ISOKINETIC KNEE MUSCLE STRENGTH ASYMMETRY IN UNIVERSITY SWEEP ROWERS

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ABSTRACT

The prevalence of musculoskeletal injuries in sweep rowing is high. As nearly 50% of power during sweep rowing is contributed by the legs, the presence of muscle imbalances may predispose rowers to overuse injuries. The purpose of the study was to assess knee muscle strength symmetry between dominant and non-dominant limbs of male and female rowers. A descriptive, quantitative research design was used. Twenty-four male and 13 female rowers aged 18–26 years participated. Bilateral isokinetic knee flexion and extension peak torque and hamstrings/quadriceps (H/Q) ratios were assessed at 60°/s and 180°/s using an isokinetic dynamometer. The data was analysed using Mann-Whitney U and Wilcoxon rank tests and significance was set at $p \leq 0.05$. In males, the dominant knee extension torque values at 60°/s and 180°/s were significantly larger than that of the non-dominant side ($p \leq 0.05$). In females, the non-dominant eccentric H/Q ratio at 60°/s was 15% larger than that of the dominant side ($p=0.019$). Bilateral differences observed in knee extension torque for males and in H/Q ratio for females highlight the need for isokinetic testing of sweep rowers, to improve performance and prevent injury.

Keywords: Injury; Isokinetic; Knee; Rowing; Strength.

INTRODUCTION

Several studies have emphasised the major role of the quadriceps muscle group in producing power during the rowing stroke (Soper & Hume, 2004). During the drive-phase of sweep rowing, nearly half of the required power (46%) is contributed by the legs, a third by the trunk (32%) and about a fifth (22%) by the arms (González, 2014). The development of muscle imbalances because of the unique training involved with rowing may predispose sweep rowers to overuse injuries and this may negatively affect their rowing performance (Wilson *et al*., 2014). Buckeridge *et al*. (2014) and An *et al*. (2015) reported asymmetries of between 6.8% and 11.4% in the lower limbs of sweep rowers. Although the relationship between bilateral muscle strength imbalances and injury incidence is not clear, it has been generally accepted that bilateral imbalances higher than 10% are considered a predisposition for injury (Dauty *et* al., 2003).

Perea and Ariyasinghe (2016) found that the prevalence of injury in male and female rowers was 68.8% and 57.1%, respectively, and that the two most prevalent injuries were lower back and knee pain. These findings were supported by Buckeridge *et al*. (2015) and by Fenwick *et al*. (2009). Currently there are no knee extension-flexion peak torque (PTQ) data available for South African sweep rowers.

PURPOSE OF RESEARCH

The aim of the present study was to assess the isokinetic PTQ symmetry between the dominant (DOM) and non-dominant (N-DOM) limbs of South African open-class male and female university sweep rowers for the knee joint.

METHODOLOGY

The research design used was quantitative, descriptive and comparative in nature, as bilateral and antagonist–agonist comparisons were made. Convenience sampling was utilised, and the participants consisted of 37 open-class university sweep rowers. Twenty-four (24) male and 13 female rowers between the ages of 18 and 26 years were recruited from two university rowing clubs. Limb dominance and rowing experience were self-reported. Participants were requested to refrain from any exercise 24 hours prior to the test and to refrain from eating or drinking for 3 hours prior to the test. Only healthy and injury-free rowers were included in the study; each participant was screened for musculoskeletal injury or systemic illness.

Stature in centimetres (cm) was measured to the nearest millimetre (mm), body mass in kilogram (kg) was measured to the nearest gram (g), and body mass index (BMI) in kg/m^2 was calculated (ACSM, 2014). Body fat percentage (BF%) was calculated from the sum of six skinfolds (triceps, subscapular, supra-iliac, abdomen, thigh and calf) (Carter, 1982).

