Effects of a Novel Rotator Cuff Rehabilitation Device on Shoulder Strength and Function

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Abstract

Savitzky, JA, Abrams, LR, Galluzzo, NA, Ostrow, SP, Protosow, TJ, Liu, SA, Handrakis, JP, and Friel, K. Effects of a novel rotator cuff rehabilitation device on shoulder strength and function. *J Strength Cond Res* XX(X): 000–000, 2019—The glenohumeral joint, a multiaxial ball and socket joint, has inherent instability counterbalanced by the muscular stability of the rotator cuff (RC) and connective tissue. Exercise has been shown to alleviate pain and disability arising from degenerative changes of the RC due to overuse, trauma, or poor posture. This study compared the training effects of ShoulderSphere (SS), an innovative device that uses resistance to centrifugal force, to TheraBand (TB), a traditional device that uses resistance to elasticity. Thirty-five healthy male and female adults (24.2 ± 2.4 years) were randomized into 3 groups: SS, TB, and control. Five outcomes were assessed before and after the twice-weekly, 6-week intervention phase: strength (shoulder flexion [Fx], extension [Ext], external rotation [ER], and internal rotation [IR]), proprioception (6 positions), posterior shoulder endurance (ShEnd), stability (Upper Quarter Y-Balance Test [YBal] (superolateral [YBalSup], medial [YBalMed], and inferolateral [YBalInf]), and power (seated shot put [ShtPt]). Data were analyzed using a 3 (group: SS, TB, and control) × 2 (time: pre and post) generalized estimating equation. Analyses demonstrated a main effect of time for all strength motions ($p < 0.01$): YBalInf ($p < 0.0001$), ShtPt ($p < 0.05$), and ShEnd ($p < 0.0001$) but no interaction effects of group × time. There were no main or interaction effects for proprioception. Both SS and TB groups had significant within-group increases in Ext, IR, YBalInf, and ShEnd. Only the SS group had significant increases in ER, Fx, and ShtPt. ShoulderSphere demonstrated comparable conditioning effects with TB and may afford additional strength gains in Fx and ER, and power. ShoulderSphere should be considered a viable alternative in RC conditioning.

Key Words: shoulder complex, shoulder joint, resistance training, exercise therapy, strengthening exercise

Introduction

The glenohumeral (GH) joint is a multiaxial ball and socket joint, which sacrifices stability for increased mobility (7). The inherent instability of the shoulder is due to the anatomical relationship of the glenoid fossa to the humeral head (41). Functional stability of the shoulder is accomplished through integration of noncontractile static stabilizers (the joint capsule and ligaments) and contractile dynamic stabilizers (the shoulder musculature) (3).

The 4 dynamic stabilizers of the shoulder are known collectively as the rotator cuff (RC) (7). The RC maintains stability of the shoulder by compressing and centering the convex humeral head into the concave glenoid fossa of the scapula and plays a vital role in biomechanical control of the shoulder complex and healthy shoulder function (44). An injured RC will lead to alteration of normal biomechanics secondary to compensation for that weakness or instability, which will reduce force coupling at the shoulder, thus making movement less efficient and ultimately painful (34).

Rotator cuff disease is the most common, nontraumatic, upper extremity (UE) cause of disability in people over the age of 50 in the United States (32). In addition, athletes who engage in overhead sports are particularly susceptible to RC injuries because of the high velocity of repetitions and excessive eccentric loading imposed on the shoulder complex during participation in these activities (46).

Previously published reports suggest that strengthening exercises may be an effective prevention of, as well as a treatment for, RC disease (2,9,17,23). Regardless of the indication, there are many existing methods and exercise protocols to optimize RC strength and function. Some of the more traditional strengthening methods used include resistance exercise using cuff weights, elastic bands (TheraBand [TB]), isokinetic machines, and medicine balls, whereas more recent methods include oscillatory devices, such as the BodyBlade, the FlexBar, and the Body Oscillation Integrates Neuromuscular Gain (B.O.I.N.G.) (4,28,38,42). Findings on the effects of shoulder exercise using oscillatory devices are mixed. Therefore, we intend to explore the unique effects of a new type of oscillatory device, the ShoulderSphere (SS), on performance outcome measures compared with a traditional shoulder rehabilitation program.

Previous investigations have studied the effects of exercising with the BodyBlade and the FlexBar (oscillatory devices) on strength and muscle activation of the shoulder complex (4,13,18,28,33,35). Exercise with these oscillatory devices (BodyBlade and FlexBar) elicited high activation of the shoulder musculature (infraspinatus and deltoid), the scapular musculature (serratus anterior, upper trapezius, and levator scapulae),

