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The Effects of an Off-season Strength and Conditioning Program on Starters and Non-starters in Women's Intercollegiate Volleyball

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Abstract

Fry, A.C., Kraemer, W.J., Weseman, C.A., Conroy, B.P., Gordon, S.E., Hoffman, J.R. and C.M. Maresh. The effects of an off-season strength and conditioning program on starters and non-starters in women's intercollegiate volleyball. *J. Appl. Sport Sci. Res.* 5(4):174-181.—*Fourteen female NCAA Division I collegiate volleyball players were monitored during a 12-week off-season strength and conditioning program. Physical characteristics (mean ± standard deviation) included: age, 19.6 ± 0.6 years; height, 171.9 ± 6.8 centimeters; weight, 64.3 ± 7.0 kilograms. Training included resistance exercise, plyometrics, aerobic endurance exercise and on-court volleyball practice. At the beginning of the study, starters (ST, n = 6) were compared with non-starters (NST, n = 8), and were found to be faster, more flexible and stronger. ST were still stronger when one-repetition maximum (1 RM) values were corrected for fat-free mass (FFM). Ten subjects completed the 12-week strength and conditioning program and participated in the post-training tests. ST and NST responded similarly to the training program for all physical and performance tests. Significant improvements were observed for FFM, sport-specific peak and mean isometric force, vertical jump (VJ), shoulder flexibility, 1 RM strength and 1 RM/FFM for the bench press, military press, squat and hang power clean, and isokinetic leg extension torque at 1.05 and 3.14 rads•sec^{-1}. Furthermore, two-mile run times and sit-up performance (in 60 seconds) also improved. Significant decreases were observed for VJ endurance. Over the course of the training program, the relationship between 1 RM strength and FFM decreased, while shoulder flexibility was increasingly related to sport-specific isometric strength. Isokinetic testing did not reflect the magnitude of changes in 1 RM tests. Thus, while differences appear to exist in physical characteristics between starters and non-starters, it was shown that most physical and performance variables for ST and NST can be improved with a comprehensive strength and conditioning program for female collegiate volleyball players.*

KEY WORDS: isometric, isokinetic, vertical jump, flexibility, sprint speed, anthropometry, resistance training

Introduction

A number of studies have been published describing the physical and performance characteristics of volleyball players (7, 8, 15, 22). Spence et al. compared the characteristics of athletes who were selected for the Pan-American team with those who were not (25). Those who were selected for the team were taller and heavier, but not necessarily stronger. Other studies also have examined the physical and performance differences between volleyball players of various calibers (12, 13, 20). The better players have been older, stronger, larger and able to jump higher. To the authors' knowledge, no research has examined performance capabilities of different calibers of volleyball players on the same squad (i.e., starters and non-starters).

The physiological changes occuring over the course of a competitive collegiate season have shown that $\dot{V}O_2$ max (11) and vertical jump and agility (9) may improve, while all other measured variables remain unchanged. Resistance training also has been shown to improve one-repetition (1 RM) strength, $\dot{V}O_2$ max, percent body fat and local muscular endurance (9), as well as jumping ability and isokinetic leg extension performance (11). Still, limited data are available concerning the effects of resistance training for

Table 1. Off-season Conditioning Program

Strength Training

	Monday and Thursday	Tuesday and Friday
Group 1	Military press* Dumbbell bump raises	Lateral 45° raises Upright rows
Group 2	Lat pull downs Seated rows	Hang power cleans **
Group 3	Bench press*	Split squats Side squats
Group 4	Single leg extensions Single leg curls	Dumbbell internal rotations Dumbbell external rotations
Group 5	Squats*	Dumbbell pullovers
Group 6	Reverse arm curls Regular arm curls	Calf raises
Group 7	Abdominals	Abdominals

3 sets of each exercise at 10 RM unless otherwise noted. Rest periods 1-2 min; heavier loads = longer rest periods.
*periodized exercises: light = 12-15 RM, medium = 8-10 RM, heavy = 3-5 RM
**periodized exercises: light = 5 RM, medium = 3 RM, heavy = 1-2 RM

Plyometric Training (Monday, Wednesday and Friday)

Warm-up	Exercises
Squat without weight	Side to-side jumps
Duck walk (10-15 m)	Front-to-back jumps
50% effort vertical jumps	Hurdle jumps
	Long jumps
	Vertical jumps (with and without added resistance)
	Depth jumps (with and without added resistance)
	Repeated depth jumps
	Box jump-ups

First 2 weeks: 3 different exercises per session
Subsequent sessions: 4 different exercises

women's volleyball and on the differential training responses of starters and non-starters from the same squad.

