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ORIGINAL ARTICLE

Auxotonic training in muscle strength and power performance of professional young volleyball players

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ABSTRACT

Auxotonic training unexplained on isotonic and isometric muscular contraction combination to develop strength and power gain. The study aimed to investigate muscle strength and power changes of professional young volleyball players on the auxotonic training effect. Volleyball players divided in AUT (auxotonic group: 16.32 y, 1.72 m, 63.63 kg) trained over 8 week and per week 2 day performing isotonic + isometric contraction combination periodization and IKT (isokinetic group: 16.23 y, 1.69 m, 60.22 kg) performed only isokinetic contraction periodization. The linear muscle strength and power processes of training periodization preferred for maximize performance. The strength changes of this study resulted on AUT and IKT for 1RM strength test and activforce isometric muscular strength adaptation test were similar, however, AUT obtained high improvement power performance ($p < .05$). Auxotonic training developed on strength and power for AUT. Additionally, showing of comparison between AUT and IKT concluded CMJ (90°) ES = 1.09 very large, vertical jump ES = 1.31 very large and handgrip right ES = 0.05 small effect size. Based on the results we obtained, current auxotonic contraction was determined on resistance training applied to young volleyball players effective in strength and power development. Auxotonic training performed on young volleyball players will bring a perspective to the coaches and athletes work in this field as a resistance training model. The auxotonic training strategy for long term performance changes on outcomes of using aimed potential muscle isotonic + isometric contraction combination may be effective maximize strength and power performance.

Keywords: Technology sport, Innovation sport, Auxotonic training, Strength, Power, Volleyball players.

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INTRODUCTION

Auxotonic resistance is one of training performance condition for upper and lower compartment maximal strength development obtained from muscular strain changes (Azeem et al., 2022). Auxotonic muscular performance of large muscle groups are combinate isotonic and isometric muscle action (Lee et al., 2018). Furthermore, isotonic muscular contraction preferred for push and speed phases of dynamic performance, other isometric muscular contraction to maximum strength and range of motion of static performance (Lee et al., 2018; Lum et al., 2023). In this case, isotonic and isometric actions detected to strength development and muscular force action (Azeem et al., 2022). Over the last study reported that 1RM-70% - 10 rep auxotonic resistance and 10 s isotonic moderate intensity training to leg performance are similar strength and power gain on acute changes (Lina-Samaniego et al., 2022). Periodic long term isotonic and isometric muscular resistance training showed that isotonic action increased in bench press 34.45%, sit-up 24.13% and flexibility 29.12% than isometric action in bench press 14.23%, sit-up 7.80% and flexibility 6.92% (Azeem et al., 2022). In resistance trained men, isotonic and isometric back squat mechanics performed on 1RM-75%, both isometric contraction (2.8%) and isotonic contraction (2.6%) developed vertical jump performance (Vargas-Molina et al., 2021). In this condition, isotonic and isometric combination limited to auxotonic training level in muscular strength and power performance on sport modalities (Lum et al., 2023). Specifically, isometric activation is common preferred for maximum strength in auxotonic training rapid force period (Lee et al., 2018; Lum et al., 2023; Comfort et al., 2022). Rapid strength transition was unexplained for isotonic + isometric contraction relationship on range of motion and speed mechanism (Lum et al., 2023; Comfort et al., 2022). In this case, early and late time-dependent resistance phases are explained on "*S = (Newton x time)*" is strength potential represented to late period 5 s and early period 1 s (Guppy et al., 2022). Isometric potential forces based on intensity of muscular contraction and proper muscle-tendon activation to range of motion increases high strength effort (Comfort et al., 2022). Indeed, auxotonic resistance is one of internal and external strength working on strain changes through strength development that isotonic + isometric actions are effective for strength loss and muscular activations (Lee et al., 2018). Different types of muscle contraction are performed on muscle strength and power development, however, auxotonic muscle strength should be known as the performance of shortening and range of motion in combined contractions (Lee et al., 2018). Why it is preferred is an important issue, because isotonic and isometric resistance training does not require special equipment, and performing exercises in very short intervals within certain ranges of motion of joints and muscles does not cause fatigue (Azeem et al., 2022; Lum et al., 2023). In this context, as isotonic and isometric strength changes increase after auxotonic training, it is necessary to conduct further research on the branch-specific use of such resistance training methods. To determine individual isotonic + isometric output used dynamic and static strength (Karagiannopoulos et al., 2022). However, maximal strength and power development strategies of auxotonic training needed for 1RM and vertical jump studies (Azeem et al., 2022). Therefore, this study aimed to auxotonic resistance training investigate on strength and power performance of professional young volleyball players.

METHOD AND MATERIALS

Participants

The study formed professional 26 female young volleyball players; AUT group (n = 13) age 16.32 ± 0.60 y, height 1.72 ± 0.05 m, weight 63.63 ± 7.74 kg isotonic + isometric training performed over 8 week and per week 2 day periodization. IKT group (n = 13) age 16.23 ± 0.59 y, height 1.69 ± 0.04 m, weight 60.22 ± 4.64 kg trained only isotonic muscular action periodization no participated isometric contraction session. Ethic permission acceded by Akdeniz University Clinic Committee Protocol-890/220/2021.

