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Research article

THE INFLUENCE OF BODY POSITION ON LOAD RANGE DURING ISOKINETIC KNEE EXTENSION/FLEXION

Brian W. Findley [1], Lee E. Brown [2]✉, Michael Whitehurst [3], Tedd Keating [4], Daniel P. Murray [2] and Lisa M. Gardner [2]

[1] Palm Beach Community College, Boca Raton, FL, USA
[2] California State University, Fullerton, Fullerton, CA, USA
[3] Florida Atlantic University, Davie, FL, USA
[4] Manhattan College, Bronx, NY, USA

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ABSTRACT

Isokinetic range of motion (ROM) has three distinct phases: rate of velocity development (RVD), load range (LR), and deceleration (DCC). The purpose of this study was to determine if differences in isokinetic knee extension/flexion LR exist between body positions. Ten subjects (4 males and 6 females, age 29.3 ± 5.4 yrs, ht 1.71 ± 0.10 m, wt 71.9 ± 12.9 kg) volunteered to participate in the seated vs. prone investigation and nine different subjects (4 males and 5 females, age 29.5 ± 6.9 yrs, ht 1.72 ± 0.09 m, wt 69.0 ± 13.8 kg) volunteered to participate in the seated vs. supine study. Each subject completed 3 maximal reciprocal concentric/concentric repetitions of dominant knee extension/flexion on a Biodex System 2 isokinetic dynamometer at 60, 120, 180, 240 and 360 deg·sec^{-1} in the supine or prone and seated positions. Repeated measures ANOVA revealed that only seated flexion at 360 deg·sec^{-1} (57.6 ± 1.7 degrees) elicited significantly ($p < 0.05$) greater LR than prone (49.2 ± 2.8 degrees). No significant differences in LR extension or flexion existed at any velocity between the supine vs. seated positions. ANOVA also demonstrated differences between seated vs. prone torque, work and power at most velocities while there was no difference between seated vs. supine. LR is the only phase of an isokinetic repetition where quantifiable resistance is maintained and this data appears to support that it may not be position-dependent but position may alter traditional performance variables.

KEY WORDS: Rate of velocity development, acceleration, deceleration.

INTRODUCTION

Isokinetic knee extension/flexion performance has customarily been measured in either the seated, prone or supine position. Previous research has shown that the dissimilar length-tension relationships and neurophysiological mechanisms, such as propagation of the stretch shortening cycle, inherent in these positions may produce disparate levels of peak torque, work, and power through a velocity spectrum (Kramer et al., 1996; Worrell et al., 1990; Worrell et al., 1989). Isokinetic evaluation of positional changes in testing the trunk musculature has also been shown to elicit significantly dissimilar levels of torque production (Findley et al., 2000). Given that the clinician has a variety of setup choices when exercising the knee extensors, they may manipulate body position according to torque goals. Since all three positions measure performance in an open kinetic chain, the

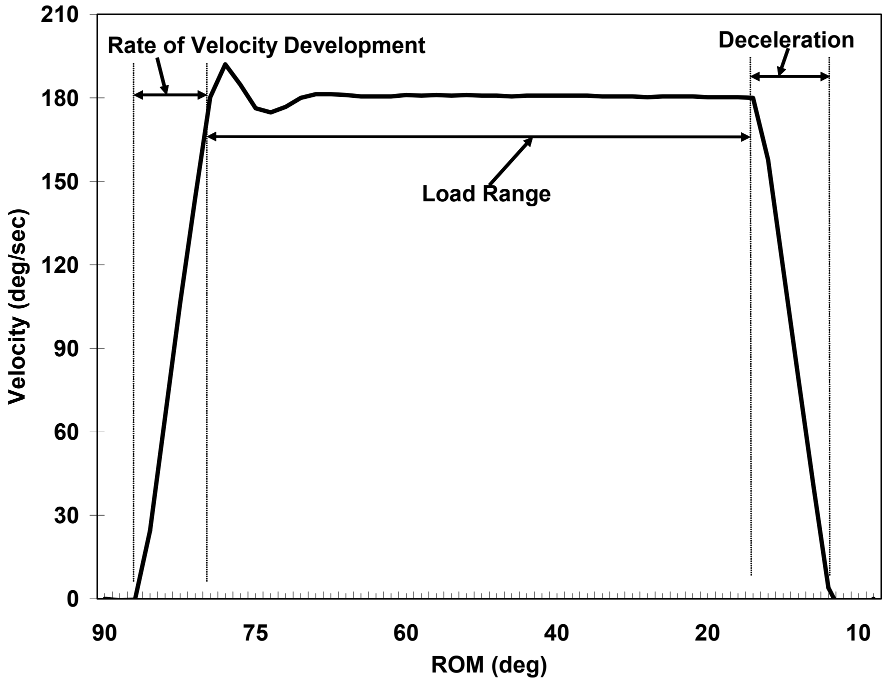

Figure 1. Three range of motion phases of an isokinetic repetition: rate of velocity development (RVD), load range (LR) and deceleration (DCC).

