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Reliability and Effects of Arm Dominance on Upper Extremity Isokinetic Force, Work, and Power Using the Closed Chain Rider System

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Objective: The purpose of our study was to assess the reliability of the Closed Chain Rider System between exercise sessions and to determine the effects of arm dominance using muscle force, work, and power measures during closed chain chest-press exercise.

Design and Setting: Sitting subjects underwent identical testing on 2 occasions and performed 5 reciprocal chest-press movements at speeds of 51 and 76 cm/s.

Subjects: Thirty-eight healthy college students.

Measurements: Average force, total work, average power, and linear range of motion were recorded. Reliability was evaluated by calculating intraclass correlation coefficients. Mean differences between the dominant and nondominant arms for the measured variables were analyzed by dependent *t* tests.

Results: For both the dominant and nondominant arms at the 51 and 76 cm/s speeds, reliabilities of average force (range = 0.85 to 0.91), total work (range = 0.88 to 0.92), and average power (range = 0.86 to 0.89) were clinically acceptable. The dominant arm produced significantly greater average force, total work, and average power compared with the nondominant arm.

Conclusions: Our results provide clinically useful information about the reliability of force, work, and power measures during multijoint bilateral chest-press movement. Clinicians should be aware of measured differences between dominant and nondominant arms.

Key Words: isokinetic testing, closed kinetic chain, arm strength

Strength training is considered an integral part of upper extremity and shoulder rehabilitation. A popular strength training method is closed kinetic chain exercise, which involves movement when the distal limb segment is fixed, body weight is supported by the extremity, or considerable external resistance is applied to the foot or hand.[1–3] In an attempt to apply the closed chain concept to the upper extremity, several researchers have proposed different classification systems of closed kinetic chain exercise to define and develop closed chain activities for upper extremity rehabilitation.[3–6] For example, Dillman et al[4] provided a classification system that is based on the mechanics of the particular exercise where the boundary condition of the distal limb segment may be either fixed or movable, whereas the external load may or may not be present at the distal segment. For the purpose of rehabilitation, closed chain strengthening exercise is performed to promote coactivation of stabilizing muscles, minimize shear forces, stimulate proprioceptors in the involved joints, provide large-resistance and low-acceleration movements, and promote dynamic stabilization.[3]

The need exists for clinically objective and reliable measures of muscle function in a closed kinetic chain movement pattern. The Closed Chain Rider System (Mettler Electronics, Anaheim, CA) is an integrated, computer-controlled, closed chain exercise and muscle evaluation system that provides isokinetic accommodating resistance with distal loading. A unique aspect of this system is the linear resistance that is produced during alternating multijoint movements at various velocities. Reliability using intraclass correlation coefficients for this system has been reported employing the legs for average force (range = 0.76 to 0.90) and total work (range = 0.79 to 0.99).[7] Measurements were reported to be clinically acceptable, regardless of the testing speed or limb. No studies have established the reliability of measurement for the upper extremity using the Closed Chain Rider System. The purpose of our study was to establish test-retest reliability using bilateral alternating chest-press movements and to examine the effects of limb dominance using muscle force, power, and work parameters during a closed chain chest-press exercise.

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METHODS

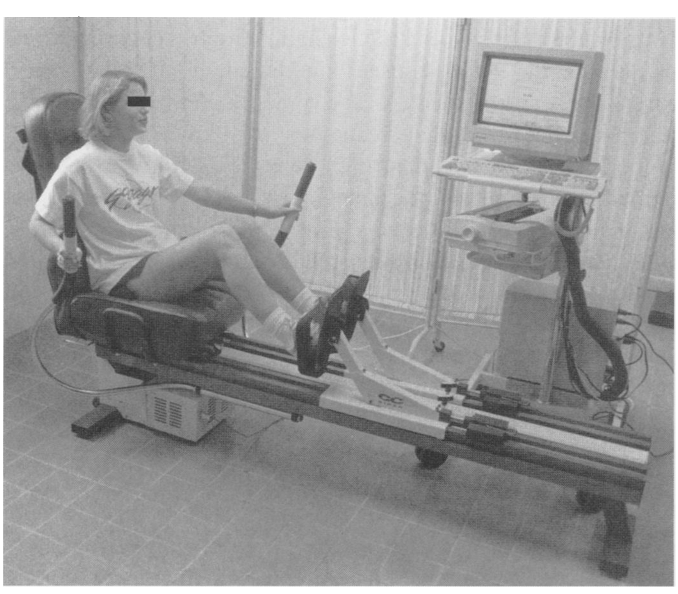
Subjects

Thirty-eight (males = 19, females = 19) healthy college students (age = 22.3 ± 2.9 years, wt = 72.7 ± 17.7 kg, ht = 168.5 ± 8.4 cm) volunteered to participate. Each subject refrained from participating in heavy-resistance weight and endurance training during the study, although the usual recreational and daily activities were allowed. Subjects refrained from vigorous exercise during the 24 hours before testing. In compliance with institutional guidelines, the study was approved by the University of South Alabama Institutional Review Board, and subjects read and signed an informed consent before data collection.

