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The Effects of Jump-Rope Training on Shoulder Isokinetic Strength in Adolescent Volleyball Players

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Objective: To investigate the effect of a 12-wk weighted-jump-rope training program on shoulder strength. ***Design:*** Pretest to posttest experimental design. ***Setting:*** University sports physiotherapy laboratory. ***Participants:*** 24 healthy volleyball players age 13–16 y. ***Intervention:*** Group 1 took weighted-rope training (n = 9), group 2 took unweighted-rope training (n = 8), and group 3 did not train with any specific program (n = 7). ***Main Outcome Measures:*** Players' strength determined with an isokinetic dynamometer (Isomed 2000) at 180 and 60°/s on external and internal rotators, supraspinatus peak torque, and total work of the dominant shoulder. Kruskal–Wallis and Mann–Whitney *U* tests were used to determine the difference among the groups. ***Results:*** At pretraining evaluation, there were no significant differences in the test scores of the isokinetic test of full can and empty can between the groups at 60 and 180°/s. There was no statistically significant difference for 60 and 180°/s between pretraining and posttraining assessment ($P > .05$) except that total eccentric work increased in groups 1 and 3 but decreased in group 2 at 180°/s during the full can ($P < .05$). There was no significant difference among the groups between the pretraining and posttraining testing at both 180 and 60°/s for the empty can ($P > .05$). Internal-rotation values at 60 and 180°/s decreased for both peak torque and total work for all groups. External-rotation peak torque and total work at 60°/s increased for group 1. External-rotation peak torque and total work at 180°/s increased for all groups. ***Conclusions:*** The results indicate that a jump-rope training program is a good conditioning method for overhead athletes because of its potential benefits to shoulder strength.

Keywords: weighted jump ropes, overhead athletes

Volleyball is a complex discipline with high technical, tactical, and athletic demands on the players.[1] Serving, passing, and setting the ball are accompanied with spiking or attacking actions.[2] It is desirable to have a strong offense, smash, or spike to achieve success in this sport. Starting with an approach followed by

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a vertical jump, one of the objectives in volleyball is to spike, aiming to hit the ball at the highest possible speed.[3] Therefore, volleyball training requires various exercises and regimens.

The jump rope has been a major training tool for many sports such as boxing, wrestling, tennis, and martial arts. Lately, it has also become popular with volleyball players among many training options. Jumping rope requires the coordination of several muscle groups to sustain the precisely timed and rhythmic movements that are integral to the exercise. The coordination of these muscle groups increases an athlete's capacity for dynamic balance.[4] Jumping rope can also be used to develop the coordination of neuromuscular skills, muscle strength, and cardiovascular endurance.[5,6] It burns calories and builds strength in the upper and lower body.[5–7]

Movements that occur during regular rope jumping primarily include movements of the ankle, knee, hip, and shoulder joints. Upper extremity conditioning might be as important as lower extremity conditioning in jumping rope. Jumping rope involves a ballistic "catapult" or "slingshot" action of the upper extremities encountered in throwing events and also involves grasping relatively light implements for long periods of time, under isometric or static conditions of a submaximal nature. During a whole cycle of jumping, the shoulder undergoes rotational movement with elevation. By the time of the preparatory phase, the shoulders hyperextend and the elbows are in full extension. During the propulsive phase the opposite motions occur, and the shoulders rotate at about 90° to 100° elevation with slightly flexed elbows, and then the arms go down toward the ground and around in circles by the side.[8]

Weighted jump ropes are thought to produce shoulder-strength adaptation by placing larger loads on the shoulder muscles. Furthermore, using weighted ropes may have additional advantages that are typically associated with core plyometrics.[8,9]

The effects of rope training on shoulder strength are not yet well known. It is also unknown whether a weighted jump rope has any additional effects in comparison with unweighted ones and controls with no jump-rope training.

Isokinetic muscle-strength measurement has been studied well and reported in many studies involving various sports.[10] It is also a reliable tool to assess specific muscle functions such as rotation and elevation of the shoulder that may mimic performance patterns in volleyball. Specifically, the supraspinatus muscle, which is activated during shoulder elevation, plays an important role in dynamic stabilization of the glenohumeral joint as a part of rotator-cuff muscles, which are very important for the functions of the shoulder during rope jumping.