Procedure

1RM (one repetition maximum) test

One repetition maximum test using report of NSCA editors performed on participants. Initially performance condition determined on 10 min standard dynamic and static warm-up. Participants for upper compartment resistance exercises on 90-100% 1RM reach by increasing 4-9+ kg tested, again 1RM test incremental at 50% (5-10 rep), 80% (3-5 rep), 90% and 100% used for each test by smith machine (ProWellness Silver Line, LX serial, TR) and free-weight and dumbbell (Diesel series). Auxotonic resistance training exercises performed on a) wrist dorsal flexion using 5 kg dumbbell, b) wrist extension using 5 kg dumbbell, c) wrist abduction using 5 kg dumbbell, d) wrist adduction using 5 kg dumbbell, e) trunk lateral flexion using 5 kg dumbbell by 2.5 kg increase, f) upper rowing using upper row machine with increasing 3-4 kg, g) triceps press down using triceps push down machine by 5 kg increase, h) hip flexion using cable rowing by opposite U smith machine, ı) hip extension using cable rowing on opposite U machine, j) ankle dorsal flexion using smith machine with increasing 7 kg, k) ankle plantar flexion using cable row machine by 5 kg increase, l) ankle inversion using cable row machine with increasing 3-4 kg, m) ankle eversion using cable row machine by 3-4 kg increase, n) biceps curl using seated barbell machine with increasing 2.5-5 kg, o) shoulder pull down using shoulder machine by 3-4 kg increase, p) chest press using chest machine with increasing 5 kg, r) hip abduction using cable row machine by 5 kg increase, s) hip adduction using cable row machine with increasing 5 kg, t) leg curl using leg curl machine by 5 kg increase, u) leg extension using leg extension machine with increasing 5 kg, v) abdominal hyperextension using free-weight on sit-up machine by 5-10 kg increase, w) trunk flexion using weight with increasing 5-10 kg, x) trunk extension using weight by 5-10 kg increase, y) trunk rotation using weight with increasing 5-10 kg. Proper stabile protocol showed on each measurement and supporting image and verbal.

Activforce isometric muscle activation

Rapid strength potential isometric force-time curve performance performed on peak and average force. Totally isometric strength test performed on individual 20 min performance. To muscle activation evaluate "*Activforce 2 hand dynamometer*" (Activforce 2, Australia) used for reliable measurement (ICC = 0.85-0.99) (Karagiannoupolos et al., 2022). Upper and lower compartment extremity measurements analysed total 24 movement related nearest joint proximal performing sit-up, sitting, prone position.

References joint range of motion points determined on a) shoulder flexion on arm epicondyle proximal, b) shoulder extension on arm epicondyle proximal, c) shoulder abduction on arm epicondyle proximal, d) shoulder adduction on arm epicondyle proximal, e) shoulder lateral-internal rotation on styloid process proximal, f) shoulder medial-external rotation on styloid process proximal, g) elbow flexion on proximal styloid process, h) elbow extension on proximal styloid process, ı) elbow supination on lateral styloid process, j) elbow pronation on lateral styloid process, k) wrist flexion on metacarpophalangeal joint proximal, l) wrist extension on metacarpophalangeal joint proximal, m) wrist abduction on metacarpophalangeal joint proximal, n) wrist adduction on metacarpophalangeal joint proximal, o) hip flexion on femoral epicondyle nearest, p) hip extension on femoral epicondyle nearest, r) hip abduction on lateral epicondyle nearest, s) hip adduction on lateral epicondyle nearest, t) knee flexion on malleoli proximal, u) knee extension on malleoli proximal, v) ankle dorsi flexion on metacarpophalangeal joint proximal, w) ankle plantar flexion on metacarpophalangeal joint proximal, x) ankle inversion on lateral malleoli proximal, y) ankle eversion on lateral malleoli proximal (Andrews et al., 1996).

Vertical jumps

Countermovement jump (CMJ) as highest jump concentric explosive vertical jump at 180 degree knee flexed, non-arm swing countermovement jump (aCMJ) as highest jump as knee flexed and arm on hip, vertical jump

(VJ) in specific technique, single leg vertical jump (SLVJ) performed on right or left leg at 180 degree knee flexed as countermovement jump. Each participant tested on 3 jump session permissions 10 s recovery (Inf, SW03, Photocell Vertical Jump Device, TR) (Kahraman, 2023).

Calisthenics
Sit-up started knee locked position and hand in ground, their chest nearest ground then elbow flexion lifting proper movement phase performed controlled during 30 second (Clemons, 2019). Push-up tested on ground position by knee locked, shoulder optimal range of motion, hand in ground then longitudinal body lowered in chest controlled way. Triceps dips on parallel bench, feet in ground and arms 90 degree flexed then performed extension position (Delavier, 2001).

Flexibility
Trunk and hamstring flexibility tested on box bench to evaluate knee and feet flatted with hand palm extended during box as maximum flexion possible by protecting 5 s proper position (Muyor et al., 2014).