The primary purposes of this investigation were to compare the physical and performance characteristics of starters and non-starters on an NCAA Division I women's volleyball team, and to monitor the effects of a 12-week supervised off-season strength and conditioning program for female volleyball players.

METHODS

Members of an NCAA Division I women's volleyball team (n = 14) volunteered to participate in this study. Subject characteristics (mean ± standard deviation) were: age, 19.6 ± 0.6 years; height, 171.9 ± 6.8 centimeters; body weight, 64.3 ± 7.0 kilograms. The squad was divided by the head coach into starters (ST, n = 6) and non-starters (NST, n = 8). Tests were performed two weeks after initiating an off-season strength and conditioning program, to allow familiarization with test protocols and initial training adaptations. Tests were performed again after 12 weeks of supervised training. The training program was completed by 10 subjects due to squad cuts and non-training injuries to four members of the NST group. Therefore, independent t-tests ($p < 0.05$) were used to assess physical and performance alterations over the course of the 12-week training program (n = 10). At each time (pre- and post-training), a Pearson product-moment correlation matrix was calculated for the entire data set.

The off-season training program is outlined in Table 1. Strength training was conducted four times per week (Monday, Tuesday, Thursday and Friday) using a split-training program in which half the exercises were performed on Monday and Thursday, and the other half on Tuesday and Friday. Each training session included seven groups of exercises, described in Table 1. Exercise groups could be performed in any order, but exercises in any particular group were performed in the order listed. Training intensities for the large muscle group exercises (i.e., bench press, squat, military press, hang power cleans) were altered throughout the program in a periodized manner (26). Plyometric training was performed twice per week, as was on-court volleyball practice. Aerobic training was conducted four times per week with 30-minute runs at approximately 80 percent of maximal heart rate.

As an addendum to this study, some physical and performance characteristics were monitored for seven of the subjects who also completed a three-month unsupervised summer strength and conditioning program subsequent to the supervised 12-week off-season training program.

The test battery included the following tests:

Muscular Strength, Power and Endurance

One RM testing (26) for free weights was assessed for the bench press (2), military press (17), parallel back squat (4) and hang power clean (3, 5). Sport-specific isometric testing was performed on a Digital Myograph Comparative Muscle Tester (model DM2000, Myotech Corp., Boca Raton, Florida). Peak force and mean force•5 sec^{-1} seconds were determined for a two-arm bump (arms at 45-degree angle to trunk), a two-arm block (arms directly overhead) and a one-arm dig (dominant arm abducted 90 degrees). Isokinetic torques were assessed at 1.05, 3.14 and 5.24 rads•sec^{-1} for dominant leg extension and flexion on a Biodex 2000 dynamometer (model 875110, Biodex Corp., Shirley, New York), which was calibrated daily according to the manufacturer's specifications. Endurance of the abdominal musculature was evaluated by the maximum number of bent-leg sit-ups performed in 60 seconds (9).

Speed and Agility

Running velocity was assessed for 9.1 meters (10 yards) and 36.6 meters (40 yards) (21). Hand-held stopwatches were used to determine times for both distances during each of two trials, with the fastest performance being recorded. The NSCA T-test was used to monitor agility (21). Following a T-shaped course, each subject ran forward 9.1 meters, shuffled (without crossing legs) to the left or right 4.6 meters, shuffled the opposite direction 9.1 meters, shuffled back 4.6 meters, and finished the test by back-pedalling 9.1 meters to the starting point. At each change of direction, the subject touched a mark on the floor. Hand-held stopwatches were used to determine the best of two trials.

Jumping Ability

Vertical jump (VJ) height was assessed both without (26) and with a running approach. A VJ endurance test was developed in which the number of jumps attaining 90 percent of maximal VJ height in a 30-second period was monitored. No approach or shuffle was allowed for any jump during this test, and each subject jumped at her own pace. The VJ endurance test did not significantly correlate ($p > 0.05$) with either VJ height ($r = 0.20$) or running VJ height ($r = -0.03$).