seated position is often preferable, as it may provide an increase in back support and lumbar stabilization in a manner consistent with subject comfort (Worrell et al., 1989; Brown and Whitehurst, 2000). However, some clinicians maintain the change in anatomical range of motion (ROM) coupled with the length tension properties of the quadriceps inherent in the prone and/or supine positions, may better simulate sport and task-specific movement (Worrell et al., 1989; Brown and Whitehurst, 2000).

Isokinetic exercise is distinguished by three phases: free limb rate of velocity development (RVD) prior to attainment of the pre-selected velocity, load range (LR) where the pre-selected velocity is maintained, and machine-controlled deceleration (DCC) (Brown and Whitehurst, 2000; Brown et al., 1995a; 1995b; 1998; Osternig, 1986; Rathfon et al., 1991) (Figure 1). During the initial acceleration phase and subsequent deceleration phase no quantifiable machine offered resistance to movement is present. Earlier research (Brown and Whitehurst, 2000; Brown et al., 1995b; Kovaleski et al., 1995) has shown that torque patterns are significantly affected when the load range phase of motion is taken into consideration. In short, this means that actual torque may differ by a large magnitude if evaluated outside the load range. Since only during the LR phase is the benefit of qualified resistance overload available (Brown et al., 1995b) and valid interpretation of the human torque output, it would be most desirable to establish if differences in LR are evidenced by manipulating subject position. Due to the change in length tension properties and subsequent contractile capabilities with varying exercise position, perhaps similar changes in limb acceleration can be expected as well. To date, it is unknown whether LR is position-dependent during knee extension/flexion exercise.

Given that hip position has demonstrated incongruent torque patterns during knee extension/flexion, with the seated position (relative hip flexion) yielding greater torque production than the supine or prone positions (relative hip extension) (Kramer et al., 1996; Findley et al., 2000; Rathfon et al.,1991), we hypothesized that these positions may elicit differences in LR as well. Thus, the purpose of this investigation was to determine whether differences in knee extension/flexion LR exist between body positions during isokinetic exercise across a velocity spectrum.

METHODS

Ten subjects (4 males and 6 females, age 29.3 ± 5.4 yrs, ht 1.71 ± 0.10 m, wt 71.9 ± 12.9 kg) volunteered to participate in the seated vs. prone investigation and nine different subjects (4 males and 5 females, age 29.5 ± 6.9 yrs, ht 1.72 ± 0.09 m, wt 69.0 ± 13.8 kg) volunteered to participate in the seated vs. supine study. All subjects provided written informed consent and completed a medical history form that was evaluated by a clinical exercise physiologist for conditions that would preclude participation. The

Table 1. Prone vs. seated knee extension/flexion degrees of load range. Data are means (±SD).

Velocity deg·sec^{-1}	Flexion Prone	Flexion Seated	Extension Prone	Extension Seated
60	88.4 (.9)	88.4 (.2)	88.6 (.4)	87.9 (.4)
120	82.4 (1.1)	82.4 (.3)	82.1 (.5)	82.6 (.5)
180	77.0 (1.3)	78.0 (.8)	77.6 (.5)	77.1 (.8)
240	68.9 (1.6)	70.8 (.4)	70.4 (.8)	68.7 (.8)
360	49.2 (2.8)	57.6 (1.7) *	53.3 (2.6)	57.8 (2.6)

*Significantly ($p < 0.05$) greater than prone.

project was approved by the hospital IRB committee prior to commencement.

