GENDER DIFFERENCES IN KNEE EXTENSOR AND FLEXOR PERFORMANCE

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The purpose of this study was to evaluate gender differences in peak torque (PT), rate of torque development (RTD), power, and work during isometric (ISOM) knee extension and isokinetic (ISOK) knee extension and flexion. Forty-four university women and men volunteered to perform the test exercises on a computerized dynamometer. Data were reduced with manufacturer software and were analyzed with an independent-samples *t*-test in order to determine gender differences. Results revealed significant differences ($P \leq 0.001$) for ISOM PT and ISOK PT, RTD, power, and work. Gender differences in knee extensor and flexor performance are present, with women demonstrating a range of 68.9 to 76.9% of their male counterparts. Conversely, the rate of force production is not gender specific during ISOM knee extension.

KEYWORDS: strength, torque power, rate of force development, sex differences

INTRODUCTION: Power is defined as the explosive nature of force production (Hakkinen and Komi, 1985). Many sports involve powerful movements, characterized by the generation of force over an acute period of time. Variables utilized to assess such movements include: rate of force development (RFD), rate of torque development (RTD), time to peak torque, and time to takeoff. Previous research has used these variables to test muscular performance within a variety of subject populations. However, normative data and gender differences and similarities are not comprehensively established in athletic populations.

Computerized dynamometry is a reliable and commonly used tool to assess peak torque (PT), RTD, power, and work during isometric (ISOM) knee extension and isokinetic (ISOK) knee extension and flexion exercises (Maffiuletti et al., 2007). Previous research has provided gender and age specific normative values for PT (Freedson et al., 1993; Lindle et al., 1997; Phillips et al., 2000) and prediction equations for PT, power, and work of nonathletic individuals (Neder et al., 1999), but has failed to provide normative values of PT, RTD, power, and work in athletic young adults. Previous studies have used PT to assess gender differences in knee flexion and extension performance, showing that women who suffer anterior cruciate ligament injuries have lower ISOK knee flexion strength compared to men (Meyer et al., 2009). Additionally, normative data for RTD is confounded due to the variety of calculations used.

Gender differences have been demonstrated in some lower body muscular strength tasks (Ebben et al., 2009; Heyward et al., 1986; Mayhew et al., 1994; Mayhew and Salm, 1990; Miller et al., 1993; Sinaki et al., 2001) but not others (Ebben et al., 2007). During vertical jumping, women have been shown to perform at 66.0 to 68.8% of their male counterparts (Mayhew and Salm, 1990; Ebben et al., 2009; Mayhew et al., 1994), whereas during the countermovement jump, women and men have shown similarities in RFD and time to takeoff (Ebben et al., 2007). Therefore, these data from static and dynamic exercises suggest women produce force at a smaller magnitude than men, but their rate of force production is the same. Thus, the purpose of this study was to assess gender differences in PT, RTD, power, and work during ISOM knee extension and ISOK knee extension and flexion.

METHODS: Forty-four university women and men volunteered for this study. Subject data are presented in Table 1.

Table 1. Subject statistics (mean ± SD)

	Women (N=22)	Men (N=22)
Age (years)	20.73 ± 1.28	21.59 ± 1.79
Height (cm)*	167.52 ± 8.94	184.23 ± 9.21
Body mass (kg)*	144.77 ± 13.1	183.86 ± 21.9
High school sports participation (years)	3.92 ± 0.29	3.81 ± 0.25
College sports participation (years)	1.99 ± 1.87	1.76 ± 1.81
Plyometric training participation (days/week)	1.24 ± 1.61	0.96 ± 1.08
Resistance training participation (days/week)	3.16 ± 0.61	3.01 ± 0.79
Aerobic training participation (days/week)	4.01 ± 1.87	3.79 ± 1.93

* Significantly different between women and men ($p \leq 0.05$)

Inclusion criteria consisted of subjects who were 18-27 years old, who participated in NCAA Division I athletics or club or intramural sports, and at least 2 months of biweekly lower body resistance training that which included knee extension and flexion exercises. Exclusion criteria included any history of knee pathology that resulted in functional limitation of the right leg. Subjects provided informed written consent. The study was approved by the institution's internal review board and designed in accordance with the ethical standards of the Helsinki Declaration.

Subjects warmed up and performed 15 seconds of lower body dynamic stretching exercises encompassing each major muscle group. Subjects were then positioned and secured in a dynamometer (System 4, Biodex Inc., Shirley, NY, USA) according to manufacturer specifications. Extraneous movement during the exercise was reduced with the use of straps across the chest, waist, right thigh, and right ankle. The right knee joint was positioned goniometrically at 90 degrees and calibrated with the system software and the mass of the limb was measured. Five seconds of ISOM knee extension were performed at 60 degrees of knee flexion, and ISOK knee extension and flexion were performed concentrically at a speed of 60 degrees · sec. Two test specific warm up sets consisting of three repetitions of each exercise, were performed at 75 and 90%, respectively, of their self-perceived maximum ability.

