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## KINESIOLOGY & COACHING

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# Isokinetic leg strength in adolescent Malaysian recreational taekwondo practitioners

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**Key words:** taekwondo, peak torque, adolescent, strength ratio, hamstrings, quadriceps

**Abstract**
Background. Improved leg strength in taekwondo athletes has been suggested as a way to help prevent hamstrings injuries.
Problem and Aim. Research on isokinetic leg strength in Malaysian taekwondo [WTF] athletes has been scarce, especially in recreational participants. The aim of this study was to compare isokinetic leg strength in adolescent Malaysian recreational taekwondo participants.
Methods. Strength was assessed in 7 females and 8 males on a Biodex System 3 during leg extension and flexion at 120°/sec and 300°/sec. A 3-way (Gender x Movement x Velocity) ANOVA with repeated measurements of the second and third factors was used to determine differences between gender, extension/flexion and angular velocity. A 2-way (Gender x Velocity) ANOVA with repeated measurements of the second factor was employed to determine differences in hamstrings/quadriceps (H/Q) ratios between the genders by angular velocity.
Results. Collapsed over angular velocity and movement, the boys recorded a higher peak torque: $eta^2 = 0.47$, 80% CI: 0.14 – 0.71, d = 1.93, 80% CI: 0.00 – 9.03 albeit unclear. When scaled to height ($m^2$), relative peak torque was still higher for the boys: $eta^2 = 0.38$, 80% CI: 0.03 – 0.65 albeit unclear but the pairwise comparison was clear: d = 1.50, 80% CI: 0.49 – 0.69. Dimensional scaling did not fully control for the effect of height on isokinetic leg strength in the girls: r = 0.17, 80% CI: 0.00 – 0.67. However, it did not in the boys: r = 0.72, 80% CI: 0.32 – 0.90.
Conclusions. The results seem to partially support the claim that, as far as isokinetic leg strength is concerned, geometric similarity may not apply. Future studies should compare theoretical strength exponents to those empirically derived in a larger sample.

## Introduction

Strength has been suggested to play an important role in many sports [Sale 1991], including taekwondo [Pieter, Heijmans 2000; Kim *et al*. 2011]. The first study on isokinetic leg strength in taekwondo participants, Pieter *et al.* [1989] investigated American university students involved in a taekwondo class. The authors reported that the taekwondo practitioners, compared to a control group, showed higher values for peak torque during knee flexion in both absolute terms and relative to lean body mass (LBM) per ratio standard. The results were expressed in p-values. It was suggested that the knee flexors in taekwondo practitioners need to be relatively strong to prevent injuries to these muscles during the many kicks in the air, especially the roundhouse kick, that they execute in training and competition [Zemper, Pieter 1989; Pieter, Taaffe 1990; Pieter, Zemper 1997; Lystad, Graham, Poulus 2013]. A higher risk of sustaining injuries to the hamstrings was reported by Pieter and Kazemi [2007] in Canadian junior taekwondo athletes but the result was not clear.

Pieter and Taaffe [1990] investigated isokinetic strength of elite American adult male and female taekwondo athletes at 120°, 180°, 240° and 300°/s during leg extension and flexion at the knee joint. When peak torque of the males was compared to that of the females relative to body mass (BM) and LBM per ratio standard, the males still scored higher but the differences became smaller, as expected. Seo *et al.* [2015] studied young adult male and female taekwondo athletes (18.9-19.4 years) at 90°/s and reported that both groups improved strength at the end of the training program.

Studies on isokinetic strength in young taekwondo athletes are scarce. Pieter and Bercades [2005] investigated young male (14.51 ± 1.51 years) and female (14,54 ± 1.66 years) American (inter)nationally competitive taekwondo athletes to assess isokinetic peak torque of the leg during extension and flexion at the knee joint in absolute terms and relative to BM and LBM at 180°/s, 240°/s and 300°/s. There was no gender by angular velocity interaction for absolute isokinetic peak torque. When scaled for BM and LBM per ratio standard, only gender main effects were found.

Recent research by Fong and Tsang [2012] revealed that there was a correlation between the experience of taekwondo athletes and isokinetic strength in adolescents. For instance, the relationship between isokinetic strength during leg extension and flexion at 60°/s and taekwondo experience was significant, albeit unclear. Another relationship was shown between leg extension and flexion at 240°/s. Based on the foregoing, the majority of the extant literature on isokinetic strength in taekwondo has focused on adult athletes. The purpose of this study, then, was to assess isokinetic leg strength characteristics in Malaysian adolescent recreational taekwondo athletes.

