

Research article

## The Effects of Multiple-Joint Isokinetic Resistance Training on Maximal Isokinetic and Dynamic Muscle Strength and Local Muscular Endurance

Nicholas A. Ratamess<sup>1</sup>✉, Noah A. Beller<sup>1</sup>, Adam M. Gonzalez<sup>2</sup>, Gregory E. Spatz<sup>1</sup>, Jay R. Hoffman<sup>2</sup>, Ryan E. Ross<sup>1</sup>, Avery D. Faigenbaum<sup>1</sup> and Jie Kang<sup>1</sup>

<sup>1</sup>Department of Health and Exercise Science, The College of New Jersey, Ewing, NJ, USA

<sup>2</sup>Institute of Exercise Physiology and Wellness, University of Central Florida, Orlando, FL, USA

### Abstract

The transfer of training effects of multiple-joint isokinetic resistance training to dynamic exercise performance remain poorly understood. Thus, the purpose of the present study was to investigate the magnitude of isokinetic and dynamic one repetition-maximum (1RM) strength and local muscular endurance increases after 6 weeks of multiple-joint isokinetic resistance training. Seventeen women were randomly assigned to either an isokinetic resistance training group (IRT) or a non-exercising control group (CTL). The IRT group underwent 6 weeks of training (2 days per week) consisting of 5 sets of 6-10 repetitions at 75-85% of subjects' peak strength for the isokinetic chest press and seated row exercises at an average linear velocity of 0.15 m·s<sup>-1</sup> [3-sec concentric (CON) and 3-sec eccentric (ECC) phases]. Peak CON and ECC force during the chest press and row, 1RM bench press and bent-over row, and maximum number of modified push-ups were assessed pre and post training. A 2 x 2 analysis of variance with repeated measures and Tukey's post hoc tests were used for data analysis. The results showed that 1RM bench press (from 38.6 ± 6.7 to 43.0 ± 5.9 kg), 1RM bent-over row (from 40.4 ± 7.7 to 45.5 ± 7.5 kg), and the maximal number of modified push-ups (from 39.5 ± 13.6 to 55.3 ± 13.1 repetitions) increased significantly only in the IRT group. Peak isokinetic CON and ECC force in the chest press and row significantly increased in the IRT group. No differences were shown in the CTL group for any measure. These data indicate 6 weeks of multiple-joint isokinetic resistance training increases dynamic muscle strength and local muscular endurance performance in addition to specific isokinetic strength gains in women.

**Key words:** Chest press, seated row, strength training, bench press.

### Introduction

Isokinetic training has been a popular form of resistance training since the late 1960s (Hislop and Perrine, 1967; Thistle et al., 1967). Isokinetic dynamometers provide the trainee with the ability to contract skeletal muscles with near-maximal or maximal effort at controlled velocities. Several studies have shown that isokinetic resistance training at a spectrum of joint angular velocities increases muscle strength (Adeyanju et al., 1983; Cadore et al., 2014; Coyle et al., 1981; Kelly et al., 2007; Lesmes et al., 1978) and power and rate of force development (Cadore et al., 2014; Kanehisa and Miyashita, 1983). In addition, isokinetic resistance training has been shown to increase knee extension rate of velocity development (Brown and

Whitehurst, 2003; Murray et al., 2007), and knee flexion and extension muscle endurance (Adeyanju et al., 1983; Lesmes et al., 1978). However, studies investigating the carryover effects of isokinetic training to dynamic maximal muscular strength and endurance performances are few (Pipes and Wilmore, 1975). Although isokinetic peak concentric (CON) and eccentric (ECC) torques at various angular velocities have been shown to correlate to several measures of performance such as vertical jump (Bosco et al., 1983), 40-yd dash sprint speed (Anderson et al., 1991), agility (i.e. figure 8 drill) performance (Anderson et al., 1991), 6-sec maximal stationary cycling performance (Wilson et al., 1997), kicking velocity (Masuda et al., 2005), and throwing velocity (Pedegana et al., 1982), part of the issue is that the vast majority of studies have only used single-joint isokinetic measures. Single-joint exercises isolate one major joint action and/or major muscle group in an open kinetic chain and may lack external validity when used to assess athletic performance (Wilson et al., 1997). The majority of athletic skills involve multiple-joint actions recruiting large muscle mass. Wilson et al. (1997) showed stronger relationships between 6-sec maximal stationary cycling performance and multiple-joint isokinetic squat performance ( $r = 0.57$  to  $0.65$ ) than 6-sec maximal cycling performance and single-joint knee extension isokinetic peak torque ( $r = 0.45$  to  $0.51$ ). Thus, multiple-joint isokinetic measures may serve as a more valid isokinetic testing and training modality for athletic purposes.

