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A Pilot Study: The Acute Effects of a Novel Kinetic Chain Weight-Supported Resistance Training Technique

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Abstract

Kinetic Chain Resistance Training (KCRT) has been used to promote gains in muscular strength. The Finisher® is a gravity-modified resistance devises which offers weight-supported kinetic chain stimuli. The purpose of this study was to investigate the effect of a six week pre- to post- Finisher® training intervention would have on muscular strength in 39 healthy volunteers. There were statistically significant increases in muscular endurance as measured by a push-up ($p = 0.010$), sit-up ($p = 0.010$), squat ($p = 0.010$), and horizontal glenohumeral joint prone abduction ($p = 0.020$). There was a significant moderate to strong positive correlations for each dependent variable ($r = 0.58$ -$r = 0.88$). There was a large effect size in the horizontal shoulder-abduction (0.91) and all dependent variables for the females (1.1-1.3) and small to large for the males (0.31-1). The kinetic chain weight-supported resistance of the Finisher® was effective in improving total body muscular endurance measures.

Keywords

Total body resistance training

Key Points

- Weight-supported Kinetic Chain Resistance Training (KCRT) utilizing multiple standing positions and push-pull motions on a horizontal plan was effective in improving muscular strength and endurance.
- The novel kinetic chain weight-supported resistance of the Finisher® provides a stimulus adequate to generate targeted muscles for both the upper and lower extremities.
- The intersegmental stability-mobility training techniques warranted during weight-supported horizontal push and pull patterns appears to engage synergy between the extremities and the musculature that support the proximal segments of the pelvis, spine and trunk.
- Improvements in horizontal glenohumeral joint prone abduction following the Finisher® intervention suggest the horizontal push-pull stimuli to be a potential resource for shoulder rehabilitation.

Introduction

Kinetic Chain Resistance Training (KCRT) has been widely used to implement a variety of overloads necessary to develop muscular strength, power and/or endurance [1-4]. KCRT is characterized by *total body movements* involving a series of multiple rigid and mobile body segments designed to work synergistically in an effort to optimize performance of a given task(s) designed to overload the musculoskeletal system [2]. Here, ground reaction forces are absorbed and transferred in a manner to generate efficiently succinct movement patterns and mimic multi-planer tasks of daily living and sport [1-4]. KCRT has been reported to target and promote increases in muscle activation, strength, power, endurance and proprioception throughout the body [3-5]. Such improvements are generally a response of a novel overload and/or the increased frequency and volume of recruited motor units created by multiple body segments acting collectively to manipulate the forces to and from

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the proximal and distal segments [1-3]. The synchronization of multiple muscle groups improves stability at the proximal segments maximizing the efficiency of energy transfer to the extremities thus optimizing the potential to generate and transfer forces. Such gains are often associated with improvements in quality of life, self-perception and performance [3,6,7].

Close kinetic chain and Olympic style lifting techniques are two very common techniques often used to improve total body muscle capabilities. However, these lifting techniques often require the use of heavy resistance and/or skilled movement patterns which place provocative loads on the musculoskeletal system [8,9]. As a result, health care providers continue to implement resistance training exercises where the influence of gravity is altered to reduce compressive and sheer force loads on the musculoskeletal system. Weight-supporting harnesses, unilateral cane mobility and hand/foot/limbed supported table slides are common examples of gravity-modified exercises. Often these techniques are reported to support the resistance in a fashion that alters loads yet have similar benefits to traditional resistance training [10]. Such exercises involve resistance training in which movement is neither assisted nor hindered by gravitational forces but provides an overload to the musculoskeletal system [10]. As a result, gravity-modified exercises are often used in the rehabilitation arena to improve muscular strength while reducing joint loads and mitigating the risk of musculoskeletal injury.

The Finisher® (Finishing Fitness, Inc. West Harris, Indi-

Figure 1: The Finisher® exercise device.

