Muscle Use During Exercise With a Mini Medicine Ball Compared to Other Abdominal Exercise Modalities

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ABSTRACT

Twelve subjects were examined to determine the level of muscle activity in the external obliques, rectus abdominus, transverse abdominus, quadriceps, hamstrings, biceps, and triceps during exercise with mini medicine balls following an exercise video. The medicine balls were about 8 inches in diameter and came in weights of 2, 4, and 6 lbs (0.9 kg, 1.8 kg, and 2.7 kg, respectively). Here, no ball exercise was compared with 2- and 6-lb ball exercise. Subjects were male and female in the age range of 20-40 years and free of cardiovascular or neurological disease. During the video, 7 exercises were evaluated and compared with abdominal crunches. The exercises were done with and without a medicine ball to further study the effect of adding the medicine ball to the exercises on muscle use. Data were compared to observe the effectiveness of the various weighted medicine balls in using the muscles for exercise as a means of physical training. The results of the experiments showed that, for the 2-lb ball, total muscle work was 12.5-times that of an abdominal crunch and specifically, for the core muscles, was 1.62-times greater than the abdominal crunch while with the 6-lb ball it was 2.16 times greater. Specific exercises were as high as 4-times greater muscle activity for the core muscles. Compared to squat exercise without a medicine ball, adding the 2- or 6-lb medicine ball increased the work on the gluteus maximus in the

Table 1. The general characteristics of the subjects.

Demographics	Age (years)	Height (cm)	Weight (kg)	Body Mass Index (kg/m²)	Resistance	Reactance	% Body Fat
Mean	25.8	167.9	68.9	24.3	587.0	67.4	26.5
SD	2.0	10.5	15.7	3.8	104.8	3.6	6.3

squat by 1.4 times and as much as 4.4 times the work for other exercises. Thus, this exercise regime with the medicine balls was a better overall and faster workout than that seen with abdominal crunches or exercise without the medicine ball.

INTRODUCTION

Death rates from obesity and associated diabetes has been rising worldwide.[1] While smoking[1] and deficiency of essential vitamins such as vitamin D in the diet[2] help predispose people to obesity and diabetes, much of the complications in obesity and diabetes described in the literature[3] are also caused by lack of exercise. Thus in recent years, the importance of home exercise programs has increased in emphasis.[4] Both heart disease and diabetes are inversely related to daily exercise and directly related to body mass index.[5] Engaging in an exercise program can dramatically reduce the incidence of diabetes as well as associated complications,[6] as regular physical exercise in cardiac patients,[7] obese people,[8] and people with diabetes[9] reduces inflammatory markers.[10] Further, back injury and lower back pain are also directly related to weakness of the core muscles including rectus abdominus and the erector spinae.[11] Therefore, strengthening these muscles not only has been proven to reduce lower back pain but also increases balance in daily activities.[12,13]

Unfortunately, exercises on commercial weight-lifting machines are very specific for particular muscles rather than groups of muscles. Most people who pay for gyms in health clubs don't enjoy the ability to commit the hours necessary to exercise on several pieces of equipment and they therefore lose interest. There is also an added benefit of privacy when exercising at home not found in a health club. This is especially a concern for many women. In addition, busy schedules often make gym visits sporadic. Exercise needs to be continued on a regular basis to become effective.[14,15]

Numerous types of abdominal (core) exercise programs have been developed.[16-19] In the present investigation, we examined medicine balls of various weights. Medicine balls have been used historically for training upper and lower body muscles as well as core muscles.[20] Medicine balls have been used in a variety of populations including resistance training in school-aged boys[20,21] to increase the motor abilities and fitness in obese children,[22] to activate shoulder and arm muscles during axial load exercises,[23] to increase physical ability in softball athletes,[24] for aerobic training in volleyball athletes,[25] and in core endurance programs for rowing.[26] Upper body exercises such as chest passes are routinely used by gymnasts,[27] whereas many other exercises are used for coordination and to strengthen muscles.[28]

In this study, a new type of mini medicine ball was tested. The difference between this and a conventional medicine ball is the size. This ball is only about 8 inches in diameter and comes in 3 weights: 2, 4, and 6 lbs (0.9 kg, 1.8 kg, and 2.7 kg, respectively). By following a

Table 2. The peak EMG amplitude (%) for each of the exercises and the mean for all muscle groups.

	Rectus Normalized	Left Obliques Normalized	Right Obliques Normalized	Back Extensors Normalized	Quadriceps Normalized	Hamstring Normalized	Gluteus Maximus Normalized	Biceps Normalized	Triceps Normalized	Average
Teeter Totter										
Mean (0 lb)	22.471	18.315	16.637	13.819	24.544	9.805	17.914	9.230	22.902	17.293
Mean (2 lb)	22.879	19.909	10.071	14.467	29.729	9.358	16.546	9.605	21.942	17.167
Mean (6 lb)	33.039	28.748	25.034	24.288	36.073	16.982	24.002	12.619	27.630	25.380
Thigh-Thigh-Shoulder										
Mean (0 lb)	18.395	13.630	7.121	13.458	23.758	4.418	22.072	7.897	23.674	14.936
Mean (2 lb)	21.008	18.423	11.180	13.760	18.163	4.793	19.454	14.471	25.044	16.255
Mean (6 lb)	29.835	21.301	20.056	30.367	31.506	5.032	31.663	23.236	28.727	24.636
Around-the-World Squats										
Mean (0 lb)	20.600	15.148	11.476	18.192	45.205	17.031	19.753	8.468	25.351	20.136
Mean (2 lb)	18.179	15.663	11.667	21.166	51.567	18.609	27.394	14.760	26.421	22.825
Mean (6 lb)	27.992	18.825	20.780	24.304	62.263	27.748	33.696	25.955	26.391	29.773
Around-the-World Lunges										
Mean (0 lb)	25.118	15.607	9.698	9.698	24.258	27.920	30.339	10.540	26.295	20.293
Mean (2 lb)	25.751	20.722	7.768	17.250	23.969	27.642	27.589	18.304	27.117	21.790
Mean (6 lb)	29.076	24.225	13.548	23.996	30.519	32.229	35.114	35.762	31.720	28.466
Back Lunge Arm Pull										
Mean (0 lb)	27.159	15.846	13.525	28.315	23.560	29.747	20.806	15.323	22.686	21.885
Mean (2 lb)	30.521	16.126	17.092	30.449	25.105	33.218	26.175	19.449	23.728	24.651
Mean (6 lb)	35.340	18.443	24.957	35.686	31.954	39.275	34.152	26.258	25.405	30.163
Toy Soldier										
Mean (0 lb)	22.983	19.953	14.036	34.111	39.133	43.358	75.704	14.583	24.011	31.986
Mean (2 lb)	39.679	23.009	21.977	33.554	45.623	53.957	86.313	23.157	23.521	38.977
Mean (6 lb)	48.403	24.009	25.126	37.387	63.315	89.902	84.488	32.067	26.362	47.895
Tuck-up Abdominal Crunches										
Mean (0 lb)	70.14	33.14	10.66	17.24	17.93	6.84	16.21	7.71	21.83	22.41
Mean (2 lb)	72.13	41.40	14.34	20.83	17.56	8.25	19.60	12.83	22.70	25.51
Mean (6 lb)	93.31	44.59	22.26	23.52	28.90	13.05	26.26	19.24	23.47	32.73
Abdominal Crunches										
Mean	20.26	13.49	13.74	7.22	2.98	2.80	3.75	3.77	22.55	10.06
Lying Leg Lifts										
Mean	9.28	13.83	5.32	27.14	6.32	98.12	65.78	5.73	35.98	29.72

Table 3. Work during each of the exercises and average work.

