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The Effects of Velocity-Spectrum Training on the Ability to Rapidly Step

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Abstract. Bera, S.G., L.E. Brown, S.M. Zinder, G.J. Noffal, D.P. Murray, and N.M. Garrett. The effects of velocity-spectrum training on the ability to rapidly step. *J. Strength Cond. Res. 21(4):1101–1107. 2007.*—Falls may occur because of a deficiency in the ability to rapidly step in the desired direction. Previous models developed to predict rapid step ability have been based on balance, video analysis, or uniplanar isokinetic performance. The purpose of this investigation was to determine the effects of multiplanar velocity-spectrum training of the hip. Seven males (23.14 years) and 16 females (23.75 years) were tested for peak torque, peak power, and rate of velocity development and on rapid step test (RST) measurements. Participants in the training group went through 8 training sessions over 4 weeks, consisting of unilateral hip flexion/extension and hip abduction/adduction of each leg, while the control group maintained regular activity throughout the 4-week span. Exercises were performed on a Biodex System 3 isokinetic dynamometer beginning at a speed of $60° \cdot sec^{-1}$, gradually increasing in speed every week up to 180, 300, and $400° \cdot s^{-1}$, respectively. Analysis of the data revealed no significant ($p < 0.05$) differences between groups on any measure. However, the data showed a significant improvement in RST time (pre: 50.87 ± 4.41 seconds; post: 49.20 ± 4.28 seconds) and number of errors (pre: 4.13 ± 2.87 errors; post: 2.75 ± 1.81 errors), implying that a learning effect took place on the RST for all individuals. Additionally, short-term isokinetic training did not translate into significant results. It was concluded that 4 weeks of velocity-spectrum training of the hip did not lead to improvements on the ability to rapidly step, as measured by the RST. Therefore, the open-kinetic-chain training should not be done for improvements on a functional, closed-kinetic-chain activity.

Key Words. isokinetic, rate of velocity development, hip, rapid step test, torque, power

Introduction

The ability to rapidly step is a very important component in various types of activities. In a sport setting, rapid stepping is often necessary to perform quick cutting movements or to increase limb turnover rate. Nonetheless, rapid stepping ability is important in everyday life as well. For example, rapid stepping ability can be an important factor when trying to recover balance from a trip or fall (24). All individuals are susceptible to falling, though older adults are especially at a higher risk of falling. Several factors put individuals at increased risk of falling, including a decline in strength (6, 10, 11) and balance impairments (9, 27). However, a decline in limb movement speed has been shown to be the most common predisposing fall risk factor (6, 24, 25, 27, 28). Thus, it is important to study how to increase the ability to rapidly step.

An individual usually goes through a sequence of steps when trying to recover from a postural perturbation. These steps include feeling the loss of balance, determining a recovery strategy, and carrying out the recovery strategy in as short of a time as possible (24). The recovery strategy usually involves taking a "compensatory" step to change the base of support and either recover from a fall or minimize the amount of injury sustained during the fall (18). There are 2 types of reactive (compensatory) strategies for fall recovery: fixed-support and change-in-support strategies (18, 19). Fixed-support strategies involve no limb movement but rather a shift in the center of mass of the body to retain balance, while change-in-support strategies involve movement of a limb to increase the base of support of the body. Taking a compensatory step would have the potential to increase the base of support and functional stability of an individual. A compensatory step involves taking an involuntary step in a direction that will increase the chances of recovery from a complete fall. Therefore, a person must quickly determine this change-of-support strategy and rapidly swing the appropriate limb in the desired direction.

Older adults typically perform compensatory step responses at significantly smaller body lean angles than younger adults, often taking more than 1 step to recover from the fall (24, 25, 27, 28). Furthermore, younger adults take longer steps and have higher torques when performing compensatory steps. Moreover, despite having similar reaction times to falls, older adults take significantly longer to complete a compensatory step than younger adults. This can be attributed to younger adults being able to accelerate and move their limbs faster than older adults, spending more time in a functional load range. Also, atrophy occurs quicker with age in fast-twitch muscle fibers than slow-twitch muscle fibers, resulting in a decline in the maximum rate of velocity development (RVD) (or limb acceleration) and muscle power (1, 4, 5, 9, 22, 23). Any of these factors can contribute to a significantly altered compensatory step reaction. Fortunately, improvements in RVD and muscle power can lead to improvements in overall limb velocity, which can be important when attempting to take a compensatory step to recover from a fall (24, 25, 27, 28).

