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Velocity-specific torque of singaporean adults

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Abstract

The purpose of the study was to examine velocity-specific composite leg extension and flexion torque of adult participants, using allometric modeling. Seventeen men (25.0y, 1.73m & 63.6kg) and 15 women (22.5y, 1.60m & 51.1kg) participated in the study. Peak concentric isokinetic leg extension and flexion torque at 1.05, 3.14, and 5.20 rad/s were determined using a Cybex 6000 isokinetic dynamometer. Composite concentric isokinetic torque (CCIT) (i.e., sum of peak extension and flexion torque) generated at 1.05 rad/s was 1.87-1.69 times that at 5.20 rad/s for men and women, respectively. CCIT in Nm in women were 59-65% that of men, but increased to 73-81% and 71-81% that of men when the data were ratio-scaled to body mass (BM) and allometrically-scaled to BM$^{b=1.0}$, respectively. Common identified $b$ exponents for men and women between CCIT and BM included $b=1.0$ for torque as predicted by geometric similarity theory, but sample specific derived $b$ exponents are recommended in order to accurately compute body size-free power function ratios.

Key words : isokinetic torque, ratio-scaling, allometric scaling

Introduction

Muscle strength testing using isokinetic devices has gained in popularity and has earned widespread acceptance among sports scientists over the last three decades, albeit, many of the earlier studies were focused primarily on physical therapy and recovery from muscle injuries, especially in athletic populations. In essence, isokinetic exercise involves performing a specified movement (e.g., leg extension or flexion) at a constant velocity using a dynamometer with an isokinetic mode. The usefulness of this form of isokinetic mode of assessment is that the researcher can garner muscle strength data of participants at specified velocities, a concept referred to as velocity specificity (Morrissey, Harman & Johnson, 1995). These data can be useful in assessing male and female differences in muscle torque, muscle deficiencies, and also in assessing the efficacy of training programs that are designed to improve sports performance.

The reliability of single joint isokinetic leg extension that involves concentric muscle contractions is reported to range between 0.85 and 0.99. The concomitant reliability coefficients for isokinetic leg flexion that involve concentric muscle contractions are between 0.76 and 0.98 (Perrin, 1993). Despite these high reliability coefficients established for single joint isokinetic assessments, differences in testing protocols can affect reliability (Brown, 2000).

Indeed, differences in isokinetic testing protocol exist - some of these differences are in the muscle group being assessed (e.g., lower extremity vs. upper extremity), the posture adopted during the assessment (e.g., upright vs. supine), the angular velocity or velocities assessed the torque of interest (extension, flexion, concentric, eccentric or composite) and whether the dominant or non-dominant limb was assessed. These differences make it difficult to compare results of testing across different laboratories.

Performances in isokinetic concentric torque of the lower limbs have commonly focused on knee extension alone (e.g., Baltzopoulos, Eston & Maclaren, 1988) or knee extension and flexion (e.g., De Ste Croix, Armstrong & Welsman, 1999), at either single (e.g., Baltzopoulos, Eston & Maclaren, 1988) or multiple angular velocities (e.g., De Ste Croix, Armstrong & Welsman, 1999). There are fewer studies, which are based on the concept of total leg strength or composite concentric isokinetic torque (CCIT), where several tests of lower extremity muscles (e.g. knee extension and flexion) are performed and the data
are summated to give a composite score (Nicholas, Strizak & Veras, 1976; Gleim, Nicholas & Webb, 1978; Boltz & Davies, 1984).

The CCIT concept allows researchers to evaluate the lower limb as a total kinetic chain (Davies, Heiderscheit & Brinks, 2000), and its use has been supported by others (e.g., Buchner et al., 1996; Boltz & Davies, 1984; Gleim, Nicholas & Webb, 1978; Nicholas, Strizak & Versa, 1976). In essence, the reason for adopting such an approach in describing muscle torque data is apparent since both muscle extension and flexion are inherently involved in many exercises like running, cycling and swimming. Such an approach has not been apparently used to examine sex differences in young men and women.

Equally important is the treatment of the data and the statistical approaches used to compare the data between groups and across different studies. Most studies use non-normalised data (i.e., absolute torque) to compare performance between sexes. Such comparisons are not very useful or appropriate since torque is highly correlated with body size, and differences in torque between sexes could be attributed to differences in body size (De Ste Croix et al., 1997).

