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PREVENTION & REHABILITATION: ORIGINAL RESEARCH

Effects of eight-week “gyroscopic device” mediated resistance training exercise on participants with impingement syndrome or tennis elbow

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ABSTRACT

Background: Rehabilitation of injuries in the upper extremity and reestablishment of muscle strength throughout the range of motion in overhead movements, are the major concerns of athletes and coaches in the sports field.
Purpose: To determine the effect of eight-week “gyroscopic device” mediated resistance training exercise on grip strength, wrist and shoulder strength and proprioception, and upper extremity performance, in participants with impingement syndrome or tennis elbow.
Design and methods: For this study, in a university rehabilitation clinic 45 volleyball players (aged 22–28) purposefully were selected and divided into 3 groups: shoulder impingement (group I), tennis elbow (group II), and control (group III). The experimental groups performed the “gyroscopic device” mediated resistance training, three sessions a week over 8 wks. Grip strength, wrist and shoulder strength and proprioception, and upper extremity performance were measured before and after implementation of the intervention (eight-week resistance training using a “gyroscopic device”) using a hand hold dynamometer, isokinetic dynamometer, and Y balance test respectively.
Results: After 8 weeks of “gyroscopic device” exercise, improvement in the shoulder, wrist and grip strength, shoulder and wrist proprioception and performance scores of both experimental groups was significant. There were no significant differences between study groups I and II, both groups, however, demonstrated significant differences when compared to the control group, but between group I and the control group, and between group II and the control group, the difference was significant. However, no significant change was seen in the control group.
Conclusions: Due to the significant effects of the “gyroscopic device” mediated exercise on grip strength, wrist and shoulder strength and proprioception, and performance of the upper extremity, use of the exercise can be recommended for subjects with impingement syndrome or tennis elbow impairment in measured variables. More research is needed to confirm the result of this study.

1. Introduction

Rehabilitation of injuries in the upper extremity and reestablishing muscle strength throughout the range of motion in the overhead movements are the major concerns of athletes and coaches in the sports field.

In overhead sports such as volleyball, while spiking and serving not only the shoulder joint but other joints of the upper extremity, such as the elbow and wrist, are at high risk of traumatic or cumulative injury due to repetitive overhead motions (McAtee, 1993). The incidence of these injuries is higher in swimming, gymnastics, tennis, volleyball, skiing, and wrestling (Ritchie, 2003).

Cumulative injuries in overhead sports are more common with a prevalence of 24–65% of tendonitis, bursitis, or impingement syndrome (McAtee, 1993) and overall incidence from 35% to 51%[6] of tennis elbow (Abrams et al., 2012). These often occur because the upper extremity relies on the surrounding muscles, ligaments, and

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capsule to control the motion. Overloading these tissues by playing for long durations can irritate and cause injury (McAtee, 1993). Also, when applying resistance against extension of the wrist and hand power movements, pain is intensified during daily activities, especially during exercise (Barr et al., 2009).

If such lesions are neglected, athletes may have to resort to invasive methods such as surgery and injections due to the progression of the pathology (Kalainov et al., 2007). In recent years a variety of therapies have been recommended to treat and prevent injuries of the shoulder and elbow. These include use of braces, steroid injections, low-energy shock waves, surgery and isolated eccentric exercises and also standard treatment motions (which include stretching the wrist extensors, wrist extensors isotonic stretching, strengthening exercises and the use of orthoses), ultrasound waves, massage, heat therapy and cold therapy (Lewis, 2016). Also, the effect of resistance training on increasing muscle strength of shoulder and elbow has been determined (Gentil et al., 2016). Also, eccentric exercises have been reported to improve some symptoms of tennis elbow disorders (McConnell, 2000).

Recent research has shown the positive effect of vibrating tools (such as the gyroscopic device) on muscle strength, range of motion, pain and health quality of people with tennis elbow injury, when compared with, for example, dumbbell exercise (Lim and Shin, 2016).

Loading the muscles of the wrist, elbow, and shoulder, as extrinsic and intrinsic, “gyroscopic device” exercise has been shown to be an effective exercise therapy in the chronic phase of tennis elbow (Pienimäki et al., 1996). The results of some studies have also shown that the use of “gyroscopic device” results in improvement of power (Lim and Shin, 2016; Adamczyk et al., 2013).

Although use of a dynamic hand gyroscope has been proven to be effective in improving strength, range of motion, function, pain, and quality of life in persons with tennis elbow (Lim and Shin, 2016; Adamczyk et al., 2013), the effects of using a gyroscopic device, in participants with tennis elbow or shoulder impingement, at the same time, remain untested.

To our knowledge, no studies to date have examined use of one intervention on shoulder impingement and tennis elbow simultaneously.

This study aimed to evaluate the effect of eight-week mediated resistance training using a “gyroscopic device” on grip strength, strength and proprioception of wrist and shoulder, and upper extremity performance in overhead athletes with impingement syndrome or tennis elbow.