	Duration (D)	Rectus Abdominus	Left Obliques	Right Obliques	Back Extensors	Quadriceps	Hamstrings	Gluteus Maximus	Biceps	Triceps	Average Work
Teeter Totter											
0 lb	3.182	56.142	31.264	30.253	45.329	78.344	23.874	60.324	21.934	71.980	46.605
2 lb		44.184	39.984	21.541	46.539	96.137	21.870	53.963	26.751	68.036	46.556
6 lb		70.223	38.787	59.769	78.940	119.000	24.755	75.455	31.957	92.145	65.670
Thigh-Thigh-Shoulder											
0 lb	3.713	47.797	25.681	12.824	54.688	89.192	17.060	78.893	21.297	86.118	48.172
2 lb		63.837	36.935	14.170	55.143	72.721	21.064	70.204	28.635	85.591	49.811
6 lb		95.278	71.872	54.987	111.236	125.063	17.440	111.870	50.684	99.316	81.972
Around-the-World Squats											
0 lb	3.600	51.447	24.540	13.478	55.866	155.815	34.696	64.714	18.973	79.814	55.483
2 lb		39.917	21.799	11.506	67.988	171.186	64.209	93.063	27.909	76.940	63.835
6 lb		66.251	67.691	63.866	71.361	209.617	44.340	116.372	49.969	107.369	88.537
Around-the-World Lunges											
0 lb	3.239	46.522	22.483	11.747	51.013	78.592	52.245	107.589	14.656	76.099	51.216
2 lb		47.263	20.313	11.903	60.541	77.250	57.904	101.433	27.828	76.342	53.420
6 lb		72.576	62.106	16.939	82.947	97.235	72.483	127.462	44.370	85.784	73.545
Back Lunge Arm Pull											
0 lb	2.467	43.965	18.672	9.400	71.368	58.754	35.275	53.076	16.554	54.437	40.167
2 lb		39.729	19.396	7.646	77.221	58.711	39.749	66.070	26.297	55.633	43.384
6 lb		85.093	20.340	8.915	86.054	77.800	48.455	83.600	36.182	60.890	56.370
Toy Soldier											
0 lb	2.049	43.229	18.974	22.480	70.200	88.390	30.607	162.963	17.359	46.368	55.619
2 lb		47.488	18.508	30.495	66.119	96.643	41.087	184.836	24.535	50.780	62.277
6 lb		66.879	29.993	7.771	74.429	135.369	56.408	181.171	34.501	59.147	71.741
Tuck-up Abdominal Crunches											
0 lb	3.98	100.83	64.95	29.66	68.05	70.00	14.90	65.70	13.27	83.98	56.81
2 lb		141.08	72.69	69.89	82.68	69.82	18.19	73.71	21.29	84.47	70.42
6 lb		171.22	100.69	118.78	93.16	116.79	15.07	109.99	31.76	107.67	96.13
Abdominal Crunches											
	1.72	13.56	8.77	7.74	3.29	2.50	3.26	3.66	4.46	7.17	6.05
Lying Leg Lifts											
	3.96	24.05	22.06	10.70	60.81	15.73	205.69	107.76	19.69	101.48	63.11

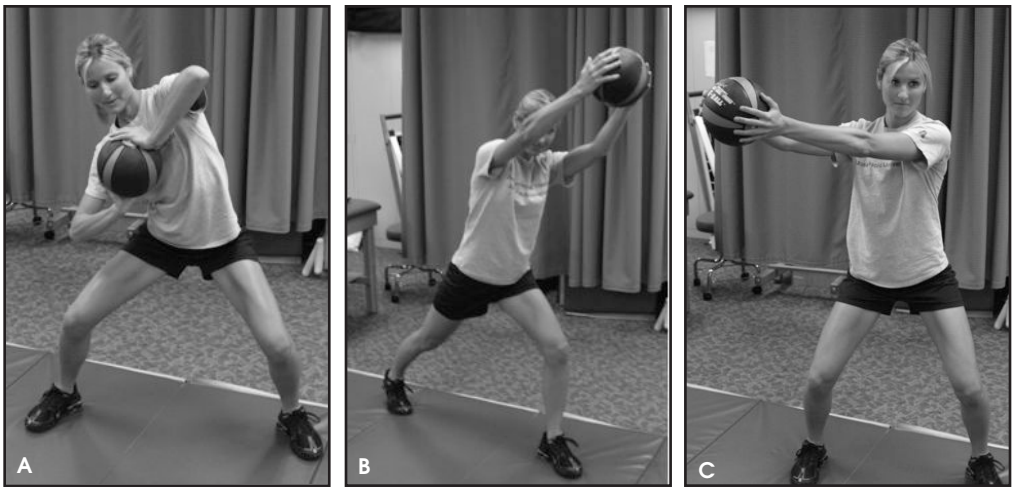

Figure 1. The teeter totter (A), the thigh-shoulder exercise (B), and around-the-world squats (C).

commercial exercise video, the goal of this project was to see if this medicine ball was effective in training the upper body, lower body, and core muscle area simultaneously. Muscle activation while using no ball, or the 2- or 6-lb mini medicine ball during 7 exercises from the associated video was compared to abdominal crunches.

SUBJECTS AND METHODS

Subjects

The subjects in the study included 12 males and females. They were in the age range of 20-40 years. They were free of any cardiovascular and neurological diseases. The general characteristics of the subjects are listed in Table 1. All methods and procedures were explained to each subject who signed a statement of informed consent. This study was approved by the Human Review Committee of Azusa Pacific University.

Determination of Muscle Activity

To determine muscle activity, the electromyogram (EMG) was used. The EMG was recorded by using 2 electrodes and a ground electrode placed above the active muscle.[29-34] The relation between tension in muscle and surface EMG amplitude is linear.[32,35] Thus, the amplitude of the surface EMG can be used effectively as a measure of activity of the underlying muscle by simply normalizing the EMG in terms of a maximal effort. Muscle activity was therefore assessed by first determining the percent of maximum EMG to calculate the percent of muscle activity. The electrical output from the muscle was amplified with a biopotential amplifier with a gain of 2000 and frequency response that was flat from DC to 1000Hz (EMG 100 C amplifier, Biopac Inc., Goleta, California, USA). The amplified EMG was digitized with a 16-bit analog to digital converter and sampled at a frequency of 2000 samples/sec (MP 100, Biopac Inc., Goleta, California, USA). The software to analyze the EMG is Acknowledge 3.9.1 (Biopac Inc., Goleta, California, USA).

Exercise

Abdominal exercise was accomplished in 1 of 2 manners. First, abdominal crunches were used. Abdominal crunches involved the subject lying on the floor in a supine position with their hands behind their head and contracting the abdominal muscles to lift the trunk approximately 30° such that the shoulders just cleared the floor. Mini medi-

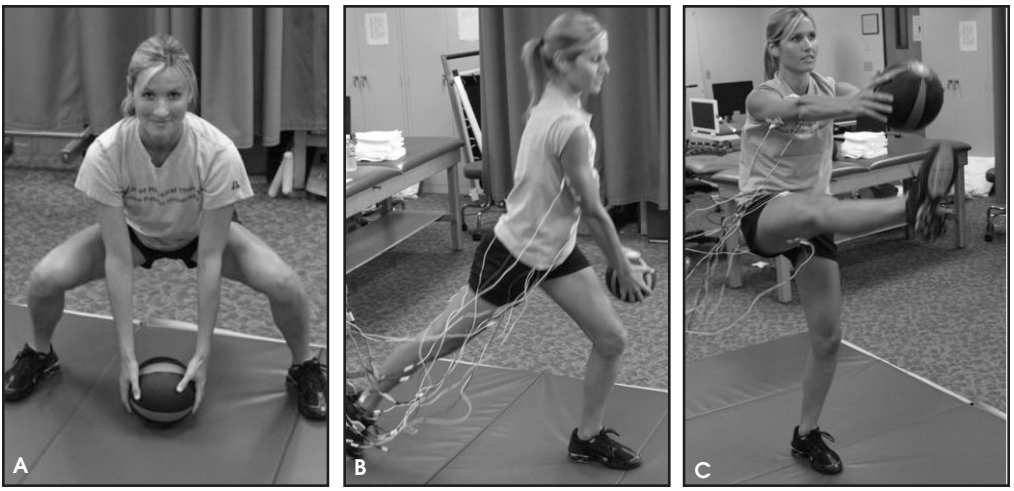

Figure 2. Around-the-world lunges (A), back lunge arm pull (B), and the toy soldier (C).

cine balls were provided by Savvier LP, (Carlsbad, California, USA) and involved 2 balls each 8 inches in diameter and weighing 2 and 6 pounds.