Two specific positions have been suggested for testing the supraspinatus muscle: the full can (humeral elevation in the scapular plane with the thumb up) and the empty can (thumb down). Jobe and Moynes[11] suggested that the empty can is the optimal position for isolating the supraspinatus muscle for strengthening and manual muscle testing. Kelly et al[12] reported that there was no significant difference in the EMG activation of the supraspinatus muscle between abduction in the scapular plane with internal rotation (IR) and abduction in the scapular plane with external rotation (ER). Because there is no consensus in the literature it is not clear which position is the best choice for testing supraspinatus muscle strength.

The purposes of this study were to investigate the effects of a 12-week weighted- and unweighted-jump-rope training program on shoulder isokinetic strength and to compare the differences in measurement between empty- and full-can positions for isokinetic supraspinatus strength in female adolescent volleyball players.

Methods

This study was a randomized controlled trial using a 3 × 2 factorial design. The independent variables were measurement (before and after training) and group (trained [unweighted jump rope and weighted jump rope] and nontrained volleyball players). The dependent variables were total work and peak torque normalized to body mass for each strength test.

The study was conducted on 24 of 26 subjects age 13 to 16 years (age 14.5 ± 1.2 y, body-mass index [BMI] 20.6 ± 2.5 kg/m^2, mean ± SD) who had played volleyball for at least 2 years. One of the players in the unweighted-rope training group was excluded from the study because she was found to have scapular dyskinesis. Another was excluded because of shoulder pain during posttraining evaluation.

The players were selected from 5 high schools and randomized individually into 3 groups: group 1, weighted-rope training (n = 9); group 2, unweighted-rope training (n = 8); and group 3, control (n = 7). Randomization was set according to a random-cases sample in the Statistical Package in Social Sciences (SPSS) program.

Exclusion criteria were having had shoulder pain for more than 3 months, having more than 50% restriction of passive range of motion in 2 or more planes, having a systemic pathology including inflammatory joint disease, having had active intervention in the last 3 months including corticosteroid/hydrodilatation injection or physiotherapy, having taken anti-inflammatory medication in the past 2 weeks, and having prior history of shoulder anterior dysfunction and symptomatic range of motion.

All subjects and their parents read and signed an institutionally approved informed-consent form before the evaluations.

Before testing, the following information was obtained: age, height, weight, years playing the sport, years in the current position, and previous dislocation and subluxation episodes. There was no difference in age, height, mass, and BMI among the 3 groups (Table 1).

The measurements were taken twice, at pretraining and posttraining on the dominant side, the dominant arm being defined as the arm used to throw and serve. The right arm was dominant in all of the players. All evaluations were conducted by the first author, who used a standardized protocol to ensure consistency of subject positioning, instructions, and overall testing procedures. Before testing, all subjects were informed about the particular requirements of the testing, and they were provided appropriate warm-up exercise.

Table 1 Subject Characteristics, Mean ± SD

Variable	Weighted-rope jumping	Unweighted-rope jumping	Control	*P*
Age (y)	15.0 ± 1.0	14.1 ± 1.3	14.4 ± 1.3	.305
Height (cm)	166 ± 6	165 ± 5	161 ± 5	.132
Mass (kg)	59.4 ± 8.3	57.7 ± 9.7	50 ± 7.8	.760
Body-mass index (kg/m^2)	21.4 ± 1.9	21.2 ± 3.1	19.1 ± 2.0	.157

A routine volleyball training program included cardio, strengthening, flexibility, and sport-specific skills at least 2 h/d, 6 times a week for all the groups. Subjects in group 1 had weighted-jump-rope training 3 times a week for 12 weeks in addition to the routine volleyball training program. Group 2 was given the same training program but with unweighted ropes. The control group followed only the volleyball training program for the same duration. The 12-week rope-training programs are detailed in Table 2.[10]

Two different kinds of rope were used in this study. The unweighted-rope training group used a cable rope (Selex, Alexandria, VA) with a length, handle weight, and total weight of 270 cm, 100 g, and 160 g, respectively. The rope used by the weighted-rope training group (Power Rope V-3067) had a length, handle weight, and total weight of 260 cm, 600 g, and 695 g, respectively.[13]

Isokinetic Testing

An Isomed 2000 program was chosen to carry out shoulder-rotator and -elevator strength tests on all subjects. Specifically, strength of shoulder external rotator, internal rotator, and supraspinatus muscle in the full-can (humeral elevation in the scapular plane with thumb up) and empty-can (thumb down) positions was evaluated.