Agility and speed
Test started initially on 10 m distance pointed then agility and speed maximal performance as possible highest speed about runner exactly 42 m, by covering the distance, the vertical jump performed through a step to the side reached, first to the right and returned to the start point, then non-stop by covering the same distance and taking a step to the left performed vertical jump (Chronometer, Kalenji).

Handgrip
Strength of right and left hand tested one handgrip device as possible maximum force reaction with 5 s contraction position.

Auxotonic resistance training
Auxotonic resistance training included in isotonic + isometric combination exercises; 1) Push-up, 2) Squat, 3) Triceps dips, 4) Calf raise, 5) Abdominal crunch, 6) Superman plank performed on the over 8 week and per week 2 day at 1 hour. Auxotonic training intensities respectively, first and second week at 50% low intensity, 3x8 rep, isom contraction 5 s, 15 s recovery, rop 30x4 rep, third and four week at 60% moderate intensity, 3x10 rep, isom contraction 7 s, 15 s recovery, rop 30x5 rep, five week at 70% moderate intensity, 3x12 rep, isom contraction 8 s, 30 s recovery, six week at 75% moderate-high intensity, 3x12 rep, isom contraction 8 s, 30 s recovery, seven week at 85% high intensity, 4x12 rep, isom contraction 10 s, 30 s recovery, and eight week at 90% high intensity, 4x12 rep, isom contraction 10 s, 30 s recovery. Whereas isotonic training was formed on isotonic contraction without isom seconds.

Statistical analysis
Population sample size using G. Power to determine statistical analysis. Two variable evaluations to detected d = 0.67 effect size used one Paired-T test after normality test to comparison. 1RM test, activforce strength test and power test comparison calculated on T-test. In this way, significant priority collocated alpha level ($p < .05$). Effect size using confidence interval of descriptors obtained from <0.25 = large, 0.25-0.50 medium, 0.50-1.00 = large, >1.00 = very large (Rhea, 2004).

RESULTS

Primarily 1RM strength, activforce isometric strength, power test comparison outcomes provided on effect sizes for strength and power development. AUT and IKT compared to 1RM strength in result of long term

linear periodization. Strength changes increase to AUT than IKT showed pre and post-test outcomes. AUT to post test showed mostly high development (Table 1, 2).

Table 1. 1RM strength outcomes comparison of AUT and IKT to pre and post-test.

1 TM TEST	Group	Pre – Post	t	*p*	ES
Wrist extension (kg)	AUT	10.57±2.08 – 12.50±2.50	-2.540	.026	0.83
Wrist abduction (kg)	IKT	11.34±2.99 – 12.30±3.30	-1.100	.293	trival
	AUT	5.03±0.92 – 7.11±0.93	-8.035	.000	2.24
Wrist adduction (kg)	IKT	5.19±0.69 – 5.00±0.00	1.000	.337	trival
	AUT	4.84±0.55 – 6.34±1.29	-4.356	.001	1.51
Trunk lateral flexion (kg)	IKT	6.00±1.54 – 5.80±1.49	1.000	.337	trival
	AUT	21.15±1.65 – 24.23±1.57	-6.121	.000	1.91
Upper rowing (kg)	IKT	22.03±2.38 – 23.26±1.20	-1.705	.114	trival
	AUT	36.69±6.40 – 38.42±4.19	-1.021	.327	trival
Triceps press down (kg)	IKT	39.69±7.07 – 37.53±4.77	1.255	.233	trival
	AUT	28.30±7.21 – 43.03±8.98	-5.713	.000	1.80
Hip flexion (kg)	IKT	25.30±5.54 – 30.53±5.66	-4.305	.001	0.93
	AUT	18.53±4.40 – 35.19±12.43	-4.963	.000	1.78
Hip extension (kg)	IKT	18.07±3.83 – 41.53±15.46	-6.151	.000	2.08
	AUT	18.46±6.99 – 31.53±7.74	-4.155	.001	1.77
	IKT	21.15±6.50 – 25.38±4.31	-1.877	.085	trival
Ankle dorsi flexion (kg)	AUT	15.03±6.33 – 19.23±5.21	-3.410	.005	0.72
	IKT	17.15±5.28 – 12.92±3.52	2.724	.018	-0.94
Ankle plantar flexion (kg)	AUT	17.53±4.78 – 22.30±4.38	-2.592	.024	1.04
	IKT	15.38±4.31 – 15.76±4.93	-0.365	.721	trival
Ankle inversion (kg)	AUT	23.07±6.30 – 31.30±5.05	-5.508	.000	1.44
Ankle eversion (kg)	IKT	19.61±5.18 – 23.46±9.65	-1.443	.175	trival
	AUT	27.50±7.90 – 31.92±7.22	-2.945	.012	0.58
Biceps curl (kg)	IKT	24.23±5.71 – 25.38±9.00	-0.454	.658	trival
	AUT	16.34±2.19 – 19.42±2.53	-4.382	.001	1.30
Shoulder pull down (kg)	IKT	14.80±2.38 – 16.15±3.90	-2.214	.047	0.41
	AUT	33.46±5.54 – 32.50±5.95	0.483	.638	trival
	IKT	31.53±5.54 – 29.23±4.93	1.389	.190	trival
Chest press (kg)	AUT	30.00±7.35 – 35.80±4.53	-2.768	.017	0.95
Hip abduction (kg)	IKT	33.19±10.82 – 33.57±9.01	-0.136	.894	trival
	AUT	47.57±8.34 – 52.84±9.90	-2.356	.036	0.57
Hip adduction (kg)	IKT	45.42±5.87 – 49.65±8.10	-2.157	.052	trival
	AUT	47.23±8.72 – 58.42±9.02	-3.964	.002	1.26
Leg curl (kg)	IKT	39.73±8.60 – 50.76±4.73	-4.285	.001	1.61
	AUT	31.92±9.25 – 40.00±5.40	-3.228	.007	1.06
Leg extension (kg)	IKT	39.23±12.22 – 38.19±6.25	0.257	.801	trival
	AUT	60.76±17.05 –72.30±10.12	-2.024	.066	trival
Calf raise (kg)	IKT	37.30±19.43 – 62.30±19.32	-3.536	.004	1.29
	AUT	40.76±9.54 – 47.11±6.75	-3.434	.005	0.76
Abdominal hyperextension (kg)	IKT	34.46±11.01 – 34.23±10.37	0.069	.946	trival
	AUT	16.07±4.35 – 21.30±4.97	-4.500	.001	1.11
Trunk flexion (kg)	IKT	18.07±5.60 – 18.84±5.82	-0.365	.721	trival
	AUT	26.73±7.63 – 31.53±9.65	-2.900	.013	0.55
Trunk extension (kg)	IKT	24.23±4.93 – 26.15±8.69	-1.000	.337	trival
	AUT	28.07±7.64 – 29.03±7.87	-0.595	.563	trival
Trunk rotation (kg)	IKT	28.84±6.17 – 22.69±6.32	2.484	.029	trival
	AUT	16.73±4.49 – 21.73±5.34	-5.326	.000	1.01
	IKT	16.15±6.81 – 14.61±3.79	0.772	.455	trival