Exercise Videos

The exercise video used in this study is called the strength building workout video . It is approximately 50 minutes long and involves a series of exercises using the mini medicine ball during upper body and lower body stretching and abdominal exercise. The following exercises were examined in this study: 1) The teeter totter. This exercise involved the subjects standing with their feet shoulder-width apart in a partial squat position and holding the ball against the chest. The subject side-flexed their trunk toward the left and right throughout their full range (Figure 1A). 2) Thigh-thigh-shoulder exercise. Here the subject was standing in a wide stance in a semi-squat position and the ball was rotated across the abdomen with arms extended from the hip to the contralateral hip, then from one shoulder toward the other (Figure 1B). 3) Around-the-world squats. This exercise involved the subject starting in a semi-squat position, holding the ball with arms extended. The subject began by squatting, holding the ball vertical toward the floor while squatting, and then circling the ball across the body and over the head, then returning to the semi-squat position (Figure 1C). 4) Around-the-world lunges. This exercise included a backward step lunge as the subject rotated the ball over their head in a circular pattern from side to side (Figure 2A). 5) Back lunge arm pull. This exercise involved the subject standing in a lunge position holding the ball above their head with their arms extended. The subject then lowered the ball toward their waist while simultaneously flexing their back hip and raising their knee in toward their chest (Figure 2B). 6) Toy soldier. The subject stood with their feet together and the ball held with their arms extending above their head. Keeping their arms extended, the subject lowered the ball to waist height directly in front of them, while simultaneously flexing an extended leg to meet as close to the ball as possible. The exercise is then repeated with the opposite leg (Figure 2C). 7) Tuck-up abdominal crunches. The subjects were in the supine position starting with the ball held over their head and arms straight. The ball was then brought over the body with the arms extended, while simultaneously one knee is brought in toward

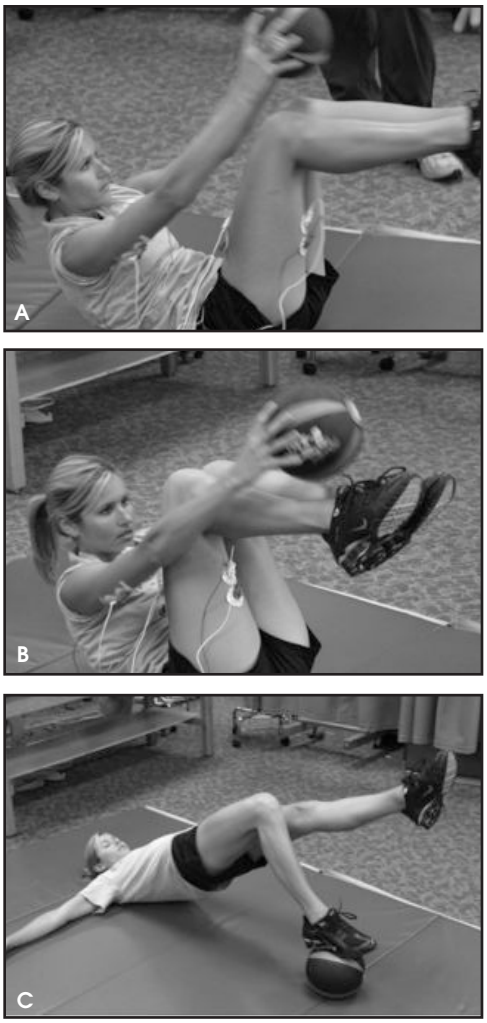

Figure 3. Tuck-up abdominal crunches (A, B) and lying leg lifts (C).

the chest. The exercise was repeated with the opposite leg, then both knees brought into the chest (Figure 3A and B). 8) Lying leg lifts. The subject was in the supine position with one leg flexed and the other foot on the ball placed alongside the opposite foot. The subject then extended their hips, raising their body off the floor (so that only the shoulders and head touch the floor) using the leg in which the foot was placed on the other ball, while simultaneously straightening the opposite leg to extend in line with level of the knees (Figure 3C).

Statistical Analysis

Statistical analysis involved the calculations of means, standard deviations, and *t*-tests, analyzed using Excel, from Office 2007. The level of significance was set at $P < 0.05$.

Procedures

Subjects entered the lab in a controlled room temperature of 20°C ± 2°C. They rested comfortably in a seated position for 10 minutes before undergoing the exercises. During this time, electrodes were placed above the left and right obliques, rectus abdominus, back extensor muscles, biceps, triceps, quadriceps, hamstring, and gastrocnemius muscles. Subjects then exercised for 3 minutes doing standard abdominal crunches. Finally, after a 5-minute rest, subjects watched and followed the exercise video performing each of the 7 different exercises without a ball or with a 2- or 6-lb mini medicine ball.

RESULTS

Results of the experiment are shown in Figures 4 through 12. The no ball exercise condition is referred to as the 0-lb ball. Obviously, there is no such entity as a zero pound ball. Here the subjects went through the exercises as if they had a ball in their hands.

Teeter Totter Exercise

The results of this series of experiments are shown in Figure 4. The peak muscle activities for the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, and triceps are listed in Table 2. When the mini medicine ball was used, the muscle activity increased. For these muscle groups, with the exercise without the mini medicine ball, the average muscle activity was 17.3% ± 3.8% for these muscle groups and 17.2% ± 5.0% with the 2 lb ball; with the 6 lb ball, average muscle activity increased to 25.4% ±

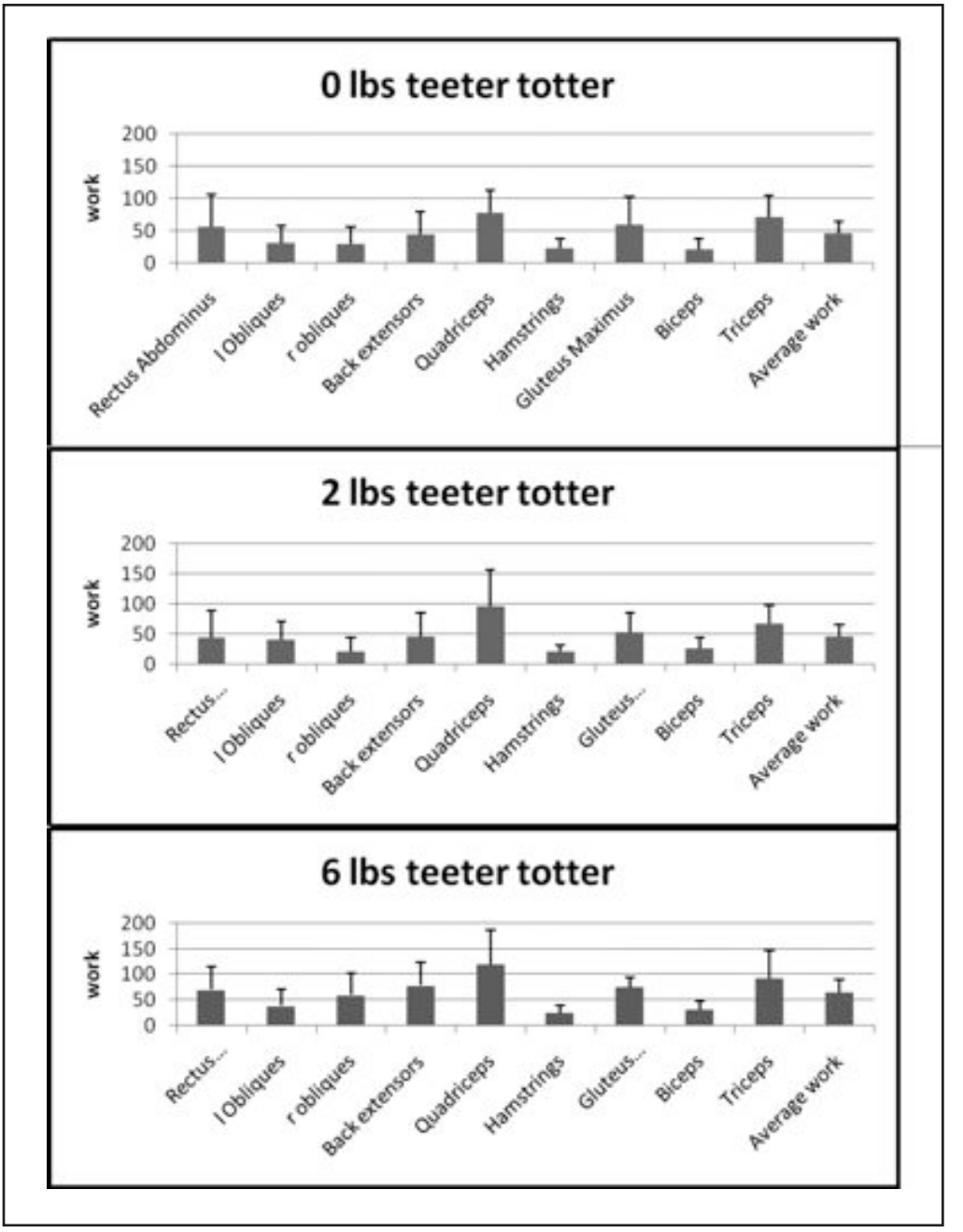

Figure 4. Illustrated in the 3 panels of this figure is a calculated work of the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, triceps, and the total average work for all muscle groups for a single exercise involving the teeter-totter exercise. The upper panel shows the average muscle work without holding the ball, whereas the middle and bottom panels show the average work when using the 2-lb and 6-lb ball, respectively, for the exercise. Each panel shows the average results ± SD for all the 12 subjects.