Flexibility

Lower back-hip-hamstring flexibility was assessed with a sit-and-reach test (1). A specially constructed box was used, with the best of two trials recorded. Shoulder flexion was determined by each subject lying prone and grasping a wooden stick at shoulder width while raising the stick as high off the ground as possible (3). Two trials were permitted, with the highest result recorded. Forced ankle dorsiflexion was assessed for both the right and left ankles with a Leighton flexometer (18).

Body Composition and Somatotype

Skinfolds were measured at the triceps, subscapular, suprailiac, abdominal, anterior thigh and medial calf sites with a Lange skinfold caliper (10 g•mm^{-2}; constant pressure). Tester reliability for these skinfolds was $r = 0.91$ to 0.99. Elbow and knee diameters were assessed with an anthropometer, while calf and flexed arm circumferences were measured with a metal tape fitted with a Gulick handle. The mean of duplicate measures was used for all skinfold circumferences and diameters. If skinfold values varied by more than 1.0 millimeter or the circumferences or diameter measurements varied by more than 0.5 centimeter, a third measure was taken, with the two most similar values recorded. Body density was estimated by the formula of Jackson, Pollock and Ward (16). Percent fat was estimated with the formula of Siri (23), from which fat-free mass (FFM) was determined. Anthropometric somatotypes were calculated by the methods of Heath and Carter (14).

Aerobic Endurance

Aerobic capacity was estimated with a maximal effort two-mile run for time. All trials were held on an indoor track (8 1/2 laps per mile). Two-mile testing was conducted according to methods of Mello, Murphy and Vogel (19).

Results

The results of independent t-tests comparing ST and NST at the beginning of the study can be seen in Table 2. The mean 36.6-meter sprint time for ST was significantly faster than for NST (5.56 seconds versus 5.84 seconds). Mean flexibility as assessed by the sit-and-reach test was greater for ST than NST (19.5 ± 4.3 centimeters versus 10.6 ± 5.0 centimeters). Mean 1 RM strength measures for the bench press, military press and hang power clean were significantly greater for ST than for NST. These differences were still evident when 1 RM values for these lifts were corrected for FFM.

Results of the supervised off-season strength and conditioning program for the entire group as determined by the

Table 2. Initial descriptive and performance data ($\bar{X} \pm SD$)

Variable	ST (n = 6)	NST (n = 8)
Age (yrs)	19.7 ± 0.5	19.5 ± 0.8
Height (cm)	170.4 ± 8.1	173.2 ± 5.2
Body weight (kg)	64.1 ± 9.5	64.4 ± 4.6
Relative fat (%)	18.7 ± 3.0	20.2 ± 2.1
Fat-free mass (kg)	52.1 ± 7.7	51.4 ± 3.4
Somatotype		
Endomorphy	3.8 ± 0.7	4.3 ± 0.8
Mesomorphy	3.4 ± 0.9	3.0 ± 1.1
Ectomorphy	2.7 ± 0.9	3.1 ± 1.0
Isometric peak force (N)		
Bump	170.6 ± 42.2	152.9 ± 34.3
Block	68.6 ± 19.6	59.8 ± 18.6
Dig	86.3 ± 14.7	95.1 ± 25.5
Isometric mean force (N)		
Bump	124.5 ± 31.4	106.9 ± 23.5
Block	42.4 ± 13.7	36.3 ± 14.7
Dig	59.8 ± 9.8	64.7 ± 19.6
Vertical jump (cm)	45.7 ± 6.9	42.4 ± 4.2
Running VJ (cm)	48.9 ± 4.5	45.1 ± 5.7
90% max VJ endurance (#•30 sec^{-1})	10.5 ± 6.2	9.1 ± 3.8
9.1m sprint (sec)	1.55 ± 0.42	1.84 ± 0.09
36.6m sprint (sec)	*5.56 ± 0.23	5.84 ± 0.24
Agility T-test (sec)	10.78 ± 0.19	11.04 ± 0.44
Sit and reach (cm)	*19.5 ± 4.3	10.6 ± 5.0
Shoulder extension (cm)	49.3 ± 11.9	40.5 ± 10.0
Dorsiflexion (°)		
Right	35.5 ± 6.3	31.8 ± 5.3
Left	31.3 ± 5.3	32.0 ± 9.0
1 RM bench press (kg)	*45.7 ± 7.1	38.6 ± 3.8
Bench press/FFM	*0.88 ± 0.07	0.76 ± 0.09
1 RM military press (kg)	*34.0 ± 3.5	28.4 ± 3.8
Military press/FFM	*0.66 ± 0.04	0.56 ± 0.09
1 RM squat (kg)	73.0 ± 11.6	61.8 ± 10.5
Squat/FFM	1.41 ± 0.22	1.21 ± 0.25
1 RM hang clean (kg)	*45.0 ± 6.5	34.0 ± 6.4
Hang clean/FFM	*0.87 ± 0.14	0.66 ± 0.11
2-mile run (sec)	999.2 ± 44.3	964.4 ± 88.9
Sit-ups (#•60 sec^{-1})	47.0 ± 5.9	43.0 ± 12.6
Isokinetic strength		
Peak torque (Nm)		
Quads 1.05 rads•sec^{-1}	147.1 ± 28.1	135.0 ± 5.7
3.14 rads•sec^{-1}	112.1 ± 20.6	107.5 ± 6.5
5.24 rads•sec^{-1}	83.1 ± 15.3	86.1 ± 9.8
Hams 1.05 rads•sec^{-1}	73.6 ± 15.6	71.2 ± 10.4
3.14 rads•sec^{-1}	59.0 ± 10.4	48.7 ± 9.1
5.24 rads•sec^{-1}	51.2 ± 8.8	46.5 ± 11.4

