Original Research

The Journal of Strength and Conditioning Research™

The Effect of a Novel Weight-Supported Kinetic Chain Resistance Training Program on Proximal Core Muscular Endurance, Trunk-to-Arm Muscular Power, and Bat Swing Speed

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Abstract

Palmer, TG, and McCabe, M. The effect of a novel weight-supported kinetic chain resistance training program on proximal core muscular endurance, trunk-to-arm muscular power, and bat swing speed. *J Strength Cond Res* 37(11): 2130–2140, 2023—Muscular stability and muscular power at the proximal core segments of the pelvis, spine, and trunk are essential attributes in maximizing bat swing speed in the sport of softball. Weight-supported kinetic chain resistance training (WsKC) is a novel closed kinetic chain technique that provides synergistic multiplanar stressors to the proximal core segments via the lower and upper extremities while limiting joint compression and sheer forces throughout the kinetic chain. The aim of this study was to assess the effect a 7-week preseason WsKC program would have on an isometric muscular endurance plank, trunk-to-arm peak muscular power (TAPP), trunk-to-arm peak velocity (TAPV), and bat swing speed (BSS) compared with a traditional isotonic weight resistance training program. Twenty-seven female high school softball players (age = 16 years, height = 167.6 cm, body mass = 62.86 kg) were assigned in a blocked randomization to one of 2 groups: a standing weight-supported kinetic chain resistance training (WsT) group ($n = 13$) or a pseudo-control traditional isotonic training (TT) group ($n = 14$). The WsT group had significant improvements ($p < 0.05$) for the isometric endurance plank ($p = 0.001$), TAPP ($p = 0.002$), TAPV ($p = 0.001$), and BSS ($p = 0.02$) compared with the TT group. The training effect size (ES) was large for the WsT group for all variables (ES = 1.0–7.4) and small to moderate for a majority of the TT variables (ES = 0.06–0.47). The simultaneous improvement in the isometric endurance plank, trunk-to-arm rotations, and BSS indicates that the WsKC contributed to subsequent improvements in BSS in high school softball players.

Key Words: softball, weight-supported kinetic chain training, power, bat swing speed

Introduction

Success in hitting a softball requires rapid bat swing speed (BSS), muscular power, and biomechanical precision of the pelvis, spine, and trunk. With less than half of one second to react to a pitch, a faster BSS allows a player more time to evaluate the ball position as it approaches home plate. A faster BSS increases the potential distance and reflected speed of the ball after bat-to-ball contact (2,15,23). The summation and manipulation of ground reaction forces via the human kinetic chain is critical in producing maximal BSSs. Specifically, the ability to develop and incrementally control the rotational momentum of the pelvis to the spine and trunk in a sequential fashion ("timing") and the ability to maximize muscular power from the ground reaction forces to that of the lumbo-pelvic-hip muscles serve as the primary contributors for maximizing BSS. Here, synergy between the rotating proximal body segments of the human kinetic chain and the force-velocity production of the contributing muscles establish swing speed (3,17,19,25,28). Thus, strength and conditioning professionals continue to seek exercises that target muscular power and coordination between the pelvis, spine, and trunk (15,37,40).

Several different types of resistance training techniques targeting BSS have been reported in the literature and often attempt to maximize appropriate resistance overloads while maintaining safety (10,11,13,37). A number of open and closed kinetic chain (CKC) resistance training programs involving upper and lower extremity push-pull movements from a variety of standing and seated positions have been introduced to maximize the power contributions between the appendicular skeletal muscles and the proximal core muscles necessary to increase BSS (4,10,11,13,31,37,40). Traditional resistance "weight" training, plyometric ball throws, resistance bands or cables, weighted bats, whole-body vibration, and body-supported sling training have been among some of the more common techniques used to target subsequent improvements in the proximal core musculature, muscular power, and swing speed (4,11,40). Not absent of dangerous or extensive sheer and compressive forces, many of the traditional strength training techniques reported in the literature often involve advanced movements. Such patterns often require extensive training and periods before noting a training effect (i.e., 12 weeks) and are very advanced weight training movements that place the upper extremity in provocative positions prone to creating adverse join stress (31,39). In addition, several studies investigating bat speed have not targeted the proximal core musculature, lack rotational sport specificity training, emphasize *strength*-only training overloads, and lacked a reasonable

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Journal of Strength and Conditioning Research 37(11)/2130–2140

comparison group to account for a true training effect (39,40). Some findings indicate that younger populations, such as high school players, may respond positively with acute improvements to BSS after a multitude of resistance training (endurance, strength, and power), yet experienced collegiate and professional players require more precise sport-specific training to promote improvements in bat speed (1,40). Regardless of the current trends in the literature, there is little empirical evidence regarding best practice for kinetic chain training and BSS performance while limiting adverse stressors associated with traditional lifting programs.