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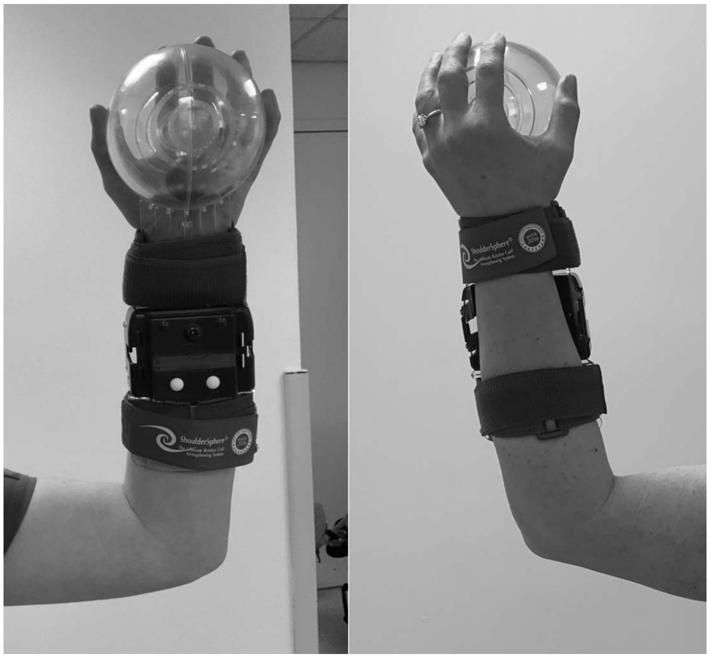

Figure 1. Photograph of the ShoulderSphere (SS) front and back (ShoulderSphere, A7; e Business International).

and accessory musculature (erector spinae, latissimus dorsi, and pectoralis major) as evidenced by electromyographic (EMG) activity (4,18,28,33,35). However, these studies did not show that oscillatory devices were more effective than traditional methods for strengthening the shoulder (42). The SS is different than previous oscillatory devices because it requires the user to resist a centrifugal force, rather than the linear force of previous oscillatory devices. As many functional activities are performed in nonlinear motions, we hypothesized that the SS's unique resistance would offer additional benefits compared with a traditional RC strengthening method (TB).

Oscillatory devices require a rhythmic pattern of alternating contractions between the agonist and antagonist muscles to achieve the desired motion (38). In comparison, methods such as elastic bands and cuff weights only provide resistance to the agonist during one exercise; an exercise in the opposite direction is needed to resist the antagonist (28). Although these methods can be modified to provide resistance throughout the range of motion (ROM), their linear pattern does not mimic the typical motion used during UE function and, therefore, may not be ideal for carryover of strength gains into functional activities (21). In addition, the direct increase of resistance with exercise range using TB may not be the ideal application because TB's greatest resistance is at the end of range, where RC muscles are weakest (26). Owing to the RC's inherent ability to "rotate" the shoulder joint, it can be theorized that rotational exercises may be more ideal for strengthening and rehabilitation of the RC. The SS is able to provide multiplanar resistance to the joint throughout the exercise excursion, therefore enhancing recruitment of multiple muscle groups.

Exercising the shoulder has been shown to have an effect on proprioception at the joint itself (28). Proprioception is essential for optimal neuromuscular control and stability of the GH joint (27) and is defined as position sense, kinesthesia, and sensation of force of the body and extremities (5). Oscillatory devices may provide more proprioceptive feedback than traditional strengthening devices because they require increased recruitment of scapular stabilizers, increased coordination and rhythmic patterns of alternating contractions between agonist and antagonist to properly operate these devices (38).

The SS (ShoulderSphere, A7; e Business International, Shenzhen, China) is a novel, patented, oscillatory, exercise device designed to optimize RC strengthening using active muscle contractions in a rotational manner (40) (Figure 1). Our study aimed to compare the effects of exercising with the SS to TB (TheraBand; The Hygenic Corporation, Akron, OH), a device traditionally used during shoulder rehabilitation, on multiple shoulder outcomes. Our hypothesis was that exercising with the SS would yield results that were at least comparable to exercising with TB in measures typically used to assess shoulder performance, i.e., shoulder strength, proprioception, power, shoulder stability, and endurance.

Methods

Experimental Approach to the Problem

A multigroup pretest-posttest study design was used to determine the effects of exercising with the SS or TB as compared to a control group (no exercise intervention). Training effects were assessed using shoulder performance outcome measures, specifically measures of shoulder strength, proprioception, endurance, stability, and power. All measured dependent variables are important components of optimal RC function. Outcome measures were assessed in all 3 groups (SS, TB, and control) 1-week before and 1 week after the 6-week intervention period.

The training intervention consisted of 6 exercises adapted from the Thrower's 10 protocol, a commonly used exercise regimen for shoulder rehabilitation (45).

Subjects

Eleven male and 24 female healthy subjects between the ages of 18 and 29 years volunteered to participate in the study. The subjects

Table 1
Characteristics for SS, TB, and control groups.*†

	SS (n = 12), mean ± *SD*	TB (n = 11), mean ± *SD*	Control (n = 12), mean ± *SD*	p
Sex ratio (m/f)	5/7	2/9	4/8	0.47
Age (yrs)	24.0 ± 2.6	24.4 ± 1.4	24.3 ± 3.0	0.94
Height (m)	1.70 ± 0.09	1.68 ± 0.10	1.67 ± 0.10	0.78
Body mass (kg)	74.5 ± 15.1	66.0 ± 10.1	69.5 ± 15.2	0.34
BMI ($kg \cdot m^{-2}$)	25.7 ± 3.6	23.4 ± 2.3	24.8 ± 3.7	0.24

*SS = ShoulderSphere; TB = TheraBand; BMI = body mass index; ANOVA = analysis of variance.