Seated vs. prone testing

A calibrated Biodex System 2 isokinetic dynamometer, which has been shown to be a valid and reliable device (Brown et al., 1993; Taylor et al., 1991) was assembled with the knee attachment according to the manufacturer's specifications (Biodex Corporation, 1991). To evaluate seated knee extension/flexion, subjects were seated with the back attachment at 110 degrees relative to the seat and the posterior lower-leg touching the end of the seat. While subjects were in this position, the dynamometer fulcrum was aligned with the lateral condyle of the dominant knee. To evaluate prone knee extension/flexion subjects were positioned with the dynamometer table in the flat position and the knee distal to the edge of the pad. Following equipment set-up, subjects performed a 5-minute warm-up on a cycle ergometer at 60-80 rpm at 1 kp to prepare the cardio-respiratory system for strenuous activity and to facilitate optimal performance (Mawdsley and Croft, 1982; Osternig, 1986). Subjects re-entered the Biodex and stabilization straps were affixed to assure accurate, reproducible testing. Subjects were passively moved by the dynamometer through a ROM of 90 degrees of flexion to 0 degrees of extension. Gravity compensation analysis was performed by the computer system software. Subjects were asked to perform 3 gradient sub-maximal and 2 maximal reciprocal concentric repetitions of knee extension/flexion at an angular velocity of 60 deg·sec^{-1} for familiarization, to eliminate learning effect and to prevent discomfort in following sessions (Mawdsley and Croft, 1982). Following a 30 second recovery period, subjects were instructed to perform five maximal reciprocal repetitions at the same angular velocity. The three middle repetitions were collected by system software and analyzed (Brown et al., 2005a; Brown et al., 2005b). Consistent, moderate (no yelling or screaming) verbal encouragement was given; however, the computer screen was not made accessible for visual feedback. Following a one-minute rest period, subjects were tested at 120, 180, 240 and 360 deg·sec^{-1}. Testing position order was randomly selected (Timm and Fyke, 1993) with a 3-7 day period between sitting and prone tests.

Seated vs. supine testing

Methods for data collection of the supine portion of the investigation were identical to those described above with the exception of subject position. To evaluate supine knee extension/flexion performance, subjects were positioned on the dynamometer table in the flat position with the dominant knee distal to the edge of the pad and aligned with the dynamometer's axis of rotation.

Windowed data were collected by Biodex System 2 software (Biodex Corporation, 1991). Since isokinetic ROM is distinguished by three phases (Figure 1): free limb RVD, LR and DCC, LR was determined by subtracting RVD ROM and DCC ROM from total ROM using the available cursors on-screen (Brown et al., 2005a; Brown et al., 2005b; Brown and Whitehurst, 2003; Kovaleski et al., 1995; Wilk et al., 1992). Peak torque, total work and average power were also collected from the three middle repetitions. Eight three way mixed factor repeated measures 2 x 2 x 5 ANOVA (position X sex X angular velocity) were used to analyze the mean values of each muscle group (quadriceps and hamstrings) by each dependent variable (load range, peak torque, total work and average power). A-priori alpha was set at 0.05.

RESULTS

Subject testing demonstrated repeated repetition coefficients of variation, as measured by Biodex System 2 software, were at or below 8.0%. This assisted in the reporting of reproducible and low variability testing throughout the investigation.

Load range

ANOVA results revealed a main effect for speed and sex for each position and muscle group. There was

Table 2. Supine vs. seated knee extension/flexion degrees of load range. Data are means (±SD).

Velocity	**Flexion**		**Extension**	
deg·sec^{-1}	**Supine**	**Seated**	**Supine**	**Seated**
60	88.6 (.4)	87.6 (.4)	88.8 (.7)	88.5 (.3)
120	83.5 (.5)	83.9 (.4)	82.4 (1.0)	83.3 (.7)
180	78.6 (.8)	79.0 (.8)	76.6 (1.1)	78.0 (.9)
240	73.5 (1.3)	75.0 (.9)	67.4 (1.3)	70.9 (1.0)
360	57.8 (1.6)	59.5 (1.5)	57.0 (2.2)	55.8 (1.5)

also an interaction of position by speed for the prone vs. seated data with only seated flexion at 360 deg·sec^{-1} producing significantly ($p < 0.05$) greater LR than prone flexion while no differences were evident at any other velocity for flexion or extension (Table 1). There were no differences between supine vs. seated LR for extension or flexion at any velocity (Table 2).

Peak torque, total work and average power

Each separate ANOVA analysis (load range, peak torque, total work and average power for each position and each muscle group) demonstrated a significant main effect for speed and sex. For the seated vs. prone data there was a significant interaction of position and speed for extension peak torque (60, 240 and 360 were not different) and flexion total work (60 and 240 were not different) otherwise all seated values for each variable were significantly greater than prone values (Table 3). There were no differences between seated vs. supine values for any variable at any velocity (Table 4).