Weight-supported kinetic chain resistance training (WsKC) is a novel CKC technique that provides synergistic multiplanar stressors to the kinetic chain and proximal core muscles via force transformation to and from the upper and lower extremities (Figures 1A and 1B; Finisher). The combination of CKC athletic stance foot position and the rotational resistance swing phase of the arms offers similar, but unique, stressors different from that of traditional CKC activities, such as a squat or push-up. The fixed foot position incorporates a functional pattern where ground reaction forces are transferred from the feet to the proximal segments using rotational muscular co-contractions similar to the sport but not necessarily typical of traditional linear CKC exercises. The weight-supported resistance at the distal end of the hand is confined to a restricted or fixed range of motion that offers changes in inertia and momentum also not experienced in traditional CKC or isotonic exercises (16). The dexterity of the exercise options available on the Finisher from multiple closed-chain standing positions and the novelty of the swing patterns offer various multiplanar push-pull movements. In addition, the ability to interchange different loads allows one to target muscular endurance, strength, and power using stimuli that offer less compressive joint loads that seem to be safer for joint health (28). The sport-specific nature of the rotational movement patterns and the weight transmission expressed from the ground reaction forces to the hands provide incremental progressive stability about the pelvis, spine, and trunk previously reported to maximize trunk and arm rotational velocities (16,18,25). Furthermore, previous studies using the Finisher have reported a large training effect after a reasonable time frames of 6 to 8 weeks (16,28). This makes it ideal for both elite and novice lifters. However, there is limited evidence regarding the effect WsKC has on muscular development associated with BSS. Therefore, the aim of this study was to assess the effect a 7-week preseason WsKC program would have on isometric muscular endurance planks, trunk-to-arm power, trunk-to-arm velocity, and BSS compared with a traditional isotonic weight resistance training program (39). It was hypothesized that either intervention could result in simultaneous improvements in isometric trunk stability, muscular power or velocity, and BSS. Noted significant improvements between the different training groups would confirm the influence targeted training of the proximal core musculature can have on BSS. However, the less compressive forces and sport-specific movements of the Finisher may prove to be adventurous to traditional training methods.

Methods

Experimental Approach to the Problem

A preintervention-to-postintervention cohort study was implemented using a randomized high school female population of convenience. The study was IRB approved by the University of Cincinnati IRB and required and received parent and participant consent before participation in the study. All participants attended 3 familiarization training or testing sessions before testing and were blinded to the implications of the specific training groups. After baseline testing, all participants were block randomized into 1 of 2 training groups for 7 weeks: a standing weight-supported kinetic chain resistance training (WsT) group ($n = 13$) or a traditional control isotonic training (TT) ($n = 14$) group. All trainings were performed by 2 independent and blinded certified strength and conditioning specialists, each with an average of 18 years of training experience. Groups trained separately and training time and intensity were matched. Testing was performed by individual blinded experts in the assessment of isometric muscular endurance planks, trunk muscular power or velocity dynamometers, and BSS. The independent variables were the 2 test groups, the training interventions relative to a pre- and post-measures. The dependent variables were an isometric muscular endurance prone plank, trunk-to-arm peak muscular power (TAPP), trunk-to-arm peak velocity (TAPV), and BSS.

Subjects

Subjects were recruited from a local group of varsity female high school softball programs (age 15–18 years; $n = 27$). Subjects were blocked by class and position and randomly assigned to one of 2 groups: weight-supported training (WsT) group ($n = 13$, average height: 171.2 cm, body mass: 72 kg, age: 16.5 years) and traditional isotonic resistance training (TT) group ($n = 14$, average height: 173 cm, body mass: 71.4 kg, age: 15.8 years). The total number of subjects consisted of 9 seniors, 11 juniors, 5 sophomores, and 2 freshmen (WsT/TT: 5/4 seniors, 5/6 juniors, 2/3 sophomores, 1/1 freshman).

The average years of playing experience for both groups was 4.8 years, and all participants had an average of 4 years of experience with weight training. Three subjects from each group reported having less than 1 year or no consistent experience with formalized resistance training (2 juniors, 2 sophomores, and 2 freshmen), whereas the remaining players reported having a minimum of 5 years of resistance training experience. Players did not qualify for the study if there was any evidence of a chronic or acute injury, did not have medical clearance or a physician physical examination declaring a healthy status, and did not report for more than 90% of all team activities. No subjects were excluded after initial testing.

Testing Procedures

All testing procedures were practiced by each participant multiple times over 3 different familiarization sessions to assure proper technique and to accommodate for a learning effect. To assess measures of power (watt) and velocity (m/s) for the muscles of the pelvis, spine, and trunk, subjects performed an In-line Lunge Lift while pulling a TENDO lanyard (TENDO Strength, Inc., Columbia, SC), Figure 2A,B (28). Previously reported as a reliable measure, the TENDO In-line Lung Lift technique was portable, easy to use, and allowed for multiple practice attempts in a reasonable amount of time (26,27). While maintaining a half-kneeling position with the feet and knee aligned in a straight line and the hip and knee flexed to 90°, subjects performed a lifting motion with a straight arm position while rotating the arms and hips rapidly to mimic a bat swing. Five maximum-effort pulls (Lift Pattern) were performed. The average of 3 scores was recorded after the high and low outliers were eliminated. Isometric muscular endurance prone planks were performed for a maximum hold time to assess proximal

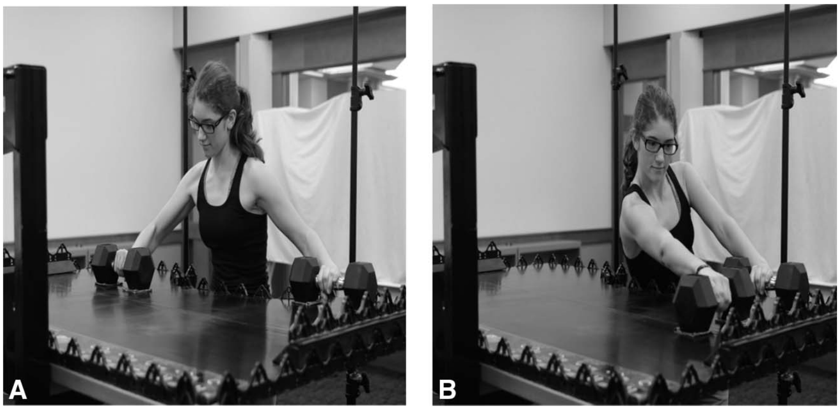

Figure 1. (A and B) A progression of the concentric phase of standing weight-supported training from a start push-to-pull multidirectional pattern with pelvis, spine and trunk in sequence as guided by the right arm.