External and Internal Rotation

The testing procedure and equipment were explained to each subject before the test. Concentric and eccentric measures on the dominant shoulder were performed with an Isomed 2000 isokinetic dynamometer with the shoulder in 90° abduction and the elbow in 90° flexion. A Velcro strap was used to secure the torso on the testing table and stabilize the body. The concentric maximal torque production (measured in Nm/kg) was evaluated in both the internal and external rotators. In this study, the tests started with an internal-rotator concentric contraction at 180°/s. The test speed was changed to 60°/s when the testing at high speed had been completed twice. The subjects underwent 3 to 5 submaximal consecutive contraction trials to familiarize themselves with the procedure and to warm up their muscles and both shoulders in the movement patterns of external (ER) and internal rotation (IR) at both velocities. During testing, the subjects were in a sitting position and restrained by straps across their shoulder girdle, chest, and abdomen. Each test lasted for 1 minute, with 10 repetitions at 180°/s and 5 repetitions at 60°/s. Subjects were given a 10-second and 3-minute rest between trials and speeds, respectively. The best 3 maximal contractions in each test were automatically selected by the software program of the dynamometer. An offset handle was provided for the nontesting extremity to grip during the testing procedure. Gravity correction was not used for this testing position, consistent with the manufacturer's recommendation. The ER was performed in the same manner as the IR. Ninety-degree IR and ER were used for range of freedom.

The exercise was performed at 90° ER and IR at 90° abduction. The 60°/s testing speed was performed first for each extremity followed by the 180°/s speed without randomization. Standardized verbal instructions and encouragement were given, with the subjects unable to receive visual feedback during the testing procedure.[10]

Table 2 Twelve-Week Jump-Rope Training Program for Groups 2 and 3

Week	Session	Training and rest duration (s)	Number of sets
1	1	30	1
	2	30	1
	3	30	1
2	4	40	1
	5	40	1
	6	40	1
3	7	50	1
	8	50	1
	9	50	1
4	10	60	1
	11	60	1
	12	60	1
5	13	30	2
	14	30	2
	15	30	2
6	16	40	2
	17	40	2
	18	40	2
7	19	50	2
	20	50	2
	21	50	2
8	22	60	2
	23	60	2
	24	60	2
9	25	30	3
	26	30	3
	27	30	3
10	28	40	3
	29	40	3
	30	40	3
11	31	50	3
	32	50	3
	33	50	3
12	34	60	3
	35	60	3
	36	60	3

Empty Can and Full Can

The subjects' upper extremities were in the scapular plane and the elbows in an extended position. An Isomed 2000 program was chosen to carry out the concentric–eccentric test during shoulder elevation and depression in the scapular plane by tilting the dynamometer approximately 30° from horizontal base position. The test for supraspinatus strength in full-can and empty-can positions consisted of concentric elevation followed by eccentric depression in the scapular plane. One set of 10 repetitions were performed for the tests at 60°/s and 5 repetitions for tests at 180°/s. The test speed was increased to 180°/s when the testing at low speed was completed. It took 1 set of 5 repetitions. The subjects were given 3 minutes rest between sets. The same protocols were applied for the empty-can position. Results taken by the Isomed 2000 software program were given as Nm/kg peak torque normalized to body mass (kg). The ratio for testing both concentric and eccentric strength was 1:1.

Statistical Analysis

The statistical analysis was performed using SPSS-PC+ (SPSS, Inc, Chicago, IL) software. The differences between pretraining and posttraining values were calculated, and a Kruskal–Wallis test was used for differences between groups. Significant differences were compared with a Mann–Whitney *U* test. Pretraining values of the groups were also determined with a Kruskal–Wallis test. The level of significance for all statistical analysis was set at $\alpha < .05$.

Results

The age, body height, body mass, and BMI of the volleyball players in each group are given in Table 1. There were no significant differences in body mass, height, and BMI among the groups ($P > .05$).

Classic isokinetic data were confirmed, and the strength–velocity curve was compiled for the different shoulder muscles for visual inspection. The eccentric mode allowed higher values than the concentric mode.

Full-Can Test

At pretraining evaluation, there were no significant differences in the scores for the isokinetic test during full can between the groups ($P > .05$). There was no statistically significant difference for 180°/s between pretraining and posttraining assessment ($P > .05$) except that total eccentric work increased in groups 1 and 3 but decreased in group 2 ($P < .05$; Tables 3A and 3B). There was no statistically significant difference for the parameters at 60°/s ($P > .05$; Tables 4A and 4B).