4.9% for these muscles. The average duration of the exercise was 3.2 ± 0.56 seconds (Table 3). Figure 4 shows the average work for this exercise, calculated when the average muscle activity was multiplied by the duration of the exer-

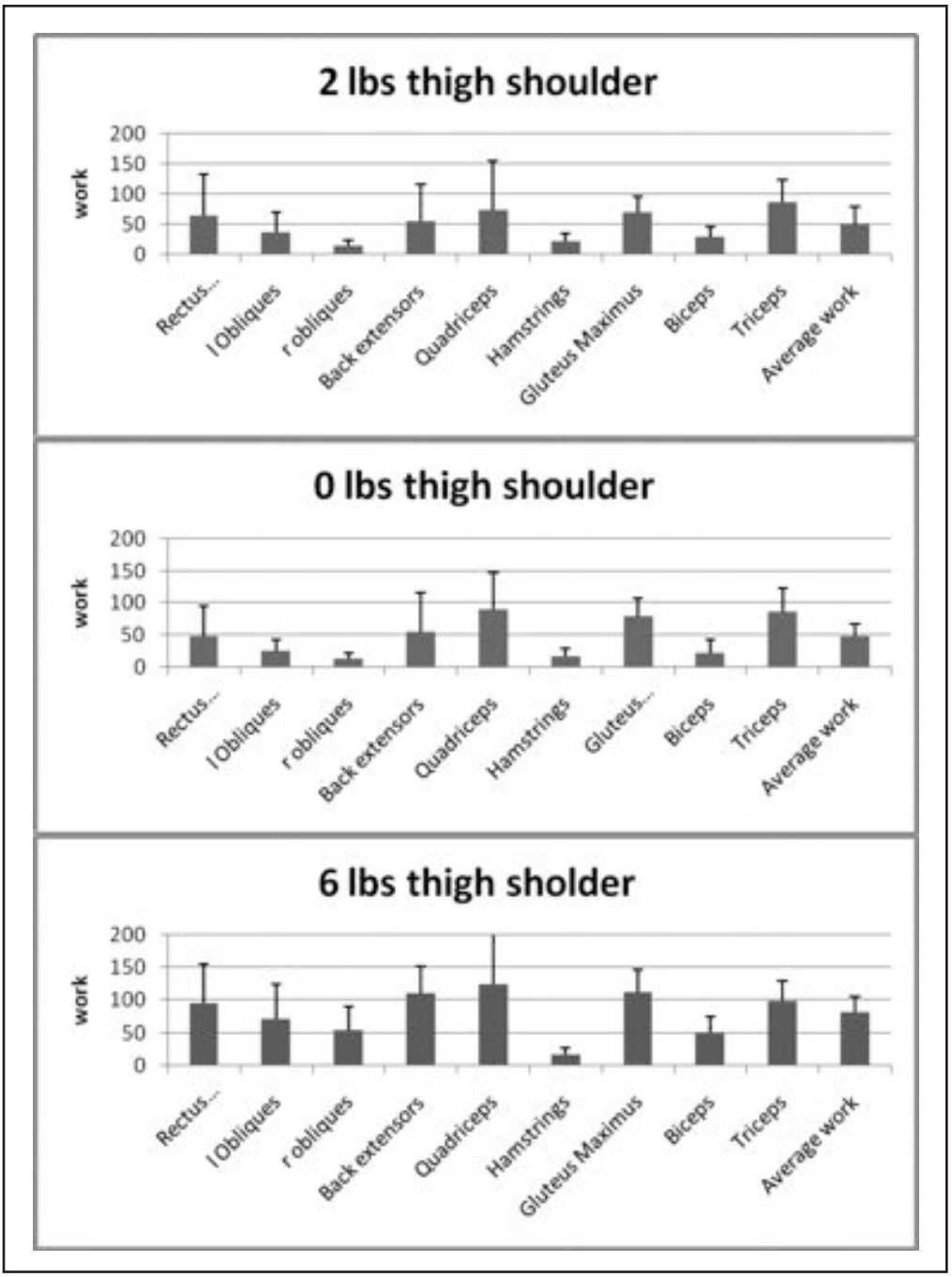

Figure 5. Illustrated in the 3 panels of this figure is a calculated work of the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, triceps, and the total average work for all muscle groups for a single exercise involving the thigh-thigh-shoulder exercise. The upper panel shows the average muscle work without holding the ball, whereas the middle and bottom panels show the average work when lifting the 2-lb and 6-lb ball, respectively, for the exercise. Each panel shows the average results ± SD for all 12 subjects.

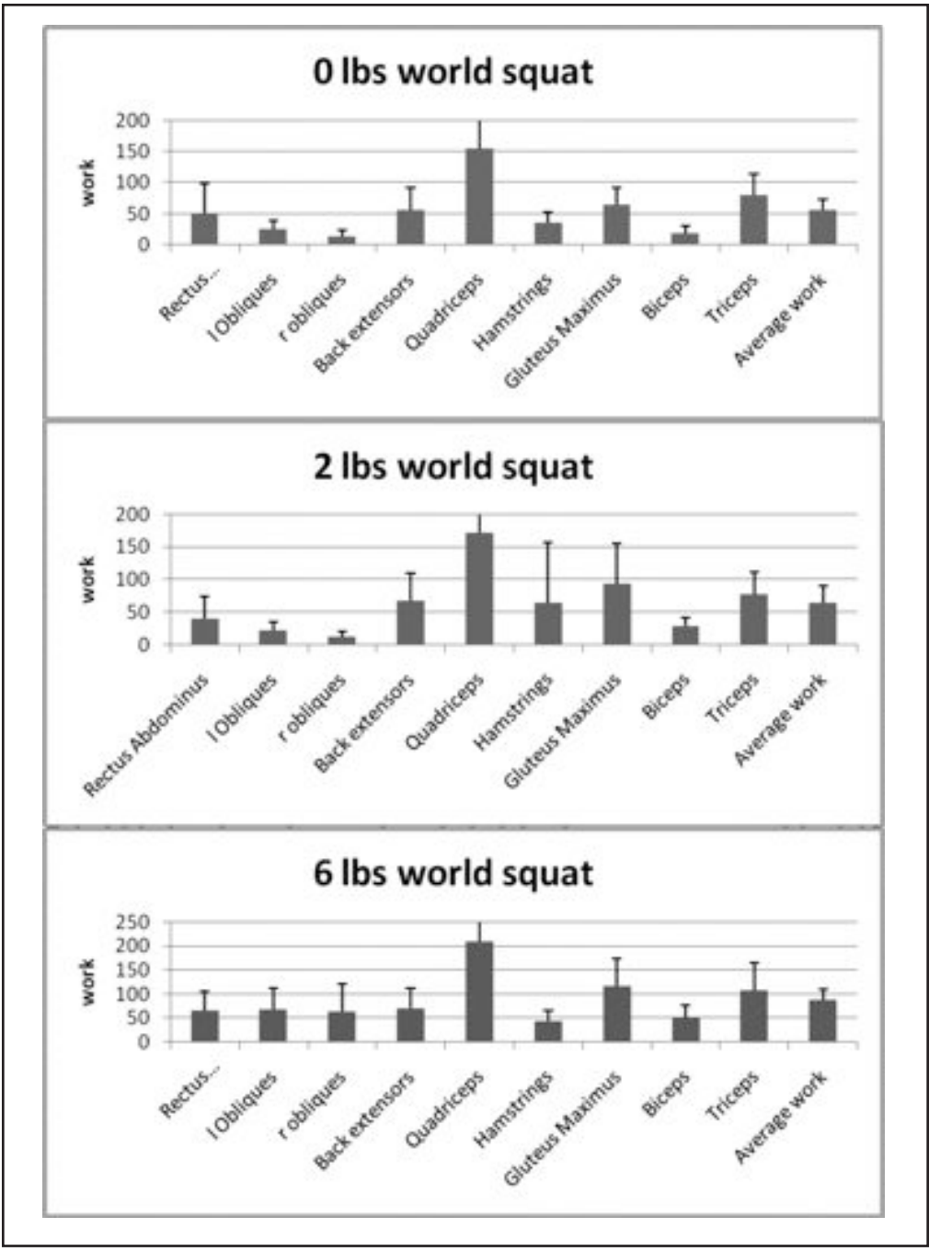

Figure 6. Illustrated in the 3 panels of this figure is a calculated work of the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, triceps, and the total average work for all muscle groups for a single exercise involving the around-the-world squats exercise. The upper panel shows the average muscle work without holding the ball, whereas the middle and bottom panels show the average work when lifting the 2-lb and 6-lb ball, respectively, for the exercise. Each panel shows the average results ± SD for all 12 subjects.