Bilateral concentric (CON) and eccentric (ECC) isokinetic knee flexion and extension PTQ were assessed at 60°/s and CON PTQ was assessed at 180°/s. All measurements were gravity-corrected using the dynamometer's software. A Humac Norm Isokinetic Dynamometer (CSMi, Stoughton, MA) was used. Prior to data collection, the dynamometer was calibrated according to the manufacturer's instructions. Each participant performed 10 minutes of rowing on a Concept2 rowing ergometer (Concept2 Inc, Morrisville, VT) at an easy self-paced intensity (10–12 on the 6–20 Borg Scale) to warm up. The participants were positioned on the dynamometer according to standardised protocols (Otten *et al*., 2013). Participants performed five familiarisation efforts (four submaximal efforts and one maximal effort) prior to each testing condition. After familiarisation, five maximal knee extension–flexion isokinetic efforts were performed. Both visual and verbal feedback were given to motivate participants to give a maximal effort (Habets *et al*., 2018). The DOM limb was tested first, followed by the N-DOM limb. Following the CON test, the ECC test was performed after a 2-minute rest period. Subsequently, CON isokinetic testing of knee flexion and extension was performed at 180°/s (after a 2-minute rest period). Only tests that contained data with a coefficient of variance (CoV) smaller than 15% were included, to ensure reliability of the isokinetic testing. On completion of their test, each participant performed light static stretching (each stretch was held for 30 seconds and repeated twice on each side).

The following isokinetic variables were used for analysis: maximum PTQ measured in Newton-metres (Nm) normalised to body weight (PTQ/BW) measured in Nm/kg, and antagonist/agonist ratios (e.g., H/Q). Bilateral comparisons between the DOM and the N-DOM limbs were performed to assess each participant's bilateral muscle balance (Kabaciński *et al*., *2018*).

Descriptive statistics (means, minimums, maximums and standard deviations) were calculated. Shapiro-Wilk tests for normality were used to determine the need for parametric (t-tests) or non-parametric statistics (Mann-Whitney U and Wilcoxon rank tests). Statistical significance was set at $p \leq 0.05$ (Pallant, 2007).

Ethical considerations

The study's research protocol was approved by the University of Johannesburg Faculty of Health Sciences Research Ethics Committee (REC-01-168-2017).

RESULTS

Both male and female sweep rowers were of similar age (21.58 years vs 21.77 years, p=0.936) and BMI (24.58 kg/m² vs 24.43 kg/m², p=0.667), but they differed significantly in terms of body mass, with the male rowers heavier than the female rowers (78.79 kg vs 68.85 kg, p=0.010). In terms of stature, the male rowers were significantly taller than the female rowers (179.2 cm vs 167.8 cm, p=0.000), and the BF% for males was significantly lower than that of the female rowers (11.25% vs 21.15%, p=0.000). The males' average rowing experience was 7.08±2.24 years, while the females' average rowing experience was 5.27±2.86 years, but this difference was not significant (p=0.062) (Table 1).

Table 1. **DEMOGRAPHICS FOR UNIVERSITY-LEVEL MALE AND FEMALE SOUTH AFRICAN OPEN-CLASS SWEEP ROWERS**

	Males (n=24) Mean ± SD (range)	**Females** (n=13) Mean± SD (range)	**Males vs females** (p-value)
Age (years)	21.58±2.08 (18–26)	21.77±2.28 (19–26)	0.936
Weight (kg)	78.79±8.88 (60–97)	68.85±12.38 (47–95)	0.010*
Height (cm)	179.2±6.7 (164–191)	168.0±8.6 (152–189)	0.000*
BMI (kg/m²)	24.58±2.62 (20.2–30.0)	24.43±3.80 (20.3–34.6)	0.667
BF (%)	11.25±2.89 (7–16)	21.15±4.83 (14–30)	0.000*
Rowing experience (years)	7.08±2.24 (3.0–12.0)	5.27±2.86 (1.5–9.0)	0.062