Figure 2: Example of a Finisher® exercise movement.

ana), displayed in Figure 1 and Figure 2, is a kinetic chain weight-supported device which allows for the modification of resistance and the influences of gravity. The versatility of the device allows for a variety of lower and upper body kinetic chain positions while implementing different weight shifting and multi-planar movement patterns seen in Figure 3a and Figure 3b. The adjustable height and reduced friction surface of the slide board allows the resistance to be pushed and pulled in various directions and heights in weight-bearing positions with limited compressive loads on the musculoskeletal system. Thus, our hypothesis was the Finisher® could promote improvements in muscular strength via KCRT [4]. However, little is known regarding the effect the Finisher® has on health-related components; such as muscular strength or endurance. Therefore, the purpose of this investigation was to evaluate the effect of a KCRT program performed over six weeks on the Finisher® would have on general muscle endurance.

Methods

Participants

A randomized convenience sample of thirty-nine healthy volunteers from a local fitness club (26 females and 13 males) with the average age 34 ± 4 years; height 168.5 ± 6.2 cm; weight 73 ± 4.4 Kg) were tested; Table 1. All subjects reported participating in routine weight and cardiovascular training sessions a minimum of 30 minutes, 3 times per week. Inclusion criteria were set at no reported injuries/pain prohibiting participation in the exercise or testing. Prior to testing all participants reviewed and signed an official institutional review board medical clearance and an informed consent to participate in the study. Each participant was asked to discontinue current training routine, abstain from any muscle compounding supplements and to follow a Finisher® training intervention exclusively (Table 1).

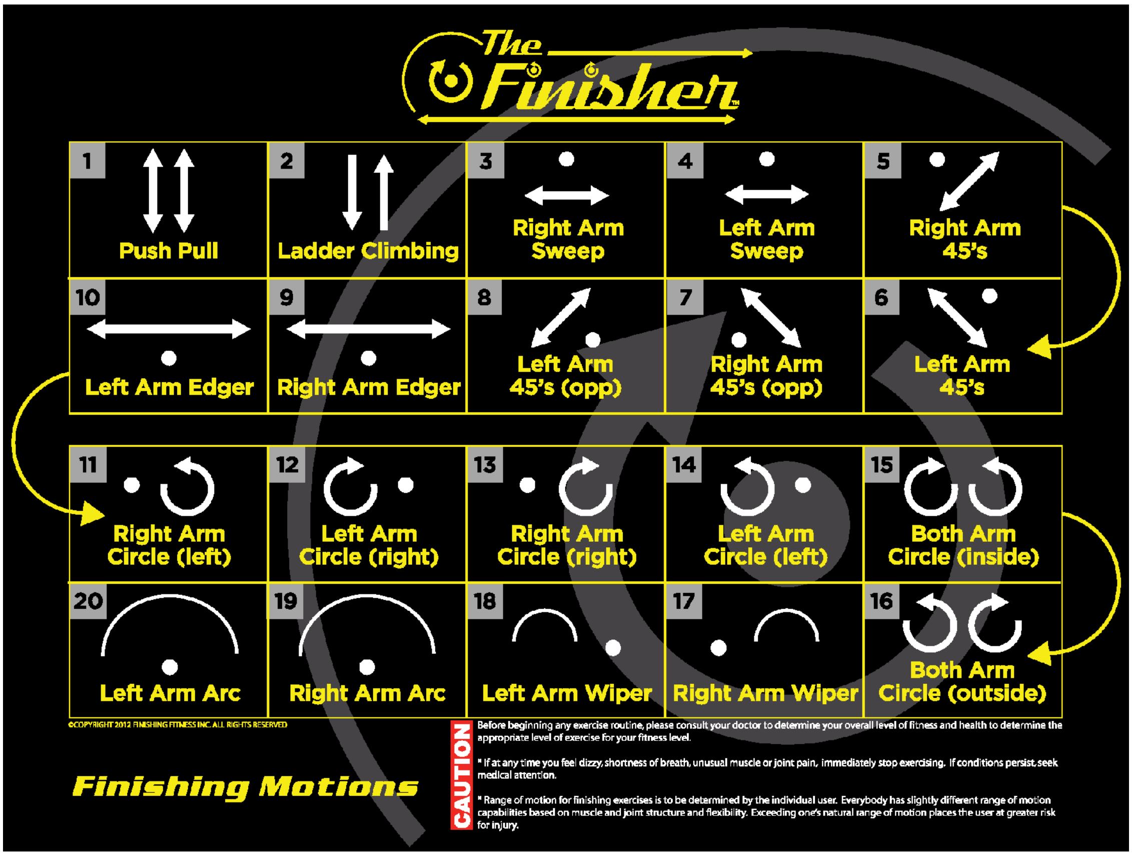

Figure 3a: Finisher motion patterns for the upper extremity.