2. Methods

In this study, the subjects were recruited from active male volleyball players (aged 22–28) during the period of a preseason with clinically diagnosed chronic impingement syndrome or tennis elbow. The Research Ethics Committee of the University approved the study. At first step, the subjects completed the consent form to participate in the study. Also, their personal information was collected. All subjects were examined by a physician who also controlled the operation of the whole protocol and examined selected subjects after the intervention period. The principal exclusion criteria with subjects having tennis elbow were symptoms over three months, cubital osteoarthritis, carpal or radial tunnel syndrome, rheumatoid arthritis, severe cervical spondylosis or cervical radicular syndrome, painful shoulder or rotator cuff tendinitis, previous fractures of arm causing limitations in arm function, and clinical signs of impingement syndrome. The inclusion criteria for subjects having tennis elbow were at least one positive result of the Thomsen test, Mill's test, resisted wrist or middle finger extension produced typical pain at the origin on the lateral epicondyle, and local tenderness on palpation over the lateral epicondyle. The principal inclusion criteria with subjects having impingement syndrome were symptoms for over three months, the painful arc of movement during flexion or abduction, or pain on resisted lateral rotation, or abduction. Exclusion criteria for these subjects were calcification or fracture; shoulder instability; previous shoulder surgery; and cervicobrachialgia or shoulder pain during neck movement and clinical signs of tennis elbow syndrome.

For preliminary, baseline, and after the intervention data, the assessors were blind to group allocation. The data analyst was only blind to treatment allocation. The physiotherapist and two trainers oversaw the training.

A total of 100 volleyball players volunteered to participate in the study, 55 were excluded due to the above exclusion criteria. Finally according to similar age, body mass index, injuries (shoulder impingement and tennis elbow), the 45 participants, met the criteria, were randomized into three groups, with 15 people in each. The study consisted of two experimental groups (15 in impingement syndrome group and 15 in tennis elbow), and one control group (8 with impingement syndrome and 7 with tennis elbow). The experimental groups performed the “gyroscopic device” mediated resistance training three sessions a week over eight weeks. During this period, the control group received self-care recommendations for tendinosis including hot pack, active range of motion, and patient education three sessions a week over eight weeks.

For pre-tests; grip strength, shoulder and wrist strength and proprioception, and performance were measured by using a hand-held dynamometer, isokinetic dynamometer, and Y test respectively. A day after the pre-tests, the experimental groups performed resistance training using a “gyroscopic device”. After the 8-week “gyroscopic device” training, the subjects in three groups conducted post-tests based on pre-tests conditions, and the results were analyzed.

All subjects complete all treatment sessions through the study. If a participant experienced incidence of joint pain, or the like, during a specific exercise, we asked them to adjust the exercise as follows: First, slightly alter intensity during the exercise. Then, the participant reduced the training repetition of the exercise. If this did not help, the participant reduced the number of sets of the given exercise in the session.

2.1. Procedure

2.1.1. Shoulder strength

After a 5-min warm-up with an isokinetic machine, the intrinsic strength of the internal and external rotators at speeds of 180 and 300° per second was measured. The examiner asked the subjects to perform the test while sitting on the chair of the device, shoulder in 90° abduction, elbow in 90° flexion, and the external rotation of the device was between 90° of external rotation and 60° of internal rotation (Noffal, 2003) Fig. 1. During the test, verbal encouragement was given to the subject to exert maximum muscle strength.

2.1.2. Grip strength

A digital handgrip dynamometer (YDM-110D, No. 4200; Yagami Ltd, Tokyo, Japan) was used to measure maximum grip strength. The examiner assessed the subject's hand-grip strength, asking him to put their upper extremity on an armrest, and elbow in 90° of flexion and pulling the handle of the dynamometer to his maximum effort while the upper extremity was held 15° in front of the trunk (Mathiowetz et al., 1984). During the test, verbal encouragement was given to the subject to exert maximum muscle strength. After each repetition, the examiner gauged the degree of force to zero. Average efforts were recorded as the score (the dynamometer has an interrater reliability of 0.93–0.94) (Yoon et al., 2015).