Table 2. 1RM strength outcomes comparison of AUT and IKT to post test.

1 RM TEST	Group	Test	t	*p*	ES
Wrist dorsal flexion (kg)	AUT IKT	20.76 ± 4.00 20.00 ± 4.56	0.457	.652	trivial
Wrist plantar flexion (kg)	AUT IKT	12.50 ± 2.50 12.30 ± 3.30	0.167	.868	trivial
Wrist abduction (kg)	AUT IKT	7.11 ± 0.93 5.00 ± 0.00	8.124	.000	3.20
Wrist adduction (kg)	AUT IKT	6.34 ± 1.29 5.80 ± 1.49	0.981	.336	trivial
Trunk lateral flexion (kg)	AUT IKT	24.23 ± 1.57 23.26 ± 1.20	1.750	.093	trivial
Upper rowing (kg)	AUT IKT	38.42 ± 4.19 37.53 ± 4.77	0.502	.620	trivial
Triceps press down (kg)	AUT IKT	43.03 ± 8.98 30.53 ± 5.66	4.244	.000	1.66
Hip flexion (kg)	AUT IKT	35.19 ± 12.43 41.53 ± 15.46	1.153	.260	trivial
Hip extension (kg)	AUT IKT	31.53 ± 7.74 25.38 ± 4.3	2.504	.019	0.98
Ankle dorsi flexion (kg)	AUT IKT	19.23 ± 5.21 12.92 ± 3.52	3.614	.001	1.41
Ankle plantar flexion (kg)	AUT IKT	22.30 ± 4.38 15.76 ± 4.93	3.571	.002	1.40
Ankle inversion (kg)	AUT IKT	31.30 ± 5.05 23.46 ± 9.65	2.595	.016	1.01
Ankle eversion (kg)	AUT IKT	31.92 ± 7.22 25.38 ± 9.00	2.042	.052	trivial
Biceps curl (kg)	AUT IKT	19.42 ± 2.53 16.15 ± 3.90	2.534	.018	0.99
Shoulder pull down (kg)	AUT IKT	32.50 ± 5.95 29.23 ± 4.93	1.525	.140	trivial
Chest press (kg)	AUT IKT	35.80 ± 4.53 33.57 ± 9.01	0.797	.433	trivial
Hip abduction (kg)	AUT IKT	52.84 ± 9.90 49.65 ± 8.10	0.899	.377	trivial
Hip adduction (kg)	AUT IKT	58.42 ± 9.02 50.76 ± 4.73	2.707	.012	1.06
Leg curl (kg)	AUT IKT	40.00 ± 5.40 38.19 ± 6.25	0.789	.438	trivial
Leg extension (kg)	AUT IKT	72.30 ± 10.12 62.30 ± 19.32	1.653	.111	trivial
Calf raise (kg)	AUT IKT	47.11 ± 6.75 34.23 ± 10.37	3.571	.001	1.47
Abdominal hyperextension (kg)	AUT IKT	21.30 ± 4.97 18.84 ± 5.82	1.158	.258	trivial
Trunk flexion (kg)	AUT IKT	31.53 ± 9.65 26.15 ± 8.69	1.494	.148	trivial
Trunk extension (kg)	AUT IKT	29.03 ± 7.87 22.69 ± 6.32	2.265	.033	0.88
Trunk rotation (kg)	AUT IKT	21.73 ± 5.34 14.61 ± 3.79	3.915	.001	1.53

Activforce isometric strength outcomes provided effect size of AUT and IKT to result muscular isom potential activation. AUT and IKT compared to activforce measurement showed on peak and average force changes increase to AUT and IKT similar to pre and post-test outcomes. AUT and IKT post-test comparison concluded non effect sizes (Tables 3,4).