Arrows indicate the direction the weight is moved across the table with the arms while maintaining an athletic stance.

Table 1: Participant demographics.

Variables	Female pre-test N = 26 Mean ± SD	Female post-test N = 26 Mean ± SD	Male pre-test N = 13 Mean ± SD	Male post-test N = 13 Mean ± SD	Total pre-test N = 39 Mean ± SD	Total post-test N = 39 Mean ± SD
Height, cm	164.5 ± 6.2	164.5 ± 6.2	173.8 ± 8.4	173.8 ± 8.4	169.9 ± 7.2	169.9 ± 7.2
Weight, Kg	63 ± 5.4	61 ± 5.3	83 ± 3.3	82 ± 3.3	73 ± 4.4	72 ± 4.4
Age, years	35 ± 5	35 ± 5	32 ± 5	32 ± 5	33 ± 5	33 ± 5

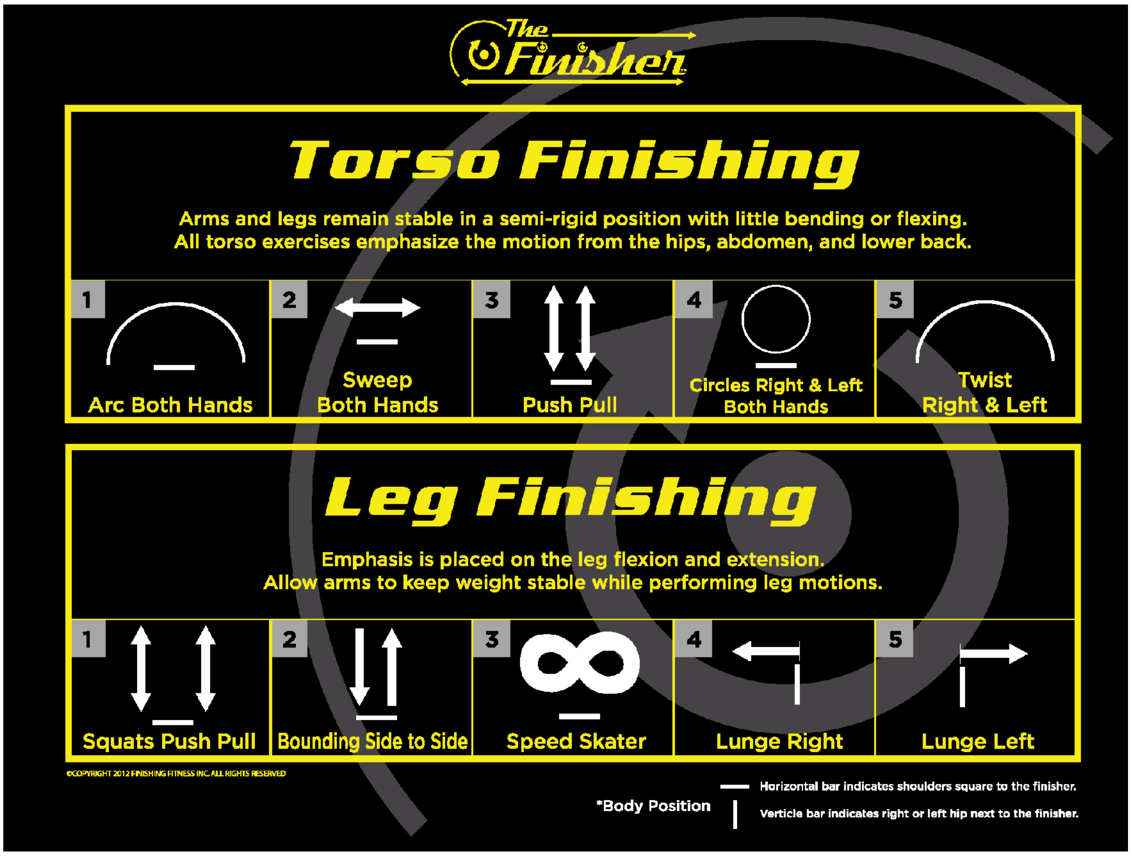

Figure 3b: Finisher motion patterns for the torso and lower extremity.