Further complicating sex comparisons in generated torque are differences in the choice of body size descriptors that have been used to describe the torque generated. Choices of the body size descriptors have included body mass (Armstrong & Welsman, 1997), stature (e.g., De Ste Croix et al., 1997), thigh muscle volume (Chia, 1998), muscle cross-sectional area (Brown, 2000), and lower limb muscle mass (Chia, 2003). However, the preferred body size descriptor is body mass due the ease of its measurement and it is conceivable that the majority of researchers will continue to use it as a marker of relative strength performance since most performances will involve the carriage of body mass (Jaric, 2002).

Ratio scaling or the simple division of performance variable of choice (e.g., torque) by the body size descriptor (e.g., body mass$^{1.0}$) has been used extensively to normalize performance data for differences in body size (Welsman & Armstrong, 2000). The main purpose of using the simple ratio method is that it is assumed that the simple division of the variable of interest (e.g., CCIT) by a body size descriptor (e.g., BM) will provide a size-free variable in Nm/kg BM.$^{1.0}$ However, in most situations involving exercise data, the simple ratio method often fails to achieve this. For instance in a group of 25 boys and 25 girls aged 10 years, Chia (1998) reported that the common $b$ exponents of 0.91 and 0.88 were identified for peak power (PP) and mean power (MP), respectively, when Wingate Anaerobic Test (WAnT) power were allometrically expressed in relation to body mass. Moreover, correlations between PP/kg BM, MP/kg BM, and BM were negative and significant, demonstrating that the data were over-scaled using ratio modeling (Chia, 1998). The weakness of using ratio standards to model peak VO$_2$ data in 106, 12-year-old boys and girls was also demonstrated by Welsman and Armstrong (2000), where smaller participants were accorded higher relative peak VO$_2$ (ml/kg BM/min) and larger participants were accorded lower relative peak VO$_2$ (ml/kg BM/min).

Prior to using the scaling method of choice, researchers should be mindful that the use of the method must not violate the assumptions for its use based on the characteristics of the specific data set. The criteria for the use of the ratio method and allometric modeling have been described in detail elsewhere (Welsman & Armstrong, 2000). In essence, the use of the ratio method is justified when the bivariate correlation between the ratio-scaled dependent variable (e.g., CCIT/BM) and the body size descriptor (e.g., BM) is not significantly different from zero.

The assumptions for the use of allometric modeling of data are that the gradients or slopes of the regression equations that describe the relationship between the dependent variable (e.g., CCIT) and the body size descriptor (e.g., BM) for males and females must be common or parallel to each other, that is, the sex-specific regression lines do not intersect (Welsman & Armstrong, 2000). Allometric (log-linear) methods are recommended as more appropriate in accounting for body size effects as they are able to accommodate data that are heteroscedastic (Welsman & Armstrong, 2000) in nature, that is, as body size increases (e.g., BM), so does the variability of the performance variable of interest (e.g., CCIT). Allometric modeling is also particularly useful for exercise data as the technique incorporates a multiplicative rather than an additive error term (Welsman & Armstrong, 2000).
In essence, the technique requires the derivation of a common $b$ exponent for two different groups, only when it is appropriate, by applying the least-squares regression to logarithmically transformed data (e.g., Ln CCIT and Ln BM) and solving for numerical values of $a$ and $b$ (where $a$ is the Y-intercept, and $b$ is the slope coefficient) from the linear form of the allometric model, $\log_e Y = \log_e a + b \log_e X$ (Welsman & Armstrong, 2000, Jaric, 2003).

Allometric scaling of performance data in relation to a body size descriptor has been advocated as statistically tenable alternative to ratio-scaling in that it can more appropriately account for body size differences in generating a size independent power function ratio, which is performance variable/body size exponent (Jaric, 2002; Welsman & Armstrong, 2000). Despite the merits of allometric modelling, its use in exercise science is still not widespread and the method warrants serious consideration from researchers.

