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Strength and Power in Filipino Varsity Taekwondo-in = Siła i moc w filipińskiej drużynie uniwersyteckiej taekwondo-in

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Obydwaj współautorzy – Willy Pieter, Ph.D. i Luigi T. Bercades, M.S., CSCS – reprezentują filipiński Uniwersytet Azji i Pacyfiku. Zwłaszcza dr W. Pieter jest wysoko ceniony jako badacz empiryk sportów walki i jako specjalista w zakresie *taekwondo* (od dawna czarny pas).

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Strength and Power in Filipino Varsity *Taekwondo-in* / Siła i moc w filipińskiej drużynie uniwersyteckiej *taekwondo-in*

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Key words: Taekwondo, strength, bench press, vertical jump

Summary
Purpose: The purpose of this study, then, was to assess strength and power components of Filipino varsity taekwondo athletes.
Methods: Participants were male (n = 9, 19.00 ± 1.50 years, 1.70 ± 0.04 m, 81.41 ± 21.94 kg) and female (n = 10, 18.50 ± 1.78 years, 1.58 ± 0.06 m, 49.25 ± 6.27 kg) taekwondo varsity athletes from a private university in the Philippines. Strength was measured by the 1-RM leg press and the 1-RM bench press. The counter-movement vertical jump (CMJ) was used to assess explosive leg power. To determine differences in strength and power between males and females, the Mann-Whitney U Test was employed.
Results: The men had more absolute lower body strength ($p < 0.001$, ES = 0.81). This difference did not change when leg strength was scaled for height (22.68 ± 6.13 kg.m^{-2} vs. 13.21 ± 1.57 kg.m^{-2}, $p = 0.001$, ES = 0.77). There was no difference in absolute explosive leg power between men and women ($p = 0.130$, ES = 0.35). This did not change when power was expressed per LBM (kg$^{0.67}$): 2.78 ± 0.84 cm.kg$^{-0.67}$ vs. 3.14 ± 0.66 cm.kg$^{-0.67}$ ($p = 0.221$, ES = 0.28).
Conclusion: Contrary to expectation, the theoretical exponent did not reduce the relationship between the body size variables and strength to (almost) zero.

Introduction

Strength and power are suggested to play an important role in many combat sports at all levels of competition. For example, Toskovic *et al.* [2004] reported both beginning and advanced male *taekwondo-in* (taekwondo athletes) to score higher than their female counterparts in the vertical jump in absolute terms. Pieter *et al.* [1989] investigated American varsity *taekwondo-in* and revealed that the taekwondo group compared to controls showed higher values for peak torque during knee flexion in both absolute terms and relative to ratio body mass. Pieter and Taaffe [1990] investigated American adult elite *taekwondo-in* and found that when isokinetic peak torque of the males was compared with that of the females relative to body mass and lean body mass in ratio standard, the males still scored higher but the differences became smaller.

Explosive power of the legs in Malaysian *taekwondo-in* was higher in boys (16 years) compared to girls (15 years) in absolute terms: 56.30 cm versus 37.72 cm (eta^2 = 0.75). When using multivariate allometric scaling, the boys still jumped higher than the girls: 6.32 cm.kg$^{-0.314}$ versus 5.58 cm.kg$^{-0.314}$ (eta^2 = 0.70) [Suzana, Pieter 2006]. Aiwa and Pieter [2007] reported that, collapsed over angular velocity and leg movement (extension and flexion) in Malaysian recreational *taekwondo-in* (17 years), peak torque for the boys (116.05 Nm) was higher than that for the girls (88.94 Nm, eta^2 = 0.47). When scaled to height (m^2), the difference between boys (41.54 Nm.m^{-2}) and girls (35.87 Nm.m^{-2}) became smaller (eta^2 = 0.38).