Few studies have looked at the RVD of hip abductors and adductors, even though these muscle groups may be very important for functional stability (11). Instead of performing a unilateral limb movement (forward, backward, and so on) during a lateral perturbation, individuals tend to swing their leg out to take a compensatory step. Step lengths are also longer during lateral perturbations than during anteroposterior perturbations (19). Additionally, lateral limb movements take longer to perform than forward or backward compensatory steps, even though foot-off for lateral movements takes approximately 20% less time (19). Isokinetic peak torque and power of hip abductors and adductors in older adults have been shown to decline by 44 and 56%, respectively, compared to younger adults (11). Impairment to the muscles responsible for lateral stepping can put all individuals at increased risk of falling and sustaining injuries from a fall (17).

As it can be seen, improving the RVD of hip muscles can potentially have very important applications, including improvements in limb movement speed and limb power. Developing velocity-dependent training programs for the muscles of the hip can potentially benefit people of all ages. Velocity-spectrum training is 1 training method that has been shown to lead to improvements in muscle power across all movement velocities, with improvements in torque at the lower movement velocities (7). The purpose of this study was to determine the effects of open-kinetic-chain velocity-spectrum training of hip muscles on closed-kinetic-chain rapid step ability and on various measures of strength, including RVD, peak torque, and peak power.

Methods

Experimental Approach to the Problem

A repeated-measures design was used to determine the effects of isokinetic velocity-spectrum training of the hip on the ability to rapidly step, as measured by the rapid step test (RST). Dependent variables included peak torque (PT), peak power (PP), RVD, RST time, and RST number of errors.

Subjects

Seven male (23.14 ± 2.97 years; 175.09 ± 4.90 cm; 79.51 ± 12.55 kg) and 16 female (23.75 ± 3.17 years; 164.94 ± 8.59 cm; 60.16 ± 7.97 kg) university students participated in this study. All participants were apparently healthy and required to participate in additional physical activity (not including regular acts of daily living) at least 2 times per week. Each subject was required to complete a physical activity readiness questionnaire and written informed consent form approved by the University Human Subjects Institutional Review Board. Subjects were excluded if they did not have medical clearance to participate in physical activity or if they had any preexisting lower-limb injuries or conditions that could possibly become worse by participation in this study. Participants were randomly assigned into either the control ($n = 11$; 3 males and 8 females) or training group ($n = 12$; 4 males and 8 females).

Procedures

Rapid Step Test and Maximum Step Length Platform. Measurements for both the RST and maximum step length were taken on a specially designed square platform. The area of the platform was approximately 6.25 m^2. Perpendicular lines were drawn directly through the center of the platform to the edge of the platform. The exact center of the platform was considered the 0-cm mark for all directions. Short markings were made at intervals of 0.5 cm, with larger markings every 5 cm for ease of measurement. A 250-cm^2 area was marked off directly in the center of the platform. This square-shaped area was designated as the starting position for all the participants.

Maximum Step Length Determination. Maximum step length (MSL) was determined following the recommendations of Medell and Alexander (21). Participants took maximal steps in the forward, backward, and sideways directions for both the left and the right legs. Individual maximal steps were taken for each of the desired directions, with the participants required to keep both arms crossed over their chest. In addition, the participants were required to keep their opposite leg firmly planted in the starting position while maintaining balance throughout the entire stepping movement (stepping out and returning back to the initial position). Three trials of submaximal stepping were taken for each leg direction prior to taking maximum step length measurements. On completion, 3 maximal step trials were taken for each leg direction. Step length was measured to be the shortest distance (cm) from the center of the platform to the edge of the participant's shoe. Maximum step length was defined as the average step length for each of the 3 trials in each of the 6 total step directions (2 sides × 3 directions).