It is critical that the appropriate normalization of exercise data for differences in body size is used as it will allow researchers to correctly interpret the results of the research. An inappropriate use of the scaling method can lead to erroneous interpretations or spurious relationships and consequently cloud our understanding of performances of different groups of participants (e.g., male vs. female, children vs. adults, and athletes vs. non-athletes) who may all differ significantly in body size.

Therefore, the purpose of the study was to examine the composite isokinetic torque of men and women using allometric scaling in relation to body mass.

**Materials & Methods**

**Participants and testing schedule**

Institutional ethical approval for all testing procedures was obtained. Seventeen men and 15 women with informed consent participated in the study. Testing took place over two occasions within 14 days and all assessments were made between 09:00 hours and 12:00 hours. Men and women were tested in two separate sessions.

On the first laboratory visit, participants anthropometric measurements (i.e., stature and body mass) were computed using standardised procedures and calibrated equipment. All participants were right lower limb dominant. Familiarisation procedures for the isokinetic strength assessment involved two practice trials in which three repetitions of sub-maximal and maximal effort leg extension and flexion of the right lower limb at each of three test velocities 1.05, 3.14, and 5.20 rad/s were conducted.

The second laboratory visit was devoted to assessments of isokinetic strength at the three velocities. The test order was randomised for each participant. All participants were instructed to refrain from strenuous exercise at least 12 hours before the tests. CCIT were not significantly different between the two practice trials.

**Determination of composite concentric isokinetic torque (CCIT)**

Concentric isokinetic knee extension and flexion were measured using a Cybex 6000 dynamometer. Proper positioning and body stabilization of the seated participant was carried out using straps at the waist and across the chest, which were individually adjusted for each participant. This was done to isolate the muscle groups of the lower limbs during testing and also to minimize the contribution from accessory muscle groups.

A standardized warm-up consisting of hamstring and quadriceps muscle stretches combined with three sub-maximal repetitions followed by three maximal repetitions. Such a warm-up protocol has been shown to provide good reliability of isokinetic measurement of knee extension and flexion torque (Perrin, 1993). Testing of the dominant lower limb, as determined by kicking preference was performed at 1.05 rad/s, 3.14 rad/s, and 5.20 rad/s, representing slow, intermediate and fast isokinetic test velocities (Perrin, 1993).

Research has established high reliability coefficients of greater than 0.95 for peak isokinetic torques for knee extension and flexion for angular velocities of between 1.05 and 5.20 rad/s (Feiring, Ellenbecker & Dersheid, 1990) and for intra-day replicates of isokinetic torques (Bohannon & Smith, 1995). The test velocity for each participant was randomly assigned by the principal investigator.

With the participant seated upright, the lever arm of the dynamometer was aligned with the lateral epicondyle of the knee, with the knee flexed at an angle of 90 degrees. The range of motion
during testing was set so that the working range constituted 90 degrees. The force pad was consistently placed 3–5 cm superior to the medial malleolus with the foot in a plantigrade position (De Ste Croix, Deigham & Armstrong, 2003).

Gravity correction procedures were carried out for each participant prior to each test in accordance to the procedures of Nelson and Duncan (1983). In essence, the procedures involved the determination of the angle-specific torque data generated during passive knee flexion of the participant and the weight of the input accessories, including the lever arm. The computer software for gravity correction recorded these data over the full range of motion for knee extension and knee flexion. Gravity correction procedures are recommended during assessments of isokinetic torque in a seated position to avoid the under-estimation of knee extension torque and the over-estimation of knee flexion torque (Brown, 2000).

The participants were instructed to push and to pull the lever arm up and down as hard and as fast as they could for three maximal efforts at each test velocity, with knee extension always undertaken first. Three maximal trials at each test velocity were performed as multiple trials (e.g. 2–6) are necessary to obtain a true maximal value of torque (Perrin, 1993).

Strong verbal encouragement was provided by the same group of testers and a 90-second rest period was allowed between test velocities. Research has documented that an interval of rest of between 30 and 60 seconds after four maximal efforts at any test velocity is sufficient for ensuring maximal efforts between trials (Perrin, 1993).

In accordance with the recommendations of Perrin (1993), the three highest concentric isokinetic torques for knee extension and flexion achieved at each test velocity were averaged and reported as average peak knee extension torque and average peak flexion torque for each test velocity. Composite concentric isokinetic torque (CCIT) for each participant was obtained by summing the average peak extension and average peak flexion torque.