*$p < 0.05$ from corresponding NST value

analysis of variance are shown in Table 3. Not indicated are the significant main effect differences between ST and NST for 1 RM bench press, 1 RM bench press/FFM and two-mile run times. Of greater interest in this study was the lack of any interactions for group (ST or NST) by time (pre- or post-training) effects for any of the test battery items, indicating that both groups responded similarly to the training program. However, there were numerous main effects for time (pre- to post-training), indicating improvements for the entire subject population. Included in these were FFM, all sport-specific isometric force measures, all jump tests, agility, shoulder flexibility, all 1 RM strength tests (both absolute values and corrected for FFM), two-mile runs, sit-ups and isokinetic leg extensions at two velocities (1.05 and 3.14 rads•sec^{-1}). These increases were observed beyond what might be attributed to learning effects and initial training adaptations, because two weeks of initial training and familiarization were used to eliminate such influences in this study.

Further analysis of the unsupervised summer strength and conditioning program (n = 7) showed that most test variables were maintained. Significant improvements were observed for sit-ups and the isometric force test for blocking. Decreased performances were significant for isometric mean bump force and peak bump force, agility and 1 RM military press (both absolute value and corrected for FFM).

Selected bivariate correlations illustrating significant relationships resulting from the present study can be found in Table 4. Over the course of the study, very high correlations were observed between the isometric mean and peak forces. At the end of the 12-week supervised training period, shoulder flexibility was significantly related to all three tests of isometric force production. Although not significant in all cases, correlations between 36.6-meter sprint times and 9.1-meter sprint times, 1 RM squat and 1 RM squat/FFM consistently increased during the course of the study. Finally, 1 RM performance for most strength tests showed decreasing relationships with 1 RM/FFM values as the training progressed. The mean somatotype was endomorphy = 4.1, mesomorphy = 3.2 and ectomorphy = 2.9, as illustrated in Figure 1.

Discussion

The subjects in this study were of similar mean age as those in previous studies (7, 8, 11, 12, 13, 22, 24, 25), and were of similar mean height and body weight, except for studies including national-level team members (8, 12, 22, 25). According to the percentile rankings developed by Hosler, Morrow and Jackson (15), the present subjects were in the 60th percentile for height, the 45th percentile for body weight and the 70th percentile for fat. For the most part, physical and performance variables for the subjects in the present study were comparable to those of female intercollegiate volleyball players reported in the scientific literature (9, 12, 13, 20, 22, 24).

As shown in Table 2, few significant differences were observed between ST and NST. Still, certain characteristics appeared to be selective for ST. Tests of sprint velocity (36.6-meter sprint), back-hip-hamstring flexibility (sit-and-reach) and 1 RM values for bench press, military press and power clean (both absolute values and corrected for FFM) demonstrated superior performances by ST. Previous studies comparing volleyball players of differing calibers have noted that successful players were taller (13, 24), heavier (24), leaner (12, 24), faster (20, 24), stronger (20), more agile (24) and had greater VJ heights (12, 13, 24) than their less successful counterparts. Each of the significantly different variables observed in the present study can be addressed with an appropriately designed training program.