Rapid Step Test Determination. Administration of the RST also followed the recommendations of Medell and Alexander (21). Participants were instructed to step in the appropriate direction and return back to the initial position as fast as possible. Steps were required to be at least 80% of the determined MSL (marked with a tape on the ground) in all the leg directions. A total of 24 steps were taken in a randomly assigned order, until completing a total of 4 steps in each of the 6 step directions. Each successive step was read off by the test administrator immediately after the participant stepped back into the initial starting position.

Three trials of the RST were performed for each of the participants. Total time and total number of errors for each trial set were recorded. Errors were defined as either a (a) loss of balance, (b) failure to return to initial position (feet not returning back to square), (c) multiple steps, and/or (d) movement in the wrong direction, with the maximum number of errors being 24. Rapid step test time and errors were defined as the respective average of the 3 trials. Measurements were taken pre- and posttraining.

Isokinetic Testing. Training took place on a Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY) using software version 3.30. Participants were secured to the isokinetic dynamometer according to the guidelines of the preinstalled software, with the axis of rotation chosen to be at the anterior superior iliac spine of the hip. Movements of combined concentric hip flexion/extension and combined hip abduction/adduction were performed at speeds of 60, 180, 300, and $400°\cdot s^{-1}$ for both the left and the right leg.

Six repetitions were performed at each of the 4 speeds, with 1 minute of rest between each set. All movements were initiated from anatomical position. Hip flexion and extension movements were performed at an absolute range of motion (ROM) of 90° (60–120°), while hip abduction and adduction movements were performed at an absolute ROM of 30° (90–120°). Consistent verbal encouragement was given to all participants throughout the test. Participants were expected to contact the preset mechanical stops and provide maximum effort during the movements. In addition, participants were told to focus on primarily using the designated hip muscles for each of the movements. Furthermore, participants were allowed to hold on to the main unit of the isokinetic dynamometer for stability; PT, PP, and RVD were recorded for each of the movements and speeds using DataPac 2k2 (Run Technologies, Mission Viejo, CA) analysis software version 3.11. Measurements were taken pre- and posttraining.

Isokinetic Training. Individuals in the training group went through 2 training sessions per week on nonconsecutive days for a total of 4 weeks, in addition to their normal physical activity. Members of the control group continued regular physical activity. Participants were secured to the isokinetic dynamometer as described above. Each workout session consisted of 3 sets of 6 repetitions of continuous concentric hip flexion and extension and continuous concentric hip abduction and adduction for each leg. Training was performed through the same ROM and starting point as that used during isokinetic testing. A 1-minute rest period was given between each set. Again, all participants were expected to give maximum effort, contact the preset mechanical stops, and use the primary hip muscles during each of the exercises.

Two training sessions were performed at each of the 4 speeds for a total of 8 training sessions. The first week of training began at $60°\cdot s^{-1}$, increasing incrementally to speeds of $180°\cdot s^{-1}$ the second week, $300°\cdot s^{-1}$ the third week, and $400°\cdot s^{-1}$ the fourth week of training, respectively. No subject was allowed to miss more than 1 training session.

Statistical Analyses

Three repeated-measures (PT, PP, and RVD) 3-way $4 \times 2 \times 2$ (velocity × group × time) factorial analyses of variance (ANOVAs) were performed to analyze the isokinetic data for main effect and interactions involving time and group for each of the 8 measured hip movements. Two additional repeated-measures (RST time and errors) 2-way 2×2 (group × time) ANOVAs were performed to analyze RST data for main effect and interactions. An alpha level of 0.05 was used for significance on all measures. All data was analyzed using SPSS (SPSS, Inc., Chicago, IL) statistical software version 12.0.

RESULTS

One-way ANOVA illustrated that men and women were not significantly different in age for this study. However, men were found to be significantly ($p < 0.05$) taller and heavier than women. No within-group differences were found inside the combined gender cells.