DISCUSSION

This study demonstrated that LR is not position dependent for the knee extensors or flexors when seated, prone and seated are compared. There was a position dependence for peak torque, total work and average power between seated vs. prone (seated was greatest). This is in agreement with previous researchers (Findley et al., 2000; Kramer et al., 1996; Rathfon et al., 1991) and convincingly demonstrates that performance variables are altered when the knee extensors and flexors length-tension relationship is changed. However, the focus of this study was LR and the human ability to achieve a constant velocity range at a given speed. As previously explained, LR is the only phase during an isokinetic movement where quantifiable resistance is maintained and where valid and reliable performance data may be collected (Brown, 1995b; Brown et al., 1998).

Since performance variables were almost completely unaffected by body position between

Table 3. Prone vs. seated peak torque (PT), total work (TW) and average power (AP). Data are means (±SD).

	Velocity	**Flexion**		**Extension**	
	(deg·sec^{-1})	**Prone**	**Seated**	**Prone**	**Seated**
PT (Nm)	60	87.1 (26.3)	99.2 (23.0) *	173.7 (45.3)	189.9 (50.3)
	120	73.9 (22.7)	91.4 (21.3) *	129.2 (44.5)	163.4 (48.3) *
	180	71.0 (18.4)	86.0 (21.0) *	115.8 (39.3)	139.9 (45.9) *
	240	66.4 (17.9)	83.5 (22.9) *	108.9 (29.4)	123.3 (44.4)
	360	67.0 (16.8)	96.7 (27.3) *	91.3 (27.3)	106.2 (42.7)
TW (Joules)	60	331.4 (132.4)	355.4 (105.3)	531.3 (165.9)	576.1 (183.4)
	120	256.7 (94.3)	347.1 (69.8) *	398.2 (180.0)	536.7 (157.0)
	180	234.7 (72.8)	314.9 (70.4) *	371.9 (151.8)	464.5 (141.4)
	240	216.7 (69.5)	260.3 (94.8)	341.2 (152.4)	396.0 (141.2)
	360	170.0 (54.9)	209.7 (76.6) *	253.3 (119.8)	310.7 (123.1)
AP (Watts)	60	61.0 (15.2)	72.2 (17.1) *	94.0 (27.1)	126.3 (36.8) *
	120	90.8 (31.0)	118.2 (41.3) *	137.2 (57.8)	209.3 (62.2) *
	180	119.1 (39.8)	139.2 (68.4) *	180.6 (65.6)	252.3 (80.7) *
	240	137.8 (42.8)	165.9 (59.0) *	209.9 (76.5)	263.9 (101.3) *
	360	132.0 (47.1)	172.2 (69.3) *	200.0 (86.9)	265.0 (105.1) *

*Significantly ($p < 0.05$) greater than prone.

Table 4. Supine vs. seated peak torque (PT), total work (TW) and average power (AP).

	Velocity (deg·sec^{-1})	Flexion		Extension	
		Supine	Seated	Supine	Seated
PT (Nm)	60	89.1 (28.3)	78.9 (25.8)	175.6 (67.5)	163.8 (62.8)
	120	81.0 (25.1)	69.7 (26.4)	158.8 (60.4)	150.3 (53.8)
	180	75.3 (24.3)	60.1 (24.2)	143.0 (55.6)	142.6 (49.7)
	240	67.2 (19.9)	64.6 (29.3)	127.9 (46.9)	131.3 (55.9)
	360	57.4 (23.2)	56.0 (22.8)	110.7 (42.3)	113.3 (45.2)
TW (Joules)	60	370.6 (163.3)	297.7 (55.2)	652.0 (276.2)	558.3 (156.3)
	120	340.3 (149.9)	273.8 (46.0)	599.1 (245.8)	556.9 (224.0)
	180	279.0 (114.2)	231.8 (51.4)	538.9 (232.5)	534.6 (200.2)
	240	229.3 (91.3)	189.3 (47.8)	446.0 (184.7)	455.2 (194.4)
	360	148.0 (66.9)	119.2 (45.8)	310.4 (129.2)	322.5 (134.2)
AP (Watts)	60	56.7 (17.7)	48.0 (11.7)	117.6 (47.5)	112.5 (68.8)
	120	96.3 (47.3)	89.5 (33.2)	189.1 (74.6)	178.3 (76.3)
	180	114.9 (53.2)	91.8 (57.1)	237.9 (96.9)	229.5 (77.4)
	240	106.5 (35.2)	102.4 (41.5)	242.4 (99.4)	241.2 (94.5)
	360	80.9 (48.7)	79.7 (45.2)	224.3 (99.3)	221.6 (64.7)

seated vs. supine it would appear that those positions may be interchanged when maximum strength values are the goal of the testing session. However, the prone position consistently produced significantly lower performance values when compared to the seated position. This appears to be an anomaly since the length-tension relationship between supine and prone is almost identical. The difference may lie in the fact that knee extension in the supine position is gravity assisted. Therefore, the less than optimal length-tension relationship may be equivocated by the assistance of gravity. This is only speculation and requires further research.