Instrumentation

Testing of the right and left upper extremities was conducted using the Closed Chain Rider System. The Closed Chain Rider System consists of 2 rail extensions that contain channels for the movement of rubber-wheeled rollers attached to a tubular handle (Figure). When engaged, the arm couplers are connected by a chain-and-sprocket system to a motor that provides the braking action for accommodating resistance during exercise. Computer software controls the braking action of the system.

The seat back was reclined to approximately 100° during testing. Subjects were secured in the seat by a pelvic strap for pelvic immobilization, along with chest straps placed over the shoulder and across the chest to stabilize the torso. The feet were placed into foot pads, secured, and locked into place with the knees positioned at a 90° flexion angle so that no movement of the lower extremity occurred during testing. During each testing session, the subjects grasped the tubular handles attached to both sides of the rail extensions approximately 5 cm from the top of the handle. Subjects performed an alternating unilateral pushing motion consisting of shoulder flexion and elbow extension, followed by the reciprocal motion of the contralateral extremity. Subject positioning and testing was performed as described in the Closed Chain Rider System instruction manual.[8]



Closed Chain Rider System.

Protocol

Subjects participated in 1 pretest and 2 test sessions, each separated by 5 to 7 days. The pretest session was used to introduce the Closed Chain Rider to the subjects, provide practice exercise, measure body weight and height, and determine arm dominance. Subjects were asked whether they were right or left handed in order to establish arm dominance. The subjects then performed 2 sets of 10-repetition reciprocating chest-press movements (shoulder flexion, elbow extension) at each testing speed to become familiar with the apparatus.

The 2 testing sessions were identical for all subjects. Before testing, a 3-minute warm-up on a hand-crank ergometer was performed. A total of 3 to 5 submaximal chest-press repetitions preceded testing at each of the 2 speeds. During each test session, 5 repetitions of alternating maximal chest-press movements at speeds of 51 and 76 cm/s (20 and 30 in/s) were performed. Subjects were instructed to perform each chest-press movement as fast and as hard as possible after hearing the word "go." A 1-minute rest period separated testing at each speed. The order of testing during the 2 days was randomly assigned and balanced using 2 different progression orders. For order 1, the 51-cm/s speed was tested first, and, for order 2, the 76-cm/s speed was tested first.

Statistical Analysis

Of the 5 repetitions performed at each speed, the first repetition was excluded from the data analysis to standardize the range of motion so that work values could be calculated.[8,9] Thus, data analysis was performed using the mean value of 4 repetitions in the statistical analysis. Test-retest reliability for average force (kg), total work (J), and average power (W) was evaluated by calculating intraclass correlations (ICC 2,1).[10] An ICC value of 0.75 or greater was considered high and clinically acceptable.[10] The standard error of measurement (SEM) was calculated as a measure of variability expected in subjects' scores.

A dependent t test was conducted to test the null hypothesis of no difference between dominant and nondominant limbs for average force, total work, and average power on day 1. A 2-tailed test at the 0.05 level of significance was used for all tests. Means and standard deviations (SDs) were used to describe the data.

RESULTS

The mean value ($\pm$SD), reliability coefficients, and standard errors for average force, total work, and average power are presented in Table 1. The reliabilities of average force (range = 0.85 to 0.91), total work (range = 0.88 to 0.92), and average power (range = 0.86 to 0.89) measurements were clinically acceptable regardless of the testing speed or arm.[10] The dominant arm produced greater ($P \leq .05$) average force, total work, and average power than the nondominant arm regardless of speed (Table 2). Average linear range of motion

Table 1. Average Force, Total Work, and Average Power for Dominant and Nondominant Arms