Statistical analyses
All relevant data were stored and analysed using SPSS for Windows (Version 11.0). The Shapiro-Wilks and Levene tests were used to check for normality of distribution and homogeneity of variance in the torque data sets, respectively. Descriptive statistics (i.e., M ± SD) of the dependent variables of the participants were generated. Sex differences in age, body mass, and stature were assessed using an independent t-test.

Differences in CCIT at 1.05, 3.14, and 5.20 rad/s between male and female participants, in absolute terms, ratio-scaled to BM and allometrically-adjusted to BM were examined using one-way ANOVA with Bonferroni correction for multiple comparisons.

Composite concentric isokinetic torque (CCIT) at 1.05, 3.14, and 5.20 rad/s were expressed allometrically in relation to BM by deriving the exact common b exponent that described the relationship between CCIT and BM, for male and female participants. This was done by entering logarithmically transformed CCIT at each angular velocity, entered in turn as the dependent variable, sex as the fixed factor, and logarithmically transformed BM as the covariate, and computing the results using least-square regression analysis (Chia, 1998; Welsman & Armstrong, 2000; Jaric, 2002).

According to Jaric (2003), the allometric formula for obtaining an index of muscle strength (S) that is independent of body size (assessed by body mass, m) is given by:

\[ S = \frac{S}{m^b} \]

where b is the identified common exponent for the groups.

In all cases, the common b exponents or slope coefficients (i.e., applicable to male and female) were derived only after ensuring that the sex-specific derived b exponents were not significantly different (i.e., all Sex*BM interactions, p> .05; see Figure 1). Power function ratios or body-size independent measures (i.e., CCIT/BM\(^b\) exponent) were subsequently computed. The level of statistical significance was set at p< .05.

Results

Normality of distribution and homogeneity of variance
Checks for normality of distribution and homogeneity of variance for CCIT at 1.05, 3.14, and 5.20 rad/s showed that there were normality of distribution (all Shapiro-Wilks statistics, p> .05) and homogeneity of variance (all p> .05)
Anthropometric and composite concentric isokinetic torque data

The descriptive data for age, stature, body mass, and CCIT are presented in Table 1. Irrespective of how the data are expressed, that is in absolute terms, ratio-scaled or allometrically-expressed in relation to BM, the male participants had significantly greater CCIT than the female participants.

Results of multiple comparisons of CCIT between male and female participants using one-way ANOVA, with Bonferroni adjustments made to the alpha level (i.e., p<0.05/9; p<0.005), showed that CCIT generated at 1.05, 3.14, and 5.20 rad/s, in absolute terms, expressed in ratio to BM and allometrically-adjusted to BM were significantly greater in male than in female participants.

Allometric relationships between composite concentric isokinetic torque and body mass

The allometric relationships between CCIT at 1.05, 3.14, and 5.20 rad/s and BM are presented in Figure 1. Results of log-linear regression analyses revealed that CCIT for the three tested angular velocities, the Sex-Ln BM interactions were not significant (i.e., p>0.05), hence a common b exponent was used to define the allometric relationship between CCIT and BM, at each of the angular velocity. It is noted that in all cases, the common b exponent included 1.0, in the 95% confidence intervals (Figure 1). The subsequent power function ratios for CCIT, expressed in relation to the specific body size descriptor, BM^b exponent for male and female adults, are also presented in Table 1.

Table 2 presents the relationships between allometrically-scaled CCIT and BM in male and female adults. In all cases, correlations between allometrically-scaled CCIT and BM were not significant (p>0.05).

Discussion

Participant characteristics

Results showed that there were significant sex differences for age, stature, and body mass. However, these data are in agreement with the age and sex-specific data reported in the National Health Survey for Singapore (National Health Survey, 1998).