stability and muscular endurance of the muscles that support the pelvis, spine, and trunk (27). Subjects were afforded 3 correction prompts before the termination of the plank test as time was recorded in seconds. BSS was measured with 2 devices: the Stalker Pro II radar gun (Atlanta, GA) and the Blast Motion Bat Sensor (Carlsbad, CA). After a swing warm-up, each player was given 5 attempts to swing toward a baseball at the top of a batting tee at waist or navel height. The swing speeds for both devices were averaged and recorded. Bat mass and length were normalized for both teams at 0.624 kg and 81.2 cm (22 oz and 32 inches), respectively (16,25–28). All testing procedures have been validated in previous literature to assess changes in performance, and assessed extensively in our private laboratory before the familiarization trials (16,25–28). Before the familiarization sessions, intersession reliability for each test was calculated in an independent laboratory. After 2 familiarization sessions, intersession reliability was 0.88–92. The best of 3 repetitions for trunk-arm peak velocity (TAPV) in m/s, trunk-arm peak power (TAPP) in watts, and BSS in m/s were recorded after 2 separate familiarization periods, at baseline and after the 7-week intervention.

Training Interventions

The 2 training groups meet separately twice weekly during the preseason for approximately 60 minutes for a total 7 weeks and 14 training sessions. All workouts for both groups occurred in the afternoon hours after school and included a warm-up and some exercises focusing spinal stability, general muscular endurance, strength, power, perturbation, and plyometric training. Changes in resistance and velocity of exercise movement allowed for the workout sets and repetitions to delineate between a muscular endurance and strength and power training workout. The work loads for each training interventions (total training time, volume, intensity, sets, and repetitions) were controlled and calculated to assure each individual groups' targeted expectations were met and had similar workloads (frequency × time × intensity). Both groups received training stimuli that emphasized the development of muscular strength and power to account for the sport specificity of BSS. The training periodization model was progressed in an undulating fashion with linear block sessions emphasizing muscular strength development for the first 3 weeks and muscular power development for the last 4 weeks. Much of the exercise training sequence and design was developed to accommodate the

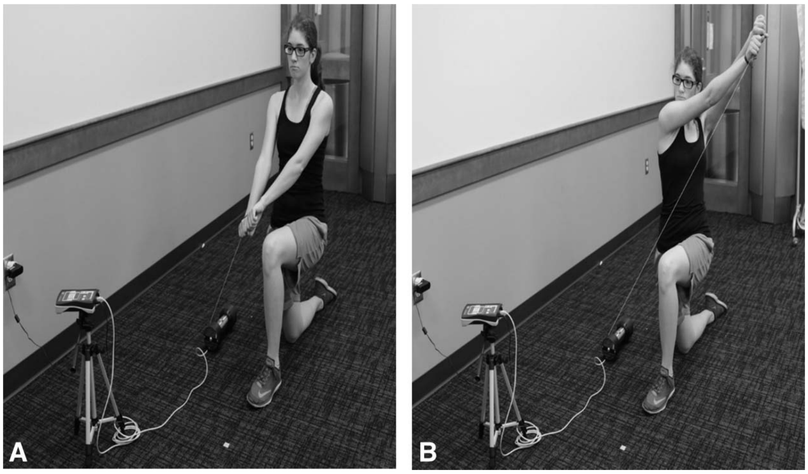

Figure 2. (A and B) A progression of the In-line Lunge Lift beginning and finished position while maintaining a straight in-line lunge position with an incrementally stable pelvis, spine and trunk.

diversity of experience of the subjects. All training sessions did include a minimum of one scheduled hydration or water break, and students were instructed to not consume energy drinks or supplements before, during, and after workouts. During the 7-week preseason, all subjects were instructed not to engage in any additional resistance or skills training sessions and to not alter eating or sleeping habits. Prior to each training session students were asked to confirm they did not participate in any additional training or had any changes in health status.

The WsT group used the Finisher devise (Finishing Sports, Inc., Figures 1A and 1B) to provide various push, pull, and rotational (concentric and eccentric) kinetic chain strength and power resistances (Figures 3A and 3B) from different standing positions. Plyometric and perturbation activities had to be modified because of the nature of the device but were included with each workout. The TT group participated in traditional dynamic isotonic, plyometric, and perturbation strength and power resistance training that emphasized upper- and lower-body pulling motions, such as bicep and hamstring curls and latissimus pull-downs or pull-too, and pushing motions, such as triceps extension or dips, bench press, and squats. The TT group performed traditional muscular endurance, strength, power, plyometric, and perturbation training exercises. Muscular endurance “core” exercises, such as planks, dead bugs, and cable chop or lift maneuvers, were a foundation to the workout design for the TT group. All training sessions were monitored by 2 separate strength and conditioning coaches. In addition, the strength coach for the WsT group was a certified Finisher professional of 8 years of experience. Both

Figure 3. A) Upper-body movement patterns. B) Torso and lower extremity movement or potions patterns.