*Statistically significant difference (p≤0.05); SD=standard deviation

The CON knee extension PTQ/BW values at 60°/s for the male rowers in the study were 2.64±0.50 Nm/kg for the DOM limb and 2.48 ±0.48 Nm/kg for the N-DOM limb (p=0.045) (Table 2). The CON knee flexion PTQ/BW values for the male rowers were 1.27±0.26 Nm/kg for the DOM side and 1.24±0.25 Nm/kg for the N-DOM side (p=0.368). The CON H/Q ratios for the male rowers were 48.92±10.05% for the DOM limb and 50.38±8.02% for the N-DOM limb (p=0.435). The CON knee extension PTQ/BW values at 60°/s for the female rowers were 2.00±0.35 Nm/kg for the DOM side and 1.84±0.34 Nm/kg for the N-DOM side (p=0.161). The CON knee flexion PTQ/BW values for the female rowers were 0.64±0.24 Nm/kg for the DOM limb and 0.65±0.19 Nm/kg for the N-DOM limb (p=0.087). The CON H/Q ratios for the female rowers were 44.00±10.89% for the DOM side and 49.54±8.21% for the N-DOM side (p=0.099) (Table 2).

***Table 2.* CON ISOKINETIC KNEE EXTENSION AND FLEXION VALUES FOR UNIVERSITY-LEVEL MALE AND FEMALE SOUTH AFRICAN OPEN-CLASS SWEEP ROWERS AT 60°/S**

	DOM (Mean ±SD)	**N-DOM** (Mean ±SD)	**% diff.**	**DOM vs N-DOM** (p-value)
	Males			
KE PTQ (Nm)	207.46±45.71	194.67±42.51	6.17	0.038*
KE PTQ/BW (Nm/kg)	2.64±0.50	2.48±0.48	6.10	0.045*
KF PTQ (Nm)	99.46±20.73	96.96±20.65	2.51	0.399
KF PTQ/BW (Nm/kg)	1.27±0.26	1.24±0.25	2.34	0.368
H/Q (%)	48.92±10.05	50.38±8.02	2.90	0.435
	Females			
KE PTQ (Nm)	137.85±33.95	126.69±32.45	8.10	0.172
KE PTQ/BW (Nm/kg)	2.00±0.35	1.84±0.34	7.98	0.161
KF PTQ (Nm)	61.85±24.66	63.00±20.75	1.83	0.694
KF PTQ/BW (Nm/kg)	0.64±0.24	0.65±0.19	1.89	0.087
H/Q (%)	44.00±10.89	49.54±8.21	11.18	0.099

*Statistically significant difference (p≤0.05)

KF=knee flexion KE=knee extension PTQ=peak torque PTQ/BW=peak torque divided by body weight Nm=Newton metre DOM=dominant leg N-DOM=non-dominant leg SD=standard deviation % diff.=percentage difference

At 180°/s, the male sweep rowers had CON knee extension PTQ/BW values of 1.98±0.32 Nm/kg and 1.90±0.33 Nm/kg for the DOM and N-DOM limbs, respectively (p=0.012), and CON knee flexion PTQ/BW values of 0.89±0.22 Nm/kg and 0.88±0.23 Nm/kg for the DOM and N-DOM limbs (p=0.572) (Table 5). Female rowers had CON knee extension PTQ/BW values at 180°/s of 1.47±0.23 Nm/kg for the DOM limb and 1.43±0.33 Nm/kg for the N-DOM limb (p=0.326), and CON knee flexion PTQ/BW values of 0.64±0.24 Nm/kg and 0.65±0.19 Nm/kg for the DOM and N-DOM sides, respectively (p=0.540). The CON H/Q ratios at 180°/s for the male rowers were 45.08±10.21% for the DOM leg and 45.88±9.96% for the N-DOM leg (p=0.692), while the female rowers reported ratios of 42.61±12.11% for the DOM side and 45.31±7.50% for the N-DOM leg CON H/Q ratio at 180°/s (p=0.234).