Variable	Day 1 (Mean ± SD)	Day 2 (Mean ± SD)	ICC (2,1)*	SEM†
Speed = 51 cm/s				
Average force (kg)				
Dominant arm	11.79 ± 4.4	11.42 ± 4.2	0.89	1.43
Nondominant arm	10.37 ± 4.0	10.47 ± 4.2	0.91	1.23
Total work (J)				
Dominant arm	192.32 ± 84.9	184.58 ± 81.4	0.92	23.52
Nondominant arm	167.34 ± 79.4	169.18 ± 79.1	0.92	22.42
Average power (W)				
Dominant arm	44.11 ± 19.3	42.84 ± 17.6	0.88	6.39
Nondominant arm	38.55 ± 17.6	40.00 ± 17.8	0.89	5.87
Speed = 76 cm/s				
Average force (kg)				
Dominant arm	9.71 ± 4.4	9.37 ± 3.8	0.88	1.42
Nondominant arm	8.63 ± 3.9	8.66 ± 3.5	0.85	1.43
Total work (J)				
Dominant arm	173.92 ± 86.7	162.24 ± 79.9	0.90	26.34
Nondominant arm	154.39 ± 79.9	149.97 ± 71.3	0.88	26.19
Average power (W)				
Dominant arm	44.97 ± 23.8	41.63 ± 21.4	0.86	8.46
Nondominant arm	40.13 ± 21.8	38.74 ± 19.8	0.83	8.58

*Intraclass correlation coefficient.
†Standard error of measurement.

Table 2. *t*-Test Comparisons and Percentage Differences Between Dominant and Nondominant Arms for Average Force, Total Work, Average Power, and Range of Motion for Day 1

Variable	Dominant (Mean ± SD)	Nondominant (Mean ± SD)	Percentage Difference	*t* Value	*P* Value
Speed = 51 cm/s					
Average force (kg)	11.79 ± 4.4	10.37 ± 4.0	12.0%	5.19	.001
Total work (J)	192.32 ± 84.9	167.34 ± 79.4	13.0%	5.78	.001
Average power (W)	44.11 ± 19.3	38.55 ± 17.6	12.6%	4.80	.001
Range of motion (cm)	105.82 ± 13.7	105.21 ± 11.9	0.6%	1.07	.291
Speed = 76 cm/s					
Average force (kg)	9.71 ± 4.4	8.63 ± 3.9	11.1%	4.95	.001
Total work (J)	173.92 ± 86.7	154.39 ± 79.9	11.2%	5.27	.001
Average power (W)	44.97 ± 23.8	40.13 ± 21.8	10.8%	4.20	.001
Range of motion (cm)	113.89 ± 15.0	114.50 ± 15.5	0.5%	0.55	.583

was not significantly different between the dominant and nondominant arms for the testing speeds ($P \geq .05$) (Table 2).

DISCUSSION

If closed kinetic chain isokinetic dynamometry is to be used for muscle performance testing, it must demonstrate test-retest reliability.[7,11] Several published reports show open kinetic chain isokinetic assessment of upper extremity muscle groups to be very reliable, with reliability coefficients for shoulder internal-external rotation peak torque ranging from 0.80 to 0.93 and those for shoulder flexion-extension ranging from 0.75 to 0.95.[12–14] The reliability coefficients we found using the Closed Chain Rider System were very similar to those reported using isolated open kinetic chain motions, despite the bilateral alternating multijoint movement that occurred during the closed kinetic chain exercise.

In the upper extremity, the scapulothoracic articulation and the acromioclavicular, sternoclavicular, and glenohumeral joints can be defined as a kinetic chain.[3] Controversy regarding the use of the term "closed kinetic chain" for the upper extremity is mentioned in the rehabilitation literature.[3,15] Weightbearing forces that create the closed kinetic chain effect do not normally occur in the upper extremity. However, Steindler[2] reported that the kinetic chain concept exists in the human when the hand meets considerable resistance versus when it is free to move, as observed in the open kinetic chain. Hand placement in the closed chain position changes neuromuscular activation due to differences in proprioceptor stimulation, muscle action, and joint compressive forces.[16–19] Clearly, many athletic activities, such as football, wrestling, and gymnastics, require the upper extremity to function as a closed kinetic chain.[15]

The 12% strength differences between dominant and nondominant arms that we observed make closed kinetic chain bilateral comparisons inappropriate because natural differences exist between extremities. For example, Perrin et al[20] reported that dominant-side muscle group strength of athletes in asymmetric upper extremity activities, such as throwing, may be up to 15% greater than the strength of the nondominant side. This difference in muscle performance between the dominant and nondominant limbs may affect the criteria for return of the injured extremity to a normal state during rehabilitation. Additional information on muscle force, work, and power during closed kinetic chain isokinetic exercise is needed so that appropriate rehabilitation norms can be established. Future studies should examine the efficacy of isokinetic closed chain exercise for pathologies involving the glenohumeral and scapulothoracic joints and should substantiate guidelines for use.

CONCLUSIONS

Regardless of testing speed or arm used during a concentric chest-press exercise pattern with the Closed Chain Rider System, the reliabilities of average force, total work, and average power were clinically acceptable. Clinicians should understand that natural limb differences exist between dominant and nondominant arms when tested in a closed kinetic chain.

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