Table 1

Pre- to post-bat swing speed, prone plank, trunk-arm muscular power, and velocity normalized by kilograms per body mass mean values, *SD*s, and *p*-value group-by-time interaction.*

	BSS (m/s/kg body mass) (mph)		Prone-plank muscular endurance (s)		TAPP (watts/kg body wt)		TAPV (m/s/kg body wt) (mph)	
Training groups	**Pre-mean ± *SD***	**Post-mean ± *SD***	**Pre-mean ± *SD***	**Post-mean ± *SD***	**Pre-mean ± *SD***	**Post-mean ± *SD***	**Pre-mean ± *SD***	**Post-mean ± *SD***
TT	60.5 ± 0.5	61.9 ± 0.5	90.8 ± 0.5	106.9 ± 22.4	4.1 ± 0.7	6.85 ± 1.2	19.3 ± 0.01	20.4 ± 0.01
WsT	62.7 ± 0.4	69 ± 0.4	93 ± 21.1	115.2 ± 21.3	4.6 ± 0.5	10.1 ± 1.3	18.9 ± 0.01	21.6 ± 0.02
Group-by-time interaction, $p \leq 0.05$	$p = 0.006$		$p = 0.015$		$p = 0.001$		$p = 0.003$	

*TT = traditional training group; WsT = weight-supported training group; BSS = bat swing speed in meters per second normalized by kilograms of body mass; prone plank = isometric static hold times in seconds; TAPP = trunk-arm peak muscular power in watts normalized by kilograms of body mass; TAPV = trunk-arm peak velocity in meters per second normalized by kilograms of body mass; m/s = velocity in meters per second; mph = velocity in miles per hour.

Significant group-by-time interaction differences ($p \leq 0.05$).

training professionals were blinded to the study intentions with an average of 18 years of training experience between them.

Statistical Analyses

All data were analyzed using SPSS-23, IBM. Data plots and histograms were observed for normality. An independent Student's *t*-test was used to examine differences between baseline data for all dependent variables. Muscle power and velocity outputs were normalized by each participant's body mass to assess the specific effect each individual had within the individual groups (25). The primary effects of resistance training on the dependent variables were analyzed using a 2 × 2 (group by time) analysis of variance with a post hoc Bonferroni adjustment. A Pearson product correlation coefficient was used to assess relationships between all dependent variables. A priori significance level was set at $p \leq 0.05$. A power analysis was performed to assess the treatment effect size (ES) of the 2 separate interventions from the WsKC activities on the Finisher and the TT training for each dependent variable. ES was based on a Cohen's *d* calculation; respectively, the intervention group mean values from pretest to posttest were subtracted to represent a true control group and divided by a pooled *SD* to determine the effect of each intervention. ES data are displayed in Table 3. Results were interpreted as small (0–0.39), medium (0.40–0.69), or large (≥0.70) (30).

Results

There was a significant group-by-time interaction for absolute and relative isometric muscular endurance, muscular power, and BSS (Table 1). The WsT group had significant improvements for the isometric static prone plank ($F = 12.3$, $df = 1, 25$, $p = 0.015$), TAPP ($F = 12.20$, $df = 1, 25$, $p = 0.001$), TAPV ($F = 13.47$, $df = 1, 25$, $p = 0.003$), and BSS ($F = 4.10$, $df = 1, 25$, $p = 0.006$) compared with the TT group. Moderate-to-strong positive correlations were evident for all variables ($r = 0.65$–0.88) displayed in Table 2. The training ES documented in Table 3 was large for the WsT group for all variables (ES = 1.0–7.4) and small to moderate for a majority of the TT variables (ES = 0.06–0.47). The WsT group had a 42, 15, and 6% greater increase in TAPP, TAPV and BSS, respectively, than the TT group.

Discussion

The ability to swing a bat with great velocity will give a batter more time to examine the ball position(s) with more precision and potentially increase the effectiveness of the collision between the bat and ball ($f = ma$) while increasing both the ball speed and the distance traveled off the bat (11,36,40). It was hypothesized that both training interventions could potentially improve BSS in tandem with improvements in isometric muscular endurance, power and velocity of the proximal core segments. Although the Finisher training was superior in improving BSS with statistical significance, there were improvements in both training groups. The simultaneous improvements in the dependent variables for both groups help to confirm that the training workloads were sufficient and appropriate in having a positive muscular endurance and power training effects for the proximal core segments, resulting higher rotational velocities. In an attempt to reduce bias, each training

Table 2

Correlation coefficient and p values normalized for bat swing velocity per kilogram of body mass and performance-dependent variables at postintervention.

Dependent variable	Prone-plank hold time, s	Trunk-arm peak power, kg/body, watts	Trunk-arm peak velocity, kg/body, m/s	Bat swing speed, m/s
Prone-plank hold time, s	1	0.08 ($p = 0.62$)	0.04 ($p = 0.86$)	0.13 ($p = 0.56$)
Trunk-arm peak power, kg/body, watts W		1	0.84 ($p = 0.001$)*	0.78 ($p = 0.002$)*
Trunk-arm peak velocity, kg/body, m/s			1	0.84 ($p = 0.002$)*
Bat swing speed, m/s				1

*Indicates correlation ($p < 0.05$).

program was designed to mimic sport-specific motions, target the proximal core muscles, and stimulate sport-specific kinetic chain muscular strength and power movements. The primary difference between the training interventions was the novelty of the weight-supported Finisher device. Overall, the simultaneous improvements in the proximal muscular and the significant group differences ($p < 0.05$) for the isometric plank, muscular power, velocity, and BSS indicate the novel overload stimulus of the Finisher to be an effective intervention for improving swing speed performance.