Both the control and the training groups improved on RST time and number of errors. A main effect was found for both time ($p = 0.01$) and number of errors ($p = 0.002$); however, analysis of the data did not reveal any significant differences between groups. The training group improved on RST time (pre: 51.59 ± 4.38 seconds; post: 49.62 ± 4.62 seconds) and number of errors (pre: 4.53 ± 3.44 errors; post: 2.75 ± 2.24 errors). The control group improved on RST time (pre: 50.09 ± 4.51 seconds; post: 48.73 ± 4.02 seconds) and number of errors (pre: 3.70 ± 2.17 errors; post: 2.76 ± 1.31 errors) as well.

Analysis of variance revealed a main effect ($p < 0.05$) for speed on all variables (RVD, PT, and PP) for each of the movements. Select graphs for right hip flexion RVD, left hip flexion PT, and right hip flexion PP can be seen in Figures 1, 2, and 3, respectively. Data for left and right hip abduction and adduction are shown in Table 1. Data for left hip flexion and extension are shown in Table 2, and data for right hip flexion and extension are shown in Table 3.

DISCUSSION

The purpose of this study was to determine the effects of velocity-spectrum training on the ability to rapidly step. Analysis of the results suggests that open-kinetic-chain (OKC) isokinetic training of the hip muscles over a velocity spectrum did not translate into significant improvements on rapid step performance, as measured by the RST, a closed-kinetic-chain (CKC) activity. The results of this study indicate that velocity-spectrum training of the hip muscles may not be a reliable training protocol to improve stepping performance.

Velocity-spectrum training is often used as a training protocol to train both type I (slow-twitch) and type II (fast-twitch) muscle fibers (15). Velocity training has been shown to induce velocity-specific adaptations in power (4, 7, 22, 23). Furthermore, velocity-spectrum training leads to improvements in strength primarily at lower velocities (14, 26), while improvements in power are seen across all velocities. In the present study, an interaction for speed and time was seen for PT in left hip flexion, extension, and abduction. Posttest PT values for right extension were higher for both groups for the slower speeds (60, 180), but lower for the faster speeds (300, 400). No other significant results were found for any of the other move-

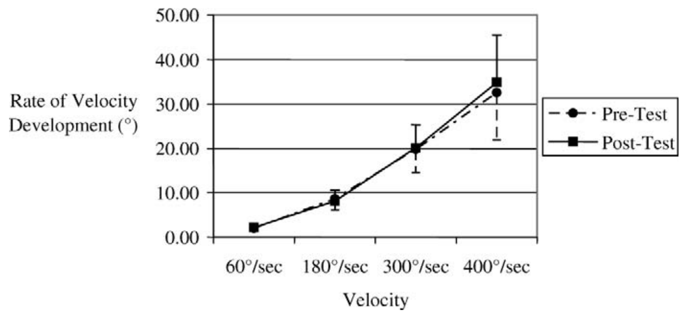

FIGURE 1. Comparison of pre- and posttest rate of velocity development (RVD) across all speeds for combined training and control groups. These data represent values for right hip flexion and are indicative of the general trend of all results.

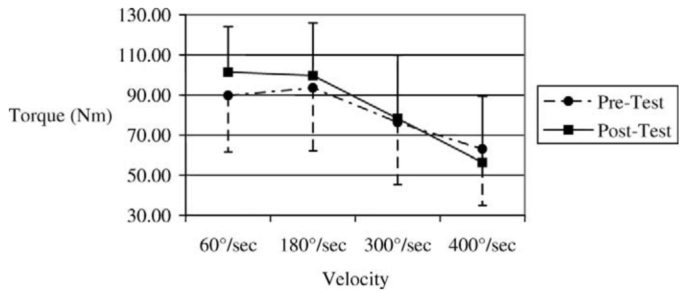

FIGURE 2. Comparison of pre- and posttest peak torque (PT) across all speeds for combined training and control groups. These data represent values for left hip flexion and are indicative of the general trend of all results.

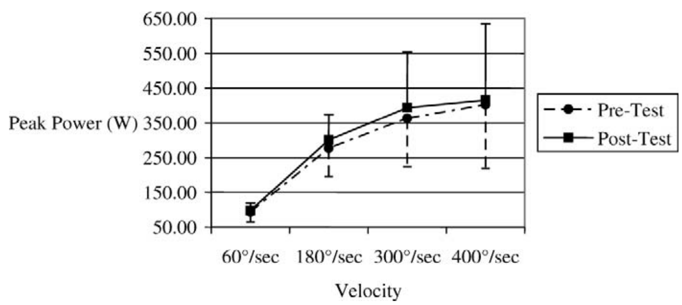

FIGURE 3. Comparison of pre- and post-test peak power (PP) across all speeds for combined training and control groups. These data represent values for right hip extension and are indicative of the general trend of all results.