Composite concentric isokinetic leg extension and flexion torque

Peak isokinetic leg extension and flexion torque of the right limb of the adult participants were combined to yield peak composite isokinetic torque at 1.05, 3.14, and 5.20 rad/s. It is noteworthy that these data represent apparently the first reported isokinetic torque data among men and women in
Table 1. Anthropometric Characteristics and Composite Concentric Isokinetic Torque of Male and Female Adults

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men (N=17)</th>
<th>Women (N=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>25.0 ± 2.4</td>
<td>22.5 ± 2.9'</td>
</tr>
<tr>
<td>Stature (m)</td>
<td>1.73 ± 0.05</td>
<td>1.60 ± 0.07'</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>63.6 ± 6.5</td>
<td>51.1 ± 8.5'</td>
</tr>
<tr>
<td>Composite torque (Nm) at 1.05 rad/s</td>
<td>318.3 ± 48.2</td>
<td>188.8 ± 33.0'</td>
</tr>
<tr>
<td>Composite torque (Nm) at 3.14 rad/s</td>
<td>214.9 ± 37.0</td>
<td>130.3 ± 31.6'</td>
</tr>
<tr>
<td>Composite torque (Nm) at 5.20 rad/s</td>
<td>170.4 ± 28.9</td>
<td>111.0 ± 23.7'</td>
</tr>
<tr>
<td>Composite torque (Nm/kg BM) at 1.05 rad/s</td>
<td>4.9 ± 0.8</td>
<td>3.6 ± 0.5'</td>
</tr>
<tr>
<td>Composite torque (Nm/kg BM) at 3.14 rad/s</td>
<td>3.3 ± 0.6</td>
<td>2.5 ± 0.4'</td>
</tr>
<tr>
<td>Composite torque (Nm/kg BM) at 5.20 rad/s</td>
<td>2.6 ± 0.5</td>
<td>2.1 ± 0.3'</td>
</tr>
<tr>
<td>Composite torque (Nm/kg BM(^{180\circ}) at 1.05 rad/s</td>
<td>11.7 ± 1.9</td>
<td>8.3 ± 1.2'</td>
</tr>
<tr>
<td>Composite torque (Nm/kg BM(^{180\circ}) at 3.14 rad/s</td>
<td>1.5 ± 0.3</td>
<td>1.2 ± 0.2'</td>
</tr>
<tr>
<td>Composite torque (Nm/kg BM(^{180\circ}) at 5.20 rad/s</td>
<td>2.1 ± 0.4</td>
<td>1.7 ± 0.3'</td>
</tr>
</tbody>
</table>

Note. Data are means ± standard deviations. *p < 0.05.

Table 2. Correlations Between Power Function Ratios and Body Mass in Male and Female Adults

<table>
<thead>
<tr>
<th>Participants</th>
<th>Power function ratio</th>
<th>Body mass (BM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Composite torque (Nm/kg BM(^{180\circ}) at 1.05 rad/s</td>
<td>r = -0.06</td>
</tr>
<tr>
<td></td>
<td>Composite torque (Nm/kg BM(^{180\circ}) at 3.14 rad/s</td>
<td>r = -0.02</td>
</tr>
<tr>
<td></td>
<td>Composite torque (Nm/kg BM(^{180\circ}) at 5.20 rad/s</td>
<td>r = -0.04</td>
</tr>
<tr>
<td>Female</td>
<td>Composite torque (Nm/kg BM(^{180\circ}) at 1.05 rad/s</td>
<td>r = -0.02</td>
</tr>
<tr>
<td></td>
<td>Composite torque (Nm/kg BM(^{180\circ}) at 3.14 rad/s</td>
<td>r = -0.03</td>
</tr>
<tr>
<td></td>
<td>Composite torque (Nm/kg BM(^{180\circ}) at 5.20 rad/s</td>
<td>r = -0.05</td>
</tr>
</tbody>
</table>

Singapore. In the extant literature, peak leg extension torque or leg flexion torque at multiple velocities (De Ste Croix et al., 1997) or single velocity (Baltzopoulos, Eston & Maclaren, 1988) have been used to describe lower limb muscle strength. It is of interest that the use of multiple angular velocities in isokinetic exercise is common in rehabilitation protocols and is described as velocity spectrum exercise, which has empirically produced desirable results, but its use is less common in exercise science (Perrin, 1993). The use of multiple velocity testing yields more information than single velocity testing and has apparently greater ecological validity since exercise tasks are normally performed over a range of contraction velocities rather than a single velocity, a view that has been echoed by others (e.g., Weiss, 2000).