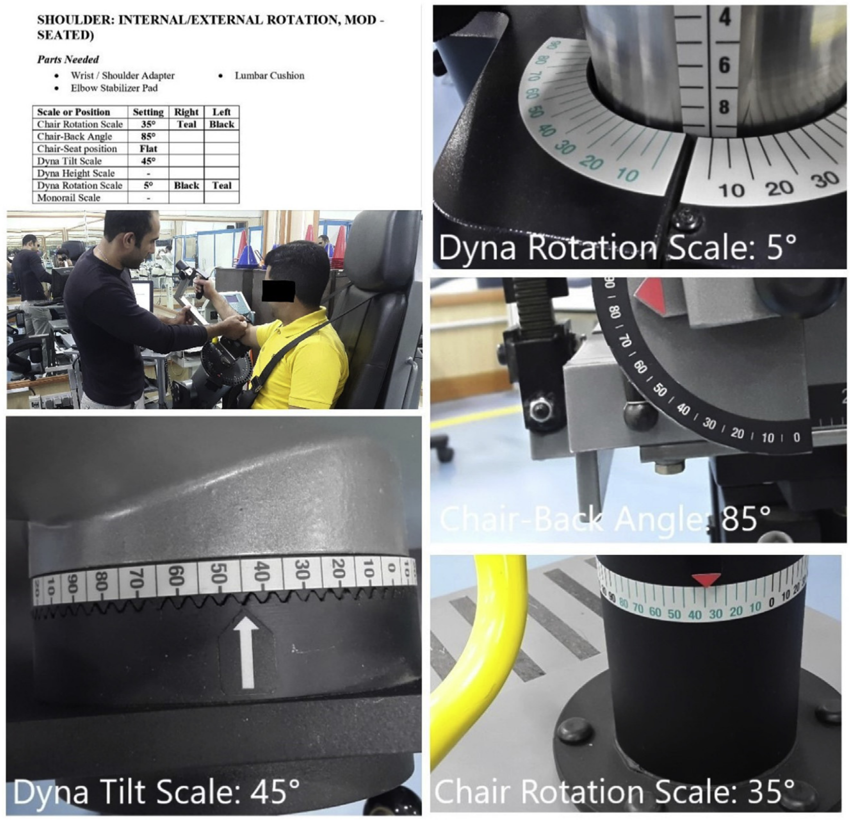


Fig. 1. Strength test of internal and external rotation of the arm Grip strength.

2.1.3. *Wrist extension strength*

Isokinetic Device Pro 3 was used to measure wrist extension and shoulder strength, and shoulder and wrist proprioception. This equipment is highly reliable in measuring the isometric contractions (ICC = 0.88), concentric and eccentric (ICC = 0.92) and power ratio of agonist to antagonist muscles (ICC = 0.62, ICC = 0.73) (Alvares et al., 2015).

The seat back of the equipment was at 90° and its seat in full horizontal mode. The special wrist attachment of the equipment was in a way that its axis was exactly in line with the wrist. A special pad was used to support the subject's forearm in horizontal mode. The subject's forearm was in full pronation. For accurate measurement, the test was conducted three times at maximum muscle strength with 1-min rest between each repetition. The average of these replications considered as wrist extension strength score (Su-Hyun, and Wan-Young, 2015) Fig. 2. In order to minimize the involvement of other muscle groups or unnecessary movement, a belt was used to fix the subject.

2.1.4. *Shoulder proprioception*

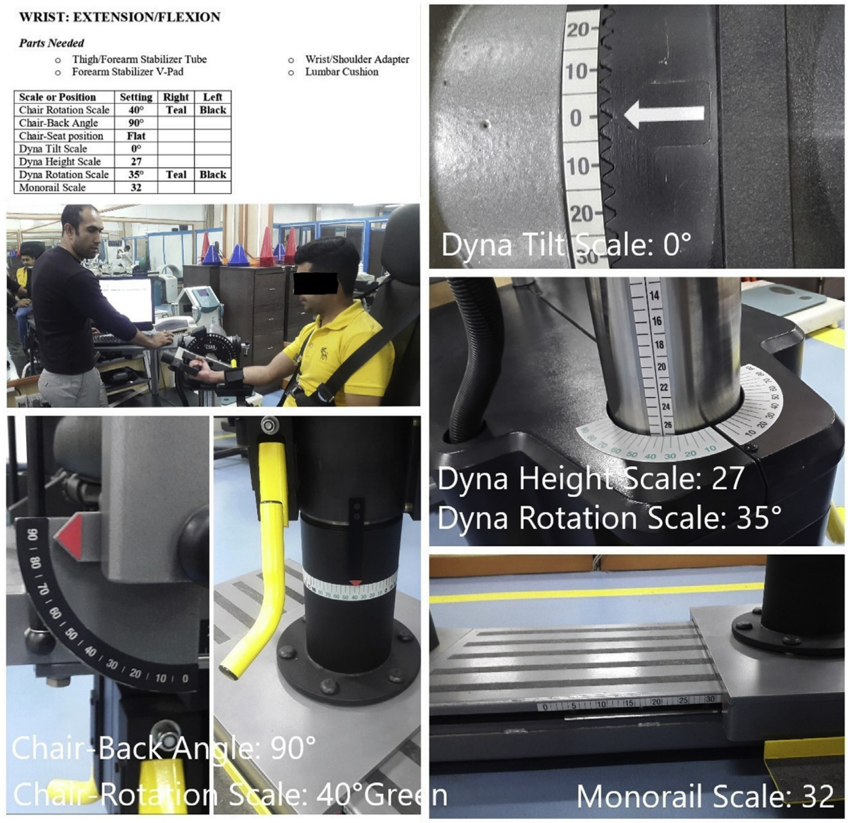
Subject's shoulder proprioception was measured at zero, 45 and 90°. At first, the device and laboratory method were introduced to the subjects. The subject sat on the isokinetic dynamometer chair with closed eyes while listening to white noise by HiFi (HiFi prevents distraction due to ambient sounds). In order to minimize the involvement of other muscle groups or unnecessary movement, straps were used to fix the subjects' chests. Dynamometer speed was at 5° per second. The damaged shoulder was in the scapular plane. Dynamometer lever arm in horizontal position considered as the zero angle. The internal and external rotation angles rebuilt by the subject included zero, 45 and 90, renovated in random order. 45-degree angle was for reconstruction zero and 90°. The subject's damaged shoulder was passively brought to each of the three target angles, kept for 10 s. The subject was asked to focus on these angles. Then the shoulder was returned to the starting position with 5 s rest between each repetition. This operation was conducted two times. For the third time, the subject was asked to rotate the shoulder actively to reach the target angles. This procedure was repeated 3 times, and the absolute value of the difference between the angles was recorded. The target angle was recorded as an error (absolute angle error), and the average was used for statistical analysis (Salles et al., 2015).