Previous literature suggests that a combination of proximal core stability exercises, perturbation, plyometric training, and strength-to-power progressive resistance training with sport-specific motions are necessary to improve velocity outcomes, such as BSS and throwing velocity (1,25). Documented in Table 4 and Table 5, each training intervention in the current study consisted of evidence-based exercises previously reported to improve proximal core muscular endurance, stability, and rotational power. Traditional isotonic resistance training has had some, but limited, positive effects on BSS (1,11,38,40). Resistance strength training with traditional bars and dumbbells help to establish the necessary muscular strength needed to develop functional power and therefore can be a practical component to any training program attempting to improve rotational force. The traditional resistance training in the current study validates such stimuli to have a positive effect on BSS of high school female participants. The TT intervention had a large training effect for the proximal core muscular endurance and a moderate effect in trunk-to-arm power (Table 3). This is likely because of the emphasis on using isometric endurance planks as part of the TT group training. However, the training effects for *all* the dependent variables were larger after the Finisher intervention. The WsT group did not perform isometric planks; however, they were required to maintain a great deal of incremental stability while standing and performing rotational and linear movements throughout the training sessions. With the kinetic chain functioning as a fulcrum between the ground reaction forces and swing resistance at the hands, the proximal segments serve to provide incremental stability, allowing forces to transfer to and from the proximal to distal anatomical segments (16,19).

In addition, previous functional increases in grip strength commonly associated with isotonic resistance training have been reported to contribute to increased BSS (1). Although grip strength was not measured in the current study, it can be surmised that the use of dumbbells in both training groups likely contributed to the improvements in the TT and the WsT. Furthermore, the inclusive nature of both programs to include strength-to-power periodization progressions and the use of perturbation, plyometric, and muscular trunk stability exercises previously reported to enhance rotational force and velocities validates the efficacy and limits bias among both training interventions (19,25).

The WsKC resulted in improved muscular endurance, strength, and power that seem to have influenced and translated into improved BSS. It is arduous to conclude for certain that the Finisher targeted and improved the proximal core musculature (pelvis, spine, and trunk) that resulted in the significant differences between the groups. However, the simultaneous improvements in BSS, trunk stability, and trunk-to-arm muscle power or velocity documented in Table 1 indicate that the weight-supported kinetic chain resistance training stimuli supplied by the Finisher was superior to traditional isotonic training. In addition, the mandated stability provided by the proximal segments during the WsKC intervention offers face validity for the targeted stimuli. The relationships documented in Table 2 mimic previous reports where targeted training of the proximal core muscles resulted in faster throwing velocities (24,25). The data also reinforce the previously proposed recommendation for the importance of resistance training programs to target the development of proximal muscular endurance and strength as a foundation to promote higher volitional trunk and arm velocities (12,15,24,25). Incremental or controlled stabilization *of the proximal segments*

Table 3

Cohen's d treatment effect size and confidence intervals for preintervention to postintervention for dependent variables.

	Weight-supported training, $N = 13$			Traditional training, $N = 14$		
		95% confidence interval			95% confidence interval	
Dependent variables	Effect size	Lower bound	Upper bound	Effect size	Lower bound	Upper bound
BSS (m/s/kg body wt)	1.04*	0.65	1.39	0.04	−0.70	0.78
Prone plank (s)	1.3*	0.19	1.83	1.1*	0.33	1.92
TAPP (watts/kg body wt)	11.3*	3.75	13.07	0.5†	−3.75	1.69
TAPV (m/s/kg body wt)	5.3*	35.01	62.2	0.0	0.71	0.74

*Indicates large effect.
†Indicates moderate effect.

Table 4
Traditional isotonic training group.

	Muscular endurance activities at approximately 15–50% lifting capacity. **Muscular strength activities at approximately 60–100% lifting capacity.** **Muscular power activities at approximately 20–60% lifting capacity.**		
Training modes:	**Sessions 1, 2, and 5 (endurance emphasis)**	**Sessions 3, 4, and 6 (strength emphasis)**	**Total time**
Warm-up	Form running, dynamic flexibility	Form running, dynamic flexibility	5 min
Endurance/mat work	Bead bugs—short, slow, 3 × 20 repetitions* Plank series: supine/lateral, 3 × 20 repetitions*	Chop/lift cable 3 × 20 repetitions* Plank series: supine/lateral, 2 × 60 s	5 min
Perturbation	BOSU—double-knee balance, 3 × 45 s Airex—Russian twists, 3 × 20 repetitions Swiss ball—double-leg curl, 2 × 20 repetitions	Swiss ball—reverse double-leg curl 2 × 20 repetitions Single-leg standing reverse toe touch 2 × 20 repetitions	5–10 min
Resistance training	Dumbbell bench press, 3 × 8–12 repetitions Dumbbell incline press, 3 × 12 repetitions Dumbbell shoulder press, 2 × 8–12 repetitions Dumbbell triceps extension, 2 × 12 repetitions Latissimus pull-downs/pull-too, 2 × 8–12 repetitions Dumbbell overhead squat, 2 × 8–12 repetitions	Dumbbell bench press, 3 × 6–8 repetitions Dumbbell incline press, 3 × 6–8 repetitions Dumbbell shoulder press, 2 × 6–8 repetitions Dumbbell triceps extension, 2 × 6–8 repetitions Dumbbell biceps curls, 2 × 6–8 repetitions Dumbbell overhead squat, 2 × 6–8 repetitions	30 min
Plyometric	Medicine ball back-to-back partner exchange Transverse, 3 × 8 repetitions Hip to head, 3 × 8 repetitions	Split squat jumps, 4 × 6–8 repetitions Medicine ball transverse throw-downs, 3 × 8 repetitions	10 min
Cool down	2-min jog and stretch	2-min jog and stretch	5 min
	Sessions 7, 8, 10, and 13 (strength/power emphasis)	Sessions 9, 11, 12, and 14 (power emphasis)	
Warm-up	Form running, dynamic flexibility	Form running, dynamic flexibility	5 min
Endurance/mat work	Plank series: supine/lateral, 3 × 20 repetitions*	Chop/lift cable 3 × 20 repetitions* Plank series: supine/lateral, 2 × 60 s	5 min
Perturbation	BOSU—double-knee balance, 3 × 45 s Airex—Russian twists, 3 × 20 repetitions Swiss ball—double-leg curl, 2 × 20 repetitions	Swiss ball—reverse double-leg curl 2 × 20 repetitions Single-leg standing reverse toe touch 2 × 20 repetitions	5–10 min
Resistance training: strength, power, transition training	Superset dumbbell bench press, 2 × 6–8 repetitions to max push-ups Dumbbell shoulder press, 2 × 6 repetitions Superset triceps extension, 2 × 6 repetitions to maximum repetition dips Dumbbell biceps curls, 2 × 8 repetitions Dumbbell overhead squat, 2 × 8 repetitions Medicine ball transverse throw-downs, 3 × 5 repetitions Romanian deadlift single leg, 2 × 5	Bar bench press, 3 × 5 repetitions Fast standing dumbbell shoulder press, 3 × 6–8 repetitions Close grip-bench press to skull crusher/triceps extension, 2 × 6–8 repetitions for each exercise Dumbbell overhead squat, 2 × 6–8 repetitions	25 min
Plyometrics	Split squat jumps, 2 × 6–8 repetitions	Double-leg squat jumps, 4 × 6–8 repetitions (distance and speed) Single-leg horizontal jumps stable landing 4 × 8 Inline lunge medicine ball toss left/right for distance, 2 × 4 repetitions	15 min
Cool down	2-min jog and stretch	2-min jog and stretch	5 min