The summation of individual peak leg extension and leg flexion torque, to derive a composite leg torque is less common, but the approach has been used to examine the relationship between composite isokinetic strength of the lower limbs and walking speed in elderly participants (Buchner et al., 1996). Composite leg strength has also been used to describe the torque-power nexus in young people (De Ste Croix et al., 1997). Others have used the same method to evaluate the relationship between leg length and total leg strength (Boltz & Davies, 1984).

The merit of summing peak concentric isokinetic leg extension and peak isokinetic flexion torque as a peak composite concentric isokinetic torque (CCIT) is that it facilitates a better understanding of the relationships between generated velocity-specific muscle torque and many aspects of functional performance such as sprinting or cycling, activities where muscles engaged in leg extension and flexion are involved. In support of this view, Brown (2000) argued that the use of a single composite torque allows researchers to evaluate the entire lower extremity as a total kinetic chain unit, and at the...
same time, to evaluate each of the links of the kinetic chain. The use of CCIT in exercise science is not widespread and given the arguments for its use, researchers should give it serious consideration.

Peak CCIT generated at 1.05, 3.14, and 5.20 rad/s in male and female adults mirrored findings reported in the literature in that absolute torque in Newton-metre (Nm) generated at a lower angular velocity (i.e., 1.05 rad/s) was significantly greater than the torque generated at a higher angular velocity (i.e., 5.20 rad/s) (Burnie & Brodie, 1986; De Ste Croix et al., 1997).

These results are in agreement with well-documented studies showing that maximal force output decreases with increasing velocities in adults (Weir et al., 1996; Weiss, 2000) and that the decrease may be more pronounced in older participants, plausibly due to increased muscle stiffness with age (Backman & Oberg, 1989). These present results confirmed the importance of assessing CCIT over a velocity-spectrum in order to better understand strength performance for a given movement pattern in adults.

**Sex difference in composite isokinetic torque**

Sex difference in absolute composite isokinetic torque at 1.05, 3.14, and 5.20 rad/s were significant with women generating 59%, 61%, and 65% of the torque attained by men at the three angular velocities. These results are in accord with those reported in the literature where sex-related differences in muscle strength have been reported at between 40% and 80% depending on the measurement protocol used, the participants tested, and the body segment tested (Kaneshisa et al., 1996).

The magnitude of sex differences in isokinetic torque or muscle strength also varies across different studies depending on whether the torque data are normalized or non-normalized. When the data are normalized, the sex difference also depends on the choice of the body size descriptor (e.g., body mass, muscle cross-sectional surface area, thigh muscle volume, etc), and also the method used to normalize the data (e.g., ratio standards, linear regression adjustment, allometric scaling).

In the present study, when CCIT was allometrically-adjusted for BM at the specific angular velocities, the sex difference in torque was reduced but remained significant (see Table 1). Women generated 71%, 80%, and 81% of the values attained by men for allometrically-adjusted composite torque at 1.05, 3.14, and 5.20 rad/s. These findings are in accord with the findings of others who reported on sex difference in isokinetic torque among athletes (Hakkinen, 1991; Weir et al., 1999) and non-athletes (De Ste Croix et al., 1997), albeit the comparisons between male and female performances were reported in absolute terms and ratio-scaled to body mass or fat-free body mass. Like the results of the present study, the sex differences in isokinetic torque were reduced when attempts at normalizing the torque for differences in body size were made. In the present study, as body composition was not measured, the gender difference in body mass-adjusted CCIT could also be attributed, in part, to differences in fat-free mass in male and female adults, if they were indeed different between male and female adults. Future studies should use lower limb muscle mass or lower limb muscle volume, as the body size descriptor of choice to scale for CCIT rather than BM.

Barring the issue of differences in body composition between male and female adults, the present results where a sex difference in allometrically-adjusted CCIT remained suggest that qualitative differences in male and female muscle tissue-muscle fiber distribution, enzyme activity, and phosphate concentrations (Komi & Karlsson, 1978) could also explain, in part, sex differences in CCIT that are independent of body size. In addition, sex differences in myoneural factors should not be discounted, especially the activation of high-threshold motor units (Milner-Brown, Stein & Yemm, 1973), electromechanical delay, and rate of force development (Bell & Jacobs, 1986), the amount of intramuscular fat and connective tissue, the level of physical activity, and anatomical differences (Eckerson, 2000). These qualitative sex differences in CCIT deserve research attention in future studies.