The results of the supervised off-season strength and conditioning program are outlined in Table 3. Numerous significant improvements were observed, although no significant interactions resulted. This indicates that ST and NST responded similarly to the training regimen. Although body weight and relative fat levels were unchanged, FFM significantly increased. Furthermore, all isometric and 1 RM strength measures demonstrated marked significant increases. These increases occurred even though the study used a two-week familiarization period for all strength training, which would decrease the effect of a simple learning process and allow clearer monitoring of physiological changes. It is recommended that future use of the sport-specific isometric testing be limited to measures of peak force, because peak force and mean force over five seconds were consistently correlated ($r > 0.88$) (see Table 4). If short-term muscle endurance is to be monitored, periods of more than five seconds are suggested. Increases of 13 percent for 1 RM bench press and 37 percent for 1 RM squat have been previously reported for female volleyball players (9). Abdominal muscular endurance as evidenced by sit-up performance in the present study showed a significant increase, as has previously been shown (9).

Although both 1 RM and 1 RM/FFM significantly increased for all four weight-training exercises tested, the correlation between absolute and corrected values markedly

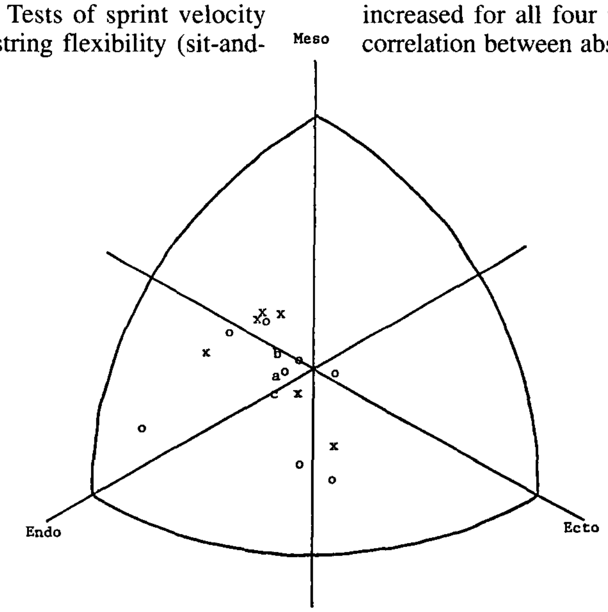

Figure 1. Individual and mean somototypes. Total mean (a) = 4.1-3.2-2.9 (n = 14); starters mean (b) = 3.8-3.4-2.7 (n = 6); non-starters mean (c) = 4.3-3.0-3.1 (n = 8). Starters = x; non-starters = o.

Table 3. Pre- and Post-training Descriptive and Performance Data ($\bar{X} \pm SD$) for Supervised Off-Season Volleyball Conditioning Program (n = 10)