2.1.5. *Wrist proprioception*

Seat back of the device was at 90° and the seat was in full horizontal mode. Special wrist attachment of the device was in a way that the device axis was exactly in line with the wrist. A special pad was used to support the forearm of the subject in horizontal mode. Subject's tested forearm was on neutral and full supination. 20 and 50° for flexion and extension, 10° for abduction and adduction, 30 and 60° for pronation and supination were considered as target angles (Fig. 3). After practicing with open eyes, the subject should reconstruct the mentioned angles for 3 times with closed eyes. The average degrees of reconstructed angles for 3 times were calculated as the individual's score (Cappello et al., 2014).

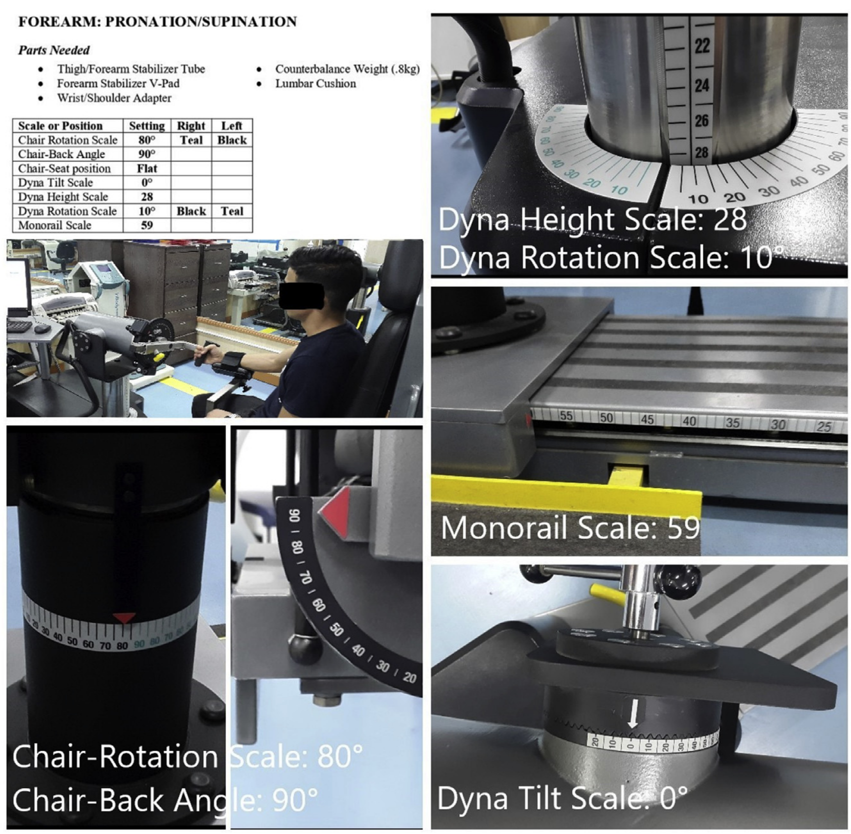
2.1.6. *Upper extremity performance*

The upper quarter Y-balance test (UQYBT) has been proposed as a closed kinetic chain assessment of upper quarter performance using a functional testing device and reported an acceptable reliability (ICC = 84.5) (Gorman et al., 2012). The assessment is performed with the subject stabilizing his or her body weight with the upper extremity being tested while performing maximal reaching in three directions (medial, Superior Lateral, and Inferior Lateral).



Scale or Position	Setting	Right	Left
Chair Rotation Scale	40°	Teal	Black
Chair-Back Angle	90°		
Chair-Seat position	Flat		
Dyna Tilt Scale	0°		
Dyna Height Scale	27		
Dyna Rotation Scale	35°	Teal	Black
Monorail Scale	32		

Fig. 2. Wrist extension strength test.



Scale or Position	Setting	Right	Left
Chair Rotation Scale	80°	Teal	Black
Chair-Back Angle	90°		
Chair-Seat position	Flat		
Dyna Tilt Scale	0°		
Dyna Height Scale	28		
Dyna Rotation Scale	10°	Black	Teal
Monorail Scale	59		

Fig. 3. The proprioception test of pronation and supination of the wrist.

Every trial in each direction was recorded. For accurate measurement, a practice of 3 times was done at maximum effort before the test, a rest was taken, and then the test was conducted. The average of 3 trials was used for analysis. The sum of the 3 average was considered as the total excursion score. The test measured with consideration given to the upper limb length. The total excursion score was divided by 3 times of the upper limb length (Westrick et al., 2012) Fig. 4.

2.2. Protocol of Powerball training

In this study, a resistance training program was designed using a “gyroscopic device”. The training was performed over eight weeks, three sessions a week and 30 min a session (Fig. 5). The “Gyroscopic device” training intensity was determined by rounds per minute according to the subject's tolerance, from 2000 up to 10,000 rounds per minutes (Table 3). The detail of the exercises used in this study is presented in Appendix 1.