**Allometric scaling of composite concentric isokinetic torque**

Allometric scaling of isokinetic torque is infrequently practiced, but there is a growing conviction among researchers that the technique can more appropriately produce a body size-independent variable (Jarc, 2002, 2003; Weisman & Armstrong, 2000) and can more exactly explain the relationship between the performance descriptor (e.g., CCIT) and the body size descriptor (e.g., BM) (Chia, 1998).
Identified common $b$ exponents for men and women between CCIT and BM were 0.79, 1.19, and 1.05, respectively for torque assessed at angular velocities of 1.05, 3.14, and 5.02 rad/s. In essence, where the $b$ exponent is less than 1.0, torque increases slower for an equivalent increase in body mass and where the $b$ exponent is greater than 1.0, then torque increases faster for an equivalent increase in body mass.

The results in the present study are in agreement with a number of studies on isokinetic torque that used allometric scaling to account for differences in body size (e.g., Neder, Nery & Silva, 1999; Jaric, 2002; Weir et al., 1999). For instance, Jaric (2002) reported that $b=1.02$ for isokinetic torque for six muscle groups in 16 men; Neder et al. (1999) showed that $b=0.91$ to 1.10 for isokinetic knee extension torque in 61 men and women while Weir et al. (1999) reported that the $b$ exponents for torque of knee extension and knee flexion in 256 young wrestlers ranged from 0.94 to 1.31.

It is noteworthy that for CCIT at the three angular velocities tested in the present study, the identified $b$ exponent included 1.0, in agreement to that predicted by geometric similarity theory (Jaric, 2002, 2003). Jaric (2003) explains that under the presumption of geometric similarity theory for human subjects, all linear body dimensions, $L$, change proportionately to body size, where all volumes and masses (including body mass, $m$) change proportionately to $L^3$. Accordingly, all areas should be proportional to $m^{0.67}$ and all linear dimensions, $L$, should be proportional to $m^{0.33}$. When muscle strength is tested with a dynamometer, the recorded force $F$ should be proportional to muscle force, $Fm$. As muscle force is expected to be proportional to the cross-sectional area of muscle, which also means that it is proportional to $L^2$ or $m^{0.67}$. However, when muscle strength is tested using isokinetic apparatus, the muscle torque measured is affected by body size ($m^{0.57}$) and also by the lever arm of the isokinetic apparatus, $L$ or $m^{0.33}$. Hence, the allometric parameter to normalize strength relative to body mass when it is measured using muscle torque should be $m^{0.33} \times m^{0.67}$, or $m^{1.0}$ (Jaric, 2003).

It is important to note, however, that human beings are not and do not behave as geometrically similar entities because of differences in body composition and differences in tissue density between individuals (Chia, 1998). This would plausibly explain why the derived mean common $b$ exponents for male and female adults were not exactly equal to 1.0. It is therefore important to derive the exact $b$ exponents, using allometric scaling, rather than to simply rely on theoretical $b$ exponents, which may not be tenable in all situations. This view has also been echoed by others (e.g., De Ste Croix et al., 1997; Welsman & Armstrong, 2000).

The results presented in <Table 2> showed that the computed power function ratios for CCIT were not correlated with BM, indicating that the respective power function ratios were indeed body size-independent. The present results buttress the findings of Batterham and Birch (1996) on 12 pairs of adult male and females for peak power measurement expressed in relation to fat-free mass. Researchers should seriously consider using allometric modeling, if appropriate, to produce power function ratios that are body size-independent.

Conclusions

The present study examined the velocity–specific CCIT of young male and female adults in Singapore. CCIT of the lower limbs decreased significantly as the angular velocity tested at was increased. Male adults had significantly higher CCIT than women at 1.05, 3.14, and 5.20 rad/s. The common identified $b$ exponents for male and female adults that specified exactly the allometric relationship between CCIT at the three tested angular velocities and BM were 0.79, 1.19, and 1.05, respectively. Computed power function ratios for CCIT expressed in relation to BM were not correlated with BM demonstrating that allometric scaling produced variables that were body size-independent.

References