## Methods

Subjects (7 females, 16.77 ± 1.01 years, 1.57 ± 0.05 m, 51.89 ± 6.07 kg and 8 males, 17.43 ± 1.95 years, 1.67 ± 0.06 m, 56.38±7.69 kg) were members of a Malaysian taekwondo [WTF] state team. Isokinetic concentric strength was measured on a Biodex System 3 [Biodex Medical Systems, Inc. New York, NY, USA] during leg extension and flexion at the knee joint at 120°/s and 300°/s (3 repetitions at each angular velocity) with a 1-minute rest between angular velocities. Peak torque was calculated as the highest torque in the isokinetic phase of the range of motion at the preset angular velocity. The dominant leg with which the athletes performed the roundhouse kick was used. Gender differences were first assessed in absolute terms. When comparing groups differing in size, dimensionality theory suggests scaling strength to height$^2$ (m$^2$) [Åstrand *et al.* 2003], hence the decision to compare isokinetic peak torque in the boys and girls relative to height$^2$ as well.

Data distributional characteristics were assessed for skewness and kurtosis, while the Kolmogorov-Smirnov test was employed to check for normality. The L-statistic was used if the statistical assumptions could not be met, even after data transformation [Thomas, Nelson, Silverman 2005]. A 3-way (Gender x Movement x Angular velocity) ANOVA with repeated measures on the second and third factors was used to determine differences between gender, extension/flexion and angular velocity. A 2-way (Gender x Velocity) ANOVA with repeated measures on the second factor was employed to determine differences in hamstrings/quadriceps (H/Q) ratios between gender by angular velocity. The level of a meaningful effect was set to 0.20.

## Results

Table 1 contains the means and standard deviations of absolute peak torque in Malaysian adolescent recreational taekwondo athletes. There was a Sex main effect for peak torque: eta$^2$ = 0.47, 80% CI: 0.14 – 0.71). Peak torque for the boys (116.05 ± 17.07 Nm) was higher than that for the girls (88.94 ± 12.29 Nm), d = 1.93, 80% CI: 0.00 – 9.03 but the difference was not clear.

When scaled to height$^2$, the difference between boys (41.54 ± 3.82 Nm/m$^2$) and girls (35.87 ± 4.30 Nm/m$^2$) became smaller, albeit unclear: eta$^2$ = 0.38, 80% CI: 0.03 – 0.65, d = 1.50, 80% CI: 0.49 – 0.69. Based on the point estimates, allometric scaling using the theoretical exponent did not completely control for the effect of the body size variable on isokinetic leg strength in the girls (r = 0.17, 80% CI: 0.00 – 0.67. In the boys, allometric scaling using the theoretical exponent did not control for the effect of the body size variable: r = 0.72, 80% CI: 0.32 – 0.90.

Table 2 contains the means and standard deviations of the H/Q ratios in the Malaysian taekwondo practitioners. There was no Gender x Angular velocity interaction: eta$^2$ = 0.03, 80% CI: 0.00 – 0.38 or main effect for gender: eta$^2$ = 0.17, 80% CI: 0.00 – 0.49 but the results were not clear. There also was a main effect for angular velocity: eta$^2$ = 0.20, 80% CI: 0.00 – 0.52. However, the effects were not clear.

## Discussion

In American adolescent counterparts competitive at the (inter)national level, there were Gender x Movement, Gender x Angular velocity, and Movement x Angular velocity interactions [Pieter, Bercades 2005]. The point estimate of the effect size for the Gender x Movement interaction was unclear (eta$^2$ = 0.12, 80% CI: 0.00 – 0.27) as was that for Gender x Angular velocity (eta$^2$ = 0.05, 80% CI: 0.00 – 0.20) and that for Movement x Angular velocity (eta$^2$ = 0.54, 80% CI: 0.23 – 0.75). Likewise, the Gender main effect in the American children was also not clear (eta$^2$ = 0.20, 80% CI: 0.05 – 0.34). Since the Americans were younger than the Malaysians, the differences between the two studies may be due to maturity status [Malina, Bouchard, Bar-Or 2004; Rowland 2005].

According to Froberg and Lammert [1996], the relationship between maturity and strength is more pronounced in boys than in girls. The difference in strength between early maturing boys and their normal and late

maturing counterparts is especially evident between 13 and 16 years of age. Once the normal and late maturing boys catch up in late adolescence, absolute strength differences decrease. In girls, the strength difference between early maturing as well as normal and late maturing counterparts is most apparent between 11 and 15 years. The difference in late adolescence is smaller than in boys [Froberg, Lammert 1996].