Five minutes rest was given before the counterbalanced testing sets. Testing consisted of three five second maximal isometric right knee extension and three maximal isokinetic right knee extension and flexion exercises performed at a speed of 60 degrees · sec.

Torque curves for each subject were analyzed using manufacturer's software. Peak torque, RTD, power, and work were calculated for each 5 second isometric sample and each isokinetic knee extension and flexion phase. Rates of torque development were calculated for the first 300 ms of each test exercise and normalized to one second. Absolute torque values were presented in order to make comparisons to previous literature.

All data were analyzed using SPSS 18.0. An independent samples *t*-test was used to evaluate gender differences in PT, RTD, power, and work, as well as differences in subject's demographic data, athletic participation, and training experiences. The *a priori* alpha level was set at $p < 0.05$.

RESULTS: Results reveal a number of gender differences in ISOM and ISOK PT, RTD, power, and work, and are presented in Table 2.

Table 2. Mean PT, RTD, power, and work during ISOM knee extension and ISOK knee extension and flexion for women and men.

	Women (N=22)	Men (N=22)	Ratio	*P*
ISOM Extension PT (Nm)	127.40 ± 18.68	173.61 ± 42.34	73.38	0.001
ISOM Extension RTD ($Nm \cdot s^{-1}$)	282.75 ± 91.28	328.76 ± 89.74	86.00	0.099
ISOK Extension PT (Nm)	118.62 ± 20.21	165.17 ± 32.65	71.82	0.001
ISOK Flexion PT (Nm)	61.33 ± 10.37	86.81 ± 13.05	70.65	0.001
ISOK Extension RTD ($Nm \cdot s^{-1}$)	299.70 ± 72.32	436.52 ± 115.01	68.66	0.001
ISOK Flexion RTD ($Nm \cdot s^{-1}$)	156.46 ± 39.61	237.38 ± 44.70	65.91	0.001
ISOK Extension power (W)	114.27 ± 19.74	161.61 ± 32.89	70.71	0.001
ISOK Flexion power (W)	63.53 ± 9.92	90.86 ± 16.69	69.92	0.001
ISOK Extension work (J)	152.61 ± 25.56	201.22 ± 43.20	75.84	0.001
ISOK Flexion work (J)	88.44 ± 17.66	114.99 ± 23.20	76.91	0.001

Data presented as (mean ± SD); Ratio = represents the ratio of women to men; *P* = *p*-value
ISOM = isometric, ISOK = isokinetic, PT = peak torque, RTD = rate of torque development, W = work

DISCUSSION: This is the first study to investigate gender differences in PT, RTD, power, and work during ISOM knee extension and ISOK knee extension and flexion exercises of an athletic university population. Gender differences were present in ISOM PT and all ISOK variables assessed. However, women and men produce knee extension torque at the same rate during static conditions.

Women in the present study demonstrated 73.4, 71.8, and 70.7% of men's ISOM knee extension and ISOK knee extension and flexion PT, respectively. These gender differences are smaller than those previously demonstrated by women who performed at 63.4, 66.4, and 56.3% the values of men, in the aforementioned variables, respectively (Phillips, et al., 2000). It should be noted that research has revealed no gender differences in lower body force production per unit cross-sectional area of strength-trained individuals (Castro, et al., 1995).

No gender differences were demonstrated in ISOM knee extension RTD, which is consistent with previous research demonstrating no gender differences in RFD and time to takeoff during the countermovement jump (Ebben, et al., 2007). No gender differences were also found in time to peak torque during ISOK knee extension and flexion exercises performed at 180 degrees · sec (De Ste Croix, et al., 2004). However, the current study revealed gender differences in RTD during ISOK knee extension and flexion, with women performing at 68.7 and 65.9% of men, respectively. This gender difference may be explained by women's longer electromechanical delay, which has been thought to result in a slower rate of force production (Bell and Jacobs, 1986). The explanation for the inconsistency in the above absence and presence of gender differences in RTD during static and dynamic powerful movements is unknown.

In the present study, women's performance of ISOK knee extension and flexion, at a speed of 60 degrees· sec , demonstrated power values of 70.7 and 69.9% of men's, respectively. Previous reports of gender differences in power, during ISOK knee extension and flexion at 300 degrees · sec, revealed women results were 61.7 and 55.9% of men's (Neder, et al., 1999). The variability in the gender differences in power is likely due to the speed at which the exercise was performed. Gender mediated differences in neuromotor control may exist thus, potentially negatively affecting women's muscle force production and speed (Karlsson and Jacobs, 1981).

Gender differences in work were also present during ISOK knee extension and flexion, with women performing at 75.8 and 76.9% of their male counterparts, respectively. Previous reports reveal larger gender differences in work, with women performing at 64.9 and 60.1% of men, during the same exercises (Neder, et al., 1999).