TABLE 1. Results (mean ± *SD*) for left abduction/adduction and right abduction/adduction rate of velocity development (RVD), peak torque (PT), and peak power (PP) for all participants. (Note: No participant was able to reach speed at 300°·s⁻¹ and 400°·s⁻¹ for abduction and adduction.)

Left abduction	60°·s⁻¹		180°·s⁻¹	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	2.06 ± 0.48 (p = 0.40)	2.16 ± 0.39 (p = 0.07)	9.43 ± 3.45 (P = 0.83)	8.85 ± 2.43 (p = 0.60)
PT (N·m)	85.02 ± 22.25 (p = 0.41)	94.87 ± 25.31 (p = 0.74)	64.26 ± 23.56 (P = 0.75)	64.97 ± 22.57 (p = 0.42)
PP (W)	89.03 ± 23.30 (p = 0.41)	99.35 ± 26.50 (p = 0.74)	201.88 ± 74.02 (P = 0.75)	204.12 ± 70.90 (p = 0.42)
Left adduction	**60°·s⁻¹**		**180°·s⁻¹**	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	3.91 ± 4.65 (p = 0.34)	3.80 ± 4.42 (p = 0.36)	13.38 ± 3.01 (p = 0.74)	13.69 ± 2.11 (p = 0.72)
PT (N·m)	77.48 ± 30.31 (p = 0.66)	92.76 ± 25.47 (p = 0.73)	69.08 ± 33.00 (p = 0.61)	75.90 ± 33.90 (p = 0.68)
PP (W)	81.14 ± 31.74 (p = 0.66)	97.14 ± 26.68 (p = 0.73)	217.01 ± 103.66 (p = 0.61)	238.45 ± 106.49 (p = 0.68)
Right abduction	**60°·s⁻¹**		**180°·s⁻¹**	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	2.22 ± 0.55 (p = 0.73)	2.32 ± 0.26 (p = 0.72)	9.10 ± 2.80 (p = 0.81)	8.64 ± 2.12 (p = 0.90)
PT (N·m)	83.24 ± 31.68 (p = 0.81)	97.10 ± 23.82 (p = 0.99)	72.03 ± 33.95 (p = 0.83)	76.07 ± 28.36 (p = 0.58)
PP (W)	87.17 ± 33.18 (p = 0.81)	101.68 ± 24.95 (p = 0.99)	226.30 ± 106.65 (p = 0.83)	238.98 ± 89.10 (p = 0.58)
Right adduction	**60°·s⁻¹**		**180°·s⁻¹**	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	3.05 ± 1.51 (p = 0.69)	2.83 ± 0.66 (p = 0.84)	14.81 ± 2.04 (p = 0.90)	14.43 ± 1.66 (p = 0.28)
PT (N·m)	81.39 ± 23.90 (p = 0.84)	96.91 ± 30.21 (p = 0.75)	60.21 ± 19.88 (p = 0.76)	62.69 ± 21.86 (p = 0.33)
RPP (W)	85.24 ± 25.03 (p = 0.84)	101.48 ± 31.64 (p = 0.75)	189.15 ± 62.45 (p = 0.76)	196.95 ± 68.69 (p = 0.33)

TABLE 2. Results (mean ± *SD*) for left hip flexion/extension rate of velocity development (RVD), peak torque (PT), and peak power (PP) for all participants.