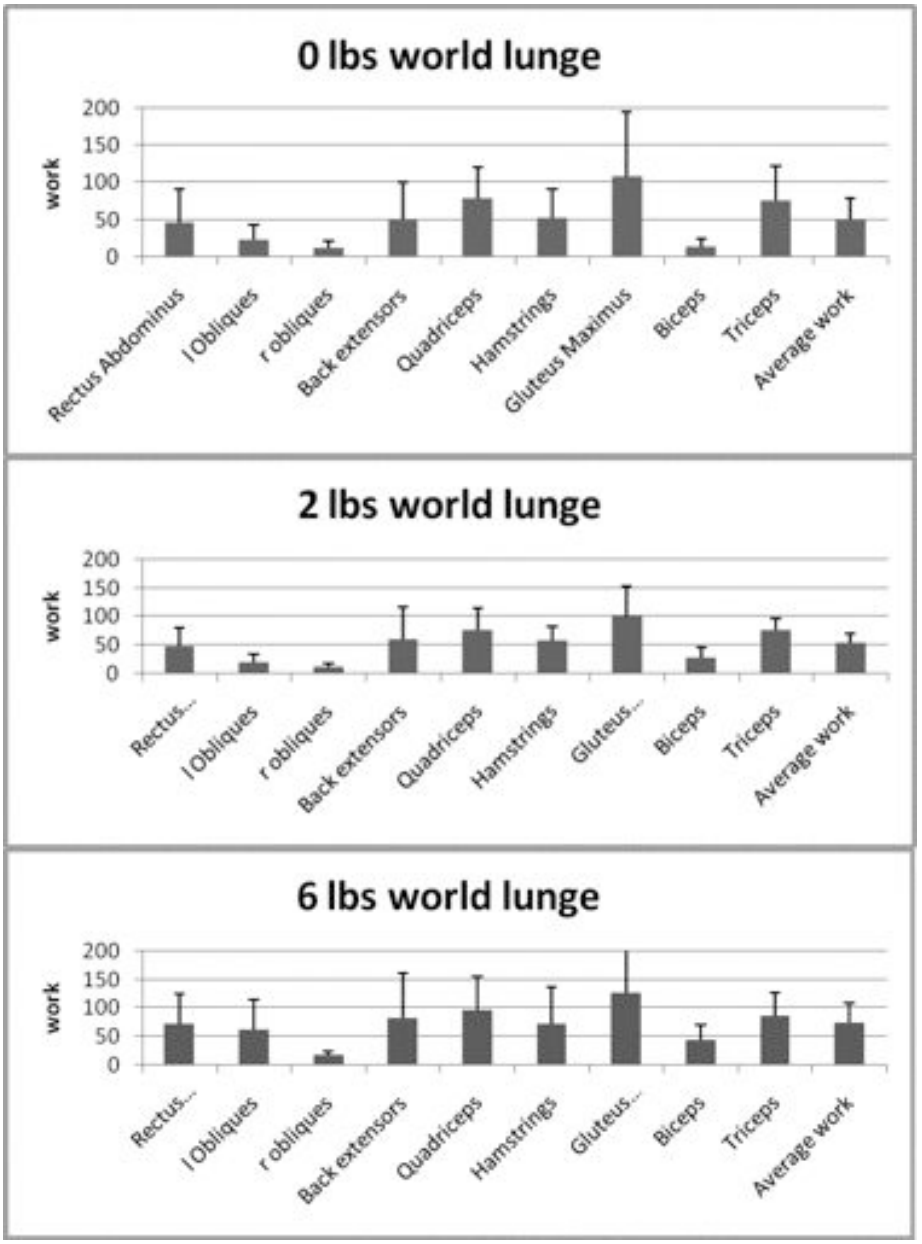

Figure 7. Illustrated in the 3 panels of this figure is a calculated work of the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, triceps, and the total average work for all muscle groups for a single exercise involving the around-the-world lunges exercise. The upper panel shows the average muscle work without holding the ball, whereas the middle and bottom panels show the average work when lifting the 2-lb and 6-lb ball, respectively, for the exercise. Each panel shows the average results ± SD for all 12 subjects.

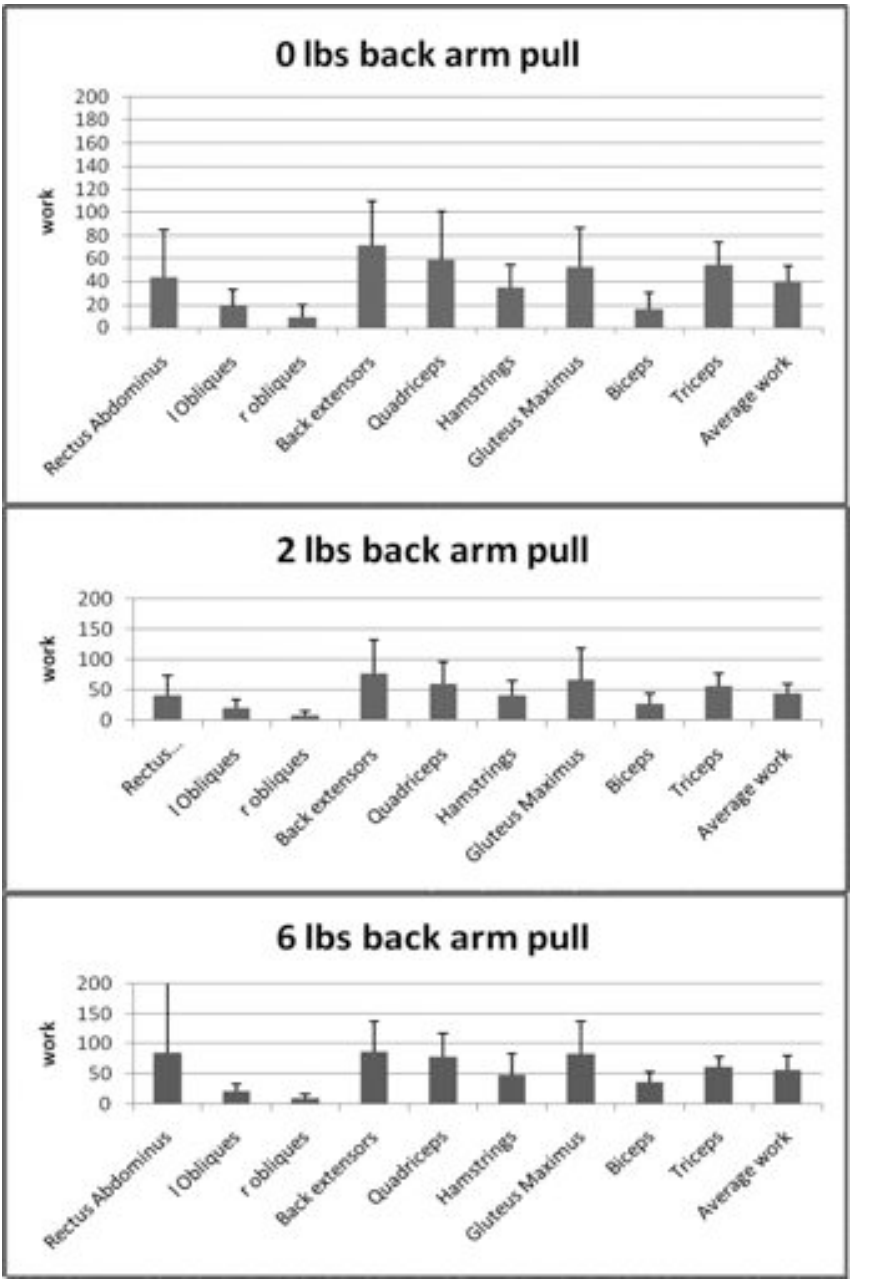

Figure 8. Illustrated in the 3 panels of this figure is a calculated work of the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, triceps, and the total average work for all muscle groups for a single exercise involving the back lunge arm pull exercise. The upper panel shows the average muscle work without holding the ball, whereas the middle and bottom panels show the average work when lifting the 2-lb and 6-lb ball, respectively, for the exercise. Each panel shows the average results ± SD for all 12 subjects.