CONCLUSION: Results from the present study demonstrate gender differences in ISOM knee extension PT and ISOK knee extension and flexion PT, RTD, power, and work, with women producing 68.9 to 76.9% of the capabilities of men. However, no gender differences were present in ISOM knee extension RTD. Ultimately, these data suggest, in athletic populations, women present smaller gender differences in ISOM knee extension and ISOK knee extension and flexion exercises than previous reports documenting gender differences in nonathletic populations. Future research should evaluate gender differences in strength and power variables of athletic and non-athletic populations.

REFERENCES:

Castro, M.J., McCann, D.J., Shaffrath, J.D., and Adams, W.C. (1995). Peak torque per unit cross-sectional area differs between strength-trained and untrained young adults. *Medicine and Science In Sports and Exercise*, 27, 397-403.

Bell, D.G. and Jacobs, I. (1986). Electromechanical response times and rate of force development in males and females. *Medicine and Science in Sports and Exercise*, 18, 31-36.

De Ste Croix, M.B.A., Deighan, M.A., and Armstrong, N. (2004). Time to peak torque for knee and elbow extensors and flexors in children, teenagers and adults. *Isokinetics and Exercise Science*, 12, 143-148.

Ebben, W.P., Flanagan, E., and Jensen, R.L. (2007). Gender similarities in rate of force development and time to takeoff during the countermovement jump. *Journal of Exercise Physiology Online*, 10, 10-17.

Ebben, W.P., Flanagan, E., and Jensen, R.L. (2009). Bilateral facilitation and laterality during the countermovement jump. *Perceptual and Motor Skills*, 108, 251-258.

Freedson, P.S., Gilliam, T.B., Mahoney, T., Maliszewski, A.F., and Kastango, K. (1993). Industrial torque levels by age group and gender. *Isokinetics and Exercise Science*, 3, 34-42.

Hakkinen, K. and Komi, P.V. (1985). Effect of explosive-type strength training on electromyographic and force production characteristics of leg extensor muscles during concentric and various stretch-shortening cycle exercises. *Scandinavian Journal of Sports Science*, 7, 65-76.

Karlsson, J. and Jacobs, I. (1981). Is the significance of muscle fiber types to muscle metabolism different in females than in males? In Borms, J., Hebbelink, M., and Venerando, A., eds. Women and sport, an historical, biological, physiological and sports medical approach. New York: Karger.

Lindle, R.S., Metter, E.J., Lynch, N.A., Fleg, J.L., Fozard, J.L., Tobin, J., Roy, T.A., and Hurley, B.F. (1997). Age and gender comparisons of muscle strength in 654 women and men aged 20-93yr. *Journal of Applied Physiology*, 83, 1581-1587.

Maffiuletti, N.A., Bizzini, M., Desbrosses, K., Babault, N., and Munzinger, U. (2007). Reliability of knee extension and flexion measurements using the Con-Trex isokinetic dynamometer. *Clinical Physiology and Functional Imaging*, 27, 346-353.

Mayhew, J.L., Bemben, D.A., Bemben, M.G., Piper, F.C., Rohrs, D. M., and Salm, P.C. (1994). Gender differences in strength and anaerobic power tests. *Journal of Human Movements Studies,* 26, 227-243.

Mayhew, J.L. and Salm, P.C. (1990). Gender differences in anaerobic power tests. *European Journal of Applied Physiology*, 60, 133-138.

Meyer, G.D., Ford, K.R., Barber Foss, K.D., Liu, C., Nick, T.G., and Hewett, T.E. (2009). The relationship of hamstrings and quadriceps strength to anterior cruciate ligament injury in female athletes. *Clinical Journal of Sport Medicine*, 19, 3-8.

Miller, A.E.J., MacDougall, J.D., Tarnopolsky, M.A., and Sale, D.G. (1993). Gender differences in strength and muscle fiber characteristics. *European Journal of Applied Physiology*, 66, 254-262.

Neder, J.A., Nery, L.E., Shinzato, G.T., Andrade, M.S., Peres, C., and Silva, A.C. (1999). Reference values for concentric knee isokinetic strength and power in nonathletic men and women from 20 to 80 years old. *Journal of Orthopaedic and Sports Physical Therapy*, 29, 116-126.

Phillips, B.A., Lo, S.K., and Mastaglia, F.L. (2000). Isokinetic and isometric torque values using a Kin-Com dynamometer in normal subjects aged 20 to 69 years. *Isokinteics and Exercise Science*, 8, 147-159.

Sinaki, M., Nwaogwugwu, N.C., Phillips, B.E., and Mokri, M. (2001). Effect of gender, age, and anthropometry on axial and appendicular muscular strength. *American Journal of Physical Medicine and Rehabilitation*, 80, 330-338.

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