Left flexion	60°·s⁻¹		180°·s⁻¹	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	2.14 ± 0.60 (p = 0.57)	2.18 ± 0.41 (p = 0.63)	2.14 ± 0.60 (p = 0.57)	2.18 ± 0.41 (p = 0.63)
PT (N·m)	89.71 ± 28.22 (p = 0.95)	101.37 ± 22.67 (p = 0.70)	89.71 ± 28.22 (p = 0.95)	101.37 ± 22.67 (p = 0.70)
PP (W)	93.94 ± 29.56 (p = 0.95)	106.15 ± 23.74 (p = 0.70)	93.94 ± 29.56 (p = 0.95)	106.15 ± 23.74 (p = 0.70)
Left flexion	**300°·s⁻¹**		**400°·s⁻¹**	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	19.34 ± 6.34 (p = 0.81)	18.35 ± 5.02 (p = 0.75)	19.34 ± 6.34 (p = 0.81)	18.35 ± 5.02 (p = 0.75)
PT (N·m)	76.20 ± 30.92 (p = 0.59)	78.23 ± 31.53 (p = 0.57)	76.20 ± 30.92 (p = 0.59)	78.23 ± 31.53 (p = 0.57)
PP (W)	399.01 ± 161.87 (p = 0.59)	409.60 ± 165.10 (p = 0.57)	399.01 ± 161.87 (p = 0.59)	409.60 ± 165.10 (p = 0.57)
Left extension	**60°·s⁻¹**		**180°·s⁻¹**	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	7.65 ± 17.57 (p = 0.49)	2.85 ± 0.61 (p = 0.96)	7.65 ± 17.57 (p = 0.49)	2.85 ± 0.61 (p = 0.96)
PT (N·m)	84.02 ± 25.98 (p = 0.49)	98.92 ± 25.61 (p = 0.86)	84.02 ± 25.98 (p = 0.49)	98.92 ± 25.61 (p = 0.86)
PP (W)	87.99 ± 27.21 (p = 0.49)	103.59 ± 26.82 (p = 0.86)	87.99 ± 27.21 (p = 0.49)	103.59 ± 26.82 (p = 0.86)
Left extension	**300°·s⁻¹**		**400°·s⁻¹**	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	33.22 ± 11.55 (p = 0.92)	32.69 ± 12.92 (p = 0.50)	33.22 ± 11.55 (p = 0.92)	32.69 ± 12.92 (p = 0.50)
PT (N·m)	65.43 ± 27.54 (p = 0.51)	72.06 ± 30.42 (p = 0.92)	65.43 ± 27.54 (p = 0.51)	72.06 ± 30.42 (p = 0.92)
PP (W)	342.61 ± 144.18 (p = 0.51)	377.29 ± 159.27 (p = 0.92)	342.61 ± 144.18 (p = 0.51)	377.29 ± 159.27 (p = 0.92)

ments. The training protocol for this study began at 60°·s⁻¹ and progressed to 400°·s⁻¹. Thus, according to previous research, participants were primarily training for torque with slower speeds and power with the faster speeds. Kovaleski et al. (16) found that beginning velocity-spectrum training at a higher speed produced greater average power (no significant results were found for power in this study). Similarly, this type of training protocol could be beneficial to torque production as well (15). This may be one of the reasons why there was a noticeable lack of findings for the current study.

Consequently, improvements in the RVD of the knee joint have been shown in as little as 2 days of isokinetic training (1, 4, 22, 23). The RVD is a very important factor in a rapid step movement. Lowering the RVD value leads to the muscles of the limb spending more time under load range, in addition to the limb reaching the desired movement velocity more quickly (4, 22–25). Even so, the data

TABLE 3. Results (mean ± *SD*) for right hip flexion/extension rate of velocity development (RVD), peak torque (PT), and peak power (PP) for all participants.