Noorul *et al.* [2008] assessed physical fitness of adolescent Malaysian recreational *taekwondo-in* (18 years) and revealed that the boys had more explosive power in the legs than the girls but the effect was moderate (eta^2 = 0.48). The difference became smaller when scaled for height (m^2): 17.39 cm.m^{-2} for boys and 14.25 cm.m^{-2} for girls (eta^2 = 0.33). When the vertical jump was expressed in

Table 1 Means and standard deviations of body composition, strength and explosive power in Filipino varsity *taekwondo-in*
Tabela 1. Średnie i standardowe odchylenie budowy ciała, mocy i siły eksplozywnej wyrzutu w filipińskiej drużynie uniwersyteckiej *taekwondo-in*

Variable	Males	Females
Age (years)	19.00 ± 1.50	18.50 ± 1.78
Height (m)	1.70 ± 0.04	1.58 ± 0.06
Weight (kg)	81.41 ± 21.94	49.25 ± 6.27
Fat (%)	26.83 ± 7.47	28.75 ± 1.54
LBM (kg)	58.14 ± 8.79	35.06 ± 4.17
Bench press (kg)	95.38 ± 30.85	40.82 ± 6.05
Leg press (kg)	65.02 ± 16.20	33.11 ± 6. 07
Vertical jump (cm)	41.33 ± 10.14	33.60 ± 5.46

terms of lean body mass (LBM, $kg^{0.67}$), the difference between boys and girls disappeared ($eta^2 = 0.13$): 3.52 $cm.kg^{-0.67}$ versus 3.06 $cm.kg^{-0.67}$.

Pieter and Bercades [2009] recently compared Filipino male and female varsity *taekwondo-in* and revealed that the men had more absolute leg strength as measured by the 1- repetition maximum (RM) leg press, which did not change when it was scaled for LBM ($kg^{0.67}$). However, there was no significant difference in absolute explosive leg power. The purpose of this study, then, was to assess strength and power components of Filipino varsity taekwondo athletes.

Methods

Participants were male (n = 9, 19.00 ± 1.50 years, 1.70 ± 0.04 m, 81.41 ± 21.94 kg) and female (n = 10, 18.50 ± 1.78 years, 1.58 ± 0.06 m, 49.25 ± 6.27 kg) taekwondo varsity athletes from a private university in the Philippines. Height and weight were measured according to the specifications by Ross and Marfell-Jones [1991]. Body composition was assessed as suggested by Deurenberg-Yap *et al.* [2000].

Strength was measured by the 1-RM leg press as well as the 1-RM bench press. The counter-movement vertical jump (CMJ) was used to assess explosive leg power in the *taekwondo-in*. However, no attempt was made to control for the angle of the knees when lowering the body before the jump, as suggested by Domire and Challis [2007]. The subjects were allowed three jumps with a 30-second rest in between. The highest jump was used for statistical analysis.

Data distributional characteristics were verified by the Kolmogorov-Smirnov Test, while skewness and kurtosis coefficients were also calculated. To determine differences in strength and power between males and females, the Mann-Whitney U Test was employed. In cases of skewed or kurtotic data, the L-statistic was used to compare groups. Upper and lower body strength and explosive leg power were scaled using the theoretical exponents for height (m^2) and lean body mass ($kg^{0.67}$) [Åstrand *et al.* 2003; Marković, Jarić 2007] as well as empirically derived exponents using multivariate allometric scaling. Regression diagnostics were employed to verify the effect of the body size variable on both males and females. Pearson correlations were calculated to assess to what extent allometric scaling, using the theoretical and empirically derived exponents, controlled for the effect of the body size variable. No adjustment for the familywise type 1 error was made for multiple comparisons [Feise 2002]. The objective was to unearth any possible leads regarding the relationship between the independent and dependent variables [Bender, Lange 2001; Rothman 1990]. The level of significance was set to 0.05.

Results

Absolute values and using theoretical exponents to scale

Table 1 shows the descriptive statistics for strength and power of the *taekwondo-in*. The males were taller than their female colleagues (p = 0.002, ES = 0.71) but not heavier (p = 0.713, ES = 0.08). There was no difference in percent relative total body fat (p = 0.086, ES = 0.39) or lean mass (p = 0.712, ES = 0.09).