RVD is the essence of isokinetics given that it is solely responsible for determining the range of motion spent under constant velocity, or LR (Brown et al., 1998; Chen et al., 1994; Osternig, 1986). While muscle force production characteristics are length-dependent, it appears that limb RVD is not reliant on hip position (with the exception of 360 deg·sec^{-1} in flexion). This may be a function of the muscles ability to produce high levels of acceleration within the mid range of length tension used in this study. Although total knee ROM in each test was a constant 90 degrees, changes in anatomical ROM, at the hip, were induced by varying body position. It appears, however that these variations had no influence on RVD and, consequently, LR.

The results of this study may be relevant to isokinetic technicians and clinicians. Primarily, it affords practitioners the ability to utilize dynamometer configurations that are the easiest to set up and monitor. The isokinetic dynamometer is most commonly used in the rehabilitation setting to train the knee, in flexion and extension, or shoulder, in external and internal rotation (Osternig, 1986). Both these joints can be trained from the seated position, and as such it is often the position of choice for those in clinical practice. Since load range during knee flexion and extension may be independent of patient position, the practitioner can feel confident that effective training is taking place in the seated position relative to load range, despite a less than ideal length tension relationship. However, the end user should remain aware that performance variables appear to be significantly affected by body position. Many clinicians appear to have been dissuaded from the continued use of the isokinetic dynamometer as some would argue that its complicated set-ups are not time efficient. If the dynamometer can be used effectively for both the knee and the shoulder in the seated position, and pre-programmed protocols are used, then dynamometer set-ups can be performed quickly and easily.

The fact that load range may be independent of patient position during knee flexion and extension will also afford clinicians the ability to choose an appropriate training position based on patient comfort. Again, the seated position may be the position of choice, as it allows the patient to feel like more of an active participant in the exercise.

Practitioners involved in selecting test and training positions must take many factors into consideration relative to the goals and objectives of the exercise. Torque production goals, low back pathology, functional status and stabilization factors are but a few of these considerations (Findley et al., 2000). However, if goals specific to velocity overload of the quadriceps and hamstring are required, hip position is independent of these goals. The greatest factor related to LR may be the limbs position relative to the end range of motion.

CONCLUSIONS

Due to the fact that many rehabilitative goals are governed by protocols specific to the overload principle, other agonist/antagonist muscle groups should be investigated under similar circumstances to determine if subject position influences LR. Other pairs of joints (ankle/knee, shoulder/elbow) cannot be assumed to share this independence with respect to LR.

Based on this information and within the limitations of this study these results indicate that LR may not be position-dependent during isokinetic knee extension/flexion exercise yet traditional performance variables such as peak torque, total work and average power may be. Therefore, it would appear that clinicians must base subject positioning on factors other than LR.

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AUTHORS BIOGRAPHY

Brian W. FINDLEY
Employment
Palm Beach Community College, Boca Raton, Florida, USA
Degree
MEd
Research interests
Education and isokinetics.
E-mail: findleyb@pbcc.edu

Lee E. BROWN
Employment
California State University, Fullerton, Fullerton, California, USA
Degree
EdD
Research interests
High velocity isokinetics.
E-mail: leebrown@fullerton.edu

Michael WHITEHURST
Employment
Florida Atlantic University, Davie, Florida, USA
Degree
EdD
Research interests
Function in the elderly
E-mail: whitehur@fau.edu

Tedd KEATING
Employment
Manhattan College, Riverdale, New York, USA
Degree
PhD
Research interests
Strength and Conditioning
E-mail: tedd.keating@manhattan.edu

Daniel P. MURRAY
Employment
California State University, Fullerton, Fullerton, California, USA
Degree
MS, PT
Research interests
High velocity isokinetics.
E-mail: d_murray77@yahoo.com

Lisa M. GARDNER
Employment
California State University, Fullerton, Fullerton, California, USA
Degree
MS
Research interests
High velocity isokinetics.
E-mail: lisabelle79@yahoo.com

KEY POINTS

- Load range is the constant velocity phase where torque is collected.
- Load range has an inverse relationship with velocity.
- Load range may not be position dependent for the knee extensors or flexors.

✉ **Lee E. Brown**
Associate Professor, Strength and Conditioning, California State University, Fullerton, Department of Kinesiology, KHS 233, 800 N. State College Blvd., Fullerton, CA 92831, USA.