Table 3. **CON ISOKINETIC KNEE EXTENSION AND FLEXION VALUES FOR UNIVERSITY-LEVEL MALE AND FEMALE SOUTH AFRICAN OPEN-CLASS SWEEP ROWERS AT 180°/S**

	DOM (Mean ±SD)	**N-DOM** (Mean ±SD)	**% diff.**	**DOM vs N-DOM** (p-value)
	Males			
KE PTQ (Nm)	155.96±29.40	149.58±29.67	4.09	0.009*
KE PTQ/BW (Nm/kg)	1.98±0.32	1.90±0.33	4.04	0.012*
KF PTQ (Nm)	69.92±17.37	68.38±17.89	2.20	0.489
KF PTQ/BW (Nm/kg)	0.89±0.22	0.88±0.23	1.12	0.572
H/Q (%)	45.08±10.21	45.88±9.96	1.74	0.692
	Females			
KE PTQ (Nm)	100.08±18.72	98.31±27.12	1.77	0.661
KE PTQ/BW (Nm/kg)	1.47±0.23	1.43±0.33	2.72	0.326
KF PTQ (Nm)	43.54±17.20	44.62±14.43	2.42	0.546
KF PTQ/BW (Nm/kg)	0.64±0.24	0.65±0.19	1.54	0.540
H/Q (%)	42.62±12.11	45.31±7.50	5.94	0.234

*Statistically significant difference (p≤0.05)
KF=Knee flexion KE=knee extension PTQ=peak torque PTQ/BW=peak torque divided by body weight Nm=Newton metre DOM=dominant leg N-DOM=non-dominant leg SD=standard deviation % diff.=percentage difference

The ECC knee extension PTQ/BW values at 60°/s for the male rowers in the study were 2.86±0.69 Nm/kg for the DOM limb and 2.53±0.63 Nm/kg for the N-DOM limb (p=0.000) (Table 4). The ECC knee flexion PTQ/BW values for the male rowers were 1.68±0.43 Nm/kg for the DOM limb and 1.59±0.54 Nm/kg for the N-DOM limb (p=0.399). The ECC H/Q ratios for the male rowers were 59.25±10.96% for the DOM side and 61.79±12.57% for the N-DOM side (p=0.317). The ECC knee extension PTQ/BW values at 60°/s for the female rowers were 2.17±0.42 Nm/kg for the DOM limb and 1.96±0.54 Nm/kg for the N-DOM limb (p=0.161). The ECC knee flexion PTQ/BW values for the female rowers were 1.15±0.42 Nm/kg for the DOM limb and 1.21±0.43 Nm/kg for the N-DOM limb (p=0.327). The ECC H/Q ratios for the female rowers were 52.23±12.26% for the DOM side and 61.77±12.26% for the N-DOM side (p=0.019).

The functional ratios, i.e., H_{ECC}/Q_{CON}, for male sweep rowers at 60°/s were 64.41±13.37 for the DOM limb and 63.68±16.80 for the N-DOM limb (p=0.834), and for the female rowers were 57.55±16.12 for the DOM limb and 64.91±13.72 for the N-DOM limb (p=0.028).

Table 4. **ECC ISOKINETIC KNEE EXTENSION AND FLEXION VALUES FOR UNIVERSITY-LEVEL MALE AND FEMALE SOUTH AFRICAN OPEN-CLASS SWEEP ROWERS AT 60°/S**

	DOM (Mean±SD)	**N-DOM** (Mean±SD)	**% diff.**	**DOM vs N-DOM** (p-value)
	Males			
KE PTQ (Nm)	216.67±70.99	199.50±56.38	7.92	0.001*
KE PTQ/BW (Nm/kg)	2.86±0.69	2.53±0.63	11.63	0.000*
KF PTQ (Nm)	131.83±35.97	121.83±36.42	7.59	0.161
KF PTQ/BW (Nm/kg)	1.68±0.43	1.59±0.54	5.38	0.399
H/Q (%)	59.25±10.96	61.79±12.57	4.11	0.317
	Females			
KE PTQ (Nm)	150.15±41.75	135.85±47.06	9.52	0.108
KE PTQ/BW (Nm/kg)	2.17±0.42	1.96±0.54	9.71	0.087
KF PTQ (Nm)	80.31±35.51	83.46±33.66	3.77	0.363
KF PTQ/BW (Nm/kg)	1.15±0.42	1.21±0.43	4.77	0.327
H/Q (%)	52.23±12.26	61.77±12.26	15.44	0.019*

*Statistically significant difference (p≤0.05)