Table 3. Activforce isometric strength comparison of AUT to pre and post peak and average force.

Isom force		Pre – Post	t	p	ES
Shoulder flexion (N)	Peak	111.95 ± 18.11 129.05 ± 14.54	-3.316	.006	1.04
	Avg	94.99 ± 12.60 108.14 ± 13.29	-3.416	.005	1.01
Shoulder extension (N)	Peak	103.33 ± 25.66 142.57 ± 31.00	-4.850	.000	1.37
	Avg	87.83 ± 21.64 113.10 ± 22.84	-3.261	.007	1.13
Shoulder abduction (N)	Peak	123.00 ± 25.68 135.17 ± 23.96	-2.000	.069	trivial
	Avg	100.02 ± 22.23 113.18 ± 24.84	2.206	.048	0.55
Shoulder adduction (N)	Peak	100.21 ± 21.65 138.89 ± 23.10	-4.633	.001	1.72
	Avg	77.55 ± 18.30 116.07 ± 20.18	-7.134	.000	1.99
Shoulder lateral/internal rotation (N)	Peak	117.28 ± 37.56 157.15 ± 26.59	-4.202	.001	1.22
	Avg	88.59 ± 23.36 131.51 ± 30.12	-5.249	.000	1.59
Shoulder medial/external rotation (N)	Peak	97.31 ± 20.49 123.27 ± 20.4	-3.209	.008	1.26
	Avg	80.83 ± 18.54 104.54 ± 16.91	-3.150	.008	1.33
Elbow flexion (N)	Peak	128.50 ± 24.77 158.76 ± 43.00	-3.168	.008	0.86
	Avg	107.27 ± 16.56 128.83 ± 36.16	-2.664	.021	0.76
Elbow extension (N)	Peak	124.99 ± 33.27 170.36 ± 30.54	-4.264	.001	1.42
	Avg	100.60 ± 27.37 141.80 ± 28.69	-4.320	.001	1.46
Elbow supination (N)	Peak	87.86 ± 21.05 123.89 ± 42.40	-2.932	.013	1.07
	Avg	92.31 ± 31.21 104.44 ± 40.40	-2.875	.014	0.33
Elbow pronation (N)	Peak	116.75 ± 45.63 121.64 ± 41.78	-0.433	.673	trivial
	Avg	74.77 ± 15.31 104.53 ± 36.20	-1.331	.208	1.07
Wrist flexion (N)	Peak	88.91 ± 26.05 102.49 ± 29.88	-2.143	.053	trivial
	Avg	77.30 ± 24.02 90.78 ± 29.13	-2.199	.048	0.50
Wrist extension (N)	Peak	71.13 ± 18.49 80.41 ± 13.90	-1.945	.076	trivial
	Avg	58.87 ± 14.25 65.50 ± 12.40	-1.791	.099	trivial

Wrist adduction (N)	Peak	70.83 ± 19.19 104.47 ± 22.85	-4.955	.000	1.59
	Avg	58.41 ± 15.58 88.55 ± 21.70	-4.666	.001	1.59
Wrist abduction (N)	Peak	93.23 ± 23.20 103.48 ± 19.47	-1.273	.277	trivial
	Avg	82.72 ± 18.83 91.73 ± 21.51	-1.130	.281	trivial
Hip flexion (N)	Peak	159.59 ± 28.87 198.17 ± 33.01	-4.762	.000	1.24
	Avg	134.04 ± 20.24 166.14 ± 23.25	-5.756	.000	1.47
Hip extension (N)	Peak	154.71 ± 73.28 239.53 ± 59.13	-4.041	.002	1.27
	Avg	122.43 ± 42.66 187.69 ± 53.91	-3.489	.004	1.34
Hip abduction (N)	Peak	126.63 ± 42.75 167.04 ± 40.38	-4.269	.001	0.97
	Avg	109.38 ± 41.14 134.64 ± 36.00	-3.204	.008	0.65
Hip adduction (N)	Peak	119.73 ± 19.59 169.02 ± 39.87	-4.951	.000	1.56
	Avg	100.31 ± 16.22 131.40 ± 38.58	-3.438	.005	1.05
Knee flexion (N)	Peak	136.57 ± 37.95 195.91 ± 49.55	-3.456	.005	1.34
	Avg	114.40 ± 30.29 157.04 ± 41.63	-2.640	.022	1.17
Knee extension (N)	Peak	180.43 ± 55.57 175.74 ± 42.40	0.340	.740	trivial
	Avg	148.80 ± 50.96 143.84 ± 39.25	0.341	.739	trivial
Ankle dorsi flexion (N)	Peak	96.45 ± 32.87 124.67 ± 25.94	-3.969	.002	0.95
	Avg	75.74 ± 20.51 110.21 ± 27.38	-5.535	.000	1.42
Ankle plantar flexion (N)	Peak	75.87 ± 10.80 121.57 ± 23.00	-5.668	.000	2.54
	Avg	57.62 ± 9.52 104.102 ± 21.97	-6.607	.000	2.74
Ankle inversion (N)	Peak	83.67 ± 17.10 101.70 ± 17.39	-2.553	.025	1.04
	Avg	70.35 ± 14.90 82.10 ± 17.57	-1.995	.069	trivial
Ankle eversion (N)	Peak	83.78 ± 26.85 95.56 ± 17.94	-2.000	.069	trivial
	Avg	70.81 ± 25.69 75.76 ± 12.46	-0.844	.415	trivial