Right flexion	60°·s⁻¹		180°·s⁻¹	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	2.03 ± 0.50 (p = 0.36)	2.16 ± 0.38 (p = 0.69)	2.03 ± 0.50 (p = 0.99)	2.16 ± 0.38 (p = 0.44)
PT (N·m)	91.06 ± 25.40 (p = 0.82)	99.97 ± 26.80 (p = 0.54)	91.06 ± 25.40 (p = 0.51)	99.97 ± 26.80 (p = 0.79)
PP (W)	95.34 ± 26.60 (p = 0.82)	104.68 ± 28.07 (p = 0.54)	95.34 ± 26.60 (p = 0.51)	104.68 ± 28.07 (p = 0.79)
Right flexion	**300°·s⁻¹**		**400°·s⁻¹**	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	19.77 ± 5.21 (p = 0.96)	20.13 ± 5.98 (p = 0.45)	19.77 ± 5.21 (p = 0.96)	20.13 ± 5.98 (p = 0.45)
PT (N·m)	76.51 ± 26.47 (p = 0.80)	72.12 ± 28.54 (p = 0.90)	76.51 ± 26.47 (p = 0.80)	72.12 ± 28.54 (p = 0.90)
PP (W)	400.58 ± 138.61 (p = 0.80)	377.54 ± 149.45 (p = 0.90)	400.58 ± 138.61 (p = 0.80)	377.54 ± 149.45 (p = 0.90)
Right extension	**60°·s⁻¹**		**180°·s⁻¹**	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	3.48 ± 89.12 (p = 0.27)	2.97 ± 0.62 (p = 0.50)	3.48 ± 89.12 (p = 0.47)	2.97 ± 0.62 (p = 0.91)
PT (N·m)	89.12 ± 26.92 (p = 0.47)	93.68 ± 20.82 (p = 0.87)	89.12 ± 26.92 (p = 0.25)	93.68 ± 20.82 (p = 0.81)
PP (W)	93.33 ± 28.19 (p = 0.47)	98.11 ± 21.80 (p = 0.87)	93.33 ± 28.19 (p = 0.25)	98.11 ± 21.80 (p = 0.81)
Right extension	**300°·s⁻¹**		**400°·s⁻¹**	
	Pretest	Posttest	Pretest	Posttest
RVD (°)	31.13 ± 11.75 (p = 0.60)	29.86 ± 7.65 (p = 0.89)	31.13 ± 11.75 (p = 0.60)	29.86 ± 7.65 (p = 0.89)
PT (N·m)	69.39 ± 26.55 (p = 0.73)	75.18 ± 30.59 (p = 0.50)	69.39 ± 26.55 (p = 0.73)	75.18 ± 30.59 (p = 0.50)
PP (W)	363.34 ± 139.04 (p = 0.73)	393.65 ± 160.16 (p = 0.50)	363.34 ± 139.04 (p = 0.73)	393.65 ± 160.16 (p = 0.50)

from this study suggest that either longer OKC isokinetic training periods may be required to see improvements in the RVD at the hip joint.

Previous research has shown a high test-retest reliability for isokinetic muscle strength (2, 8). The current study did not show significant differences between the training and control group. Participants were encouraged and assumed to be providing maximum effort during each of the training and testing trials. Isokinetic dynamometers provide accommodating resistance, meaning that no matter how hard or how little a subject contacts the machine, the limb will be allowed to move at only the designated speed. Thus, an individual can give a submaximal effort, with the isokinetic attachment still moving at the same relative speed. This may have been another inherent limitation to this study.

Unlike knee extension movements, where the quadriceps muscle group provides all the necessary muscle power to move the joint, movements about the hip require the aid of various muscles, including the quadriceps, hamstring, and gluteal muscles. Isokinetic hip strength and power has previously been measured in both a gravity-dependent and a gravity-independent position on the isokinetic dynamometer. A gravity-dependent position placed the hip in a more functional setting, while a gravity-independent position better isolated the muscles and movement about the hip (6). A gravity-dependent training position was chosen in an attempt to lead to improvements in functional rapid step ability. In the present study, participants were encouraged to focus on isolating movement of the lower limb at the hip joint during isokinetic training and testing. But OKC isokinetic training was not shown to lead to significant improvements on CKC rapid step ability and performance, which may be attributed to the lack of training specificity and neuromuscular adaptation for the task (RST). It has been reported that isokinetic testing is best used as a measure for strength, while functional tests should be used to measure performance levels (2, 13, 20). Nonetheless, isokinetic testing does not affect the reliability of functional tests (2, 20).