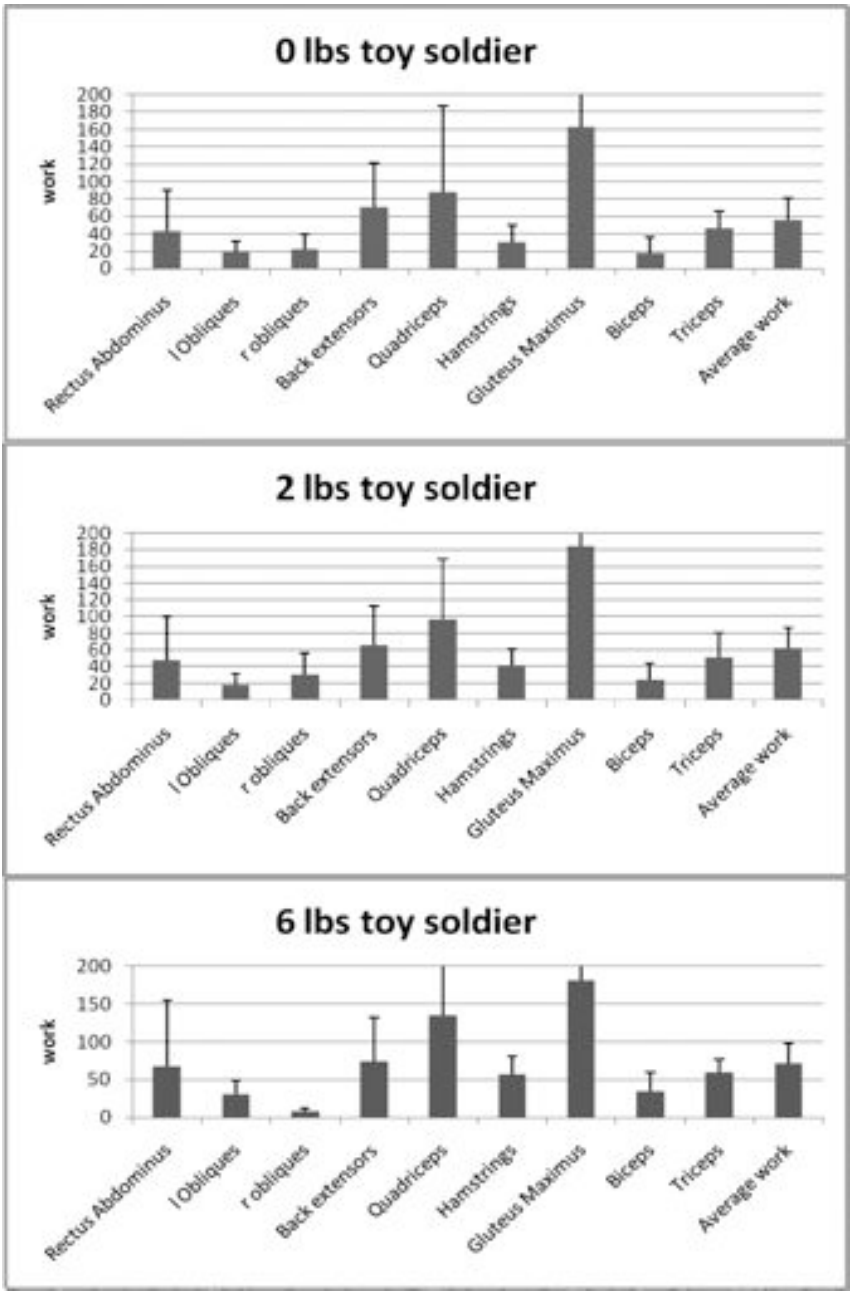

Figure 9. Illustrated in the 3 panels of this figure is a calculated work of the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, triceps, and the total average work for all muscle groups for a single exercise involving the toy soldier exercise. The upper panel shows the average muscle work without holding the ball, whereas the middle and bottom panels show the average work when lifting the 2-lb and 6-lb ball, respectively, for the exercise. Each panel shows the average results ± SD for all 12 subjects.

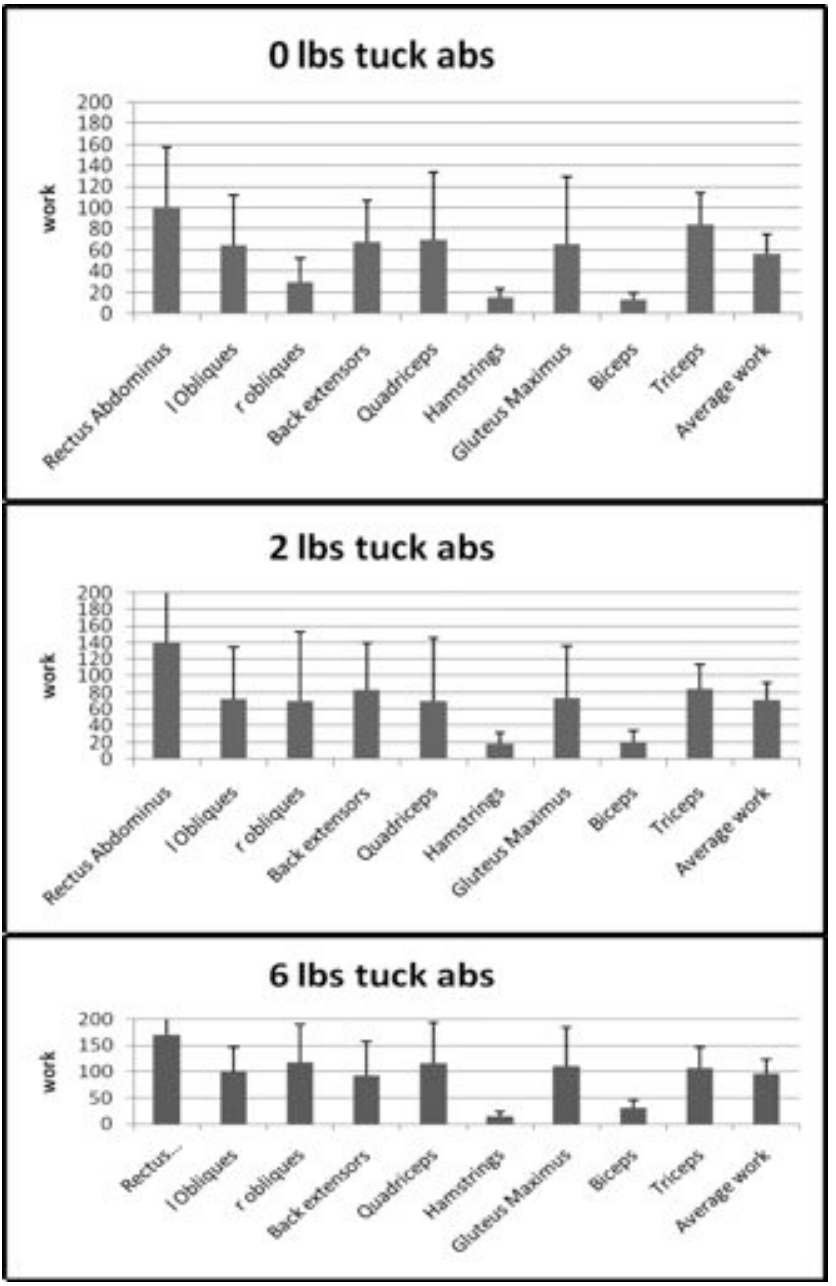

Figure 10. Illustrated in the 3 panels of this figure is a calculated work of the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, triceps, and the total average work for all muscle groups for a single exercise involving the tuck-up abdominal crunches exercise. The upper panel shows the average muscle work without holding the ball, whereas the middle and bottom panels show the average work when lifting the 2-lb and 6-lb ball, respectively, for the exercise. Each panel shows the average results ± SD for all 12 subjects.

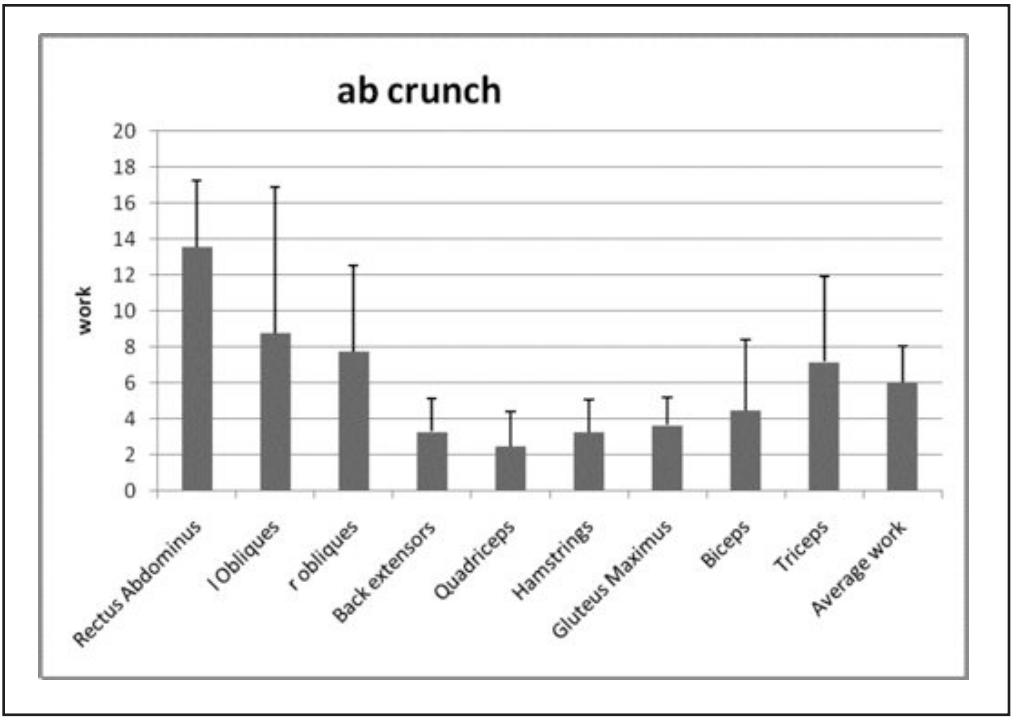

Figure 11. This figure shows the results of all 12 subjects for work ± SD calculated for the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, triceps, and the total average work for all muscle groups during an abdominal crunch.