Arrows indicate the direction the weight is moved across the table while incorporating various combinations of torso rotations and leg exercises.

Procedure

A randomized clinical trial was used to assess the effect a 6 week, 45 minute, twice weekly training intervention using the Finisher® would have on strength measures. The dependent variables were the number of repetitions performed in 1 minute for push-ups, sit-ups, squats, and prone horizontal shoulder abduction. The intervention was performed in an exercise class setting directed by a certified Finisher® Strength Specialist. Participants reported on average a 98% attendance rate to all training sessions.

Procedures

Exercise testing and training procedures:

Testing procedures

All demographic information for each participant regarding height (cm), weight (kg), age (years) was collected and is displayed in Table 1. After two familiarization periods each participant performed a series of one-minute timed exercises to assess general muscular strength and endurance: push-up, sit-up, squat, and prone glenohumeral joint horizontal abduction. Tests were administered using a Latin Square randomization schedule. Participants performed each test and received a 4:1 work to rest ratio between tests. Participants completed as many repetitions as possible within one-minute. A team of certified athletic trainers, physical therapists and certified fitness experts with a combined 40 years of experience monitored each test, assured proper form and counted repetitions for each test.

a. The *Push-up Test* was performed using a traditional position and modified kneeling position for the males and females, respectively. Participants were required to lower the chest below the elbows and to maintain an erect posture in the ascending and descending positions [3-5]. Repetitions were not counted if the hip, spine or torso became flexed/extended or rotated.

b. The *Sit-up Test* was performed in a traditional supine position with knee flexion to 90 degrees and arms folded across the chest. A repetition was counted if the inferior angle of the shoulder blades lifted off and touched the ground [3-5].

c. The *Squat Test* was unweight and performed from a standing hands on hips position. Participants were required to descend from full knee extension to 90 degrees of knee flexion [3-5].

Table 2: Pearson product correlation coefficient for push-up, sit-up, squat, and horizontal shoulder abduction.

Dependent variables (N = 39)	Push-up	Sit-up	Squat	Horizontal abduction
Push-up	1	0.63 (0.003)*	0.75 (0.001)*	0.58 (0.010)*
Sit-up		1	0.88 (0.001)*	0.73 (0.012)*
Squat			1	0.81 (0.001)*
Horizontal abduction				1

*Indicates significant correlation in a 2-tailed test (P < 0.050).

Table 3: Cohn's *d* treatment effect size, confidence intervals for pre- to post-intervention for dependent variables.

Dependent variables	N	Pre-test Mean ± SD	Post-test Mean ± SD	95% Confidence interval		Effect size
				Lower bound	Upper bound	
Push-up	39	28 ± 14	36 ± 15	-27.5	-11.6	0.58#
Sit-up	39	37 ± 14	46 ± 16	-22.3	-3.8	0.66#
Squat	39	42 ± 15	46 ± 15	-25.8	-7.8	0.50#
Horizontal abduction	39	35 ± 9	46 ± 16	-12.7	0.88	0.91*

* = Indicates large effect, # = Indicates moderate effect.

Table 4: Sex differences Cohn's *d* treatment effect size, confidence intervals for pre-to post-intervention for dependent variables.

Variables	Female pre-test N = 26 Mean ± SD	Female post-test N = 26 Mean ± SD	Effect size	95% Confidence interval		Male pre-test N = 13 Mean ± SD	Male post-test N = 13 Mean ± SD	Effect size	95% Confidence interval	
				Lower bound	Upper bound				Lower bound	Upper bound
Push-up	21 ± 9	31 ± 9	1.1*	6.6	29.3	41 ± 16	46 ± 20	0.31	12	23.5
Sit-up	32 ± 11	46 ± 13	1.2*	4.9	18.2	45 ± 15	52 ± 20	0.46	3.3	24.8
Squat	36 ± 11	49 ± 14	1.1*	7.2	21.8	52 ± 16	62 ± 15	0.62#	10	27.3
Horizontal abduction	32 ± 9	44 ± 11	1.3*	1	15.7	38 ± 10	48 ± 15	1*	3.3	18.7

* = Indicates large effect, # = Indicates moderate effect.

d. The *Prone Glenohumeral Joint Horizontal Abduction Test* was performed with dumb-bells lying prone on a treatment table with the dominate arm extended in a 90 degrees of glenohumeral joint horizontal flexion. Pilot data determined male participants would perform repetitions with a 5 lbs. dumb-bell and the women with a 2 lbs. dumb-bell to accommodate for sex-related shoulder girdle size and strength differences. A repetition was counted once the hand was lifted to body height at 90 degrees of glenohumeral joint abduction [1,11].