†Group averages for the sex ratio (male/female), age (in years), height (in meters), body mass (in kilograms), BMI (in $kg \cdot m^{-2}$); statistical comparisons used chi-square for the sex ratio and 1-way ANOVA for age, height, body mass, and BMI. Significance threshold was set at $p < 0.05$.

represented a convenience sample of students and staff from, or visitors to, the undergraduate and graduate programs of New York Institute of Technology (NYIT), Old Westbury, NY. This study was approved by the Biomedical and Health Sciences Research-Institutional Review Board (BHS-IRB) of NYIT, and all subjects signed the IRB-approved consent form signifying that they understood the study purpose, methods, benefits, and risks before volunteering to participate.

Subjects were included for study if they demonstrated good overall health as determined by the PAR-Q form, were able to communicate in English, had shoulder ROM within normal limits, as per normative values reported by the American Academy of Orthopedic Surgeons (AAOS), at least 4/5 shoulder strength as assessed by a manual muscle test, and were free of shoulder pathology, as evidenced by negative findings for the following clinical tests: Neer Impingement test for RC impingement, O'Brien's test for labral tears, Drop Arm test for RC musculature integrity, and Jobe subluxation/relocation test for instability. Subjects were excluded from study if they participated in any NCAA collegiate sports team, were allergic to latex, had a history of any shoulder surgery, a shoulder injury within the past 6 months, any cardiovascular disease, were taking any cardiac or blood pressure medications, or had any neurological condition affecting muscle performance that would impair shoulder function.

Subjects were randomly assigned to one of 3 groups, SS or TB (exercise groups) or control (no-exercise group) using a computer-generated randomization tool (Simple Interactive Statistical Analysis). The 3 groups did not differ in characteristics (Table 1).

Procedures

All subjects in all groups were assessed 1-week before and 1 week after a 6-week intervention period. The following 5 outcome measures were assessed:

Strength. Strength was measured using a hand-held dynamometer (HHD) (Chatillon Model #K-DMG-500; AMETEK M&CT Division, Largo, FL). A systematic review by Stark et al. (41) compared HHD with the gold standard, isokinetic dynamometry, for assessment of muscle strength in the clinical setting. They concluded that HHD is a reliable and valid instrument for measuring changes in muscular strength. Subjects were tested in 4 motions: standing shoulder flexion (Fx) and extension (Ext) with the shoulder at neutral and elbow fully extended and seated shoulder external rotation (ER) and internal rotation (IR) with the shoulder at neutral and elbow at 90° of flexion. The HHD was secured so that the line of pull was parallel to the floor and the cable taut without tension before the pulling phase. Subjects were given 2 practice trials (5-second submaximal isometric effort), followed by 3 consecutive trials for each tested motion (5-second maximal isometric effort (42). Subjects were given a 20-second rest between each trial and a 2-minute rest period between each tested motion. For Fx and Ext, subjects were instructed to stand with their feet shoulder-width apart using a staggered stance (foot in front was opposite the arm being tested). For Fx, subjects stood facing away from the tester and were instructed to pull into the direction of forward flexion. For Ext, subjects faced the tester and were instructed to pull into the direction of shoulder extension. For shoulder ER and IR, subjects were seated in a chair with their trunk erect, feet on the floor and shoulder-width apart, and a towel roll between the elbow and the torso. For ER, subjects were instructed to rotate the arm away from the body into ER. For IR, subjects were instructed to rotate the arm toward the body into IR. The average of the 3 trials for each motion was recorded.

Proprioception. Proprioception was tested with an iPhone app, Clinometer (Breitling Peter; Plaincode Software Solutions, Gunzenhausen, Germany). Subjects were tested on their ability to reproduce several target joint angles while blindfolded: shoulder flexion and abduction at 50 and 90° while seated and shoulder ER and IR at 45° while supine. For shoulder flexion and abduction, the iPhone was secured to the lateral aspect of subject's UE using a Velcro strap, with the middle of the iPhone aligned with the lateral epicondyle. For shoulder ER and IR, the iPhone was secured to the ulnar aspect of the subject's forearm using a Velcro strap with the middle of the iPhone aligned with the olecranon (11). To familiarize subjects with the test positions, each test began with a passive trial where the researcher positioned the subject's arm to within 1–2° of the target angle, removed support, and instructed the subject to maintain that position for 10 seconds. The subject was then instructed to perform 3 trials, where they actively moved their UE to the previously positioned angle and maintained that position for 2 seconds. The calculated difference between the target angle and the actively reproduced angle for all 3 trials was averaged and recorded (11).

Power. Power was measured by throwing distance during a seated one-arm shot put (ShtPt) (39). Subjects were seated in a secured chair with their lower extremities extended and resting on the seat of a second chair directly in front of them. The nonthrowing arm was placed across the subject's chest, strapped diagonally across the body, and secured to the chair so the subject could not rely on trunk rotation during the throwing motion. Subjects performed a shot put motion with a 2.72 kg medicine ball. Each subject performed 4 warm-ups at 25, 50, 75, and 100% of their maximum effort. After a 2-minute rest, subjects performed 3 maximum effort trials. The distance from the anterior aspect of the chair to where the ball landed was measured, and the average of the 3 trials was calculated and recorded (39).