The concept of multiple-joint isokinetic exercise dates back to the 1970s (Pipes and Wilmore, 1975) although relatively few studies have examined its utility. Several researchers have used multiple-joint isokinetic assessment protocols for exercises such as the leg press (Dvir 1996; Engle, 1983; Levine et al., 1991), squat (Fry et al., 2000; 2003; Hortobagyi and Katch, 1990; Weiss and Relyea, 1997; Weiss et al., 1996; 1998; Wilson et al., 1997), and bench press/chest press (Hoffman et al., 2011; Hortobagyi and Katch, 1990; Miyaguchi and Demura, 2012) and have generally shown high testing reliability (Fry et al., 2000; 2003; Weiss et al., 1996; Wilson et al., 1997). Weiss and Relyea (1997) showed that multiple-joint isokinetic squat testing across a spectrum of linear velocities produced similar force-velocity and power-velocity curves to single-joint isokinetic assessments.

However, only few studies have investigated strength and local muscular endurance increases during multiple-joint isokinetic resistance training. In particular,

the potential for multiple-joint isokinetic resistance training to elicit transfer of training effects to non-isokinetic measures of muscle strength and endurance performance remains under studied. Pipes and Wilmore (1975) showed that isokinetic resistance training (including three multiple-joint exercises) significantly increased isokinetic (elbow flexion, extension, shoulder extension, bench press at 24 and 136°/sec), isometric (bench press, elbow flexion, extension, knee extension at 90° and 135°), and dynamic leg press, bench press, arm curl, and bent-over row 1RM strength. Sharp et al. (1982) showed that 4 weeks of training on a quasi-isokinetic dynamometer designed to replicate a swim stroke increased arm power by 18.7% and swim performance by 3.8%. Papadopoulos et al. (2014) investigated 8 weeks (2 times per week) of ECC isokinetic leg press training and reported significant increases (13 to 26%) in drop jump height and maximal power in addition to large increases in maximal ECC (65%) and CON (32%) leg press force. It appears from the results of only few studies that multiple-joint isokinetic resistance training may enhance non-isokinetic performance. However, potential transfer effects to dynamic maximal strength and endurance performance remain largely unknown despite increasing popularity of new isokinetic dynamometers developed during the past 10 years.

Therefore, the purpose of the present study was to investigate the magnitude of isokinetic and dynamic strength and muscular endurance increases using a recently-developed dynamometer. It was our hypothesis that 6 weeks of multiple-joint isokinetic resistance training alone would significantly increase free-weight (bench press and bent-over row) maximal strength and upper-body local muscular endurance in women. This study design enabled us to investigate the potential for multiple-joint isokinetic resistance training to increase isokinetic and dynamic muscular strength and endurance performance. Specifically, the primary objective of the present study was to investigate potential transfer of training effects of multiple-joint isokinetic training to dynamic 1RM strength and local muscle endurance (modified push-up) performance and not to compare multiple-joint isokinetic resistance training to other resistance training modalities. Thus, only one isokinetic training group was examined for this purpose.