Table 4. Activforce isometric strength comparison of IKT to pre and post peak and average force.

Isom force		**Pre – Post**	**t**	***p***	**ES**
Shoulder flexion (N)	Peak	95.15 ± 24.53 129.13 ± 21.45	-3.649	.003	1.47
	Avg	71.44 ± 16.96 104.87 ± 15.87	-5.738	.000	2.05

Shoulder extension (N)	Peak	93.38 ± 18.12 144.44 ± 35.07	-5.310	.000	1.82
	Avg	78.69 ± 15.48 110.97 ± 18.77	-5.843	.000	1.87
Shoulder abduction (N)	Peak	96.74 ± 19.98 133.95 ± 21.14	-5.560	.000	1.80
	Avg	83.78 ± 21.42 109.71 ± 19.87	-3.577	.004	1.25
Shoulder adduction (N)	Peak	83.46 ± 21.46 136.14 ± 18.82	-7.886	.000	2.61
	Avg	69.33 ± 18.52 109.49 ± 11.80	-7.952	.000	2.58
Shoulder lateral/internal rotation (N)	Peak	92.58 ± 32.36 148.38 ± 38.74	-4.882	.000	1.56
	Avg	75.85 ± 28.27 117.16 ± 32.09	-3.600	004	1.36
Omuz medial/external rotation (N)	Peak	78.41 ± 17.94 121.09 ± 22.96	-5.958	0.000	2.07
	Avg	66.08 ± 15.44 97.43 ± 12.87	-6.346	.000	2.20
Elbow flexion (N)	Peak	132.69 ± 42.27 139.38 ± 38.26	-0.596	.562	trivial
	Avg	101.71 ± 34.80 113.37 ± 25.61	-1.119	.285	0.38
Elbow extension (N)	Peak	102.56 ± 32.06 162.86 ± 30.38	-5.177	.000	1.93
	Avg	84.37 ± 26.97 131.41 ± 22.56	-4.253	.001	1.89
Elbow supination (N)	Peak	84.21 ± 24.40 137.53 ± 30.76	-5.310	.000	1.92
	Avg	66.93 ± 16.99 116.38 ± 24.02	-5.458	.000	2.37
Elbow pronation (N)	Peak	105.30 ± 26.65 125.50 ± 23.83	-2.145	.053	trivial
	Avg	84.52 ± 21.24 106.90 ± 18.60	-2.924	.013	1.12
Wrist flexion (N)	Peak	85.45 ± 18.50 110.89 ± 17.61	-4.167	.001	1.40
	Avg	71.01 ± 17.71 95.20 ± 15.90	-4.206	.001	1.43
Wrist extension (N)	Peak	85.28 ± 18.17 85.07 ± 24.52	0.025	.980	trivial
	Avg	69.28 ± 15.54 70.67 ± 20.16	-0.173	.865	trivial
Wrist adduction (N)	Peak	67.21 ± 19.43 99.95 ± 14.41	-4.613	.001	1.91
	Avg	56.30 ± 16.87 80.28 ± 10.75	-4.929	.000	1.69
Wrist abduction (N)	Peak	88.08 ± 43.10 121.63 ± 42.52	-2.056	.062	trivial
	Avg	70.49 ± 32.74 98.68 ± 32.84	-2.291	.041	0.85
Hip flexion (N)	Peak	139.86 ± 44.12 209.21 ± 41.19	-4.011	.002	1.62
	Avg	116.92 ± 39.27 169.77 ± 23.57	-4.384	.001	1.63