The age range of the American taekwondo athletes was between 11.50 – 17.67 years in boys and 11.92 – 17.33 years in girls. The median of self-assessed maturity according to the Tanner stages was 4 in both boys and girls. [Self-assessment of maturity was validated in the US ( Broekhoff *et al.* 1995)], however, 21.43% of the girls were pre-menarcheal. No maturity assessment was done for the Malaysians, but the age range for the boys was 13.75 – 20.08 years and for the girls, 15.42 – 17.92 years. In other words, some of the Malaysian males were young adults.

Fong and Tsang [2012] reported correlations between the experience of the athletes and isokinetic leg strength at 240°/s during leg extension to be r = 0.639, 80% CI: 0.418 – 0.788 and flexion: r = 0.472, 80% CI: 0.199 – 0.677 (the confidence intervals were calculated based on information in the article).

The difference in age and maturation between the American and Malaysian adolescents and their effect on strength may also have been mediated by neuro-motor maturation and control [Blimkie, Sale 1996]. More mature or older boys and girls may be better able to exert a higher level of neural drive and motor units recruited [Baltzopoulos, Kellis 1996; Froberg, Lammert 1996]. This information is based on both isometric and isokinetic strength investigations, so it might be that the biological differences between the Americans and Malaysians had their effect on not only the statistical interactions and main effects as alluded to above, but also with regards to the effect sizes.

As mentioned above, according to dimensionality theory, peak torque should be scaled to height$^2$ to control for size differences when comparing groups, since strength is related to cross-sectional area of the contracting muscles [Åstrand *et al.* 2003; Malina *et al.* 2004; Rowland 2005]. However, it was also found that strength increased at a greater rate to height than predicted by geometric similarity theory [Rowland, 2005], while others have suggested that humans, both athletic and sedentary, may not be geometrically similar in strength [Nevill *et al.* 2004]. The empirically derived exponent for the subjects in the current study was 2.418, which is statistically not different from 2, but that may be due to the small sample size [Malina *et al.* 2004].

Scaling isokinetic peak torque to height$^2$ did not control for the effect of the body size variable in the boys. In other words, peak torque in the girls could sufficiently be explained by muscle cross-sectional area. In the boys, strength may be more a function of size-independent factors, such as neurological factors, muscle contraction and fiber architecture [Rowland 2005], i.e., qualitative dimensions. Muscle tissue may not lend itself to scaling according to geometric expectations due to individual variations in fiber length, angle of pennation, type of bony insertion, and division of fibrous septa [Rowland 2005].

Although the concentric H/Q ratio, which is used regardless of the angle of the joint in which peak torque occurs, has its obvious limitations [Coombs, Garbutt 2002], it was deemed appropriate as an initial measure of muscle balance. A more functional assessment would be the eccentric hamstrings to concentric quadriceps ratio [Islam, De 2018]. In taekwondo, the hamstrings will be contracting eccentrically during such techniques as the roundhouse kick, which would predispose them to injury, especially at the end of the range of motion (ROM) to prevent hyperextension of the leg at the knee joint [Pieter, Heijmans 1989; Pieter, Taaffe 1990].

The H/Q ratios at 300°/s for the Malaysians compare favorably to those of their Iranian pre-fatigue adolescent karate counterparts [Boroushak and Anbarian, 2017]. The Iranians recorded a ratio of 56±6%. Stronger hamstrings will not only help prevent injuries to this muscle group, especially when kicking in the air, but it will also aid in kicking more forcefully [Pieter, Taaffe 1990].

Injury to the hamstrings is not only related to their strength. Zemkova [2018] noted that a synergistic relationship exists between the muscles of the core and limbs, and that deficiencies in any of these muscles could lead to injury. It is therefore, worth considering the assessment of core muscles of taekwondo athletes in future research.

## Conclusions

Scaling isokinetic peak torque to height$^2$ did control for the influence of the body size variable in the girls but not in the boys. Qualitative factors are suggested to be at the basis of this difference. The results seem to partially support the claim that, as far as isokinetic strength is concerned, geometric similarity may not apply [Nevill *et al.* 2004]. Future studies should compare theoretical strength exponents to those empirically derived in a larger sample.

Malaysian recreational taekwondo athletes compare favorably to their American elite counterparts when it comes to H/Q ratios at 300°/s but they score lower at 120°/s. It is suggested to incorporate strength training in their conditioning program. From a functional movement perspective, future studies should examine the eccentric hamstrings to concentric quadriceps ratios at various angular velocities [Coombs, Garbutt 2002]. The assessment of core stability should also be considered in future investigations [Zemkova 2018].