## Methods

### Subjects

Seventeen healthy women agreed to participate in the present study (Table 1). None of the women were actively participating in resistance training prior to the study. Seven of the subjects had no resistance training experience whereas 10 subjects had previous experience but had not trained within a 6-month period prior to initiating the present study. Subjects underwent one week of familiarization (2-3 sessions) with study procedures prior to testing and refrained from all other exercise throughout the experimental period. Familiarization focused on subjects' ability to perform the testing exercises and accustom them to the isokinetic dynamometer. During this time, height

was measured using a wall-mounted stadiometer and body mass was measured using an electronic scale. Percent body fat was estimated via a three-site skinfold test. The sites measured were the triceps, suprailiac, and thigh skinfolds for women using methodology previously described (Jackson and Pollock, 1980). Body density was calculated using the equation of Jackson and Pollock (1980) and percent body fat was calculated using the equation of Siri (1956). The same research assistant performed all skinfold assessments. This study was approved by the college's Institutional Review Board and conformed to the policy statement with respect to the Declaration of Helsinki. Each subject was informed of the study requirements, criteria, and risks and subsequently signed an informed consent document prior to participation. No subject had any physiological or orthopedic limitations that could have affected exercise performance as determined by completion of a health history questionnaire.

**Table 1.** Descriptive characteristics of subjects. Data are means ( $\pm$ SD).

	IRT (n = 10)	CTL (n = 7)
Age (yrs)	20.5 (1.0)	20.9 (2.0)
Height (m)	1.66 (.05)	1.61 (.06)
Body Mass (kg)	62.6 (11.1)	58.0 (7.2)
Percent Body Fat (%)	23.0 (7.4)	22.3 (7.8)
1RM Bench Press (kg)	38.6 (6.7)	36.0 (7.2)
1RM Bent-over Row (kg)	40.4 (7.7)	42.9 (6.6)

### Testing procedures

In order to examine the primary hypothesis of the present investigation, subjects were randomly divided into an isokinetic resistance training (IRT) group or a non-exercising control (CTL) group. The IRT group underwent 6 weeks of training (2 days per week on nonconsecutive days) consisting of 5 sets of 6-10 repetitions at 75-85% of subjects' peak CON and ECC strength for the isokinetic chest press and seated row exercises at an average linear velocity of 0.15 m·s<sup>-1</sup> (3-sec CON and 3-sec ECC phases). Peak CON and ECC force during the chest press and seated row, 1RM bench press and bent-over row, and maximum number of push-ups performed were assessed pre and post training.

### Free-weight strength testing

One-repetition maximum strength was assessed for the barbell bench press and bent-over row using a standard protocol (Kraemer et al., 2006; Ratamess et al., 2007) during the same testing session. For each exercise, a warm-up set of 5-10 repetitions was performed using 40-60% of the perceived 1RM. After a 1-min rest interval, a set of 2-3 repetitions was performed at 60-80% of the perceived 1RM. Subsequently, 2-4 maximal trials were performed to determine the 1RM with 2-3 min rest intervals between trials. A complete range of motion and proper technique was required for each successful 1RM trial. For the bench press, the bar was lowered until it touched the lower-to-mid sternum (with no "bouncing") and was lifted to full elbow extension (with no excessive arching of the back). For the bent-over barbell row, subjects initiated the exercise from the floor position and

raised the bar until it touched the upper rectus abdominis with minimal hip motion.

### Local muscle endurance assessment

Local muscle endurance was assessed using the maximal number of push-ups to exhaustion test pre and post training (Hoffman 2006). A modified push-up (with knees flexed and on the ground) was performed due to difficulty some of the women had in performing a standard push-up. Studies have shown that there is an 8-16% reduction in the percentage of body weight supported during a modified push-up (Ebben et al., 2011; Suprak et al., 2011). Standardized technique was used where hand spacing was self-selected (wider than shoulder width), measured, and marked with tape so each intra-subject test was performed under identical conditions. To standardize range of motion, a female research assistant was positioned superior to the subject with a fist positioned under the subject's sternum. The subject had to descend until their sternum touched the research assistant's fist and then subsequently performed the "up" phase in order for a repetition to count at a self-selected cadence. Any repetitions failing to meet this criterion were discarded. Subjects were instructed to perform as many repetitions as possible using a self-selected cadence and were not allowed to rest in between repetitions in order to prolong the set.