KF=knee flexion KE=knee extension PTQ/BW=peak torque divided by body weight
Nm=Newton-metre DOM=dominant leg N-DOM=non-dominant leg
SD=standard deviation % diff.=percentage difference

Table 5. **H_{ECC}/Q_{CON} RATIOS FOR UNIVERSITY-LEVEL MALE AND FEMALE SOUTH AFRICAN OPEN-CLASS SWEEP ROWERS AT 60°/S**

	DOM (Mean±SD)	**N-DOM** (Mean±SD)	**% diff.**	**DOM vs N-DOM** (p-value)
H_{ECC}/Q_{CON} (%) (males)	64.41±13.72	63.68±16.80	1.16	0.834
H_{ECC}/Q_{CON} (%) (females)	57.55±16.12	64.91±13.72	15.23	0.028*

*Statistically significant difference (p<0.05)

SD=standard deviation % diff.=percentage difference H_{ECC}=eccentric knee flexion peak torque Q_{CON}=concentric knee extension peak torque DOM=dominant leg N-DOM=non-dominant leg

DISCUSSION

From an injury-prevention perspective, a bilateral deficit of more than 10% is clinically significant; however, from a performance perspective, even small bilateral deficits may negatively impact on performance (Dauty *et al.*, 2003). The current study's results indicate that the sample of male sweep rowers had bilateral deficits between the DOM and the N-DOM limb knee flexion of between 1.12% and 7.59% and between 4.04% and 11.63% for knee extension. In male sweep rowers, the significant bilateral deficits between the DOM and N-DOM sides were observed for both CON and ECC knee extension at 60°/s and for CON knee extension at 180°/s. The largest bilateral deficit (11.63%) was observed in the male rowers for ECC knee extension PTQ/BW at 60°/s.

Although An *et al.* (2015) also reported mean bilateral PTQ deficits ranging from 7.1% to 11.4%, Kabaciński *et al.* (2020) and Parkin *et al.* (2001) reported no significant bilateral differences in CON isokinetic knee extension or knee flexion PTQ between the lower extremities of male sweep rowers at 60°/s. These differences in previous research findings may reflect differences in respective national rowing squads, as each country will follow a unique approach to the training of their athletes in preparation for competitions. Ideally, competitive rowers should be tested regularly, and any significant deficits should be addressed timeously to prevent injury and aid performance.

When the present study sample of male sweep rowers knee extension and flexion PTQ values are compared with those of previous research findings, they are mostly lower. Lawton *et al.* (2011) reported a CON knee extension PTQ value of 300 Nm at 60°/s for male rowers, compared with the present study's range of 195 Nm (N-DOM) to 208 Nm (DOM). Riganas *et al.* (2010) found CON knee extension PTQ values of between 217 Nm and 286 Nm in male rowers at 60°/s, which are also higher than in the present study. Furthermore, Riganas *et al.* (2010) reported CON knee flexion PTQ values between 113 Nm and 132 Nm for male rowers, which are also slightly higher compared with the current study's CON knee flexion PTQ values (which ranged from 97 Nm for the N-DOM to 99 Nm for the DOM side). The male rowers from the present study also had lower CON isokinetic knee extension PTQ/BW values at 60°/s (2.48–2.64 Nm/kg) compared with those of previous studies (Riganas *et al.*, 2010; Lawton *et al.*, 2011; Zahiran, Ong & Shaharudin, 2020; Kabaciński *et al.*, 2020). Kabaciński *et al.* (2020) reported CON knee extension PTQ/BW values for Polish national team male rowers between 2.96 and

3.04 Nm/kg at 60°/s. The male rowers from the present study also had lower CON knee flexion PTQ/BW values at 60°/s (1.24–1.27 Nm/kg) compared with the value reported by Zahiran *et al.* (2020) (1.34 Nm/kg) and compared with the values reported by Kabaciński *et al.* (2020) (1.64–1.65 Nm/kg). The CON H/Q ratios at 60°/s ranged between 48.9% and 50.4% for the present study; this compares well to the 50.1% reported by Zahiran *et al.* (2020) for Malaysian national male rowers, but it is slightly lower than the H/Q ratios reported for Polish national male sweep rowers of 54.3% to 55.4% (Kabaciński *et al.,* 2020). Since the present study's participants were university rowers and not Olympic or national-level rowers, and because there is a well-established relationship between quadriceps strength and rowing performance (Moody *et al.* 2009), it is plausible that the present study's rowers would exhibit lower PTQ values than those of national and Olympic level rowers. However, this information could be valuable to coaches preparing young rowers aiming to become elite Olympic competitors.