2.3. Statistics analysis

Data was analyzed using SPSS 20 software. Descriptive statistics mean and standard deviation was used to describe the demographic data. The difference between groups at pre-test was compared using 1-way analysis of variance (ANOVA). Shapiro-wilk test used to test normality showed our data is normal. Therefore, the paired *t*-test was used to show within group changes from pre-test to post-test and covariance test was used to show between group differences after 8 weeks intervention. When the mean differences between three groups were significant LSD was used to show between which two groups this difference was significant. Statistical significance was at $p < 0.05$.

3. Results

The subjects' general characteristics (age, height and weight) are presented in Table 1. Significant differences in general characteristics were not observed between the experimental and the control groups.

After 8 weeks, improvement in shoulder, wrist and grip strength, shoulder and wrist proprioception and performance scores of both experimental groups was significant. However, the control group did not show any significant change. There was not any significant difference between two experimental groups in post-test, but between the group I and the control group, and between group the group II and the control group the difference was significant (Table 2).

4. Discussion

This study aimed to evaluate the effects of eight weeks gyroscopic device mediated resistance training on subjects with tennis elbow or shoulder impingement syndrome. The results showed that both the experimental groups had significant improvements in grip strength, strength and proprioception of wrist and shoulder, and upper extremity performance in participants with impingement syndrome or tennis elbow. However, results from the control group showed no improvement on these variables.

There was a significant increase in muscle strength concentric and eccentric strength of internal rotators, concentric and eccentric

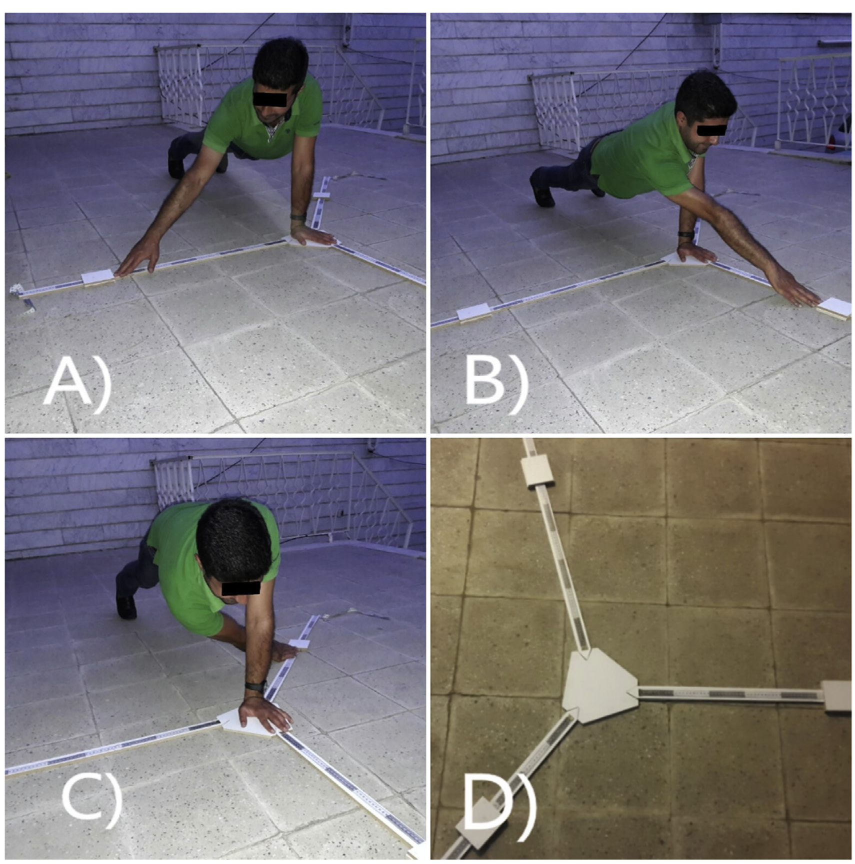


Fig. 4. Upper Quarter Y-Balance Test - Direction of reach is named relative to the stationary upper extremity. *A. Medial Reach Direction, B. Superior Lateral Reach Direction, C. Inferior Lateral Reach Direction.*

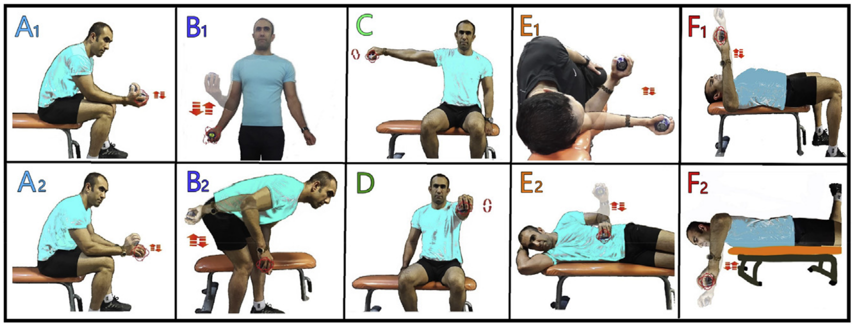


Fig. 5. Powerball exercises: A) Wrist Flexion and extension, Sitting on the table. B) Elbow Flexion, standing and Elbow Extension in Standing (Trunk flexion). C) Shoulder Flexion, Sitting on the table. D) Shoulder Abduction, Sitting on the table. E) Shoulder External and Internal Rotation, side Lying on the table. F)Shoulder Internal Rotation, lying prone on the table and Shoulder External Rotation, lying supine on the table.