*Exercises with abdominal hollowing.

serves as practical component to nearly all sports movements. However, athletes often neglect the priority of developing such muscle capacities at the proximal segments before training volitional movements (25,33).

Previous research has reported limited improvements in sport-specific rotational velocities when isolated gains in muscular endurance or strength or power occur at the proximal segments. It has been suggested that muscular endurance and strength should be established to maximize incremental stabilization about the proximal segments. The local spinal stabilizing muscles serve as a foundational support for the development of the muscular power that promotes higher rotational velocities (6,25,27). As a result, previous studies not using interventions to establish muscular endurance in combination with sport-specific strength-to-power progressions have had limited success in improving rotational velocities. In conjunction with previous literature, the low correlations and simultaneous improvements reported in the current study between muscular endurance and power measures suggest further that these separate constructs collectively assist in improving BSS (25). Similar collective muscular improvements about the spine were reported previously for rotational velocities involving overhead throwing but not BSS (25). Therefore, it seems reasonable that collective morphological changes in muscular endurance, strength, and power between the proximal and distal musculature are necessary to maximize rotational velocities (9,34). At a minimum, neurological improvements and muscular synaptic potentiation likely contributed to faster BSS.

Increases in strength and power have been associated with improvements in swing speed (32,40); however, there are limited studies that indicate muscular endurance at the proximal core muscles to be a contributor to improved power and velocity at the distal extremities, such as in BSS. Cholwicki et al. suggested that spinal stability requires submaximal muscular contributions,

Table 5

The finisher training; refer to reference 3a and b.