Training intervention

The Finisher® training intervention was approximately 45 minutes consisting of a 7-10 minute warm-up, cool-down and a 30 minute Finisher® workout displayed in Figure 3a and Figure 3b. The warm-up consisted of a low intensity slow exercise regimen using the Finisher® exercises to promote upper and lower extremity mobility. The Finisher® workout protocol was a combination of 30 total-body kinetic chain resistance exercises in a standing position. Different exercises were performed concurrently using 30 second intervals between exercises with an additional rest period for approximately 1-2 minutes after each set of 10 exercises. The cool-down consisted of several Finisher® exercises at a slow pace and reduced resistance with emphasis on the terminal ROM.

Data analysis

All data was analyzed using SPSS-23, IBM. Data was assessed for normality using a Mann-Whitney U test. A paired sample t-test was used to assess pre- to post-test statistical significant differences for all dependent variables; push-up, sit-up, squat, prone horizontal shoulder abduction. An independent t-test was used to assess sex differences at pre- and post-test for all variables. A Pearson Product Correlation Coefficient displayed in Table 2 was used to assess relationships between all dependent variables. A priori significance level was set at $p \leq 0.050$. A power analysis was performed to assess the treatment Effect Size (ES) of the Finisher® intervention for each dependent variable. ES was based on a Cohn's *d* calculation; respectively the intervention group means from pre- to post-test were subtracted to represent a true control group and divided by a pooled standard deviation to determine the effect of each intervention [12]. ES data are displayed in Table 3 and Table 4. Results were interpreted as small (0-0.39), medium (0.40-0.69) or large (≥ 0.70) [13].

Results

It was hypothesized that there would be a statistically significant increase ($p \leq 0.050$) in all dependent variables following a six week training period with the Finish-

Table 5: Total group pre-to post-comparison of dependent variables.

Variables	N	Pre-test Mean ± SD	Post-test Mean ± SD	Percent change	P-value
Push-up	39	28 ± 14	36 ± 15	29	0.010
Sit-up	39	37 ± 14	46 ± 16	24	0.010
Squat	39	42 ± 15	46 ± 15	10	0.010
Horizontal abduction	39	35 ± 9	46 ± 16	31	0.020

Table 6: Independent sex differences of dependent variable.

Variables	Female pre-test N = 26 Mean ± SD	Female post-test N = 26 Mean ± SD	Percent change	Male pre-test N = 13 Mean ± SD	Male post-test N = 13 Mean ± SD	Percent change	P-value
Push-up	21 ± 9	31 ± 9	48	41 ± 16	46 ± 20	12	0.010*
Sit-up	32 ± 11	46 ± 13	44	45 ± 15	52 ± 20	16	0.080
Squat	36 ± 11	49 ± 14	36	52 ± 16	62 ± 15	19	0.710
Horizontal abduction	32 ± 9	44 ± 11	38	38 ± 10	48 ± 15	26	0.330

*Significance difference at p ≤ 0.050, F = F value for independent sample test with equal variance, df = Degrees of Freedom for independent sample test with equal variance.

er®. Table 5 indicates the push-up, sit-up, squat and the glenohumeral joint horizontal abduction tests had significant improvements pre- to post-intervention which supports the hypothesis that the Finisher® intervention would improve strength and endurance test measures in each dependent variable.

Females had a significantly greater increase in the push-up (p = 0.010) following the Finisher® intervention. There was no significant sex difference for all other dependent variables at post-intervention as reported in Table 6.

There were moderate to strong positive correlations for each dependent variable as reported in Table 2. The strongest correlations were found between the squat and sit-up (r = 0.88) and the squat and shoulder abduction (r = 0.81). The remaining correlations were moderate between the push-up and sit-up (r = 0.63), the push-up and squat (r = 0.75), the push-up and shoulder abduction (r = 0.58) and the sit-up to squat (r = 0.73).