Stability. Stability was measured using the Upper Quarter Y-Balance Test (UQYBT) (Functional Movement System. Y-Balance Test. 2010). Following an established protocol for the administration of the UQYBT (15), subjects maintained a one-arm plank position on the Y-balance apparatus and were instructed to slide the "reach box" with the unweighted UE as far as possible in the test direction. The tested "stance" limb was the subject's dominant limb. Three directions were tested: medial (YBalMed), inferolateral (YBalInf), and superolateral (YBalSup). Subjects maintained contact with the box throughout each motion so as not to "throw" the reach box. One complete trial included pushing the reach box as far as possible in all 3 directions. The subject completed 1 practice trial, followed by 3 performance trials, with a 60-second rest between each trial. Subjects completed 3 full trials, and the average excursion score was established for each direction (15).

Shoulder Endurance. Following a protocol for Posterior Shoulder Endurance Test (PSET) previously established by Moore et al. (30), subjects lay prone on a plinth, while holding a dumbbell that was approximately 2 percent of their body weight, as measured by a calibrated scale. With their tested UE off the plinth and perpendicular to the floor, subjects were instructed to horizontally abduct their UE to the level of a string, which was set at 90° of horizontal shoulder abduction. Subjects were instructed to lift and lower the dumbbell as many times as possible at a rate of 2 seconds per repetition, which was in sync with a smartphone metronome app set to 30 bpm (Smart Metronome 5.1.1; Apple Inc., Tomohiro Ihara, Japan). Maximal shoulder endurance (ShEnd) was defined by the total number of repetitions performed until the subject was unable to hold the end position for 1 second, complete the maneuver, or elevated their upper torso (30).

Exercise Interventions. After baseline assessment, subjects performed shoulder exercises twice-weekly for 6 weeks with either the SS or TB (exercise groups), or no exercise other than their typical daily physical activities (control group). The exercise groups performed 6 exercises in the standing position adapted from the Throwers 10 protocol: (a) shoulder ER at 0° of shoulder abduction, (b) shoulder IR at 0° of shoulder abduction, (c) shoulder ER at 90° of shoulder abduction, (d) shoulder IR at 90° of shoulder abduction, (e) UE D2 extension and, (f) UE D2 flexion (Figures 2 and 3) (45). All sessions were supervised.

Group Conditions: ShoulderSphere. Because the SS provides concurrent, rhythmic pattern of alternating contractions between agonist and antagonist muscles (38), the following exercise motions were combined: ER and IR at 0° of shoulder abduction, ER and IR at 90° of shoulder abduction, and D2 extension and flexion. Thus, 6 motions were combined into 3 exercises.

Subjects in the SS group ($n = 12$) began the 6-week exercise training period with the 4-inch sphere, containing a 2-ounce ball, and performed 3 sets of 60 seconds for each of the 3 compound exercises. Subjects had a rest period of 45–60 seconds between each set and 2 minutes between each exercise. If the subject rated the perceived intensity as <6/10 on the OMNI-RES scale (8) (0 = no effort to 10 = maximal effort) after completing 3 sets of the exercise, exercise intensity was progressed by adding a 20-second interval until reaching a maximum of 120 seconds for each set. Once the subject was able to successfully perform 3 sets of 120 seconds continuously and reported a score <6/10 on the OMNI-RES scale, the subject was progressed to the larger 6-inch sphere, which contained a 7-ounce ball inside the sphere. Proper performance while using the SS was defined by the ability to continuously rotate the weighted ball inside the hollow sphere without a loss of momentum or the ball "dropping" inside the sphere. The subject was allowed one "drop" of the ball followed by regaining continuous momentum of the ball to qualify for progression.

Theraband. Subjects in the TB group ($n = 11$) were assigned an appropriate starting resistance (color) of TB during the pretest session. The TB length was individually standardized according to the UE length of the subject, as measured by the distance from their axilla to the tip of their third digit. According to TB Academy guidelines, all subjects were initially provided with blue TB and performed 10 repetitions of each exercise during the presession (22). After performing a specific exercise using the blue TB, the subject was asked to rate their effort level on the 0–10 OMNI-RES scale. If the subject reported a value <6/10 on the scale, the blue TB remained as their baseline color for that specific exercise. If the subject reported a value in the 6–10 range for any particular exercise, the resistance/color of TB was decreased to green, which the subject then used as their baseline color. Observation of proper form and subjective intensity using the OMNI-RES scale determined the appropriate color/resistance of TB with which the subject would initiate the 6-week exercise intervention.