	Muscular endurance activities at approximately 15–50% lifting capacity. **Muscular strength activities at approximately 60–100% lifting capacity.** **Muscular power activities at approximately 20–60% lifting capacity.** **Right/left arm transitions for all Finisher movements except when illustrated.**		
Training modes:	**Sessions 1, 2, and 5 (endurance emphasis)**	**Sessions 3, 4, and 6 (strength emphasis)**	**Total time**
Warm-up	Dynamic flexibility and light finisher progressions: push/pull/sweeps/squats/lunges	Dynamic flexibility and light finisher progressions: push/pull/sweeps/squats/lunges	5 min
Endurance	Push-pull, ladder climb, torso circles, torso twist, 45 diagonals: 60 s high pace (30-s rest between exercises)	45 diagonals, ladder climbs: 2 × 60 s Torso arch, torso push-pull, torso circles (15-to 30-s rest between exercises)	5–10 min
Perturbation	Wide squat stance, push-pull, 3 × 45 s Narrow squat stance, push-pull, 2 × 45 s Arm sweep, 45 diagonals 1 × 20 repetitions Wide perpendicular stance speed skater, 3 × 20 repetitions (15-s rest between exercises)	Single-leg push-pull, each leg, 2 × 20 repetitions In line staggered stance front push pull, 2 × 20 repetitions Bounding side to side, 2 × 60 s (45-s rest between exercises)	5–10 min
Resistance training: strength, power, transition training	Wiper, 3 × 8–12 repetitions Torso sweep arms together, 3 × 8–12 repetitions Arch, 2 × 12 repetitions Torso twist, 2 × 12 repetitions Squat push/pull, 2 × 8 repetitions Lunge left, right, 2 × 8 repetitions	Explosive wiper, arch, arm edge 2 × 45 s repetitions Torso sweep arms together, 2 × 45 s, slow/heavy resistance Torso arc, 2 × 8 repetitions, slow/heavy resistance Torso twist, 2 × 8 repetitions, slow/heavy resistance Explosive squat push/pull, 2 × 8 repetitions	30 min
Plyometric	Split squat push pull 3 × 45 s Bounding side to side 3 × 45 s	Close stance, speed skater, 4 × 6 repetitions Lunge left/right, 4 × 6 repetitions L/R synchronous circles, 4 × 6 repetitions	10 min
Cool down	2-min jog and stretch	2-min jog and stretch	5 min
	Sessions 7, 8, 10, and 13 (strength/power emphasis)	Sessions 9, 11, 12, and 14 (power emphasis)	
Warm-up	Dynamic flexibility and light finisher progressions: push/pull/sweeps/squats/lunges	Dynamic flexibility and light finisher progressions: push/pull/sweeps/squats/lunges	5 min
Endurance/mat work	Push-pull, ladder climb, torso circles, torso twist, 45 diagonals: 60-s high pace (30-s rest between exercises)	45 diagonals, ladder climbs: 2 × 60 s Torso arch, torso push-pull, Torso circles (15–30 s rest between exercises)	5 min
Perturbation	Wide squat stance, push pull, 3 × 45 s Narrow squat stance, push pull, 2 × 45 s Arm sweep, 45 diagonals 1 × 20 repetitions Wide perpendicular stance speed skater, 3 × 20 repetitions (15-s rest between exercises)	Single-leg push-pull, each leg, 2 × 20 repetitions In line staggered stance front push-pull, 2 × 20 repetitions Bounding side to side, 2 × 60 s (45-s rest between exercises) Power emphasis: low weight/explosive pattern	5–10 min
Resistance training: strength, power, transition training	Wiper, 3 × 6 repetitions Torso sweep arms together, 2 × 6 repetitions Arch, 2 × 6 repetitions Torso twist, 2 × 6 repetitions Squat push/pull, 2 × 6 repetitions Lunge left, right, 2 × 6 repetitions Power emphasis: moderate to light weight/explosive pattern	Explosive wiper, arch, arm edge 2 × 45 s repetitions Torso sweep arms together, 2 × 45 s, slow/heavy resistance Torso arc, 2 × 8 repetitions, slow/heavy resistance Torso twist, 2 × 8 repetitions, slow/heavy resistance Explosive squat push/pull, 2 × 8 repetitions Power emphasis: moderate to light weight/explosive pattern	25 min
Plyometric	Split squat push pull 3 × 45 s Bounding side to side 3 × 45 s	Close stance, speed skater, 4 × 6 repetitions Lunge left/right, 4 × 6 repetitions L/R synchronous circles, 4 × 6 repetitions	10–15 min
Cool down	2-min jog and stretch	2-min jog and stretch	5 min

such as those required during a plank and even during heavy resistance training (7,8). The endurance characteristics noted in the current study suggest that the combined training focus of muscular endurance and strength about the local muscular of the proximal spine, pelvis, and trunk may be necessary to establishing a proximal base of support for distal power (5,7,8,19,25). More research may be needed to fully understand the relationship between incremental stability, muscular endurance, and power development as contributing factors for improved BSS. There are limited studies evaluating softball BSS and the muscular contributions; however, our data offer novel insight reinforcing the necessity for developing both muscular endurance or stabilization and muscular strength to serve as a proximal base of support at the proximal segments to promote rotational BSS (1,3,7,8,10,18,19,25,28). Such outcomes have been reported to be associated with increased throwing velocity, but not BSS (25). Therefore, the similar improvements noted in plank performance in both the TT and the WsT groups indicate that the incremental proximal stabilization and multidirectional forces warranted during the WsKC enhanced proximal muscular endurance stabilization and strength more effectively than the traditional resistance training (19,25).

The inherent CKC nature of having to use ground reaction forces while maintaining a stable body position and manipulating resistance during a Finisher weight-supported workout places a targeted emphasis on establishing stability at the pelvis, spine, and trunk (1,32). Furthermore, the WsKC stimuli and stability training creates a self-perpetuated perturbation and proprioceptive overload that was previously reported to increase muscle activation at the proximal core musculature and contribute to increases in swing speeds and throwing velocity (25,32). However, the swing speed improvements from perturbation stimuli in previous literature were acute effects after a whole-body vibration stimuli, partial weight-supported treadmill running, or sling-suspension training (10,32,37). Perturbation stimuli from the WsKC seem to reinforce the biomechanical principles that enhance long-term force production from the ground to the bat. The resistance provided by the WsKC intervention seems to be a similar perturbation experienced during vibration platforms, partial weight-supported treadmill, or sling-suspension training (29). Such stimuli train the body to overcome inertia and shifts in momentum commonly associated with poor force velocity relationships between the ground and body segments (12,15,24,39,40). Similar to the Finisher, these training techniques are characterized by modifying the gravitational forces and promoting perturbation stabilization states. The self-perpetuated perturbation stimuli created by the WsKC results in counterforce movements between the appendicular and axial skeleton that enhances proximal incremental stabilization properties at the pelvis, spine, and trunk previously discussed by McGill, thus influencing explosive rotational power (18,25,29). The different arm swing patterns require a variety of variable incremental stability and mobility sequences between the ground, pelvis, spine, and trunk (3,17,19,25,28). And although our data are similar to studies using similar perturbation stimuli, the volume and intensity dosage parameters for all these techniques remain under investigation. McKneill et al. reported a reduction in metabolic expenditure and improved running efficiency as partial weight-support was increased for treadmill training; however, the gained metabolic efficiency was not directly proportionate to the percentage of body mass supported (21). Pedersen et al. and others have reported improvements in functional strength, balance, and kicking velocity after sling-suspension training. The common training attribute among these studies was the use of submaximal body mass resistances and stability or perturbation training (29,33,35). Such stimuli seem to offer different stressors not consistent with traditional resistance training techniques devices. These moments require and train incremental stabilization throughout the kinetic chain. Such stimuli seem to enhance force production, resulting in better controlled stabilization and faster velocities at the distal extremities (19,25,28). Thus, the weight-supported overload offered by the Finisher horizontal platform may offer similar alterations in resistance, resulting in more efficient metabolic development and rotational velocities when compared with traditional isotonic kinetic chain resistance training (16,21,28,34). The sliding platform of the Finisher allows transitions for push-pull or acceleration-deceleration moments obscure to traditional resistance training (16,28). The weight-supported system provides the ability to train in several degrees of freedom otherwise not accessible with traditional methods when propelling weight distal to the body's center of mass. It seems these training moments promote total body strength that is otherwise difficult to mimic in the weight room setting or with other devises.