Empty-Can Test

There were no significant differences among the 3 groups in the isokinetic test during empty can at the pretraining evaluation ($P > .05$). There was no significant difference among the groups between the pretraining and posttraining testing at either 180 or 60°/s ($P > .05$; Tables 3A, 3B, 4A, and 4B).

Table 3A Shoulder Isokinetic Strength During Full Can at 180°/s, Mean ± SD, Median (Min–Max)

Group		PT Conc, Nm/Kg	PT Ecc, Nm/Kg	TW Conc, J	TW Ecc, J
Weighted rope	Pretraining	0.27 ± 0.06	0.61 ± 0.28	36 ± 10	141 ± 86
		0.26 (0.19–0.38)	0.52 (0.21–1.07)	33 (27–60)	117 (27–255)
	Posttraining	0.33 ± 0.12	0.73 ± 0.30	72 ± 40	188 ± 93
		0.27 (0.26–0.61)	0.85 (0.21–1.11)	61 (36–157)	210 (31–303)
	Difference	0.06 ± 0.11	0.11 ± 0.28	36 ± 41	47 ± 78
		0.04 (–0.11 to 0.26)	0.15 (–0.41 to 0.50)	27 (–3 to 117)	56 (–60 to 165)
Unweighted rope	Pretraining	0.25 ± 0.04	0.87 ± 0.32	33 ± 9	202 ± 112
		0.26 (0.19–0.33)	0.93 (0.21–1.26)	35 (15–43)	203 (25–414)
	Posttraining	0.31 ± 0.07	0.84 ± 0.32	35 ± 8	173 ± 120
		0.29 (0.21–0.42)	0.90 (0.40–1.27)	34 (24–49)	152 (28–343)
	Difference	0.05 ± 0.09	–0.02 ± 0.21	2 ± 9	–29 ± 59
		0.02 (–0.04 to 0.23)	–0.02 (–0.39 to 0.28)	0 (–6 to 22)	–51 (–76 to 99)
Control	Pretraining	0.27 ± 0.08	0.86 ± 0.30	25 ± 11	163 ± 93
		0.26 (0.20–0.45)	1.04 (0.51–0.17)	18 (15–42)	121 (88–339)
	Posttraining	0.29 ± 0.07	1.01 ± 0.27	40 ± 23	198 ± 83
		0.29 (0.19–0.39)	0.13 (0.59–1.38)	37 (9–84)	201 (82–346)
	Difference	0.01 ± 0.11	0.15 ± 0.39	15 ± 26	33 ± 71
		–0.02 (–0.11 to 0.19)	0.05 (–0.22 to 0.80)	11 (9–66)	7 (–42 to 153)
P		.426	.618	.094	.042

PT, peak torque; Conc, concentric; Ecc, eccentric; TW, total work.

Table 3B Shoulder Isokinetic Strength During Empty Can at 180°/s, Mean ± SD, Median (Min–Max)

Group		PT Conc, Nm/kg	PT Ecc, Nm/kg	TW Conc, J	TW Ecc, J
Weighted rope	Pretraining	0.21 ± 0.05	0.57 ± 0.24	20 ± 19	128 ± 95
		0.21 (0.14–0.31)	0.46 (0.33–0.93)	12 (3–64)	78 (28–306)
	Posttraining	0.34 ± 0.12	0.77 ± 0.21	62 ± 43	185 ± 61
		0.30 (0.22–0.57)	0.75 (0.44–1.10)	60 (12–142)	187 (69–277)
	Difference	0.13 ± 0.09	0.19 ± 0.20	42 ± 50	58 ± 67
		0.15 (0.02–0.28)	0.20 (–0.18–0.42)	48 (–30 to 114)	76 (–29 to 151)
Unweighted rope	Pretraining	0.26 ± 0.04	0.81 ± 0.32	32 ± 9	202 ± 112
		0.26 (0.19–0.33)	0.93 (0.21–1.26)	35 (15–43)	203 (25–414)
	Posttraining	0.31 ± 0.07	0.85 ± 0.32	35 ± 8	173 ± 120
		0.29 (0.21–0.42)	0.91 (0.42–1.27)	34 (24–49)	152 (28–343)
	Difference	0.05 ± 0.09	–0.02 ± 0.21	2 ± 9	–29 ± 59
		0.02 (–0.4 to 0.23)	–0.02 (–0.39 to 0.28)	0 (–6 to 22)	–51 (–76 to 99)
Control	Pretraining	0.20 ± 0.05	0.75 ± 0.23	12 ± 15	127 ± 83
		0.20 (0.15–0.31)	0.76 (0.47–0.98)	3 (0–36)	109 (42–283)
	Posttraining	0.3 ± 0.13	0.84 ± 0.29	31 ± 35	177 ± 101
		0.28 (0.15–0.57)	0.77 (0.45–1.23)	18 (0–105)	168 (33–303)
	Difference	0.09 ± 0.14	0.08 ± 0.24	19 ± 38	51 ± 78
		0.09 (–0.06 to 0.36)	0.30 (–0.21 to 0.54)	10 (–10 to 102)	20 (–15 to 168)
P		.362	.328	.302	.145