During training, subjects in the TB group performed 3 sets of 10 repetitions of each exercise using their baseline TB color, with the band elongated to 100% of its length. Each repetition required a metronome-regulated 3 seconds for each of the concentric and eccentric phases. Subjects had a rest period of 45–60 seconds between each set and 2 minutes between each exercise. Resistance was progressed for each exercise based on observation of proper form and subjective reporting of intensity, as described previously. A 2-step method was used to increase exercise difficulty: (a) increasing repetitions from 10 to 20 repetitions and (b) advancing to a harder color/resistance. Once the subject performed 3 sets of 10 repetitions at 100% of TB length with a rated resistance of <6/10 on the OMNI-RES scale, exercise difficulty was increased by performing 3 sets of 20 repetitions (22). Once the rated difficulty of 3 sets of 20 repetitions was <6/10, the color/resistance of the band was increased, and the subject performed 3 sets of 10 repetitions with the new band color.

Control. Subjects in the control group ($n = 12$) were instructed to continue with their typical physical activity schedule and not to add any new physical exercise or sport for the 6-week period.

Statistical Analyses

A 3 (group: SS, TB, and control) × 2 (time: pre/post intervention) generalized estimating equation (GEE) was performed to determine significant main effects of time and interaction effects of group × time. If significant main or interaction effects were determined, post hoc analyses were performed using *t*-tests. An alpha level of 0.05 was set as the threshold for significance for all comparisons. Statistical analyses were performed using SPSS Version 24. Our sample size calculation was based on a previous investigation of elastic bands and an oscillatory device on RC strength, which reported an effect size of $f = 0.3$ (42). Sugimoto et al. required a total of 30 subjects to detect the effect size of $f = 0.3$ for a statistical power of 80% at alpha = 0.05 (42). We decided to recruit 35 subjects to account for possible subject attrition or cases of missing data.

Figure 2. Photograph of the starting and ending position of D2 extension exercise with the TheraBand.

Results

The results of GEE analysis demonstrated a significant main effect of time for all strength motions ($p < 0.01$): YBalInf ($p < 0.0001$), ShtPt ($p < 0.05$), and ShldEnd ($p < 0.0001$). However, no significant interaction effects of group × time were found for any of these measures. No main or interaction effects for proprioception were demonstrated (Table 2).

Post hoc within-group analyses of the measures with significant main effects were performed using paired *t*-tests and revealed the following:

Strength (Dyno)

Both SS and TB groups demonstrated significant within-group change in (a) Ext ($p < 0.01$ and $p < 0.05$, respectively) and (b) IR ($p < 0.05$) (Table 2). For ER and Fx strength, only the SS group demonstrated significant within-group increases ($p < 0.0001$ and $p < 0.05$, respectively) (Table 2).

Power (ShtPt)

Only the SS group demonstrated a significant within-group change in the ShtPt ($p < 0.01$) (Table 2).

Stability (Upper Quarter Y-Balance Test)

Both the SS group and the TB group demonstrated significant within-group improvements ($p = 0 < 0.01$) in YBalInf. There were no significant main effects for the YBalSup and YBalMed motions (Table 2).

Figure 3. Photograph of the starting and ending position of D2 flexion exercise with the TheraBand.

Table 2

Comparison of preintervention and postintervention assessment of strength of shoulder flexion (DynoFx), extension (DynoExt), external rotation (DynoER), internal rotation (DynoIR) and stability in inferolateral direction (YBalInf), endurance (ShldEnd), and power (ShtPt).*†