cise. As can be seen here, the greatest work was in the rectus abdominus, quadriceps, gluteus maximus and triceps muscles respectively. This was especially true with the 6-lb mini medicine ball exercise. However, muscle activity was high for all muscle groups examined. Thus, the average work with no ball and the 2-lb ball was 46.6 ± 18.8 and 46.6 ± 18.5 work units, respectively, compared with 65.7 ± 24 work units for all muscle groups with the 6-lb ball.

Thigh-Thigh-Shoulder Exercise

As shown in Figure 5, the total muscle activity and total work was slightly different for the thigh-thigh-shoulder exercises. Whereas the majority of muscle activity was for the quadriceps, triceps, and rectus abdominus for the teeter totter exercises, for the thigh-thigh-shoulder exercises, there was significant activity for the quadriceps, back extensors, rectus abdominus, triceps, and gluteus maximus muscles, especially when using the 6-lb ball. The maximum muscle activities for the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, and triceps are shown in Table 2. For each muscle group, muscle activity with the 0- and 2-lb balls was not significantly different ($P > 0.05$). However, comparing the 6-lb ball with the 2-lb ball and the 0-lb ball, muscle activity was significantly higher for each muscle group (analysis of variance [ANOVA], $P < 0.05$). The muscle activity with the 6-lb ball averaged 24.6% ± 5.4% of total muscle activity, which was significantly higher than the average muscle activity with the 0- and 2-lb balls (ANOVA, $P < 0.01$). With an average duration of 3.7 ± 0.8 seconds (Table 3), the work, as

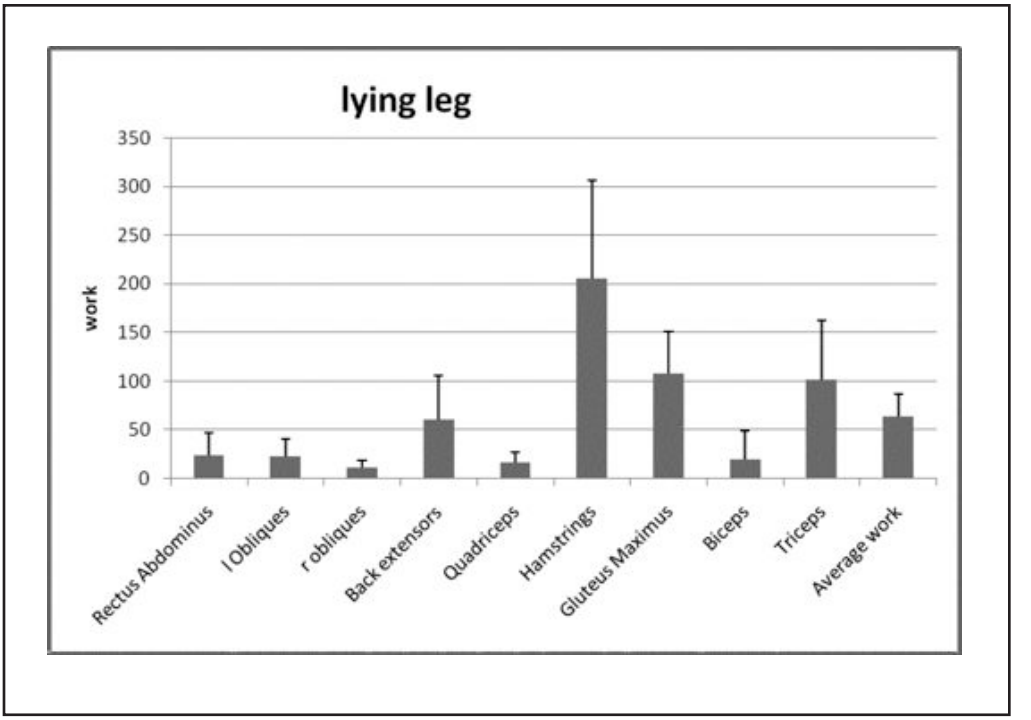

Figure 12. This figure shows the results of all 12 subjects for work ± SD calculated for the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, triceps, and the total average work for all muscle groups during a lying leg raise.

shown in Figure 5, was similar for the 0- and 2-lb balls, but work was significantly higher for the 6-lb ball. Here, the average work was 48.2 ± 18.9 work units for the 0-lb ball, 49.8 ± 29.3 units for the 2-lb ball, and 82.0 ± 24.0 units for the 6-lb ball ($P < 0.01$ vs 0-lb ball and 2-lb ball average work).

Around-the-World Squats

For around-the-world squat exercise, the average muscle activity was higher than for the teeter totter or the thigh-thigh-shoulder exercise, averaging 20.1% ± 6.1% of muscle activity for all muscle groups with the 0-lb ball, 22.8% ± 8% of muscle activity with the 2-lb ball, and 29.8% ± 8.6% muscle activity with the 6-lb ball (Table 2). Muscle activity with the 2- and 6-lb balls was significantly higher than with the 0-lb ball ($P < 0.05$). The average duration of the exercise was 3.6 ± 1.3 seconds (Table 3). Here, due to the fact that squats were being done, the quadriceps had significantly higher activity than in the previous 2 exercises. For example, for the 6-lb ball, the quadriceps muscle showed activity of 62.3% ± 28.7% of total muscle activity as compared to the thigh-thigh-shoulder exercise quadriceps peak activity of 31.5% ± 14.1% of total muscle activity, a significance of $P < 0.01$. The lowest muscle activity was to the obliques whereas there was significant activity, as shown in Figure 6, for the rectus abdominus and triceps. Triceps work also progressively increased. For example, with the 6-lb ball, triceps activity was 26.4% ± 9.1% of total activity. When work was calculated, as shown in Figure 6, the average work was 55.5 ± 18.3 work units with the 0-lb ball, 63.8 ± 26.1 work unit with the 2-lb ball, and 88.5 ± 21.3 work unit with

the 6-lb ball. Thus, with the 2- and 6-lb balls, work was significantly higher than with no ball. Further, work with the 6-lb ball was significantly higher here than in the other 2 exercises ($P < 0.05$).

Around-the-World Lunge

Muscle activity changed here from the previous exercises because this exercise involved lunges, a different form of exercise. Unlike the other exercises, gluteus maximus activity, as shown in Figure 7, increased considerably in this exercise. This was especially true when using the 6-lb ball. Thus, looking at quadriceps, gluteus maximus, and hamstring activity with the 6lb ball, the muscle use for gluteus maximus was 35.1% ± 17.8% of total muscle activity, whereas the hamstring activity was 32.2% ± 22.3% of the total muscle activity (Table 2). Quadriceps remained at similar levels at 30.5% ± 16.5% of the total muscle activity. Thus, the quadriceps activity here was less than with the around-the-world squats. Quadriceps activity and gluteus maximus activity significantly increased ($P < 0.05$) as compared to the activity of the biceps. For the biceps, activity significantly increased for the 6-lb ball from 26.0% ± 11.9% of the total muscle activity to 35.8% ± 18.7% of total muscle activity ($P < 0.01$). Triceps had similar activity as in the round the world squat as compared to rectus abdominus and the left and right obliques. Here, rectus abdominus activity for the 0-, 2-, and 6-lb balls averaged 25.1% ± 24.2%, 25.8% ± 26.3%, and 29.1% ± 26.3% total muscle activity, respectively. With an average duration of 3.2 ± 1.1 seconds, the average total work for this exercise was 73.5 ± 34.5 work units with the 6-lb ball compared to 51.2 ± 27.7 units with no ball (Table 3).