Hip extension (N)	Peak	124.75 ± 32.81 239.23 ± 41.97	-7.260	.000	3.06
	Avg	99.39 ± 33.97 182.75 ± 36.00	-5.534	.000	2.38
Hip abduction (N)	Peak	117.30 ± 28.33 169.44 ± 38.89	-4.601	.001	1.53
	Avg	95.06 ± 27.14 131.87 ± 29.90	-4.514	.001	1.28
Hip adduction (N)	Peak	100.67 ± 17.58 182.41 ± 48.88	-5.361	.000	2.22
	Avg	84.66 ± 17.27 143.31 ± 37.29	-4.932	.000	2.01
Knee flexion (N)	Peak	130.57 ± 23.66 194.90 ± 48.33	-4.130	.001	1.69
	Avg	108.20 ± 22.09 157.54 ± 39.27	-3.515	.004	1.54
Knee extension (N)	Peak	165.08 ± 46.67 177.44 ± 51.74	-0.844	.415	trivial
	Avg	136.70 ± 34.16 135.68 ± 27.24	0.110	.914	trivial
Ankle dorsi flexion (N)	Peak	86.73 ± 21.18 123.15 ± 29.66	-4.204	.001	1.41
	Avg	71.97 ± 19.77 107.29 ± 27.24	-4.408	.001	1.48
Ankle plantar flexion (N)	Peak	78.29 ± 20.79 123.41 ± 32.00	-4.203	.002	1.67
	Avg	60.32 ± 19.15 103.87 ± 25.76	-4.729	.000	1.91
Ankle inversion (N)	Peak	79.88 ± 17.24 106.06 ± 18.48	-4.063	.002	1.46
	Avg	65.97 ± 14.89 83.67 ± 17.80	-2.994	.011	1.07
Ankle eversion (N)	Peak	85.25 ± 8.81 100.08 ± 24.63	-2.184	.050	trivial
	Avg	70.63 ± 6.27 80.63 ± 16.80	-2.145	-2.145	trivial

Table 5. Power comparison of AUT to pre and post-test.

Power	**Group**	**Pre – Post**	**t**	***p***	**ES**
Sit-up	AUT	19.23 ± 2.24 – 21.53 ± 3.84	-2.540	.026	0.73
	IKT	17.69 ± 3.11 – 23.69 ± 4.30	-7.899	.000	1.59
Push-up	AUT	22.15 ± 9.33 – 23.38 ± 7.76	-0.686	.506	trivial
	IKT	12.61 ± 5.72 – 21.15 ± 8.89	-3.517	.004	1.14
Triceps dips	AUT	22.61 ± 7.48 – 26.07 ± 5.10	-2.347	.037	0.54
	IKT	21.38 ± 5.31 – 28.30 ± 6.71	-5.105	.000	1.14
Countermovement jump	AUT	24.11 ± 3.65 – 24.61 ± 3.59	-0.495	.629	trivial
	IKT	21.80 ± 6.95 – 23.84 ± 5.91	-1.204	.252	trivial
Countermovement jump (90°)	AUT	27.15 ± 5.97 – 27.92 ± 6.10	-1.059	.310	trivial
	IKT	22.53 ± 3.09 – 24.57 ± 5.96	0.143	.889	trivial
Vertical jump	AUT	28.92 ± 4.59 – 29.23 ± 4.24	-0.362	.724	trivial
	IKT	24.57 ± 5.96 – 24.38 ± 3.04	0.101	.921	trivial
Single leg vertical jump (right)	AUT	11.38 ± 3.81 – 12.30 ± 2.95	-1.369	.196	trivial
	IKT	9.69 ± 2.98 – 10.38 ± 1.75	-0.962	.355	trivial
Single leg vertical jump (left)	AUT	11.84 ± 3.26 – 12.69 ± 3.79	-1.058	.311	trivial
	IKT	8.00 ± 1.87 – 9.53 ± 1.80	-2.857	.014	0.83

Flexibility	AUT IKT	24.23 ± 6.83 – 25.76 ± 6.62 21.30 ± 6.47 – 24.76 ± 7.10	-2.922 -3.212	.013 .007	0.22 0.50
Handgrip (right)	AUT IKT	28.38 ± 3.82 – 27.99 ± 3.60 26.19 ± 3.87 – 27.79 ± 3.06	0.368 -1.738	.719 .108	trivial trivial
Handgrip (left)	AUT IKT	27.61 ± 3.11 – 28.24 ± 2.85 25.71 ± 3.74 – 25.53 ± 3.56	-0.885 0.147	.394 .886	trivial trivial
Agility	AUT IKT	14.47 ± 0.88 – 14.28 ± 0.87 15.11 ± 0.85 – 14.56 ± 0.72	0.813 2.839	.432 .015	0.21 0.69

Table 6. Power outcomes comparison of AUT and IKT to post test.

Power	**Group**	**Pre – Post**	**t**	***p***	**ES**
Sit-up	AUT IKT	21.53 ± 3.84 23.69 ± 4.30	-1.345	.191	trivial
Push-up	AUT IKT	23.38 ± 7.76 21.15 ± 8.89	0.681	.502	trivial
Triceps dips	AUT IKT	26.07 ± 5.10 28.30 ± 6.71	-0.954	.350	trivial
Countermovement jump	AUT IKT	24.61 ± 3.59 23.84 ± 5.91	0.401	.692	trivial
Countermovement jump (90°)	AUT IKT	27.92 ± 6.10 22.38 ± 3.79	2.778	.010	1.09
Vertical jump	AUT IKT	29.23 ± 4.24 24.38 ± 3.04	3.345	.003	1.31
Single leg vertical jump (right)	AUT IKT	12.30 ± 2.95 10.38 ± 1.75	2.017	.055	trivial
Single leg vertical jump (left)	AUT IKT	12.69 ± 3.79 9.53 ± 1.80	0.371	.714	trivial
Flexibility	AUT IKT	25.76 ± 6.62 24.76 ± 7.10	-1.880	.072	trivial
Handgrip (right)	AUT IKT	27.99 ± 3.60 27.79 ± 3.06	2.136	.043	0.05
Handgrip ((left)	AUT IKT	28.24 ± 2.85 25.53 ± 3.56	-0.907	.373	trivial
Agility	AUT IKT	14.47 ± 0.88 15.11 ± 0.85	0.152	.880	trivial