Outcome		SS (*n* = 12), mean ± *SD*	TB (*n* = 11), mean ± *SD*	Control (*n* = 12), mean ± *SD*	Time, *p*	Group*Time‡, *p*
DynoFx (kg)	Pre	9.22 ± 3.86	6.47 ± 2.6	9.36 ± 4.92	**0.001**	0.405
	Post	10.83 ± 3.38‡	7.03 ± 2.3	9.89 ± 5.41		
	95% CI	2.94 to 0.28	1.34 to −0.22	1.6 to −0.07		
	Effect size	0.65	0.4	0.51		
DynoExt (kg)	Pre	8.96 ± 2.44	7.09 ± 2.23	8.59 ± 3.43	**<0.001**	0.288
	Post	10.82 ± 3.01§	8.02 ± 2.12‡	9.22 ± 4.28		
	95% CI	2.93 to 0.78	1.80 to 0.06	1.97 to −0.71		
	Effect size	0.94	0.62	0.25		
DynoER (kg)	Pre	6.22 ± 1.37	5.06 ± 1.67	6.00 ± 2.43	**<0.001**	0.063
	Post	8.05 ± 3.01∥	5.58 ± 1.1	6.94 ± 4.34		
	95% CI	2.72 to 0.94	1.15 to −0.12	2.32 to −0.43		
	Effect size	1.09	0.47	0.38		
DynoIR (kg)	Pre	9.09 ± 3.45	7.54 ± 2.17	8.54 ± 3.74	**<0.001**	0.468
	Post	10.67 ± 3.64‡	8.26 ± 2.32‡	9.72 ± 5.27		
	95% CI	2.94 to 0.22	1.37 to 0.07	2.21 to 0.19		
	Effect size	0.64	0.6	0.62		
YBalInf (cm)	Pre	65.6 ± 15.2	68.0 ± 11.0	68.4 ± 10.8	**<0.001**	0.264
	Post	74.5 ± 13.9§	72.1 ± 13.5§	72.2 ± 10.0		
	95% CI	14.18 to 3.48	7.13 to 1.02	7.66 to −0.08		
	Effect size	0.89	0.75	0.53		
YBalMed (cm)	Pre	75.4 ± 11.7	72.5 ± 18.8	74.2 ± 4.9	0.053	0.064
	Post	79.9 ± 11.8	78.4 ± 10.7	72.4 ± 4.1		
	95% CI	8.11 to 0.87	12.15 to −0.39	2.87 to −6.57		
	Effect size	0.67	0.53	0.21		
YBalSup (cm)	Pre	52.8 ± 11.0	51.2 ± 9.9	50.3 ± 8.7	**0.024**	0.943
	Post	54.5 ± 14.6	53.7 ± 11.3	52.6 ± 10.9		
	95% CI	6.07 to −2.82	5.15 to −0.09	4.49 to 0.12		
	Effect size	0.20	0.54	0.58		
ShldEnd (reps)	Pre	24.8 ± 9.3	41.6 ± 20.8	28.0 ± 8.0	**<0.001**	0.133
	Post	41.2 ± 28.5‡	52.1 ± 26.4‡	31.9 ± 11.1		
	95% CI	30.03 to 2.81	19.52 to 1.39	8.33 to −0.5		
	Effect size	0.65	0.65	0.47		
ShtPt (cm)	Pre	355.4 ± 99.8	321.8 ± 50.6	325.2 ± 80.2	**0.014**	0.484
	Post	375 ± 101.1§	330.1 ± 49.9	333.3 ± 102.3		
	95% CI	33.5 to 5.8	24.3 to −7.6	27.5 to −11.4		
	Effect size	0.76	0.29	0.22		
PrpFx50 (°)	Pre	5.2 ± 3.4	4.8 ± 4.1	6.6 ± 3.8	0.581	0.873
	Post	4.6 ± 2.7	4.9 ± 3.7	5.9 ± 4.1		
	95% CI	−0.67 to 2.01	−3.01 to 2.71	−2.22 to 3.61		
	Effect size	0.27	0.29	0.13		
PrpFx90 (°)	Pre	6.1 ± 4.3	5.1 ± 3.1	4.0 ± 2.7	0.105	0.092
	Post	5.3 ± 3.2	2.9 ± 2.4	4.6 ± 0.8		
	95% CI	−0.72 to 2.40	0.25 to 4.11	−2.17 to 1.01		
	Effect size	0.29	0.65	0.2		
PrpAbd50 (°)	Pre	7.3 ± 3.9	8.4 ± 5.0	9.4 ± 4.2	0.690	0.468
	Post	8.4 ± 4.4	7.5 ± 3.5	8.3 ± 4.4		
	95% CI	−3.87 to 1.76	−1.63 to 3.45	−1.05 to 3.11		
	Effect size	0.21	0.20	0.26		
PrpAbd90 (°)	Pre	5.6 ± 4.7	4.3 ± 2.2	4.9 ± 2.6	0.140	0.854
	Post	4.5 ± 3.5	3.1 ± 2.3	4.5 ± 3.1		
	95% CI	−1.14 to 3.34	−0.17 to 2.47	−1.97 to 2.75		
	Effect size	0.27	0.49	0.09		
PrpER (°)	Pre	7.4 ± 5.5	2.7 ± 1.6	5.1 ± 4.7	0.445	0.235
	Post	5.0 ± 3.8	3.7 ± 2.9	4.8 ± 3.5		
	95% CI	−1.18 to 5.93	−2.92 to 0.92	−1.63 to 2.41		
	Effect size	0.36	0.29	0.10		
PrpIR (°)	Pre	4.9 ± 3.8	5.5 ± 2.3	4.3 ± 2.7	0.776	0.907
	Post	4.4 ± 3.1	5.7 ± 3.2	4.0 ± 3.5		
	95% CI	−2.21 to 3.11	−1.58 to 1.27	−1.70 to 2.15		
	Effect size	0.09	0.06	0.06		

*SS = ShoulderSphere; TB = TheraBand; CI = confidence interval.

†Bolded *p* values signify significant main effects of time or significant interaction effects of group*time. 95% CI reflect within-group, pre-to-post comparisons. Effect size is Cohen's *dz* for within-group, pre-to-post comparisons. Effect sizes of 0.2, 0.5, and 0.8 were considered small, medium, and large, respectively. Significance threshold was set at $p < 0.05$.

‡Significant within-group differences before intervention to after intervention $p < 0.05$.

§Significant within-group differences before intervention to after intervention $p < 0.01$.

∥Significant within-group differences before intervention to after intervention $p < 0.001$.

Endurance (ShEnd)

Both SS and TB groups demonstrated significant within-group changes in ShEnd ($p < 0.05$) (Table 2).

Proprioception

Because no significant main or interaction effects were found for proprioception, no post hoc analyses were performed (Table 2).

Discussion

Our study's findings support our hypothesis that in young healthy adults, exercising with the SS would yield results that were at least comparable to exercising with TB because both groups improved in areas of shoulder strength (Ext and IR), stability (YBalInf), and endurance. Only the SS group improved in Fx and ER strength and power. However, because there were no significant interaction effects, we cannot definitively state that exercising with the SS was superior to exercising with the TB. Neither method yielded improvements in proprioception. Further research is needed to confirm the possible additional benefits of the SS in comparison with TB and other strengthening devices in populations with shoulder pathology as well as in healthy populations of different age groups.