The treatment effect from pre-to post-test was further analyzed by calculating an Effect Size (ES) with corresponding 95% Confidence Intervals (CI) for each dependent variable [12]. Prone horizontal glenohumeral joint abduction had a strong effect size for the entire group (0.91) while the remaining variables had moderate to small effects (0.27-0.66). Sex effect sizes were large for all dependent variables for the females (1.1-1.3) and small to large for the males (0.31-1) Table 3 and Table 4.

Discussion

The novel total body kinetic chain stimuli provided by the Finisher® was adequate to promote improvement in each of the dependent variables. The statistically significant improvements in each test indicate the Finisher® provides loads that generate targeted muscle activations for both the upper and lower extremities. The transfer of energy about the kinetic chain is likely a result of proximal stability about the pelvis, spine and trunk [14]. Previous literature has reported increases in muscular strength at the proximal segments with KCRT as a result of increased muscle activation [14-16]. The standing position often limits the amount of force the whole body can produce, however it enhances muscle activation about the proximal muscles which provides a stable base for the limbs to transfer and absorb forces [14]. Santana, et al. demonstrated inferior force output from a standing cable row verse a flat bench press; however the standing resistance had superior spine and trunk muscle activation [4]. A majority of the training on the Finisher® was from a standing position while the arms pushed and pulled a resistance. The synchronization of multiple muscle groups and redistribution of gravity appears to improve stability at the proximal segments maximizing the efficiency of energy transfer to the extremities. The end result being improved ability for the extremities to generate and sustain forces [4,8]. Our data suggests the improvement in the individual tests resulted from a variety of multi-planar loads offered by the Finisher® at the torso and the extremities from a standing position. Although not directly measured, improvements in these types of muscular strength performance are likely a result of morphological changes combined with enhanced neuromuscular activation between the proximal and distal kinetic chain musculature [4]. Such benefits are not uncommon for total body resistance training, however the weight-supported mechanism likely offers unique load transfers with likely less compressive loads.

Closed kinetic chain training or total body resistance training similar to that provided by the Finisher® has been reported to impact performance in strength movements, sport performance and in the rehabilitation of injury [3,17-19]. However, the sliding platform and the push-pull/acceleration-deceleration moments seem to offer a different type of overload not seen in traditional kinetic chain training. Transitions between the acceleration and deceleration of the weight provide strength benefits within a reaching and pulling range of motion obscure to traditional lifting. The weight-supported system seems to provide the ability to train in several degrees of freedom which can enhance range of motion that is not restricted when propelling the weight out from the center of the body's mass. The unique push and pull patterns of the Finisher® on the horizontal/diagonal plans places emphasis on acceleration/deceleration moments throughout the exercise movements. It appears these training moments promote total body strength that is otherwise difficult to mimic in the weight room setting [4]. Further investigation is needed to investigate the outcomes of traditional style resistance training verse a Finisher® intervention.

The Finisher® seems to provide advantageous overloads that result in improved functional strength while reducing compressive loads on the body. While we did not measure compressive forces the partial weight-supported platform reduces the vertical load on body segments when compared to other Olympic style or total body lifts such as a squat. Indications from previous reports suggest partial weight-supported modification of the resistance provided by the platform results in less overall metabolic and muscle exertion when compared to traditional kinetic chain or Olympic style lifting [4,20]. However, the potential benefits from the Finisher® and related weight-supported devices are not fully understood. Weight-supported KCRT, such as, partial weight-supported treadmill and sling-suspension training are characterized by modifying the gravitational pull on the body. Our data is similar to previous kinetic chain weight-supported training; however volume and intensity dosage parameters remain under investigation. McKneill, et al. reported a reduction in metabolic expenditure and improved running efficiency as partial weight-support was increased; however the gained efficiency was not directly proportionate to the percentage of body weight supported. Pedersen, et al. and others have reported improvements in sport skills following sling-suspension training, however the only common training attribute among these studies was linked to submaximal resistances and limitations in stability, not training dosage [3,21,22]. Further, there remains limited data as to the effect weight-supported linear verse undulating progressions have on strength performance. Our data suggests that the kinetic chain resistance provided by the Finisher® models those of the sling-suspension training. The combination of off-loading the body in multiple-planes warrants the proximal segments to attain stability with the intention of optimizing distal extremity function [23]. The strength benefits and possible reduction of compressive forces proposes the Finisher® to have a potential training advantage over traditional resistance and/or rehabilitation training [24]. Investigations are warranted to examine traditional training doses verse the Finisher®. The cause and effect relationship of the Finisher® and its effects on sport, rehabilitation, and fitness parameters is not fully understood, but pose as a sensible training stimulus.