PT, peak torque; Conc, concentric; Ecc, eccentric; TW, total work.

Table 4A Shoulder Isokinetic Strength During Full Can at 60°/s, Mean ± SD, Median (Min–Max)

Group		PT Conc, Nm/kg	PT Ecc, Nm/kg	TW Conc, J	TW Ecc, J
Weighted rope	Pretraining	0.31 ± 0.08	0.79 ± 0.33	30 ± 11	116 ± 37
		0.30 (0.20–0.40)	1.0 (0.0–1.0)	30 (13–49)	129 (34–157)
	Posttraining	0.38 ± 0.11	0.82 ± 0.15	47 ± 23	123 ± 36
		0.34 (0.27–0.63)	0.81 (0.55–1.02)	40 (19–97)	121 (85–193)
	Difference	0.06 ± 0.11	–0.06 ± 0.36	17 ± 25	7 ± 30
		0.01 (–0.03 to 0.24)	–0.15 (–0.45 to 0.8)	10 (–9 to 58)	6 (–35 to 51)
Unweighted rope	Pretraining	0.27 ± 0.08	0.97 ± 0.17	25 ± 12	144 ± 29
		0.30 (0.10–0.40)	0.97 (0.74–1.26)	29 (4–39)	146 (105–183)
	Posttraining	0.27 ± 0.06	0.87 ± 0.21	25 ± 10	122 ± 37
		0.26 (0.19–0.38)	0.87 (0.51–1.14)	27 (6–37)	137 (73–168)
	Difference	–0.01 ± 0.06	–0.10 ± 0.11	0 ± 8	–23 ± 17
		–0.01 (–0.08 to 0.14)	–0.12 (–0.23 to 0.15)	4 (–15 to 7)	–24 (–45 to 3)
Control	Pretraining	0.30 ± 0.13	1.02 ± 0.20	16 ± 14	108 ± 36
		0.20 (0.20–0.50)	0.97 (0.68–1.27)	10 (0–40)	108 (53–163)
	Posttraining	0.32 ± 0.17	0.79 ± 0.37	24 ± 21	120 ± 75
		0.34 (0.11–0.64)	0.68 (0.30–1.44)	24 (0–64)	75 (48–248)
	Difference	0.02 ± 0.21	–0.22 ± 0.27	8 ± 22	12 ± 86
		–0.05 (–0.19 to 0.44)	–0.16 (–0.65 to 0.17)	4 (–16 to 54)	–9 (–55 to 195)
P		.147	.692	.443	.098

PT, peak torque; Conc, concentric; Ecc, eccentric; TW, total work.

Table 4B Shoulder Isokinetic Strength During Empty Can at 60°/s, Mean ± SD, Median (Min–Max)

Group		PT Conc, Nm/kg	PT Ecc, Nm/kg	TW Conc, J	TW Ecc, J
Weighted rope	Pretraining	0.21 ± 0.09	0.74 ± 0.21	15 ± 16	100 ± 34
		0.19 (0.10–0.34)	0.80 (0.40–1.10)	18 (0–48)	97 (30–141)
	Posttraining	0.36 ± 0.19	0.75 ± 0.16	38 ± 28	112 ± 26
		0.32 (0.15–0.67)	0.76 (0.51–1.00)	42 (9–87)	103 (78–165)
	Difference	0.15 ± 0.20	0.01 ± 0.25	23 ± 37	12 ± 31
		0.17 (–0.13 to 0.48)	0.01 (–0.36 to 0.43)	25 (–38 to 69)	12 (–36 to 67)
Unweighted rope	Pretraining	0.23 ± 0.09	0.78 ± 0.26	16 ± 11	118 ± 49
		0.24 (0.08–0.38)	0.85 (0.40–1.10)	20 (0–31)	126 (33–193)
	Posttraining	0.19 ± 0.08	0.79 ± 0.19	14 ± 12	118 ± 40
		0.19 (0.08–0.35)	0.85 (0.40–0.96)	10 (0–36)	120 (51–184)
	Difference	–0.04 ± 0.09	0.01 ± 0.17	–2 ± 12	0 ± 24
		–0.07 (–0.13 to 0.11)	–0.08 (–0.14 to 0.38)	–3 (–22 to 18)	–7 (–30 to 48)
Control	Pretraining	0.19 ± 0.09	0.84 ± 0.28	11 ± 14	92 ± 45
		0.19 (0.10–0.37)	0.90 (0.40–1.10)	3 (0–37)	82 (27–150)
	Posttraining	0.26 ± 0.11	0.78 ± 0.26	16 ± 18	89 ± 37
		0.25 (0.09–0.40)	0.76 (0.44–1.13)	16 (0–51)	85 (46–151)
	Difference	0.06 ± 0.14	–0.06 ± 0.28	5 ± 22	–3 ± 19
		0.00 (–0.06 to 0.28)	0.02 (–0.56 to 0.26)	0 (–16 to 51)	–4 (–28 to 22)
P		.110	.334	.243	.439