The current study sample of female sweep rowers did not have any significant bilateral strength deficits; they only demonstrated significant bilateral deficits for the ECC H/Q ratio at 60°/s and for the H_{ECC}/Q_{CON} ratio at 60°/s. A bilateral deficit of 15.44% was observed in the female rowers for the ECC H/Q ratio at 60°/s. Although the current study's female rowers did not display any significant bilateral deficits in isokinetic knee extension or flexion, they did have lower CON knee extension PTQ values compared with previous research (Moody *et al.*, 2009; Lawton *et al.*, 2011). Lawton *et al.* (2011) reported a CON knee extension PTQ of 200 Nm, and Moody *et al.* (2009) reported a value of 165 Nm, whereas the present study's female rowers had CON knee extension values between 127 Nm (N-DOM) and 138 Nm (DOM).

Koutedakis *et al.* (1997) noted that an H/Q ratio of less than 50% at 60°/s was observed in rowers who reported suffering from lower back pain. They suggested that a low H/Q ratio might interfere with the lumbo-pelvic rhythm, leading to increased stress on the lumbar spine. The causes of such imbalances in rowers are not yet known but could be due to the repetitive nature of rowing. The significant deficits reported in the present study's ECC H/Q and H_{ECC}/Q_{CON} ratios at 60°/s for the female sweep rowers may therefore predispose them to lower back injury.

Limitations of the current research included the fact that a small sample size from one geographical region was used, which makes extrapolation of the findings to all rowers in the country impossible. However, as this is the first study reporting on the isokinetic strength of sweep rowers, it may assist future researchers to replicate the methods used and it may serve as a basis for comparing future findings. Another limitation is that only the knee joint musculature was tested. Future studies on sweep rowers may include upper limb strength comparisons, e.g., CON and ECC shoulder medial and lateral rotation PTQ. Lastly, the present study did not consider the effects of rowing port or starboard, as several rowers reported that they switched sides during the season, e.g., when injured rowers had to be replaced. However, future studies may include this aspect in the analysis to determine its possible effects on muscle asymmetry.

RECOMMENDATIONS

We recommend that male and female university sweep rowers undergo regular isokinetic testing to ensure that they achieve optimal bilateral knee extension and flexion strength and to ensure that they have healthy H/Q ratios. This will aid performance and help prevent injuries, as possible muscle imbalances may be detected and rectified timeously. The results of the present sample indicates that on average, the male rowers required CON and ECC strengthening of their knee extensors (quadriceps femoris muscle group) and that the female rowers required CON and ECC strengthening of their knee flexors (hamstrings muscle group).

CONCLUSIONS

Although previous research has been conducted on the CON isokinetic knee extension–flexion PTQ values of Olympic and other open-class sweep rowers, the present study may add to this body of knowledge by adding ECC values for both male and female university sweep rowers at an isokinetic velocity of 60°/s and by reporting on the CON PTQ values of competitive university sweep rowers at 180°/s. Compared with previous research findings, the present study's male and female rowers demonstrated lower CON knee extension–flexion PTQ values when compared with Olympic or national sweep rowers. The present study identified significant bilateral differences in knee extension PTQ in male rowers, but also found significant deficits in H/Q ratios in female rowers. These findings may negatively affect the rowers' performance and predispose them to injury. The results of the present study highlight the need for regular isokinetic testing of sweep rowers; this may assist in improving performance and in preventing injury, by addressing possible muscle strength asymmetries timeously.

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(*Subject editor: Prof. Jeanne Grace*)