Table 1
Mean and standard deviation of anthropometric properties of experimental and control groups.

Group[a]	Impingement (N = 15)	Tennis elbow (N = 15)	Control (N = 15)
Age (years)	25.5 ± 1.05	27.2 ± 2.02	28.2 ± 2.02
Height (cm)	177.5 ± 3.52	178.3 ± 6.21	179.8 ± 4.62
Weight (kg)	81.2 ± 10.74	76.8 ± 7.11	81.7 ± 5.39

[a] The results showed that there were no significant differences in anthropometric of the subjects of three groups.

external rotators, grip strength, wrist extension strength in the experimental groups after the 8-week intervension. Whereas in the control group, there were no differences in the muscle strength, suggesting that the applied exercises contributed to the improvement of muscle strength in shoulder, wrist, and hand.

Previous studies, support our results of increased handgrip strength using "gyroscopic device" (Lim and Shin, 2016; Bosco et al., 1999). But, the results of the present study are contrary to those of Balan and Garcia-Elias (2008). Despite increasing muscular endurance, Balan and Garcia-Elias (2008) did not report any statistically significant altered in hand grip strength. This conflict report can be due to an inadequate number of subjects and the type and duration of the training program to assure the power of the conclusions.

There are different proposed reasons why strength increases. The studies show that strength may initially increase due to neuromuscular adaptation (more motor recruitment) (Salles et al., 2015), muscle hypertrophy (Baechle et al., 2000), and likely the change in the type of muscle fibers (Whyte, 2006).

Lateral Tennis Elbow and Shoulder Impingement Syndrome are the most frequent myotendinous and can be responsible for substantial pain, loss of function, and muscle strength of the affected limb but articular and neurological signs are normal (Ajimsha et al., 2012; McAtee, 1993). Muscular biomechanics characteristics and equipment are important to improve the conditions (Waseem et al., 2012; Conroy and Hayes, 1998).

Although debatable, the muscular control that is required to counteract the centrifugal forces generated by this sort of apparatus is, in fact, an eccentric exercise, inducing active fiber elongations (LaStayo et al., 2003). Eccentric training strengthens the muscle by having it contract as it lengthens. This type of training could also save time by combining the strengthening and flexibility components into one activity (Nelson and Bandy, 2004). Since the wrist muscle theoretically adapts to the imposed demand (Bandy and Sanders, 2001), we expect increasing grip strength due to neuromuscular adaptation (Salles et al., 2015) of eccentric forces developed by the gyroscope.

How an exercise program can improve strength remains uncertain. It is claimed the eccentric phase of the resistance training results in tendon strengthening by stimulating mechanoreceptors in tenocytes to produce collagen, which is probably the key cellular mechanism that determines recovery from tendon injuries (Ohberg et al., 2004; Stanish et al., 1986).

Significant changes in muscle strength of the experimental groups are possibly the result of the vibration resistance training using the "gyroscopic device" (Lim and Shin, 2016; Bosco et al., 1999) in improving collagen alignment of the tendon and stimulate cross-linkage collagen formation, both of which improve tensile strength (Alfredson et al., 1998) as supported by experimental studies on animals. The positive effects of an exercise program for tendon injuries may be attributable to either the effect of eccentric phase, with a lengthening of the muscle-tendon unit and consequently less strain experienced during grip hand, or the effects of vibration within the muscle-tendon unit, with hypertrophy and increased tensile strength in the tendon (Alfredson et al., 1998). During the eccentric phase of the training, the blood flow may stop in the area of damage, and this leads to neurovascularisation, the formation of new blood vessels, which improves blood flow and healing in the tissue, which can be a hypothesis for improving muscle strength in experimental groups (Ohberg et al., 2004).

Results show that "gyroscopic device" training increases the upper extremity performance tested by the Y test in three directions (medial, anterolateral, and posterolateral).

The improvement in muscle performance after vibrating training has been quoted (Bosco et al., 1999) to be similar to that occurring after several weeks of heavy resistance training (Hakkukinen et al., 1985). Therefore, the improvement in muscle function after "gyroscopic device" training as a vibrating stimulation can be the effect of the enhancement of neuromuscular behavior (Salles et al., 2015) caused by an increasing activity of higher motor centers. The improvement of muscle performance induced by "gyroscopic device" training may suggest that a neural adaptation have occurred in response to this intervention. In this connection, the duration of the stimulus would seem to be important. Adaptive response of human skeletal muscle to simulated hyper gravity conditions, applied for only 3 weeks, has been found to cause an improvement in the behavior of the leg extensor muscle (Bosco, 1985).

Thus it is likely that both neural adaptation and 8 weeks "gyroscopic device" of the stimulus play important roles in the improvement of muscle performances indicated in Y test results.

The intervension applied in our study with the chronic

Table 2
Shoulder, wrist and grip strength, shoulder and wrist proprioception and performance scores at pre- and post-training.