Variable		Pre-training	Post-training	Summer**
Height (cm)		170.8 ± 6.8	169.6 ± 6.8	—
Body weight (kg)		62.4 ± 6.9	63.2 ± 6.7	NC
Relative fat (%)		19.2 ± 2.4	19.1 ± 2.7	NC
Fat-free mass (kg)		51.2 ± 6.0	*52.1 ± 6.2	NC
Isometric peak force (N)				
Bump		162.7 ± 41.2	*252.0 ± 43.1	DEC
Block		63.7 ± 17.6	*107.8 ± 29.4	NC
Dig		89.2 ± 24.5	*133.3 ± 29.4	NC
Isometric mean force (N)				
Bump		116.7 ± 30.4	*225.5 ± 40.2	DEC
Block		39.2 ± 13.7	*77.5 ± 21.6	INC
Dig		60.8 ± 17.6	*114.7 ± 27.5	NC
Vertical Jump (cm)		44.7 ± 5.7	*48.0 ± 4.2	NC
Running VJ (cm)		47.6 ± 5.0	*51.8 ± 5.6	NC
VJ endurance ($\# \cdot 30sec^{-1}$)		10.2 ± 5.1	*8.2 ± 4.2	NC
9.1m sprint (sec)		1.67 ± 0.35	1.82 ± 0.07	NC
36.6m sprint (sec)		5.67 ± 0.28	5.62 ± 0.24	NC
Agility T-test (sec)		10.87 ± 0.34	*11.16 ± 0.38	INC
Sit and reach (cm)		17.3 ± 4.9	16.4 ± 6.2	—
Shoulder extension (cm)		45.1 ± 12.4	*50.4 ± 12.1	—
Dorsiflexion (°)				
Right		33.6 ± 6.4	36.2 ± 8.1	—
Left		31.5 ± 7.5	33.3 ± 7.6	—
1 RM bench press (kg)		42.7 ± 6.9	*46.8 ± 7.5	NC
Bench press/FFM		0.835 ± 0.095	*0.900 ± 0.110	NC
1 RM military press (kg)		32.0 ± 4.5	*35.1 ± 4.1	DEC
Military press/FFM		0.629 ± 0.079	*0.675 ± 0.061	DEC
1 RM squat (kg)		68.0 ± 11.7	*82.1 ± 12.2	NC
Squat/FFM		1.339 ± 0.239	*1.586 ± 0.248	NC
1 RM hang clean (kg)		41.3 ± 7.6	*50.8 ± 6.6	NC
Hang clean/FFM		0.804 ± 0.146	*0.972 ± 0.120	NC
2-mile run (sec)		966.6 ± 56.5	*946.2 ± 58.2	NC
Sit ups ($\# \cdot 60sec^{-1}$)		46.5 ± 7.6	*52.7 ± 7.6	INC
Isokinetic strength				
Peak torque (Nm)				
Quads	1.05 $rads \cdot sec^{-1}$	142.7 ± 22.2	*153.3 ± 26.2	—
	3.14 $rads \cdot sec^{-1}$	107.7 ± 16.8	*115.8 ± 21.0	—
	5.24 $rads \cdot sec^{-1}$	83.0 ± 12.3	88.8 ± 19.4	—
Hams	1.05 $rads \cdot sec^{-1}$	74.8 ± 12.7	77.8 ± 10.3	—
	3.14 $rads \cdot sec^{-1}$	55.5 ± 8.5	59.2 ± 9.1	—
	5.24 $rads \cdot sec^{-1}$	51.7 ± 10.4	48.5 ± 8.1	—

*$p < 0.05$ from corresponding pre-training values
** $p < 0.05$; significant change over unsupervised summer program
NC = no change, INC = increase, DEC = decrease (n = 7)

decreased during the course of the study as shown in Table 4. The only exception to this trend was the 1 RM squat and squat/FFM relationship after the unsupervised summer training (r = 0.96). The decreasing relationships could indicate a decreasing reliance on absolute muscle mass for increased strength levels, and may indicate a greater reliance on neural factors and/or motor pattern development.

Shoulder flexibility significantly improved in this study. This joint-specific flexibility is of great importance for the sport of volleyball, and again shows that properly performed resistance exercise positively influences joint flexibility (26). Interestingly, the relationship of sport-specific isometric strength and shoulder flexibility increased during the supervised off-season training, as shown in Table 4. The sit-and-reach values observed in this study were slightly lower than values reported for other female volleyball players (mean = 19.8 centimeters) (9).

Sprint acceleration and velocity, as assessed by the 9.1-meter and 36.6-meter sprints, did not show any significant improvements over the course of the training program, while agility times significantly increased. This may simply reflect the lack of sprint and agility drills during the off-season program. It should be noted that the relationships of 36.6-meter sprint times with 9.1-meter sprint times, 1 RM squat and 1 RM squat/FFM consistently increased during the study (see Table 4). It is possible that the increased lower body strength, as evidenced by squat performance, resulted in greater stride length, and that those subjects exhibiting the greatest acceleration capabilities (i.e., the lower 9.1-meter times) were most affected. If this was the case, sprint work ideally could be incorporated into the training protocal toward the end of the study to optimally develop sprinting acceleration and velocity. Other female volleyball players have exhibited similar 9.1-meter sprint times (20), and also have reported decreases in sprint times during off-season training programs (9). This study demonstrates that a need exists to specifically address each performance component (e.g., speed/agility). Additionally, this study suggests that strength training and plyometrics, despite significant strength and jumping improvements, do not improve speed/agility performances in female athletes.

Two-mile run times significantly decreased and were reflective of estimated $\dot{V}O_2$ max values of approximately 45 $ml \cdot kg^{-1} \cdot min^{-1}$ (19). This value is similar to those reported for other female volleyball players (9, 22, 25) and considerably greater than those reported by Fardy, Hritz and Hellerstein (33.0 $ml \cdot kg^{-1} \cdot min^{-1}$) (11). It is possible that endurance run training may have partially interfered with speed/agility development, as suggested by Callister et al. (6). Further study of the effects of endurance training on speed/agility in female athletes is warranted.