The mechanics of shoulder motion are quite complex. Strong RC muscles and a stable GH joint afford optimal shoulder function. As stability increases, there are congruent increases in functional strength and power of the shoulder girdle and UE, and as strength increases, there are increases in stability (28). Wuelker et al. (47) demonstrated that a 50% decrease in RC strength resulted in nearly a 50% increase in anterior displacement of the humeral head in response to external loading at all GH joint positions.

It is important to strengthen both prime mover and dynamic stabilizer muscles of the shoulder because this inherently unstable joint depends heavily on dynamic stabilizers for its stability (12). Both the SS group and TB group demonstrated significant strength gains in shoulder Ext and IR. However, only the SS group demonstrated significant within-group increases in strength for shoulder ER and Fx (Table 2).

It remains unclear how effective another oscillatory device, the BodyBlade, was in strengthening the RC muscles. Sugimoto and Blanpied (42) compared strength in shoulder IR and ER between subjects using BodyBlade or TB to a control group after an 8-week intervention period and did not find significant increases in strength for the BodyBlade group. Contrastingly, our study suggests that exercising with the SS produced similar strength gains in shoulder Ext and IR when compared with identical exercises performed with TB.

A case study conducted by Buteau et al. (6) demonstrated an increase in IR strength after 6 weeks of training with the BodyBlade in an 18-year old male patient recovering from an acute shoulder dislocation. The authors noted that the study was limited in that the exercise protocol was not standardized throughout the 6-week training period. This variation in the exercise protocol could have influenced their results. Lake et al. conducted a study in which baseball players were trained with the BodyBlade during a 10-week exercise program. Their results failed to find significant improvements in shoulder IR and ER strength, but did find improvements in throwing velocity (24). In a study conducted by Lister et al. (28) electromyographic analysis was used to compare muscle activity in the upper trapezius, lower trapezius, and serratus anterior while using the BodyBlade, cuff weights, or TB. They showed greater electromyography activity and coactivation of scapular musculature when using the BodyBlade.

We speculate that the SS has similar oscillatory properties to previously studied exercise devices such as the BodyBlade, the Flex Bar, and the B.O.I.N.G., which cause a rapid, rhythmic pattern of alternating contractions between the agonists/antagonists of shoulder musculature (4,12,28,33,35,38,42). These contractions were most likely achieved with the SS when subjects were able to consistently produce centrifugal force to keep the weighted ball in constant rotation inside the sphere. Proper muscle recruitment resulted in perceived intensity of RC exertion increasing on the OMNI-RES scale due to the rapidity and near constancy of the contractions. This reported intensity and the recruitment of scapular and core muscles may have provided the necessary stimulus that resulted in the within-group improvements in shoulder ER and Fx strength noted only in the SS group (Table 2).

According to Langer et al. (25) normal strength of the muscles of shoulder ER, combined with abduction and forward elevation strength, is important to perform unimpaired activities of daily living (ADL).

Muscular strength and power of the shoulder flexors and elbow extensors, along with scapular stability, are necessary to perform the seated shot put (19). Only the SS group demonstrated a significant within-group increase in the ShtPt (Table 2).

We believe that the greater amount of stability required of the GH joint and scapulohumeral muscles during active SS oscillation provided the stability and strength needed for improvement in the ShtPt. The ShtPt motion and the muscle groups used are similar to those incorporated in ADL, such as pushing up from a chair, lifting loads overhead, and pushing doors open. Muscular power of the shoulder is also an important component of overhead throwing activities and necessary for actions such as throwing a baseball (44).

Both the SS group and the TB group demonstrated significant within-group improvements in stability in the YBalInf direction only (Table 2). We speculate that subjects primarily used eccentric posterior cuff control to stabilize the UE throughout the ROM of the YBalInf test because the musculature of the supporting UE was lengthening during maximal reaching. The RC and surrounding scapular and core musculature play a significant role in dynamic stabilization of the shoulder during UE function. Strong abdominals reduce the amount of force placed on the shoulder and elbow during throwing activities and reduce the risk of injury (1). The UQYBT challenges static and dynamic balance of the core musculature (16). A stable core and strong shoulder complex result in improved GH stabilization, which contributes to the subject achieving their furthest potential reaching distance (16).

The anatomical attachments of the posterior RC exert a posteroinferior force on the humeral head, thus resisting superior and anterior humeral translation and providing GH compression (36). We theorize that stability of the UE throughout the inferolateral motions of the UQYBT was achieved through activation of the posterior RC of the supporting limb. Variable muscular contractions, overall strength, and ROM are needed when reaching far outside the subject's base of support (16). A study conducted by Uhl et al. (43) reported that the 1-arm plank position produced significant shoulder electromyographic activity, secondary to the supporting shoulder controlling and preventing an excessive drop of the contralateral side while maintaining the anterior trunk parallel to the floor (43). This weight-bearing position seems to preferentially activate the infraspinatus and posterior deltoid musculature (43).