### Measurement of peak isokinetic force

Peak CON and ECC force was measured with a multiple-joint isokinetic dynamometer (Exerbotics, Tulsa, OK) using methods previously described (Hoffman et al., 2011). The exercises selected for testing were the chest press and seated row. Each subject assumed a vertical position on the device, was properly fitted and stabilized, and the exercise range of motion was established and standardized for all subsequent sessions. Range of motion was established so that dynamometer arm was aligned with the torso at one end (i.e. at the beginning of the CON phase) and to a position of  $\sim 5\text{-}10^\circ$  short of full elbow extension at the opposite end (i.e. at the end of the CON phase) for the chest press. For the seated row, the dynamometer arm was positioned near full elbow extension for the beginning of the CON phase and to a position aligned with the torso for the end of the CON phase. Dynamometer linear velocity was set at 3 sec for each CON and ECC phase which corresponded to approximately  $0.15\text{ m}\cdot\text{s}^{-1}$ . Subjects performed 3 maximal repetitions consecutively and the highest CON and ECC force output was recorded for analysis. Force values obtained during the initial and final segments of each repetition were not considered to minimize potential acceleration and deceleration effects. For the ECC phase, each subject was carefully instructed to resist the dynamometer arm as maximally as possible. For the CON phase, each subject was carefully instructed to "push" (for the chest press) or "pull" (for the seated row) as maximally as possible. Force was measured via force transducers built into the dynamometer and was displayed on the computer monitor located directly in front of the subject. The isokinetic device produced real-time force output thereby enabling the subject to visualize effort and adjust force output accordingly. Peak CON and

ECC force was measured before and after the training period and each time subjects came to the laboratory after a general warm-up. Test-retest reliability of the dynamometer force measures has been established in our laboratory as  $r = 0.99$  (Hoffman et al., 2011).

### Isokinetic resistance training program

The IRT group underwent 6 weeks of isokinetic resistance training (2 days per week) totaling 12 workouts. The training program consisted of performing 5 sets of the chest press and seated row for 6 – 10 repetitions per set at 75-85% of peak CON and ECC force, respectively, with 2-min rest intervals in between sets. Intensity was initiated at 75% of peak CON and ECC force (for 10 repetitions) but then progressed to 80% (8 repetitions) and 85% (6 repetitions) in two-week intervals. The duration of the CON and ECC phases of each repetition was set at 3 sec or a slow linear velocity of approximately  $0.15\text{ m}\cdot\text{s}^{-1}$ . Prior to each training session subjects peak CON and ECC force was measured on the dynamometer in order to accurately prescribe training intensity. The isokinetic device monitor displayed peak force and a line representing the force curve needed to attain the targeted intensity (i.e. 75-85% of peak force) throughout the exercise range of motion. Subjects were instructed to provide enough force so that the real-time force output paralleled the target line on the monitor. In the event subjects could no longer reach the targeted intensity due to fatigue, they were encouraged to provide maximal effort until the required numbers of repetitions were performed. Subjects attended 2-3 familiarization sessions prior to beginning the study to accommodate to the device but also to practice providing force sufficient to match the curves. The CTL group did not participate in any exercise program during the experimental period.

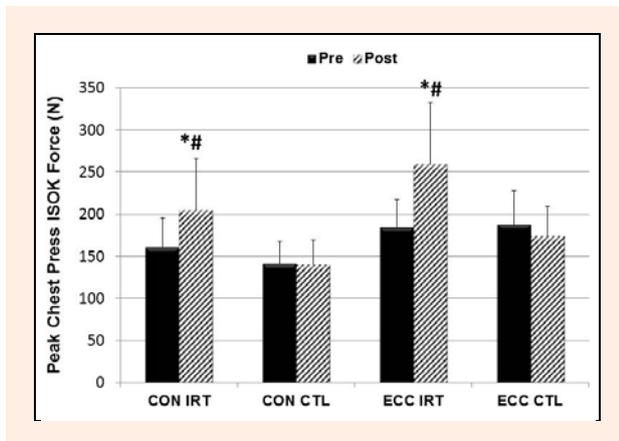
### Statistical analyses

Descriptive statistics (means  $\pm$  SD) and tests of normality were calculated for all dependent variables. A two (group)  $\times$  two (time point) analysis of variance (ANOVA) with repeated measures was used to analyze performance data. Subsequent Tukey's *post hoc* tests were utilized to determine differences when significant main effects or interactions were obtained. Partial eta-square ( $\eta^2$ ) effect sizes were determined for time and treatment effects and interpreted using the following criteria: 0.01 = small; 0.06 = medium; and 0.13 = large. For all statistical tests, a probability level of  $p \leq 0.05$  denoted statistical significance.