**Table 1.** Descriptive statistics (80% CI) of absolute peak torque (Nm) in Malaysian adolescent female recreational taekwondo practitioners by movement and angular velocity

| Girls (n = 7) | |
|---|---|
| Extension 120°/s | Flexion 120°/s |
| 121.36 (114.28 – 128.71) ± 13.50 (10.14 – 22.27) | 62.81 (59.29 – 66.33) ± 6.47 (4.86 – 10.68) |
| Extension 300°/s | Flexion 300°/s |
| 95.19 (86.39 – 103.99) ± 16.16 (12.13 – 26.66) | 76.41 (66.38 – 86.44) ± 18.43 (13.51 – 29.70) |

**Table 2.** Descriptive statistics (80% CI) of absolute peak torque (Nm) in Malaysian adolescent male recreational taekwondo practitioners by movement and angular velocity

| Boys (n = 8) | |
|---|---|
| Extension 120°/s | Flexion 120°/s |
| 154.34 (143.11 – 165.57) ± 22.45 (17.13 – 35.29) | 97.77 (85.43 – 110.11) ± 24.66 (18.82 – 38.76) |
| Extension 300°/s | Flexion 300°/s |
| 122.24 (107.97 – 136.51) ± 28.53 (21.78 – 44.85) | 89.87 (79.45 – 100.29) ± 20.82 (15.89 – 32.73) |

**Table 3.** Descriptive statistics of the hamstrings/quadriceps ratios (80% C I) by gender and angular velocity in Malaysian adolescent recreational taekwondo practitioners

| Angular velocity | Boys (n = 8) | Girls (n = 7) |
|---|---|---|
| 120°/s | 65.39 (54.42 – 76.36) ± 21.93 (16.71 – 34.47) | 51.99 (47.10 – 56.88) ± 5.29 (3.41 – 11.65) |
| 300°/s | 74.51 (67.97 – 81.05) ± 13.08 (9.98 – 20.56) | 79.59 (68.94 – 90.24) ± 11.52 (7.42 – 25.37) |

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## Izokinetyczna siła nóg malajskich młodocianych zawodników uprawiających rekreacyjnie taekwondo

**Słowa kluczowe:** taekwondo, szczytowy moment obrotowy, młodociany, stosunek wytrzymałości, ścięgna, mięsień czworogłowy

**Streszczenie:**
Tło. Zwiększenie siły nóg u zawodników taekwondo zostało zasugerowane jako sposób zapobiegania urazom ścięgien.
Problem i cel. Badania nad izokinetyczną siłą nóg malezyjskich sportowców taekwondo [WTF] są rzadkością, zwłaszcza tych ćwiczących rekreacyjnie. Celem pracy było porównanie izokinetycznej siły nóg nastoletnich malezyjskich zawodników rekreacyjnego taekwondo.
Metody. Siłę oceniano u 7 kobiet i 8 mężczyzn w systemie Biodex 3 podczas rozciągania i zginania nóg w temp. 120o/s i 300o/sec. W celu określenia różnic ze względu na płeć, rozciągnięcie/zginanie i prędkość kątową wykorzystano 3-trójstronną (płeć x ruch x prędkość) analizę ANOVA z powtarzającymi się pomiarami drugiego i trzeciego czynnika. W celu określenia różnic w stosunkach między płciami za pomocą prędkości kątowej zastosowano dwustronną (Gender x Velocity) analizę ANOVA z powtarzającymi się pomiarami drugiego czynnika.
Wyniki. Przy pomiarach prędkości kątowej i ruchu u chłopców odnotowano wyższy szczytowy moment obrotowy: eta2 = 0,47, 80% CI: 0,14 - 0,71, d = 1,93, 80% CI: 0,00 - 9,03 aczkolwiek wyniki były niejasne. W odniesieniu do skali wysokości (m2), względny szczytowy moment obrotowy był jeszcze wyższy dla chłopców: eta2 = 0,38, 80% CI: 0,03 - 0,65, co nie dawało jasnych wyników, w przeciwieństwie do porównania w parach, które było jasne: d = 1,50, 80% CI: 0,49 - 0,69. Skalowanie wymiarowe nie w pełni kontrolowało wpływ wzrostu na wytrzymałość izokinetyczną nóg u dziewcząt: r = 0,17, 80% CI: 0,00 – 0,67, u chłopców wynosiło: r = 0,72, 80% CI: 0,32 - 0,90.
Wnioski. Wyniki wydają się częściowo potwierdzać twierdzenie, że w odniesieniu do wytrzymałości izokinetycznej nóg podobieństwo geometryczne może nie mieć zastosowania. Przyszłe badania powinny porównywać teoretyczne wykładniki wytrzymałości z wykładnikami uzyskanymi empirycznie u większej grupy badanej.