Although we did not measure compressive forces on the body, the partial weight-supported platform reduces the vertical gravitational load on body segments when compared with other Olympic style or total body lifts such as those seen in the traditional training group (6). Further investigation is needed to compare the shear and compressive forces between the traditional-style resistance training and the WsKC intervention. The traditional strength training programs for sports of baseball and softball typically focus on developing overloads that promote maximizing full rotational range of motion about the proximal segments while developing muscular strength and power (14,25,40). Strength overloads often require technical and linear movement patterns using heavy compressive resistances at slower speeds with lower repetitions for multiple sets. Such exercises are restricted to linear movement patterns to maintain safe joint and biomechanical stability. Traditional lighter overload resistances used to develop muscular power necessary for bat speed is performed at a higher velocity at multiple rotational angles, with the intent to mimic sport-specific movement patterns and stressors that target the proximal core muscles (22,27,40). Some studies have reported a limited positive advancements in rotational velocities when combining both strength and power resistance training stimuli (1,13,31,32,40). Therefore, training interventions targeting the improvement of BSS should place emphasis on the development of muscular strength and power. However, the complexity and often applied heavy resistance required during ballistic strength and power motions can be dangerous and accompanied by extensive joint compressive forces associated with potential injury (6,20). In addition, such strength training movements are often too technically advanced, inappropriate, or difficult for preadolescent populations. Noted improvements in the literature have resulted from a combination of traditional resistance training activities and traditional lifts with variations of perturbation or vibration training (2,15), thus suggesting the perturbation stimuli to have a positive effect on power outputs (19,25). In a different manner, the closed kinetic standing positions combined with the movement patterns of the upper body on the Finisher seem to provide advantageous overloads that result in improved functional muscular strength and power while potentially reducing compressive loads on the body. In addition, the Finisher served as a universal weight training tool as we were able to implement a linear periodization model using the novel weight-supported kinetic chain resistance to target improvements in BSS. Emphasis should be placed on rotational movement patterns with muscular endurance or perturbation loads that mimic general resistance training protocols (sets or repetitions) and periodization models for the development of muscular strength and power.

The combination of off-loading the body of compressive sheer forces in multiple planes elicits the proximal segments to attain stability with the intention of optimizing distal extremity function (25,28). The strength benefits and possible reduction of compressive forces implicates the Finisher to have a potential training advantage over traditional resistance and rehabilitation training (6). Further investigations are warranted to examine more explicit areas related to dose tolerance and effectiveness between traditional training and the Finisher.

The absence of a true control group (no training) may challenge the internal validity of the current study; however, the random selection and pseudo-control comparison group (traditional training) does allow for isolation of the independent variable's effect (TT, WsKC) on the outcomes and can help rule out alternative explanations of the experimental results. Furthermore, it was unethical to not provide strength training to the test participants because it was a normal procedure. Variance in training status yielded 6 subjects who were not regularly accustomed to participating in resistive weight training. These subjects could be expected to see greater relative improvements compared with subjects of higher baseline fitness and training status. Such disparity could have resulted in higher group mean improvement scores, especially given the overall sample and group sizes ($n = 14$ and $n = 13$, respectively). However, the blocked randomization attempted to account for this bias. Given the novelty of the Finisher and the lack of formal investigations into its utilization and efficacy, calculating training volume accuracy may have some limitations with respect to the consideration of exercise intensity. It is plausible that the calculated workload for the WsT group was misinterpreted, leading to a greater potential volume, thus amplifying training adaptations compared with TT group. However, there was an attempt to maintain equal calculated volume, intensity, and total training times for each group.

A 7-week novel standing weight-supported kinetic chain resistance training program was superior in promoting improvements in isometric muscular endurance, peak power, and velocity of the muscles that support the pelvis, spine, and trunk when compared with the traditional resistance training. It seems feasible that the improvements in trunk-to-arm power or velocity accompanied simultaneous with improved BSS resulted from the training intervention. The data from the current study are similar to previous research using targeted training to the proximal core muscles (25,29). However, the horizontal push-pull movements offered unique levels of joint stress at the spinal column that provided perturbation and stabilization stimuli from a functional standing position while also providing periodized resistance overloads necessary to improve rotational power and velocity. The improvements in BSS require further research to investigate the full utility of the novel standing weight-supported kinetic chain resistance training program on muscle capacity and sport performance.

Practical Applications

Clinicians should consider incorporating linear periodization models with novel weight-supported kinetic chain resistance to target improvements in BSS. Progressing various push-pull movement patterns on the weight-supported platform in tandem with different CKC positions at the feet seems to be a key in promoting proximal synergy about the pelvis, spine, and trunk. Emphasis should be placed on movement patterns that promote rotational movements at the proximal segments and mimic the rotational movements of the bat swing. Here, perturbation moments can be used to enhance training stages that focus on muscular endurance, strength, and power contributions in helping develop rotational velocity and BSS.

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