Both VJ and running VJ performances significantly improved during this study. This is in contrast to other studies that have reported no change in VJ (9) and running VJ (24) during an off-season training program. The inclusion of plyometric exercises and hang power cleans by the subjects in the present study may have contributed to the increased performances observed and offset any possible negative influences of the endurance running program. On the other hand, VJ endurance showed a significant decrease. The exact cause of this increase is unclear. Apparently, the increase in VJ performance did not positively affect VJ endurance when a relative value of 90 percent of maximum was used as the criterion. Isokinetic peak torque measures for leg extension and flexion resulted in significant increases for only leg extension at 1.05 and 3.14 $rads \cdot sec^{-1}$. The transfer of strength from 1 RM to isokinetic performances does not appear to be great, because increases of 20.7 percent for 1 RM squat and 23.0 percent for 1 RM hang power cleans resulted in increases of 7.7 percent and 7.6 percent for leg extension at 1.05 and 3.14 $rads \cdot sec^{-1}$, respectively. Therefore, the use of isokinetic measures as direct indicators of the magnitude of dynamic constant external resistance (isotonic) strength performances appears questionable. The values for isokinetic leg extension at 3.14 $rads \cdot sec^{-1}$ in the present study are considerably lower than those reported by Smith et al. (24). An important difference between the studies was that Smith et al. used an isokinetic-like device for training, which may have contributed to superior performance on an isokinetic test. Thus, training and test specificity are important considerations. It appears that there is a lag in isotonic to isokinetic strength transfers, and longer training time may be needed to reflect such short-term changes.

The results of the unsupervised summer strength and conditioning program is reported in the last column of Table 3. In general, most variables were maintained. Of particular interest were the decreased performances involving shoulder strength (isometric peak and mean force for the bump, 1 RM military press and 1 RM military press/FFM). While it is possible that the frequency and/or intensity of the workouts may have decreased somewhat during the unsupervised phase of training due to non-adherence, only shoulder strength variables exhibited a significant decrease. This may reflect a need for continual emphasis on shoulder strength in female athletes. Furthermore, it may indicate that detraining effects may be more dramatic in shoulder musculature of women.

Table 4. Pearson Product Moment Correlations (r) Between Selected Variables

Variables	Pre-training (n = 14)	Post-training (n = 10)	Summer (n = 7)
Isometric mean and peak force			
Block	0.94*	0.95*	0.88*
Bump	0.96*	0.95*	0.95*
Dig	0.97*	0.94*	0.93*
Isometric peak force and shoulder extension			
Block	0.26	0.69*	—
Bump	0.70*	0.74*	—
Dig	0.55*	0.71*	—
36.6m and 9.1m sprints	0.40	0.54*	0.78*
36.6m sprint and 1 RM squat	0.05	-0.23	-0.57
36.6m sprint and SQ/FFM	-0.05	-0.44	-0.59
1 RM BP and BP/FFM	0.71*	0.66*	0.49
1 RM MP and MP/FFM	0.71*	0.36	0.03
1 RM SQ and SQ/FFM	0.80*	0.65*	0.96*
1 RM CL and CL/FFM	0.82*	0.49	0.03

*$p < 0.05$
BP = bench press, MP = military press, SQ = squat, CL = hang power clean, FFM = fat-free mass

Practical Applications

Starters on a female volleyball team were stronger and had greater sprinting velocity than non-starters. ST and NST responded equally to an off-season strength and conditioning program. Increased 1 RM strength was not closely associated with muscle mass by the later stages of the training program. Thus, for players concerned about muscle hypertrophy, this indicates that during a 12-week training program, factors other than hypertrophy may account for much of the increased strength. Because shoulder flexibility was increasingly related to isometric strength, the inclusion of an appropriate flexibility program may facilitate the training process. The use of isokinetic modalities did not appear sensitive enough to accurately assess the magnitude of acute training changes in dynamic constant external resistance performance (i.e., 1 RM tests). The lack of improvements on sprint tests may indicate the need to incorporate sprint and agility exercise training programs and reduce the endurance training after an aerobic base has been developed. Finally, a comprehensive training program can be used as in the present study without detrimental effects of overtraining. Still, careful design of programs to eliminate or reduce any detrimental effects of training incompatibility is needed. As previously suggested, emphasis on upper body strength training is warranted in female volleyball players.

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