PT, peak torque; Conc, concentric; Ecc, eccentric; TW, total work.

ER and IR Tests

The only difference was found at IR peak torque at 60°/s between groups for pretraining results, which was not important clinically ($P < .05$).

IR values at 60°/s decreased for both peak torque and total work for all groups. The only difference was seen between groups 1 and 3 for peak torque ($P < .05$). ER peak torque and total work at 60°/s increased for group 1, whereas there was no difference for group 3. Total work for group 2 increased, but peak torque did not change. Group 1 had higher results for ER total work (Table 5).

IR values at 180°/s decreased for both peak torque and total work for groups 2 and 3. Group 1's peak torque did not change, but total work increased. IR total work also differed between groups 2 and 3 ($P < .05$). ER peak torque and total work at 180°/s increased for all groups. Group 1 had higher results than the other groups, but the only difference was for peak torque between groups 1 and 2 (Table 6).

Discussion

Our results showed that ER strength improved in the weighted-jump-rope group, so this could be a good method for strengthening the shoulder's external rotators.

The volleyball spike is a complex skill that requires many components of movement, technical, and muscle qualities.[1–3] The effectiveness of skills in volleyball has been attributed to an energy transfer in a kinetic-chain concept from the lower limb to the upper extremity, depending on flexibility, strength, and coordination.[4,14] Because training in a kinetic-chain model has become popular, athletes have recently been using weighted- or unweighted-jump-rope training.

Lee[8] explained that the weighted-rope training would improve the strength of upper extremity muscles. Masterson and Brown[9] studied the effects of weighted-jump-rope training on upper extremity performance. They evaluated upper extremity performance with a bench-press test and showed that there were significant improvements between pretraining and posttraining measurements.

Pretraining to Posttraining Within Groups

Peak ER torque and the total work of group 1 increased from pretraining to posttraining testing at both 180 and 60°/s. Group 1 had the highest increase. Weighted-rope jumping seems to have an advantage for peak ER torque and total work. On the other hand, IR at 60°/s decreased in all groups in both peak torque and total work. The degree and strength of IR during throwing are decreased according to the literature.[1,15] This is because of the decrease of IR strength for all 3 groups.

When we review other sports activities described in the published literature, the isokinetic results and field performances seem varied. Focusing on handball players, Bayios et al[15] found that peak torque of shoulder IR and ER was not a good indicator of throwing velocity, except for the number of jump shots correlated with IR peak torque. Bartlett et al[16] reported, in baseball, a significant correlation between shoulder adductors and throwing speed but no relationship with the rotators. In a recent study,[17] they demonstrated strong correlations between ER and IR isokinetic peak torque in baseball players. To date, we have found no study on the effects of weighted-rope training on upper extremity strength in volleyball players.