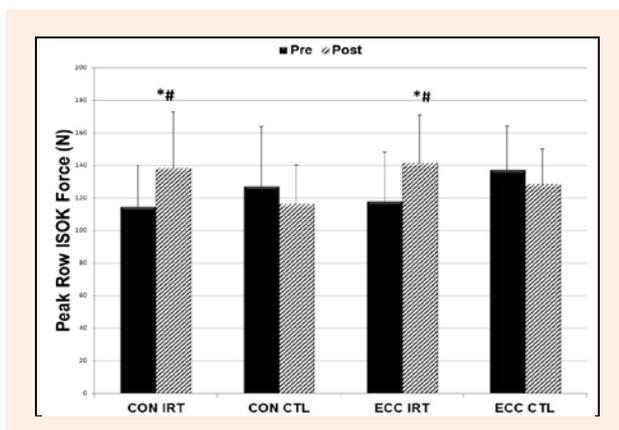
### Results

Peak CON and ECC isokinetic force data for the chest press and seated row are presented in Figures 1 and 2. A significant time effect was observed in peak CON ( $p = 0.003$ ;  $\eta^2 = 0.47$ ) and ECC ( $p = 0.04$ ;  $\eta^2 = 0.46$ ) force where only the IRT group showed significant increases for the chest press. A significant time effect was observed in peak CON ( $p = 0.05$ ;  $\eta^2 = 0.21$ ) and ECC ( $p = 0.04$ ;  $\eta^2 = 0.27$ ) force where only the IRT group showed significant increases for the row. A significant interaction was shown for ECC chest press ( $p = 0.0001$ ;  $\eta^2 = 0.63$ ) and

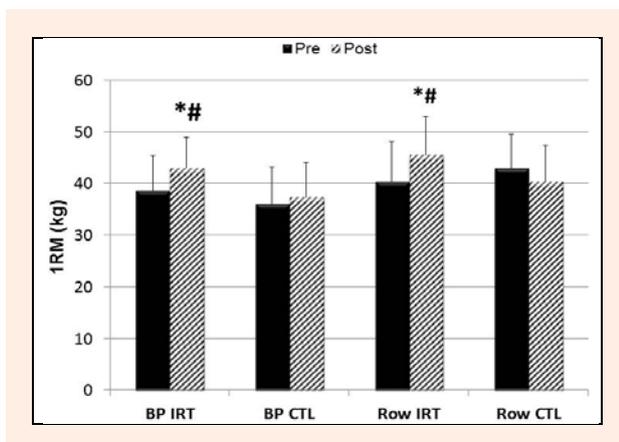
row peak force ( $p = 0.001$ ;  $\eta^2 = 0.59$ ). A significant interaction was also shown for the CON chest press ( $p = 0.003$ ;  $\eta^2 = 0.48$ ) and row ( $p = 0.03$ ;  $\eta^2 = 0.29$ ). No significant changes were observed in the CTL group.



**Figure 1.** Changes in peak isokinetic CON and ECC chest press force (N). CON – concentric; ECC – eccentric; \*  $p \leq 0.05$  from corresponding pre-training time point. #  $p \leq 0.05$  interaction between groups.