The men had more absolute lower body strength (p < 0.001, ES = 0.81). This difference did not change when leg strength was scaled for height (22.68 ± 6.13 $kg.m^{-2}$ vs. 13.21 ± 1.57 $kg.m^{-2}$, p = 0.001, ES = 0.77) or lean body mass ($kg^{0.67}$): 4.29 ± 1.08 $kg.kg^{-0.67}$ vs. 3.05 ± 0.43 $kg.kg^{-0.67}$, p = 0.006, ES = 0.64).

The men also had more absolute upper body strength (p < 0.001, ES = 0.85). When it was scaled for height, the difference did not become appreciably smaller: 33.41 ± 11.86 $kg.m^{-2}$ vs. 16.46 ± 2.80 $kg.m^{-2}$ (p = 0.001, ES = 0.77). When scaled for LBM ($kg^{0.67}$), the men recorded 6.33 ± 2.20

Table 2. Comparative data for upper body strength (kg)
Tabela 2. Dane porównawcze dla siły górnej części ciała (kg)

Variable	Males	Females
This study	95.38	40.82
Croatian *taekwondo-in* [Marković *et al.* 2005]	–	51.2
American novice *taekwondo-in* [Toskovic *et al.* 2004]	86.1	36.1
American experienced *taekwondo-in* [Toskovic *et al.* 2004]	84.3	37.1
Japanese *karateka* [Imamura *et al.* 1998]	87.1	--
Filipino varsity arnis athletes [Pieter, Bercades 2009]	117.19	51.60
Brazilian *judoka* [Franchini *et al.* 2007]	110	--
Serbian and Montenegro *judoka* [Bratić *et al.* 2005]	82.12	--

Table 3. Comparative data for lower body strength (kg)
Tabela 3. Dane porównawcze dla dolnej części ciała (kg)

Variable	Males	Females
This study	65.02	33.11
Filipino varsity *taekwondo-in* [Pieter, Bercades 2009]	68.95	33.26
American novice *taekwondo-in* [Toskovic *et al.* 2004]	196.4	147.9
American experienced *taekwondo-in* [Toskovic *et al.* 2004]	217.1	151.4

Table 4. Comparative absolute vertical jump height (cm) in *taekwondo-in*
Tabela 4. Porównanie wysokości absolutnej dla skoku wzwyż (cm) w *taekwondo-in*

	Males	Females
This study	41.33	33.60
Filipino varsity athletes [Pieter, Bercades 2009]	40.60	32.50
Malaysian recreationalists [Noorul *et al.* 2008]	52.07	34.04
Malaysian recreationalists [Erie *et al.* 2007]	35.63	26.00
Malaysian international juniors [Suzana, Pieter 2006]	56.14	36.11
Malaysian national juniors [Yiau *et al.* 2004]	53.03	36.59
American recreational beginners [Toskovic *et al.* 2004]	43.7	32.1
American recreational advanced [Toskovic *et al.* 2004]	51.5	31.3
Croatian elite athletes [Marković *et al.* 2005]	--	34.9

kg.kg$^{-0.67}$ vs. 3.79 ± 0.61 kg.kg$^{-0.67}$ for the women (p = 0.009, ES = 0.60).

The theoretical exponent adequately removed the effect of the body size variable from leg strength when scaled for height: r = -0.49 (p = 0.177) in men and r = 0.61 (p = 0.059) in women. It also removed the effect of the body size variable when scaled for LBM: r = -0.09 (p = 0.823) in men and r = 0.25 (p = 0.481) in women. For upper body strength, when scaled for height, the coefficients were r = -0.68 (p = 0.044) in men and r = -0.46 (p = 0.184) in women. When scaled for LBM: r = -0.22 (p = 0.574) in men and r = -0.38 (p = 0.282) in women.

However, there was no difference in absolute explosive leg power between men and women (p = 0.130, ES = 0.35). This did not change when power was expressed per m^2: 14.37 ± 3.62 cm.m^{-2} vs. 13.58 ± 2.68 cm.m^{-2} (p = 0.683, ES = 0.09). It also did not change when scaled for LBM (kg$^{0.67}$): 2.78 ± 0.84 cm.kg$^{-0.67}$ vs. 3.14 ± 0.66 cm.kg$^{-0.67}$ (p = 0.221, ES = 0.28).