Back Lunge Arm Pull

As shown in Figure 8, for the back lunge arm pull exercise, the total work was somewhat less whereas muscle activity was fairly uniform for each of the 9 muscle groups examined; muscle activity was slightly higher for rectus abdominus, the back extensors, quadriceps, and gluteus maximus than in some of the other muscle groups. Thus, as shown in this figure, the peak muscle activity for the rectus abdominus, left obliques, right obliques, back extensors, quadriceps, hamstrings, gluteus maximus, biceps, and triceps were even for the 6-lb ball. The averaged muscle activity for all 9 muscles groups was 21.9% ± 4.5%, 24.7% ± 16.2%, and 30.2% ± 5.7% total muscle activity for the 0-, 2-, and 6-lb ball, respectively (Table 2). The increase in muscle activity for all 9 muscle groups between the 0-, 2-, and 6-lb balls was significant ($P < 0.05$). When looking at the total work, with an average duration of 2.47 ± 0.55 seconds, the total average work was 40.2 ± 13.2, 43.4 ± 16.1, and 56.4 ± 23.9 work units for the 0-, 2-, and 6-lb balls, respectively. This increase in work with each progressive ball was significant ($P < 0.05$). Total work here was, for each work load, less than in the lunges described in the paragraph above.

Toy Soldier

The results of the toy soldier exercises are shown in Figure 9. This exercise showed significant muscle activity for the gluteus maximus, quadriceps and back extensors. In addition, the core muscles also showed significant activity but not at the same levels as some of the other muscle groups (Table 2). The average muscle activity for each progressive exercise was 32.0% ± 8.6% muscle activity for 0-lb ball, 39.0% ± 13.4% muscle activity with the 2-lb ball, and 47.9% ± 16.3% muscle activity with the 6-lb ball. This increase in the percentage of total muscle activity was significant for each muscle group with progressively increasing work loads ($P < 0.05$). The increase

in work for the gluteus maximus, even with the 2-lb ball, was significantly higher than any other exercise described above ($P < 0.01$). With an average duration of 2.0 ± 0.43 seconds, the average work, as shown in Figure 9, displayed the peak muscle activity in the gluteus maximus, quadriceps, and back extensors described above. The total average work for this exercise was 55.6 ± 25.4, 62.3 ± 24.8, and 71.7 ± 26.4 work units with no ball, or the 2-lb and 6-lb balls, respectively. This increase in total average work for all the muscle groups was significant. Gluteus maximus showed the greatest work in this exercise, peaking with the 6-lb ball to 181.2 ± 121.2 work units.

Tuck-up Abdominal Crunches

The results of the tuck-up abdominal crunches exercise is shown graphically, as work, in Figure 10. As can be seen for this exercise, average muscle activity averaged 21.4% ± 6.6%, 25.5% ± 8.1%, and 32.7% ± 7.58% with the 0-, 2-, and 6-lb balls, respectively, as a percentage of the maximum activity of the muscles (Table 2). For this particular exercise, there was relatively high muscle activity except on the hamstrings and biceps muscles for all exercises. With an average duration of 3.98 ± 1.21 seconds, the average work with no ball was 56.8 ± 18.4 work units, with the 2-lb ball 70.4 ± 25.9 work units, and with the 6-lb ball 96.1 ± 27.4 work units (Table 3). Thus, this exercise exhibited the highest average work of any exercise that was accomplished ($P < 0.01$).

Abdominal Crunches

The result of abdominal crunch is shown in Figure 11. As can be seen in this figure, work was very light with the abdominal crunch, most of the work being done by the rectus abdominus muscles and the obliques (Table 2). The triceps showed some activity due to the placement of the arm behind the head and holding the arms in position, but activity was actually fairly low. An average muscle use of 10.0% ± 1.37% of total muscle activity was achieved. Compared to all the other exercises described above, for each muscle group, muscle activity here was significantly less ($P < 0.01$). With an average duration of 1.72 ± 0.39 seconds, the average work was 6.05 ± 2.0 work units (Table 3). Compared with the other exercises, even without use of the ball, the work was about 10% of the other exercises. When using a 6-lb ball, compared with some of the exercises such as the world squats or the toy soldier, the total work was about 1/15th that of the other exercises.

Lying Leg Lift

The final exercise was a lying leg lift, as shown in Figure 12. As can be seen here, the majority of muscle activity was on the hamstring, gluteus maximus, and triceps. This exercise did not use the balls. However, the average muscle activity was 29.7% ± 7.3% compared to 10% for the abdominal crunch. Thus, muscle activity was about 3 times the activity of a crunch. Furthermore, the duration was longer, averaging 3.96 ± 1.2 seconds. Thus, the total average of work averaged 63.1 ± 23.2 units, a value more than 10 times higher than that for the abdominal crunch.

DISCUSSION

Numerous studies have shown that exercising with a medicine ball can dramatically increase muscle use, especially in children.[23,36] This is also true for adults, especially for the abdominal muscles.[26] Thus, the use of medicine balls for exercise is joined by other core exercise devices.[16-19] Medicine balls have been used in gyms as well as for resistance training for school boys[20] and rehabilitation of the shoulder in adults.[23] In the

present investigation, the use of mini medicine balls has been tested. This mini medicine ball comes in 2-, 4-, and 6-lb balls. The advantage of these medicine balls is that they are small and easy to store under the bed and therefore, a program is able to be implemented in the home environment to exercise the upper body muscles, lower body muscles, and core muscles. The core muscles are especially important because, when strengthened, there is reduced incidence of back injury and chronic low back pain.[37-39]

In the present investigation, various exercises on the mini medicine ball were compared to abdominal crunches. The muscle use in these studies showed that even with a 2-lb ball, the muscle activity during various exercises for the core muscles was much greater than that of the abdominal core muscles during sit ups. For example, during the tuck-up abdominal crunches exercises, the average core muscle recruitment for the 4 core muscle groups examined here was 37.1% of muscle activity compared with 13.68% for an abdominal crunch. This core muscle use was almost 300% higher for this exercise. Further, when the weight was progressively increased to the 6-lb ball, muscle activity was substantially higher, averaging 49.9% of total muscle activity for the abdominal muscles, showing an increase of about 400% over an abdominal crunch. Thus, abdominal muscles were exercised very extensively following the exercise video. Further, whereas crunches only uses a limited number of muscles, that is rectus abdominus and obliques, by using a mini medicine ball, significant muscle activity is also seen in the arm and leg muscles. Thus, the medicine ball provides a better whole body exercise workout than just doing abdominal crunches. Finally, these exercises were longer in duration than abdominal crunches, average, for all exercises, 3.3 seconds compared with 1.72 seconds for an abdominal crunch. Therefore, for each exercise, the total work was double that of the crunch alone due to the longer duration. Further, unlike crunches where core muscle use was the only use except for some triceps activity to hold the arms behind the head, almost all muscle groups were active. Thus for the 9 muscle groups examined here, the average work was 41.6 for no ball, 55.7 for the 2-lb ball, and 75.2 for the 6-lb ball. The average work for a crunch was 6.1. Thus, there was 9.2 times the work of an abdominal crunch for a 2-lb ball and 12.5 times for the 6-lb ball. For all exercises averaged together, for the core muscles, the average muscle use was 1.62 times the core muscle use of a crunch with the 2-lb ball and 2.16 times the abdominal use for the 6-lb ball. Adding either the 2- or 6-lb ball showed a significant increase in work performed for the same exercises. The 2-lb ball made the exercise 1.3 times more effective while the 6-lb ball made the exercise 1.8 times more effective.

Exercise is generally conducted through movement of the body. The medicine ball exercises studied here, like many types of exercise, allowed for muscle use in many more muscles than simple abdominal crunches. It was interesting that even a 2-lb ball caused such a large increase in muscle use. However, the arms form a lever arm such that the effect of a 2-lb weight is to dramatically increase torque on the shoulders when the ball is held away from the body. Thus even the 2-lb ball would have its effect on muscle use amplified by the lever arm established by the arm's length. This lever arm then increases additional muscle use even further on the core section of the body to stabilize the truck; here there is a double lever arm, one from the ball to the shoulder and a second from the shoulder to the lower abdominals, ampli-

fying the effect of the weight and the corresponding muscle use even further. As an example, the toy soldier, when looking at the rectus abdominus without the medicine ball, was 22.98% peak EMG amplitude and by adding the 2-lb ball almost doubled muscle use to 39.7% peak EMG amplitude. It is quite astonishing that a 6-lb ball can almost double the total body work performed, but predictable when analyzing the biomechanical effects of lever arms when used as part of exercise. Thus the use of small weight when leveraged with large lever arms can be very effective for increasing the intensity of exercise.

Finally, for people who might have had a hard time getting on and off the floor, this type of the workout is predominately in sitting or standing positions, which could provide a much safer environment than lying on the floor.

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