Table 5 Shoulder Isokinetic Strength During ER and IR at 90° of Abduction at 60°/s, Mean ± SD, Median (Min–Max)

Group		PT IR, Nm/kg	PT ER, Nm/kg	TW IR, J	TW ER, J
Weighted rope	Pretraining	0.61 ± 0.14	0.21 ± 0.06	149 ± 34	45 ± 16
		0.68 (0.39–0.74)	0.21 (0.10–0.28)	136 (102–214)	40 (22–64)
	Posttraining	0.52 ± 0.11	0.30 ± 0.07	126 ± 28	70 ± 20
		0.52 (0.34–0.69)	0.30 (0.18–0.41)	120 (91–174)	78 (42–99)
	Difference	–0.09 ± 0.12	0.09 ± 0.06	–22 ± 33	25 ± 16
		–0.13 (–0.21 to 0.15)	0.10 (0.00–0.21)	–15 (–63 to 42)	24 (2–51)
Unweighted rope	Pretraining	0.63 ± 0.14	0.20 ± 0.04	150 ± 20	39 ± 14
		0.66 (0.43–0.78)	0.19 (0.15–0.30)	143 (126–181)	36 (24–67)
	Posttraining	0.42 ± 0.09	0.20 ± 0.07	99 ± 12	45 ± 14
		0.41 (0.32–0.60)	0.18 (0.10–0.30)	99 (87–112)	50 (24–61)
	Difference	–0.21 ± 0.09	–0.00 ± 0.04	–51 ± 20	6 ± 11
		–0.20 (–0.40 to –0.10)	0 (–0.09 to 0.06)	–47 (–86 to –26)	9 (–10 to 20)
Control	Pretraining	0.79 ± 0.11	0.21 ± 0.05	153 ± 15	37 ± 12
		0.77 (0.58–.88)	0.21 (0.15–0.28)	154 (129–171)	39 (12–51)
	Posttraining	0.52 ± 0.11	0.22 ± 0.06	101 ± 7	38 ± 13
		0.52 (0.35–0.72)	0.19 (0.16–0.32)	99 (90–111)	36 (16–57)
	Difference	–0.26 ± 0.10	0.01 ± 0.06	–52 ± 19	3 ± 16
		–0.28 (–0.39 to 0.05)	0.00 (–0.07 to 0.11)	–53 (–79 to –18)	–3 (–18 to 30)
P		.014	.008	.05	.028

PT, peak torque; IR, internal rotation; ER, external rotation; TW, total work.

Table 6 Shoulder Isokinetic Strength During ER and IR at 90° of Abduction at 180°/s, Mean ± SD, Median (Min–Max)

Group		PT IR, Nm/kg	PT ER, Nm/kg	TW IR, J	TW ER, J
Weighted rope	Pretraining	0.47 ± 0.17	0.18 ± 0.06	209 ± 90	56 ± 33
		0.56 (0.18–0.63)	0.19 (0.06–0.25)	225 (72–315)	43 (15–100)
	Posttraining	0.45 ± 0.11	0.31 ± 0.10	225 ± 63	128 ± 51
		0.46 (0.23–0.61)	0.28 (0.18–0.51)	223 (124–324)	130 (54–196)
	Difference	−0.02 ± 0.11	0.13 ± 0.09	16 ± 82	71 ± 49
		−0.02 (−0.16 to 0.21)	0.12 (−0.02 to 0.32)	9 (−114 to 193)	81 (−27 to 138)
Unweighted rope	Pretraining	0.61 ± 0.17	0.16 ± 0.03	265 ± 57	50 ± 24
		0.67 (0.30–0.78)	0.16 (0.13–0.20)	274 (154–352)	60 (15–75)
	Posttraining	0.37 ± 0.12	0.20 ± 0.05	176 ± 69	87 ± 33
		0.40 (0.10–0.50)	0.22 (0.13–0.26)	189 (15–240)	93 (21–132)
	Difference	−0.24 ± 0.09	0.04 ± 0.04	−89 ± 37	36 ± 41
		−0.26 (−0.40 to −0.12)	0.04 (−0.02 to 0.09)	−98 (−139 to −29)	30 (−19 to 117)
Control	Pretraining	0.65 ± 0.13	0.17 ± 0.40	237 ± 47	53 ± 19
		0.61 (0.48–0.88)	0.19 (0.10–0.24)	226 (172–304)	58 (25–76)
	Posttraining	0.51 ± 0.06	0.23 ± 0.04	216 ± 50	88 ± 33
		0.48 (0.40–0.60)	0.24 (0.15–0.28)	208 (136–292)	93 (36–136)
	Difference	−0.14 ± 0.14	0.05 ± 0.08	−21 ± 59	35 ± 38
		−0.14 (−0.29 to 0.12)	0.06 (−0.09 to 0.16)	−36 (−99 to 94)	36 (−25 to 102)
P		.006	.022	.008	.207

PT, peak torque; IR, internal rotation; ER, external rotation; TW, total work.