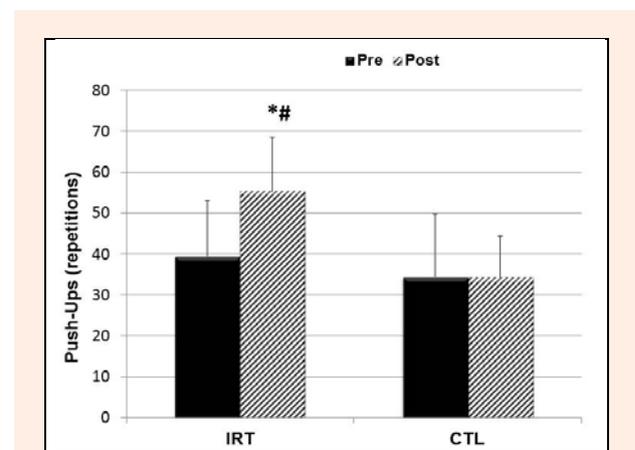
**Figure 2.** Changes in peak isokinetic CON and ECC seated row force (N). \*  $p \leq 0.05$  from corresponding pre-training time point. #  $p \leq 0.05$  interaction between groups.



**Figure 3.** Changes in 1RM bench press and bent-over row strength. \*  $p \leq 0.05$  from corresponding pre-training time point; #  $p \leq 0.05$  interaction between groups.

One repetition-maximum strength and modified

push-up results are shown in Figures 3 and 4. Repeated measures ANOVA revealed significant time effects for the 1RM bench press ( $p = 0.0001$ ;  $\eta^2 = 0.69$ ) and bent-over barbell row ( $p = 0.047$ ;  $\eta^2 = 0.27$ ). 1RM bench press (by 10.2%) and bent-over barbell row (by 11.2%) increased significantly only in the IRT group from pre to post training. In addition, a significant group interaction was observed for the 1RM bench press ( $p = 0.009$ ;  $\eta^2 = 0.39$ ) and bent-over row ( $p = 0.0001$ ;  $\eta^2 = 0.80$ ). For the maximal push-up test, a significant time effect ( $p = 0.004$ ;  $\eta^2 = 0.34$ ) and group interaction ( $p = 0.002$ ;  $\eta^2 = 0.38$ ) was observed where only the IRT group significantly increased the number of repetitions completed by 28.6%. No significant differences were observed in the CTL group for 1RM strength or maximal number of modified push-ups performed from pre to post training.



**Figure 4.** Changes in maximal push-up performance. \*  $p \leq 0.05$  from corresponding pre-training time point. #  $p \leq 0.05$  interaction between groups.

## Discussion

The salient finding of the present study is that six weeks of multiple-joint isokinetic resistance training increases dynamic maximal muscular strength and local muscular endurance in addition to maximal isokinetic strength in relatively untrained women. Large effect sizes were shown when examining increases in dynamic and isokinetic maximal strength and endurance. Subjects in the IRT group significantly increased 1RM strength in the bench press (10.2%) and bent-over barbell row (11.2%) exercises and increased maximal push-up performance by 28.6%. The results of the present study provide evidence that multiple-joint isokinetic resistance training has direct beneficial carryover effects to dynamic exercise performance in addition to modality-specific CON and ECC strength gains. The carryover effects may be attractive to strength training and conditioning professionals seeking to include alternative modalities to resistance training programs.

The use of multiple-joint isokinetic dynamometers for strength, power, and endurance testing and training has been limited. Some researchers have used multiple-joint testing protocols for exercises such as the leg press

(Dvir 1996; Engle, 1983; Levine et al., 1991), squat (Fry et al, 2000; 2003; Hortobagyi and Katch, 1990; Weiss and Relyea, 1997; Weiss et al., 1996; 1998; Wilson et al., 1997), and bench press/chest press (Hoffman et al., 2011; Hortobagyi and Katch, 1990; Miyaguchi and Demura, 2012) for assessing isokinetic muscular strength and power. However, only a few studies have investigated isokinetic multiple-joint training. Pipes and Wilmore (1975) compared dynamic (3 sets of 8 repetitions with 75% of 1RM) to slow (3 sets of 8 repetitions at 24°/sec) and fast (3 sets of 15 repetitions at 136°/sec) isokinetic training (3 days per week for 8 weeks) using the bench press, biceps curl, leg press, and bent row exercises. The authors reported that isokinetic training produced superior increases in isometric and isokinetic strength. In addition, isokinetic training increased dynamic 1RM strength by 10 to 21% with high-velocity multiple-joint isokinetic training producing more comprehensive increases in 3 of the 4 exercises. Isokinetic training also increased vertical jump height and reduced 40-yard sprint times. Sharp et al. (1982) showed that 4 weeks of training on a quasi-isokinetic dynamometer designed to replicate a swim stroke increased arm power by 18.7% and swim performance by 3.8%. Papadopoulos et al. (2014) investigated 8 weeks (2 times per week) of eccentric isokinetic leg press training and reported significant increases (13 to 26%) in drop jump height and maximal power in addition to large increases in maximal eccentric (65%) and concentric (32%) leg press force. These studies have demonstrated the potential utility of multiple-joint isokinetic resistance training for improving several different fitness components.

