronator and supinator on both the right ($P=0.684$) and left ($P=0.796$) sides. In particular, the supinator WR on the left side of the golf group (8.20±1.23 Nm) was significantly lower compared to the supinator WR on the right side (11.20±3.55 Nm). Therefore, it showed a possible imbalance on the WR bilateral ratio (30.60%±12.93%; if over 20%, abnormal status) in golfers.

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Table 7. Differences of ipsilateral and bilateral ratios in shoulder horizontal abductor/adductor peak torque and work per repetition

Item	Right		Left		Bilateral ratios		Z*	*P*-value
	Golf	Control	Golf	Control	Golf	Control		
Peak torque (Nm)								
Abductor	47.60±8.38	48.40±13.08	44.40±7.43	43.50±9.50	11.80±9.20	9.70±8.87	-0.568	0.579
Adductor	41.40±6.88	43.50±18.08	37.90±7.84	44.20±15.29	10.90±8.99	14.90±11.10	-0.796	0.436
Ipsilateral ratios	118.60±25.11	118.60±20.75	120.80±27.45	102.00±16.14				
Z*	0		-1.664					
P-value	1		0.105					
Work per repetition (Nm)								
Abductor	88.20±11.82	88.30±27.17	81.60±15.98	74.80±16.12	13.50±9.07	14.30±8.62	-0.455	0.684
Adductor	73.20±15.35	75.70±33.21	65.30±16.12	74.40±29.49	12.90±9.87	16.60±10.43	-0.871	0.393
Ipsilateral ratios	124.20±27.02	124.70±23.77	131.00±39.32	108.20±23.86				
Z*	-0.038		-1.248					
P-value	0.971		0.218					

Values are presented as mean±standard deviation.
*Statistical differences in ipsilateral and bilateral ratios by Mann–Whitney *U*-test.

Differences of ipsilateral and bilateral ratios in elbow flexor/extensor PT and WR

In Table 6, there were no significant differences between groups in terms of the PT bilateral ratios of the elbow extensor (P = 0.089) and flexor (P = 0.247). Moreover, the PT ipsilateral ratios of the elbow extensor and flexor in both the right (P = 0.165) and left (P = 0.579) sides were not significantly different between groups.

In Table 6, the WR ipsilateral ratios of the elbow extensor and flexor in the right (P = 0.579) and left (P = 0.912) sides were not significantly different. However, although the WR bilateral ratio of the elbow extensor was not significantly different (P = 0.739), that of the elbow flexor was significantly different (P = 0.050) between groups. In other words, the elbow flexor WR on the left side of the golf group was significantly lower compared to the elbow flexor WR on the right side. Therefore, it showed a possible imbalance on the WR bilateral ratio (16.40%±10.29%) of elbow flexor for the left side of golfers.

Differences of ipsilateral and bilateral ratios in shoulder horizontal abductor/adductor PT and WR

In Table 7, the PT bilateral ratios of the horizontal abductor (P = 0.579) and adductor (P = 0.436) were not significantly different between groups. Moreover, the PT ipsilateral ratios of the horizontal abductor and adductor for the right (P = 1.000) and left sides (P = 0.105) were not significantly different between groups. In Table 7, the WR bilateral ratios of the horizontal abductor (P = 0.684) and adductor (P = 0.393) were not significantly different between groups. Moreover, the WR ipsilateral ratios of the horizontal abductor and adductor in the right (P = 0.971) and left (P = 0.218) shoulder joints were not significantly different between groups.

DISCUSSION

The imbalance of muscle strength indicators has its own inner nature, and in the case of significant asymmetries, it increases the probability of muscle injuries, or deterioration of sport performance (Malý et al., 2010). Croisier et al. (2005) indicate that the isokinetic strength assessment before the start of the season enables identification of strength indicators as predictors of possible muscle injury. Lehance et al. (2009) listed three important reasons that result in the diagnostics of strength abilities in athletes. Two of the three reasons are to ascertain the absence of muscle strength imbalances between the extremities (bilateral ratio) and to ensure that muscle strength is well balanced between the agonist and antagonist (ipsilateral ratio). Muscular balance is often expressed in terms of relative strength between joint agonist and antagonist, or by contralateral comparisons. Muscles on opposite sides of a joint act reciprocally to produce smooth and coordinated movements. Therefore, deficiency in a muscle or muscle group may lead to imbalanced movements in that joint (Campbell and Glenn, 1979).

Monitoring these movements of particular muscle groups around the articulation reflects its integrity and stability (Chung et al., 2014). The bilateral comparison of muscle strength of extremity muscle groups (e.g., the right vs. left arm or leg) or the comparison between the agonist and antagonist strength (e.g., elbow flexor vs. extensor) may indicate potential weaknesses of the muscle system, which are predisposed to muscle injury (Baratta et al., 1988; Knapik et al., 1991). Knapik et al. (1991) state that athletes with muscle strength imbalances higher than 15% at bilateral comparison of extremities had 2.6 times higher frequency of injuries when compared to athletes who had a difference lower than 15%. Dauty et al. (2003) indicate that in the case of muscle strength imbalances of knee flexors lower than 10%, we can exclude muscle injury of the particular muscle groups, or after muscles have fully recovered from injury. Fowler and Reilly (1993) state that a 20% difference in the bilateral deficit of muscle strength in professional players is a predisposition to injury. The ratio of muscle strength of the knee flexor and extensor for healthy people is in the range of 50–60%, while values for soccer players range from 41–81%, depending on the angular velocity of the performed movement (Knapik and Ramos, 1980).