With that in mind, each volleyball player tested in the study underwent isokinetic assessment of the dominant shoulder. The peak torque in the full can at 60°/s and the empty can at180°/s in eccentric conditions showed a satisfactory result. This finding led us to postulate that improving supraspinatus strength could increase ball velocity during the spike, even though the study could only show associations, not prove cause and effect between some correlated factors and spike velocity. Further study needs to be done regarding the relationship between supraspinatus strength and spike velocity. The implication of altered arc motion is that a physiologic adaptation to the throwing motion occurs in the dominant shoulder, stretching the anterior capsule and tightening the posterior capsule.[18] Tight posterior shoulder tissues may also contribute to a loss in shoulder rotation range of motion, although this has not been proven.

Empty and Full Can

We found no differences in any group during full can and empty can at either 60 or 180°/s except during full-can eccentric total work at 180°/s. This difference may not be very important clinically. Because there were no differences between 180 and 60°/s in empty can and full can for either concentric or eccentric work in all groups, it might be concluded that both tests could be suitable to assess elevation in the scapular plane with the stabilization effect of supraspinatus muscle, which may mimic the performance of jumping rope.

In the published literature, there are some studies related to the evaluation of the supraspinatus muscles in the empty-can and full-can positions. Kelly et al[12] reported that there was no significant difference in supraspinatus muscle EMG activation between abduction in the scapular plane with IR and abduction in the scapular plane with ER. In the Takeda et al[19] study related to magnetic resonance imaging (MRI), no significant differences were found between these 2 positions using MRI. Those results are similar to ours.

The lack of a training effect in the current study might be partially related to a lack of muscle hypertrophy, possibly caused by an insufficient volume or duration of training in the adolescent stage of athletes. Training volume is a product of the resistance used and the number of repetitions performed. The volume of training in the current study would have been higher with a greater number of repetitions per training session, a greater number of training sessions, or increased resistance. With regard to the exercise frequency and duration, we followed a protocol (3 times per week for 12 wk) from a similar strengthening-exercise study by Malliou et al.[20] Because muscle-fiber hypertrophy generally begins after 4–8 weeks of resistance training, the 12-week training interval in the current investigation might have been insufficient to promote a significant hypertrophic response for adolescent volleyball players.

The total weight of the weighted rope was 695 g. This might be insufficient to improve supraspinatus muscle strength with rhythmic and repeated movements. Therefore, wide-range movement at the shoulder during rope skipping was not formed.

Giannakopoulos et al[21] trained rotator-cuff muscles by isolated exercises with 2-kg dumbbells for 6 weeks and found no significant differences in isokinetic muscle strength before and after training. Malliou et al[20] conducted similar research by dividing their subjects into 4 groups: dynamic resistance training, isolated exercises with 2-kg dumbbells, isokinetic strengthening, and a control group. There were no significant differences among the groups in rotator-cuff isokinetic strength between pretraining and posttraining. They showed that the strength ratios in all the experimental groups had altered after the exercise period, with the isokinetic group showing the most significant improvement. Carter et al[17] studied the effect of plyometric exercises on isokinetic strength of the shoulder rotators in college baseball players for 8 weeks and found no significant differences between pretraining and posttraining.

For Smith et al,[22] the team players who reached a significantly higher block-and-spike jump had more desirable characteristics because of years of physical conditioning and playing, in addition to innate genetic endowment. Training thus has a significant role in the preparation of international-caliber volleyball players.

There were limitations to our study. Our sample was a homogeneous group of healthy young students. It is unclear whether our results can be applied across other populations. However, no other studies have been conducted on weighted- and unweighted-jump-rope training during volleyball training. Future researchers should investigate the effect of these training programs on scapular kinematics during volleyball training, as well as in throwing athletes. Another aspect when interpreting the results from this study is that the influence of psychosocial factors such as motivation during test and training sessions, individual characteristics, and relationships with team, coach, and friends are unknown, because no instrument covering this area was used. To our knowledge, this is the first randomized trial involving unweighted-jump-rope, weighted-jump-rope, and no specific training of adolescent volleyball players.

In conclusion, the study showed that weighted-jump-rope training programs would be even more effective in volleyball players by increasing the strength levels in ER. The rope appears feasible, given that this training method is not cost prohibitive and may increase ER strength by following the guidelines of exercise prescription for adolescent volleyball players. Because there is no difference between empty- and full-can test results when maintenance of the subacromial space is important, the full-can test seems most appropriate for mechanically measuring selective strength of the supraspinatus muscle.

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