A primary finding in the present investigation was multiple-joint isokinetic resistance training resulted in large strength training effects ( $\eta^2 = 0.27$  to  $0.80$ ) as dynamic 1RM strength in the bench press and bent-over barbell row increased by 10.2% and 11.2%, respectively. These strength increases were less than those reported by Pipes and Wilmore (1975) who reported 1RM bench press increases of 13.7 to 14.2% and 1RM bent row increases of 10.7 to 21.4%. The greater increases reported by Pipes and Wilmore (1975) may have been due to use of male subjects, untrained status of the subjects, training velocity, and duration of the present study (i.e. 8 weeks [24 workouts] versus 6 weeks [12 workouts] in Pipes and Wilmore [1975] and the present study, respectively). The results of these studies indicate that multiple-joint isokinetic resistance training does have significant carryover effects to dynamic maximal muscular strength increases.

Multiple-joint isokinetic resistance training significantly increased peak isokinetic CON and ECC force production ( $\eta^2 = 0.21$  to  $0.63$ ). Peak CON and ECC chest press force increased by 21.8 and 29.0%, respectively, while CON and ECC seated row peak force increased by 17.2 and 20.5%, respectively, in the IRT group. These results support several studies that have shown that single-joint isokinetic resistance training increases CON and ECC peak torque (Adeyanju et al., 1983; Coyle et al., 1981; Lesmes et al., 1978). Papadopoulos et al. (2014) investigated 8 weeks (2 times per week) of ECC isokinetic leg press training and reported significant increases in

maximal ECC (65%) and CON (32%) leg press force. Pipes and Wilmore (1975) reported that isokinetic resistance training increased isokinetic strength at 24 and 136°/sec up to 96%. The results of previous studies, in addition to the results of the present study, indicate a high degree of training specificity.

Peak isokinetic ECC force increased to a greater extent than peak CON force. Although subjects in the IRT group in the present study were exposed to both isokinetic CON and ECC resistance training, these results support previous studies indicating greater increases in ECC strength following ECC strength training than CON strength following CON strength training (Hortobagyi et al., 1996a; 1996b; Roig et al., 2009). Eccentric training involves higher mechanical tension, greater potential for muscle hypertrophy, and invokes increased neural activation and selective recruitment of fast-twitch motor units compared to CON training (Hortobagyi et al., 1996a; 1996b; Nardone et al., 1989; Roig et al., 2009). Thus, the larger increases seen in ECC versus CON peak force were not surprising. In addition, the subjects in the present study had diverse resistance training backgrounds but were far less accustomed to specific ECC training than CON training, indicating a potential greater window of adaptation for ECC muscle strength enhancement.

A unique finding of the present study was that 6 weeks of multiple-joint isokinetic resistance training increased maximal modified push-up performance by 28.6% ( $\eta^2 = 0.34$ ). Push-up tests have been used as a measure of upper-body muscle strength and endurance (Mayhew et al., 1991). Ground reaction force studies have shown that 64-75% of body weight (depending on posture and segment of the range of motion) is supported during a regular traditional push-up, and 49-61% of body weight is supported during a modified push-up which must be overcome during the ascent or "up" phase (Ebben et al., 2011; Suprak et al., 2011). Thus, a blend of strength and endurance is needed to overcome the resistance of body weight and perform a large number of push-ups. Previous studies have shown significant positive correlations ( $r = 0.47$  to  $0.71$ ) between absolute and relative push-up performance and maximal bench press performance (Mayhew et al., 1991; Vaara et al., 2012). Thus, it is likely that CON and ECC strength increases observed in the present study contributed to the augmented modified push-up performance. In particular, the kinetics of the isokinetic chest press exercise were similar to and sufficient to induce a carryover strength/endurance effect, indicating that multiple-joint isokinetic resistance training has the ability to increase non-isokinetic measures of strength and endurance.