	Group	Pre-test	Post-test	Difference from pre-test to post-test (Measured with Paired *t*-test)	Difference among groups (measured with covariance)		
					Group 1 and 3	Group 2 and 3	Group 1 and 2
Int rot. concentric strength	1	64.27 ± 17.98	69.87 ± 20.68	−5.60 ± 3.3*	3.33*	2.71*	0.65
	2	66.27 ± 14.98	70.21 ± 17.99	−3.6 ± 3.1*	P = 0.005*	P = 0.009*	P = 0.43
Mean ± SD	3	68.91 ± 21.13	70.20 ± 14.23	−1.6 ± 7.1			
Ext rot. Concentric strength	1	61.33 ± 11.53	67.47 ± 12.41	−7.14 ± 1.12*	4.12*	3.43*	0.56
	2	60.21 ± 11.53	66.47 ± 12.22	−6.26 ± 1.31*	P = 0.009*	P = 0.013*	P = 0.46
Mean ± SD	3	67.27 ± 11.10	68.53 ± 12.14	−1.24 ± 1.4			
Int rot. eccentric strength	1	55.27 ± 19.33	61.27 ± 12.21	−6±7.12*	4.17*	4.03*	0.54
Mean ± SD	2	55.41 ± 17.70	60.23 ± 14.33	−5.18 ± 3.37*	P = 0.008*	P = 0.019*	P = 0.43
	3	59.99 ± 21.17	61.21 ± 16.7	−1.22 ± 5.10			
Ext rot. Eccentric strength	1	54.13 ± 8.87	63.16 ± 11.17	9.3 ± 3.7*	6.13*	5.74*	0.89
Mean ± SD	2	53.85 ± 9.14	59.20 ± 8.51	6.65 ± 1.37*	P = 0.003*	P = 0.005*	P = 0.93
	3	60.27 ± 15.7	60.43 ± 12.21	−0.16 ± 3.51			
Int rot. eccentric strength	1	90.41 ± 6.17	102.87 ± 14.55	−12.46 ± 8.38*	6.79*	4.87*	0.78
Mean ± SD	2	93.21 ± 7.43	104.51 ± 24.33	−11.30 ± 17.10*	P = 0.001*	P = 0.004*	P = 0.69
	3	94.33 ± 22.11	93.21 ± 21.15	1.11 ± 1.04			
Int rot. eccentric strength	1	25.27 ± 2.11	38.87 ± 4.18	−13.60 ± 2.07*	6.86*	4.33*	0.59
Mean ± SD	2	25.33 ± 1.63	35.36 ± 2.47	−10.3 ± 1.16*	P = 0.002*	P = 0.006*	P = 0.47
	3	28.52 ± 3.31	28.33 ± 1.17	−1.19 ± 2.14			
Shoulder proprioception	1	9.13 ± 2.12	4.23 ± 12.14	5.1 ± 10.2*	3.27*	3.02*	0.59
Mean ± SD	2	8.33 ± 1.88	4.47 ± 2.16	4.14 ± 1.72*	P = 0.018*	P = 0.021*	P = 0.49
	3	6.27 ± 2.4	6.12 ± 3.1	0.15 ± 1.3			
Wrist proprioception	1	3.27 ± 1.53	0.9 ± 1.68	2.33 ± 0.15*	3.06*	1.44*	0.78
Mean ± SD	2	3.69 ± 1.98	1.87 ± 1.68	1.82 ± 0.3*	P = 0.007*	P = 0.032*	P = 0.69
	3	2.47 ± 2.24	1.20 ± 1.68	−1.27 ± 1.44			
Performance (Y balance test)	1	53.33 ± 5.17	62.23 ± 6.47	−9.1 ± 1.3*	6.76*	6.87*	0.68
	2	55.31 ± 7.11	64.47 ± 6.31	−9.16 ± 1.2*	P = 0.001*	P = 0.001*	P = 0.56
Mean ± SD	3	64.38 ± 6.32	65.35 ± 5.31	−1.3 ± 1.1			

Group 1: Impingement/Group 2: Tennis elbow/Group 3: Control.
*The mean difference is significant at the $p < 0.05$.

impingement syndrome and tennis elbow group induced a significant improvement of shoulder proprioception and wrist proprioception tested by Isokinetic Device Humac Norm (Cybex Co.). Resistance training improves motor control and performance of upper extremity performance in people with tendencies (Roy et al., 2009). Strength training produced an improvement in JPS, suggesting improvements in the sensitivity of muscle spindles and, hence, better neuromuscular control in the shoulder (Salles et al., 2015). Muscle spindles, muscle length, and sensors that detect changes in the rate of lengthening are responsible for JPS during voluntary muscle activation (Herrington et al., 2010). Besides sending sensory information, spindles also receive efferent motor connections (gamma motorneurons) that activate regulatory system sensitivity during voluntary muscle contraction (Hung and Darling, 2012). Thus, the physiologic reason for the improvement of performance in our study is to have more sensitive proprioceptive spindles after the training as resistance training, resulting in better position detection, and motor control as previously proposed (Salles et al., 2015; Roy et al., 2009).

Since both impingement syndrome and tennis elbow in volleyball players are repetitive overhead motions resulting in bursitis (Ajimsha et al., 2012; McAtee, 1993), also lack of adequate subjects met the exclusion and inclusion criteria, the study had only one control group.

Although this study showed the positive effect of the "gyroscopic device" exercise on 22–28 volleyball players, the possible effects on other groups are not known. Therefore, further studies that will investigate the effects of applying "gyroscopic device" on untrained people are needed.