The RST has been shown to be a valid and highly reliable measure of rapid step ability and fall risk assessment (21). Previous research on the RST had measured testing trials over only a single day, while RST trials were taken before and after a 4-week training period in the current study. Both the training and the control groups improved on average RST time and number of errors, implying that a learning effect may have taken place on this test. As a result, the reliability of the data may have been diminished. Some of the learning effect could have possibly been alleviated by performing additional (submaximal and/or maximal) trials of the RST prior to taking actual measurements on the test.

The design of the RST is to force individuals to take steps in various directions as quickly as possible (3, 21). Although a modest relationship was found between the RST and functional ability, maximum step length may actually have a stronger relationship to an individual's functional ability (3). Young adults have step lengths that are between 10% (12) and 16% (21) greater than older adults. Thus, younger adults may have a natural advantage over older adults on both maximum step length and the RST. Impaired muscle control of the hip can be an indicator of increased risk of falls and a reduction in functional ability (17). The current study was performed on a young, healthy, university-based population as opposed to an older population. A physically active population can be understood to have longer step lengths and better neuromuscular control than an older or inactive population. As a result, it can be assumed that the RST may not be descriptive or discriminate enough to measure deficiencies in an apparently healthy population.

Even though the primary goal of the RST is to test functional ability, there are intrinsic cognitive components to the test. For example, an individual must hear, recognize, and then step in the instructed direction (3). Additionally, the subject must also concentrate on seeing the designated target line, limit their errors, and return to the starting position as quickly as possible. Sight and hearing are known to decline with age, again placing older adults at a comparative disadvantage on the RST than younger adults. This may be yet another reason why the RST may not be an appropriate test to measure functional and rapid step ability in a young and healthy population.

Even though RST time and number of errors has been shown to have high correlations with other clinical measures of functional ability and risk of falling (21), the number of errors had a very low correlation with RST performance. Participants were marked down with an error if they moved in the wrong direction, lost balance, took multiple steps, or did not return to the starting position. However, if a person took a step in the wrong direction, they were not required to take a step in the correct direction. Thus, stepping in the wrong direction did not necessarily increase the total RST time, though it did increase the number of errors. Higher correlations in previous research may have been affected by the inclusion of a young population as well as a balance-unimpaired older adult population (3). These populations typically have more consistent and error-free performances (21). Additionally, there may be a perceptible experimental error, with RST time possibly being affected by how quickly the test administrator reads off the next leg-direction command (3). Combining both time and errors into a single score may provide an alternate measure of complete RST performance.

Future studies can possibly look at increasing the training intensity and volume and/or performing training only at select speeds. In addition, the study can be performed on an older population to determine if velocity-spectrum training can lead to improvements in any of the measures for an older age-group. Perhaps a device to better stabilize the body and the hip in a gravity-dependent isokinetic movement may be beneficial in receiving more accurate results. In addition, various other measures can possibly be used to determine rapid step performance, such as high-speed video analysis or the use of sensor plates.

In summary, 4 weeks of OKC velocity-spectrum training of the hip on an apparently healthy university population did not lead to improvements in CKC rapid step performance, PT, PP, or rapid step ability. Additionally, short-term isokinetic training of the hip did not lead to significant improvements in PT and PP. Finally, a learning effect may have taken place with the RST.

Practical Applications

Physical therapists, athletic trainers, and strength and conditioning professionals all agree that specificity is an important component to any training program. The present study demonstrated that short-term OKC training of the hip flexors, extensors, abductors, and adductors did not lead to significant improvements on a functional, CKC activity. Four weeks of velocity-spectrum isokinetic training was performed on a university-based population. Testing and training were performed in a gravity-dependent position. This was done in an attempt to resemble the movements of the functional task (RST) as closely as possible. Nonetheless, the isokinetic dynamometry was still considered a form of OKC training. Neither the control nor the training group showed significant improvements on PT, PP, or RVD; however, both groups were able to improve on RST time and number of errors. Since there were no significant differences between groups, the improvement on the RST may be attributed to a learning effect. As such, the RST may not be an appropriate measure of functional ability in a university-based population. Health and fitness professionals may want to administer alternative functional tests when using similar populations. Furthermore, based on the data from the current study, professionals should focus on performing OKC training when seeking to improve on an OKC task, while CKC training should be used when seeking to improve on a CKC task.

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