It is important to view the results of the present study within the context of the study limitations. For example, we only investigated novice women with a limited background in resistance training. Thus, multiple-joint isokinetic RT in trained male and female populations warrants further study. Future research should also address different training programs at various linear velocities in a comparative design. We examined only one program utilizing a slow velocity ( $0.15 \text{ m}\cdot\text{s}^{-1}$ ) with a limited intensity (75 to 85%) and repetition (6-10) range. In addi-

tion, new dynamometers have been developed to utilize other multiple-joints exercises (i.e. squat, leg press) in addition to the exercises utilized in the present study.

## Conclusion

In summary, six weeks of multiple-joint isokinetic resistance training increased dynamic maximal muscular strength and endurance in addition to maximal isokinetic strength in women. Subjects in the IRT group significantly increased 1RM bench press and bent-over strength, isokinetic CON and ECC strength, and increased maximal modified push-up performance. These data show that multiple-joint isokinetic resistance training has direct beneficial carryover effects to dynamic exercise performance in addition to isokinetic strength gains. The carryover effects may be attractive to strength training and conditioning professionals seeking to include isokinetic exercises into a resistance training program.

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### Key points

- Multiple-joint isokinetic resistance training increases dynamic maximal muscular strength, local muscular endurance, and maximal isokinetic strength in women.
- Multiple-joint isokinetic resistance training increased 1RM strength in the bench press (by 10.2%), bent-over barbell row (by 11.2%), and maximal modified push-up performance (by 28.6%) indicating a carryover of training effects to dynamic exercise performance.
- The carryover effects may be attractive to strength training and conditioning professionals seeking to include alternative modalities such as multiple-joint isokinetic dynamometers to resistance training programs.

✉ **Nicholas A. Ratamess, Ph.D., Professor**  
Department of Health and Exercise Science, The College of New Jersey, Ewing, NJ 08628, USA

### AUTHOR BIOGRAPHY



#### **Nicholas A. RATAMESS**

##### **Employment**

The College of New Jersey

##### **Degree**

PhD

##### **Research interests**

Strength training and conditioning

**E-mail:** ratamess@tcnj.edu

#### **Noah A. BELLER**

##### **Employment**

The College of New Jersey

##### **Degree**

MS

##### **Research interests**

Resistance training

**E-mail:** nabj06@gmail.com



#### **Adam M. GONZALEZ**

##### **Employment**

The University of Central Florida

##### **Degree**

MEd

##### **Research interests**

Sports science

**E-mail:** adam.gonzalez@ucf.edu



#### **Gregory E. SPATZ**

##### **Employment**

Resilient Performance Physical Therapy at Peak Performance NYC

##### **Degree**

BS, DPT

##### **Research interests**

Sports science, Rehabilitation

**E-mail:** spatz4@gmail.com



#### **Jay R. HOFFMAN**

##### **Employment**

The University of Central Florida

##### **Degree**

PhD

##### **Research interests**

Sports science

**E-mail:** jay.hoffman@ucf.edu



#### **Ryan E. ROSS**

##### **Employment**

Medical University of South Carolina

##### **Degree**

MEd

##### **Research interests**

Health and rehabilitation

**E-mail:** rossre@muscc.edu



#### **Avery D. FAIGENBAUM**

##### **Employment**

The College of New Jersey

##### **Degree**

EdD

##### **Research interests**

Resistance training

**E-mail:** faigenba@tcnj.edu



#### **Jie KANG**

##### **Employment**

The College of New Jersey

##### **Degree**

PhD

##### **Research interests**

Sports nutrition and exercise science

**E-mail:** kang@tcnj.edu