The large treatment effect (ES = 0.91) for the prone glenohumeral joint horizontal abduction test was likely due to a potential isolated muscular weakness within our population. This exercise has been identified as a scapular stabilizing exercise with high effectiveness in activating and training the terse major and infraspinatus muscles for healthy and pathological populations. Due to the fact that our population was healthy and reported no episodes of shoulder pathology the Finisher® intervention likely targeted a muscle synergy weakness commonly reported to contribute to glenohumeral joint instability [25]. As our population was reported to participate in regular exercise routines and resistance training it seems reasonable to surmise that training on the Finisher® maybe superior in targeting scapular stability when compared to general fitness training. It seems reasonable that the push and pull patterns on the platform at waist height resulted in a reduction of over activity of the levator scapulae and upper trapezius by forcing use of the mid and lower scapular stabilizers [19]. The protraction-to-retraction exchange is a primary movement requiring controlled scapular mobility while under stress, but not compressed. Not carrying the weights may have also contributed to proper scapular force coupling of the stabilizers which represent the kinetic chain connection between the shoulder complex and the posterior muscles about the lumbothorasic fascia and the lower extremity.

Based on our results, the Finisher® can be classified as a true kinetic chain resistance devise. While it seems to emphasize upper extremity involvement the improvements noted throughout all the dependent variables and the moderate to high correlations between the squat and the upper extremity tests (0.75, 0.81) suggest otherwise. In fact, the squat had the highest correlation with all the tests (0.63-0.81). The manipulation of the resistance/weight on the Finisher® platform in essence provided an off-loading of the overall bodyweight and in return reduced the load on the spine and hip complex while likely necessitating increased stability at the proximal segments. Further, a variation of mini-squats and staggered foot positions are inherent and necessary to maximize the use of ground reaction forces throughout all training sessions. Such positioning enhanced the development of the strength and stability from the hand to the ground.

The statistical significant increases and the effect sizes among sexes in the current study mimic similar training effects noted from traditional resistance training [11]. Therefore, it was not surprising that there were no statistical differences via P-value between Sexes, however the greater effect sizes among the females (ES = 1.1-1.3) when compared to the males (ES = 0.31-1) indicates there was a potentially greater impact on females regarding muscular endurance gains. This was likely due to a ceiling effect of the strength measures among the males. Generally speaking, males tend to carry more mass and potentially leaner muscle mass making them stronger regardless of fitness levels [11]. However, the population in the current study was physically active which indicates they had a significant degree of dedication to exercise and had good strength and fitness levels [11]. Thus, the novel training style appears to be advantageous for individuals currently participating in a regular scheduled weekly exercise program.

Our intension was to determine if the Finisher® device was effective in promoting strength/endurance gains. The overall improvements in the data provide evidence that the Finisher® is a viable training device regardless of sex. A primary limitation in the study was the lack of a matched control group as it limits the generalizability of the outcomes. Matched control studies would strengthen the generalizability of the utility for the Finisher®. Yet these outcomes indicate the Finisher® and similar techniques have promise for a multitude of training interventions. Despite these limitations, our data provides a good foundation regarding the cause and effect relationships a Finisher® intervention has on muscle gains among a general fitness population. As such, the resistance provided by the device may serve as an additional option for clinicians to progress rehabilitation and training protocols. Future research should aim to target both general fitness groups, sport and/or rehabilitation groups that require decreased compressive loads. In addition, training specificity for injury prevention and/or sport are areas to exploit in future research regarding different loading patterns and progressions of weight-supported exercise [3].

Conclusion

The Finisher® is an effective KCRT device for providing improvements in strength with a novel multi-planar weight-supported platform. The construct of the Finisher® offers weight-supported training that reduces joint loads and compressive forces. The outcomes from out study are promising but further research is needed to determine the full utility of the Finisher® for sport and rehabilitation practices.

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