To improve athletic performance without any muscular injuries, it is important for amateur golfers to know the muscles involved in each movement and to practice so as to enhance their muscular functions. To make this possible, motion analysis and an isokinetic muscular strength function test are the primary tools. This study assessed the isokinetic torques in the trunk, wrist, forearm, elbow, and shoulder joints of male amateur golfers who had practiced golf swings and had taken part in playing golf for over 20 months. The aim of this study was to investigate the bilateral and ipsilateral asymmetries of strength (PT) and endurance (WR) in male golfers compared to a normal healthy group.

In the present study, the PT and WR in the trunk flexor (e.g., abdominis)/extensor (e.g., erector spinae) of golfers were higher than those of the control group. The PT and WR in the trunk extensor of golfers were higher than those of the trunk flexor of golfers. Moreover, the ipsilateral ratios between both groups were not significant. In other words, the lumbosacral joint of the amateur golfers mean neither 'possibly abnormal' nor 'abnormal ratio.' Such ratios revealed similar results in the shoulder horizontal abductor (e.g., posterior deltoid)/adductor (e.g., anterior deltoid and pectoralis major) PTs and WR.

Unlike these results, the isokinetic torques in the wrist, forearm, and elbow joints of amateur golfers in this study represented 'possibly abnormal' or 'probably abnormal' levels. Similar to these results, Kannus (1994) reported that the possibly abnormal level of bilateral ratios mean the discrepancy values between 10% to 20% and the probably abnormal level of bilateral ratios mean the discrepancy value is greater than 20%. He also reported that those values might usually be found on the left side (aiming side) of golfers. Actually, the muscular functions generated by golf swings of amateur golfers mostly influence the muscles, ligaments, and joints on the left side. By looking at the analysis of golf swings in this study (Table 2), the amateur golfers showed decent club speed, ball speed, and driving distance in the test using three types of clubs. The result of the swing analysis by professional golfers was not different compared to other papers. Therefore, the amateur golfers in this study may have had problems in ipsilateral and bilateral ratios similar to the results of the previous study (Bae et al., 2012).

In particular, the isokinetic WR of the wrist extensor (14.805 ± 12.01%) and elbow flexor (16.40% ± 10.29%) of the golfers in this study represented 'possibly abnormal' levels and the isokinetic WR of the forearm pronator (21.00% ± 13.19%) of the golfers in the present study showed a 'probably abnormal' level according to the research data of Kannus (1994). The data from the results of this study were significantly different from those of the control group. Recently, Bae et al. (2012) reported that the comparisons between professional golfers and a healthy control group showed a significant difference in the PT of the left side at 60°/sec. In the results of their study, professional golfers tended to show greater PTs than the control group. In other words, the left side, which presumably strengthened through repeated practice, was superior to that of the right (nonaiming) side. Lindsay and Horton (2006) also reported that the PT toward the left side tended to be consistently higher than that toward the right side. However, unlike the results from the researchers (Bae et al., 2012; Lindsay and Horton, 2006), the isokinetic strength and endurance of amateur golfers in this study were lower than those of the control group. Specifically, the endurance (WR) of the wrist extensor, elbow flexor, and forearm pronator of golfers tended to be weak on the left side. In other words, the bilateral ratios of the wrist, forearm and elbow joints of amateur golfers revealed possible imbalances similar to the results of previous studies. It also showed that the left side of amateur golfers, which is used to aim, supports the hypothesis in this study and validates the differences in the wrist, forearm, and elbow joints between amateur golfers and the control group. Eventually, it is important for golf practitioners to know that the imbalance of ipsilateral and bilateral ratios appeared not in the strengthening phase, but in the endurance phase. Moreover, to prevent injuries from playing golf, they should take an endurance training program for the wrist extensor, elbow flexor, and forearm pronator.

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Golf is characterized by intermittently performed rotary motions and instant impulses rather than steady movements for a long period of time, thus amateur golfers might have been trained to employ steady endurance (WR) rather than strength for avoiding injuries of the wrist, forearm, and elbow joints. In conclusion, the WR of the wrist flexor, forearm pronator, elbow flexor on the left side of amateur golfers showed imbalances in bilateral ratios. Moreover, the WR of the wrist flexor and elbow flexor on the left side of amateur golfers were significantly lower than those of the wrist extensor and elbow extensor. Therefore, amateur golfers should strive to prevent further injuries of the wrist, forearm, and elbow joints and to reinforce the endurance of the wrist flexor, forearm pronator, and elbow flexor on the left side.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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