In our study, these posterior muscles, which perform ER, were preferentially strengthened in the SS group, as noted previously. In the TB group, it seems that the improved strength in shoulder Ext and IR and increased ShldEnd were sufficient to improve stability in YBalInf. However, the minimal detectable change (MDC) for YBalInf has previously been reported to be 6.1 cm (16). Although both the SS and TB groups had statistically significant within-group changes, only the SS group exceeded the MDC threshold at 8.8 cm, thus indicating that the SS may be superior in promoting shoulder stability.

When exercising with TB, subjects were limited to unidirectional movement, which focuses on the specific muscles that power that motion. The SS engages the shoulder, scapula, and core simultaneously. Given that the SS group improved in all 4 planes of strength and ShEnd, we speculate that a larger sample size and longer intervention period may demonstrate significant between-group differences.

Endurance was required to maintain proper form during the SS exercises as the muscles of the shoulder joint were subject to a constant and consistent amount of tension. By contrast, during the TB exercises, the shoulder muscles were subject to greater tension at the end range of the motion and less at the beginning. Despite these differences, we speculate that the continuous activation of the shoulder muscles led to significant improvements in shoulder endurance in both exercise groups (Table 2). A pre-post difference of 4 repetitions for the PSET has been considered as the MDC for shoulder endurance (30). Both groups exceeded the MDC threshold for the PSET.

Lister et al. (28) demonstrated higher electromyographic activation during the motions of shoulder flexion and abduction using the BodyBlade than either TB or cuff weights. They surmised that the "additive overloads of moving the weight of the BodyBlade, applying the forces necessary to generate the oscillation, and reacting to the inertial changes during the oscillation, while TB or cuff weights require the muscles to respond solely to external resistance," resulted in the differences in electromyographic activity (28). We speculate that the submaximal, but constant effort required to oscillate the SS may be more favorable to induce endurance gains compared with TB. Therefore, we speculate that a larger sample size and longer intervention period may demonstrate significant between-group differences.

Previous studies have looked at proprioception in regards to the shoulder joint in a variety of forms (5,11,27). The evidence necessary to validate a standardized test setup, reproduction angles, number of necessary tests, and calculation of angle deviations is lacking (5). We adopted a protocol from Edwards et al. using a readily available iPhone app, the Clinometer (Breitling Peter; Application for mobile device, 2017), but did not find significant main or interaction effects for proprioception (11).

Proximal joints are known to have a lower sensory threshold than distal joints (5). Lin et al. (27) found that closed-chain exercises improved joint position sense greater than open-chain exercises. It is important to note that both the TB and SS groups used open-chain exercises. Second, all subjects recruited into our study were free of shoulder injury. Although we did not find evidence of significant improvements in proprioception, previous investigations have found that proprioception improved with strength training in subjects with shoulder pathology (10,31). Therefore, our outcomes may have been different had we studied subjects with a history of shoulder pathology.

Because of our relatively small sample size and young and healthy population, these results cannot be extrapolated to individuals with RC disease, the geriatric population, sedentary adults, athletes, etc. In addition, although the gender distribution among groups was not significantly different (as per chi-square analysis), the ratio of females/males across groups (SS: 7/5, TB: 9/2, and control: 8/4) may have contributed to gender-biased responses to upper-body strength training (29). The relatively short duration of our exercise intervention period (6 weeks) may have limited the potential for muscular morphological changes to occur (14). We recognize that our testing was performed in an isometric manner, and we assessed dynamic functional variables. However, Salter (37) found no significant difference between improvement of strength measured isotonically and isometrically following isometric and isotonic methods of training. Thus, the isometric testing with HHD in our study has been shown to be a comparable criterion of improvement in muscle strength, regardless of the training method. Finally, although all subjects were advised not to engage in any new physical activities other than the SS or TB exercises, no confirming activity logs were requested.

Practical Applications

The SS presents as a viable alternative shoulder rehabilitation method that compares favorably with the widely accepted TB and may provide additional benefits in shoulder strength and functional power. We studied young, healthy adults without shoulder problems and not adults with shoulder pathology. Therefore, trainers, coaches, and physical therapists should be aware of the potential of the SS as a helpful tool to use as a preventative measure for shoulder injury, as well as a method of warm-up before participation in sport in the noninjured population.

The SS is a relatively light and easily transportable device. Its resistance can be varied by changing the speed of oscillations or by choosing the larger or smaller device. The SS makes a distinctive sound when used correctly. The higher frequency sound is produced by the constant acceleration of the ball traveling within the sphere when the user correctly performs relatively short-radius spherical movements. These short-radius movements require the user to engage the stabilizing muscles of the shoulder. Larger-radius movements, which increase the contribution of UE prime movers, produce a lower frequency sound. Inconsistent acceleration of the ball can result in the ball dropping in the sphere, which creates its own distinctive sound. Therefore, a constant, higher frequency sound can provide valuable auditory feedback to the user that proper form is being maintained. When compared with TB, the SS takes less time to complete the same exercise regimen due to the rapid, reciprocal alternating contractions of the RC muscles throughout the exercise. In addition, the SS is a viable alternative for individuals who have an allergy to latex and therefore cannot use TB.

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