5. Conclusion

The purpose of this study was to clarify the relevance of effects of eight-week Powerball mediated resistance training exercise in the outcome of chronic impingement syndrome and tennis elbow treatment.

Results of this study suggest that an 8-week program including "gyroscopic device" mediated resistance training exercise improves the concentric and eccentric strength of internal rotators, concentric and eccentric external rotators, grip strength, wrist extension strength, shoulder proprioception, wrist proprioception, and upper extremity performance. There was not any significant difference between two experimental groups in post-test, but between group 1 and control group, and between group 2 and control group the difference was significant.

This current study did not include EMG recordings. Therefore it is not possible to directly assess any neurogenic enhancement. To better understand how shoulder control is modified, further studies need to evaluate changes in muscle and interjoint coordination using electromyography and motion analysis systems. Nonetheless, this study provides preliminary evidence to support the use of "gyroscopic device" mediated resistance training exercises to promote better function in people with tendinopathy. Future studies should focus on the long-term beneficial effects of this new program and on understanding the other tissular adaptive mechanisms following this exercise loading.

Although none of the volunteers experienced significant pain or discomfort with application of the "gyroscopic device", the generated force may become quite important in weak or improperly trained musculatures for a higher pain index and damage of the muscular ultrastructure.

Conflicts of interest

The authors declared no potential conflicts of interest concerning the authorship and publication of this article.

Appendix 1. The exercise protocol of Powerball

Table 3
The exercise protocol of Powerball.

week	Type of group[a]	Exercise (time* set)	Name of training	Rest between sets	Rest between each exercise	Situation implementation of exercise
1	A	Exercise 1: (3*30s)	Wrist Flexion	60s	120s	Sitting on the table
	A	Exercise 2: (3*30s)	Wrist Extension	60s	120s	Sitting on the table
	B	Exercise 3: (3*30s)	Elbow Flexion	60s	120s	standing
2	A	Exercise 1: (4*30s)	Wrist Flexion	60s	120s	Sitting on the table
	A	Exercise 2: (4*30s)	Wrist Extension	60s	120s	Sitting on the table
	B	Exercise 3: (4*30s)	Elbow Flexion	60s	120s	standing
3	A	Exercise 2: (4*45s)	Wrist Extension	90s	180s	Sitting on the table
	B	Exercise 3: (4*45s)	Elbow Flexion	90s	180s	standing
	B	Exercise 4: (3*30s)	Elbow Extension	60s	120s	Standing (Trunk flexion)
	C	Exercise 5: (3*30s)	Shoulder Flexion	60s	120s	Sitting on the table
4	A	Exercise 2: (5*45s)	Wrist Extension	90s	180s	Sitting on the table
	B	Exercise 3: (5*45s)	Elbow Flexion	90s	180s	standing
	B	Exercise 4: (4*30s)	Elbow Extension	60s	120s	Standing (Trunk flexion)
	C	Exercise 5: (4*30s)	Shoulder Flexion	60s	120s	Sitting on the table
5	B	Exercise 3: (5*60s)	Elbow Flexion	120s	240s	standing
	B	Exercise 4: (4*45s)	Elbow Extension	90s	180s	Standing (Trunk flexion)
	C	Exercise 5: (4*45s)	Shoulder Flexion	90s	180s	Sitting on the table
	D	Exercise 6: (3*30s)	Shoulder Abduction	60s	120s	Sitting on the table
	E	Exercise 7: (3*30s)	Shoulder ER	60s	120s	Sitting on the table
6	B	Exercise 3: (6*60s)	Elbow Flexion	120s	240s	standing
	B	Exercise 4: (5*45s)	Elbow Extension	90s	180s	Standing (Trunk flexion)
	C	Exercise 5: (5*45s)	Shoulder Flexion	90s	180s	Sitting on the table
	D	Exercise 6: (4*30s)	Shoulder Abduction	60s	120s	Sitting on the table
	E	Exercise 7: (4*30s)	Shoulder ER	60s	120s	Sitting on the table
7	B	Exercise 4: (5*60s)	Elbow Extension	120s	240s	Standing (Trunk flexion)
	C	Exercise 5: (5*60s)	Shoulder Flexion	120s	240s	Sitting on the table
	D	Exercise 6: (4*45s)	Shoulder Abduction	90s	180s	Sitting on the table
	E	Exercise 7: (4*45s)	Shoulder ER	90s	180s	Lying on its side on the table
	E	Exercise 8: (3*30s)	Shoulder IR	60s	120s	Lying on its side on the table
	F	Exercise 9: (3*30s)	Shoulder Horizontal Abduction	60s	120s	Lying supine on the table
8	C	Exercise 5: (6*60s)	Elbow Flexion	120s	240s	Sitting on the table
	D	Exercise 6: (5*45s)	Shoulder Abduction	90s	180s	Sitting on the table
	E	Exercise 7: (5*45s)	Shoulder ER	90s	180s	Lying on its side on the table
	E	Exercise 8: (4*30s)	Shoulder IR	60s	120s	Lying on its side on the table
	F	Exercise 9: (4*30s)	Shoulder External Rotation	60s	120s	Lying supine on the table
	F	Exercise 10: (3*30s)	Shoulder Internal Rotation	60s	120s	Lying prone on the table

[a] Level of exercise values: A = low, B = mild, C = moderate, D = severe, E & F = very severe.

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