Power outcomes showed a high significant of power improvement in calisthenic, vertical jump, flexibility and hand strength measurements before and after auxotonic resistance training to AUT and IKT. According to AUT IKT, vertical jump performance showed a high effect size in the post-test comparison (Tables 5,6).

DISCUSSION

Auxotonic resistance training performed to evaluate on strength and power changes of young volleyball players over 8 weeklong term linear periodization. Performance research process of young volleyball players had included some maximal strength, isometric strength, calisthenic, power, flexibility and agility tests. The comparison of AUT and IKT after auxotonic resistance training reported 1RM strength was very large effect size according to AUT IKT. Auxotonic resistance training continued development of strength without changing mechanic range of motion during linear periodization, however, current research showed that mechanical range of motion limited by other measurements and insufficient maximal force production to subsequent strength development (Azeem et al., 2022). On the other hand, auxotonic resistance training develops muscle mechanic isometric contraction potential to maximal strength development, however, maximal strength not developed on mechanic range of motion by isometric time-dependent force. That is, the potential peak and

average force related isometric muscle contraction should be limited to 5-7 s for the lower compartment (Comfort et al., 2022). Furthermore, some evidence to combination isotonic + isometric contraction in 1RM bench press of isometric 14.23%, and isotonic 35.45% proper strength planning on compartment muscle limited range of motion, thus potential isometric peak and average muscle force must be constructed for strength increase based time-dependent trials after resistance exercise (Azeem et al., 2022; Comfort et al., 2022). Similarly, research outcomes observed that the use of isometric or isotonic exercise in incorrect planning resulted in similar strength outcomes especially for energy potential production of specific muscle group did not provide strength increases via auxotonic resistance training. In this condition, performance outcomes had relationship auxotonic resistance training outcomes for muscle contraction mechanics based on the combination of muscle strength increases with isometric muscle contraction, supporting the potential fast contraction force production of the muscle. Within isotonic muscle contractions in the joint range of motion that therefore, static and dynamic forces in AUT provide more meaningful results than IKT. Auxotonic resistance training was highly effective resistance training method during long term training periods including isometric muscle contraction periods. It was seen in one study that only the mechanical range region reported shoulder region muscle force was evaluated in isometric activation, but in our study, isometric contraction sessions supported the resistance training period in both the upper and lower compartment regional muscles (Karagiannapoulos et al., 2022). Therefore, increase of muscle strength are variable, regional compartment studies not used in different auxotonic exercises for sports performance athletes for peak and average effects of actual strength should be evaluated specifically for each athlete. Activforce isometric results AUT and IKT were compared and the reason why no significant outcomes were obtained is that similar age and strength characteristics are not the same for individual evaluations in isometric muscle contraction activations. The reason why power improves in auxotonic resistance training is that it includes high repetition time-dependent exercises (4). At the same time, more effective regional auxotonic training changed the performance values in these strength test parameters, especially strength.

CONCLUSİON

This research determined the effect of auxotonic resistance training on muscle strength and power in young volleyball players. However, muscle strength tests and power performance were specific to athletes and different results were obtained compared to other studies using auxotonic resistance training. In the research, auxotonic resistance training was in isometric and isotonic combination and was examined in two separate groups for performance changes. Therefore, muscle strength gains had similar effects in both groups on 1RM measurements. Although the AUT and IKT were similar in the peak and average isometric values where muscle strength was examined regionally, a larger effect size was observed in the IKT. Likewise, after auxotonic resistance training, the calisthenic, flexibility and agility results of the AUT and IKT were similar. AUT achieved more significant results in jumping performance than the IKT group. Therefore, as a result of the research, planning auxotonic resistance training at a level that will increase isometric and isotonic performances, which is a combination of muscle contraction, improves muscle strength and power parameters individually in athletes. In the research, indeed auxotonic resistance training improves muscle strength 1RM performances and isometric muscle contraction potential when applied at any time during annual training periods. For this reason, our research shows that auxotonic resistance training should be implemented in young athletes during the periods when annual muscle strength and power training is planned. At the same time, there is a greater need for studies that will demonstrate high jumping performance when isometric muscle contraction combinations, which are easier and simpler than other strength training for muscle strength increases, are combined with technical training.

AUTHOR CONTRIBUTIONS

For this study showed any conflict of interest, funding preparation, no ethic statement. All rights hidden in ethic committee and Helsinki declarations. Authors; YK and FK have research design, methodological approach, and assay structure.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

DATA AVAILABILITY

Data are available under reasonable request to corresponding author. Included both original data generated in the study research and supports of results and analyses.

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