The theoretical exponent for height adequately removed the influence of the body size variable on explosive power in both men (r = -0.19, p = 0.626) and women (r = -0.54, p = 0.111). However, the theoretical exponent for LBM did not remove the influence of the body size variable from the vertical jump in both men (r = -0.72, p = 0.029) and women (r = -0.66, p = 0.036).

Using empirically derived exponents to scale

For the leg press, the empirically derived exponent for height was 2.04 (SE = 1.70, 95%CI: -1.57 – 5. 64), which was not different from the theoretical exponent. The empirically derived exponent for LBM was 0.76 (SE = 0.38, 95%CI: -0.05 – 1.57), which was also not different from the theoretical exponent.

For the bench press, the empirically derived exponent for height was -2.25 (SE = 2.00, 95%CI: -6.48 – 1.99), which was considered not to be different from the theoretical exponent. The empirically derived exponent for LBM was 0.24 (SE = 0.49, 95%CI: -0.81 – 1.28), which was not different from the theoretical exponent either.

As for the vertical jump, the empirically derived exponent for height was -0.62 (SE = 1.65, 95%CI: -4.12 – 2.89), which was not different from the theoretical exponent. The empirically derived exponent for LBM was -0.78 (SE = 0.35, 95%CI: -1.52 – -0.05), which was different from the theoretical exponent. Using the above exponent for LBM, there was a significant difference ($p < 0.001$, ES = 0.82) in explosive power between men (11.01 ± 0.61 cm.LBM$^{0.781}$) and women (9.42 ± 0.41 cm.LBM$^{0.781}$). The empirically derived exponent controlled for the influence of LBM on explosive power in both men ($r = -0.17$, $p = 0.668$) and women ($r = 0.21$, $p = 0.564$).

Regression diagnostics revealed that the effect of height on the leg press was the same for both males (95%CI: -13.583 – 6.158) and females (95%CI: 1.844 – 6.041), as it was for LBM (95%CI: -0.867 – 2.147 and -0.051 – 1.938 for males and females, respectively). The same was true for the effect of height on the bench press (95%CI: -19.513 – 2.403 vs. -3.544 – 3.244) as well as LBM (95%CI: -1.735 – 2.364 vs. -0.983 – 1.232). The effect of height on the vertical jump was also the same for males and females (95%CI: -9.580 – 9.832 vs. -4.408 – 2.687) as was the effect of LBM (95%CI: -2.181 – 0.324 vs. -1.653 – 0.531).

Discussion

Comparative data for upper body strength are shown in Table 2, while those for leg strength are displayed in Table 3. Table 4 shows comparative data for the vertical jump. The discrepancy in strength between the upper and lower body in the Filipinos is attributed to the emphasis on upper body strength in training. However, the reason for this is not clear.

Similar to previous studies [Erie *et al.* 2007; Noorul *et al.* 2008], the difference in absolute explosive leg power between men and women in the current investigation was significant. In addition to such factors as motivation, differences in body composition, training background, genetic disposition, etc. [Cleather 2006], the differences between the groups depicted in the tables may be due to muscle physiological factors. For instance, fiber cross-sectional area and total number of fibers per unit of lean mass or per unit of height have been shown to be larger in males [Alway *et al.* 1989]. The ability of the *taekwondo-in* to recruit the greatest percentage of motor units may also play a role [Cleather 2006] as may the effect of the proportion of non-contractile tissue to body mass [Ford *et al.* 2000].

Based on geometric similarity theory, strength may be expected to be proportional to height (m^2) and (lean) body mass ($kg^{0.67}$). However, strength may not scale geometrically [Alexander 1985]. It is suggested that strength increases at a higher rate than predicted by geometric similarity theory [Rowland 2005], while athletic and sedentary humans were found not to be geometrically similar in strength [Nevill *et al.* 2004]. It was for this reason that in addition to theoretical exponents, those derived empirically were also calculated to arrive at dimensionless strength and power dependent variables [Batterham, George 1997]. Jarić *et al.* [2002] found an average exponent of 1.14 (95%CI: 0.93 – 1.35) when strength was scaled to body mass in elite athletes and their pubertal and pre-pubertal counterparts of various sports. Ford *et al.* [2000] revealed an empirically derived exponent of 2.16 for height in male and female weightlifters.

The negative exponents for height and LBM when scaling the bench press and vertical jump in the current study may be attributable to so-called “negative allometry” where the exponent is lower than predicted by geometric similarity [Batterham, George 1997]. This may be due to the variation in body mass and, subsequently, LBM, in the current subjects, thus violating the homogeneity of body composition assumption as well as the assumption of muscle mass representing a constant proportion of total body mass in especially the heavier athletes. Allometric scaling may therefore penalize subjects at the tail ends of the (lean) body mass distribution, which may necessitate separate scaling models for men and women [Batterham, George 1997]. On the other hand, the allometric model used in this study may have suffered from not controlling the inclusion of a maximum weight limit, since the heaviest individuals in the sample could also have more fat as well as lean mass [Cleather 2006].

Contrary to expectation [e.g., McArdle *et al.* 2001], the theoretical exponent did not reduce the relationship between the body size variables and strength to (almost) zero. The effect of height on both upper and lower body strength in men was larger than predicted by the theoretical exponent. The effect of lean mass on lower body strength in the men was sufficiently removed by using the theoretical exponent as it was for height and the vertical jump. The empirically derived exponent for LBM was better able to control for the influence of the body size variable on explosive power in both men and women. Jarić *et al.* [2002] reported a b-exponent of 0.61 for body mass to arrive at strength independent of body mass in elite athletes from various sports. The authors suggested that using a measure like lean leg volume would be more effective than employing whole body mass.

While plyometrics have been around for decades as an effective modality for improving functional power, there have been other more recent methods to improve performance that coaches and practitioners may use. A recent study that compared the effects of plyometrics and dynamic stabilization and balance training (BAL) on power, balance and landing forces reported that both training modes increased measures of neuromuscular power and control [Myer *et al.* 2006]. BAL training emphasizes neuromuscular training particularly in decelerating skills, such as landing and directional change.

An increase in flexibility may aid in power production through the enhancement of the eccentric prestretch during the stretch shortening cycle [Ishikawa *et al.* 2006]. Coaches and practitioners should modify stretching techniques prior to practice and competition to include more dynamic types of exercise to reduce potential performance insufficiencies. Likewise, training the elastic response of muscles at selected times during the athlete's preparation cycle will improve power production in actual performance.

Future research on Filipino athletes should again employ both theoretical and empirically derived exponents to assess differences in physiological function between genders. Attempts have been made to correlate maximal upper body strength as measured by the 1-RM bench press to upper body power [e.g., Cronin, Owen 2004]. While maximal strength is somewhat related to power, training and assessment might be more geared towards greater velocity if the sport requires this specific type of speed.

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Cel: Celem pracy była ocena komponentów siły i mocy wśród filipińskich zawodników taekwondo-in .
Metody: Uczestnikami byli mężczyżni i kobiety w wieku ok. 19 lat z drużyny uniwersyteckiej taekwondo-in na Filipinach. Siła mierzona była przy pomocy prasy do nóg 1-RM i ławki 1-RM. Skok wzwyż z obrotem był używany do oceny mocy eksplozywnej nóg. Aby ocenić różnicę w sile i mocy pomiędzy mężczyznami i kobietami skorzystano z U testu Manna i Whitneya.
Rezultaty: Mężczyżni mieli więcej absolutnej siły dolnych częśći ciała (p<0,001, ES=0,81). Różnica ta nie zmieniała się kiedy siła nóg była mierzona w stosunku do wzrostu. Nie było różnicy w absolutnej mocy eksplozywnej nóg pomiędzy mężczyznami a kobietami (p=0,130, ES=0,35). Nie zmieniało się to kiedy moc była wyrażona w LBM (kg).
Konkluzja: Wbrew oczekiwaniom, teoretyczny wykładnik nie redukował związku pomiędzy zmiennymi rozmiaru ciała i siłą (prawie) do zera.