Introduction

Numerous evident have shown body size and strength contributes to motor performance. The increase in strength is related to increase in total muscle mass (Ostojic, Mazic, & Dikic, 2006). Significant positive correlation between strength and performance indicate that stronger individuals were the individuals who performed better (Ball, Massey, Misner, Mckeown, & Lohman, 1992). However, the pattern of improvement of strength and physical performance is not uniform in all tasks. Strength may be important to the successful performance of some motor performances but not as important to others. It is likely that performance related to power events would show a similar trend to that of strength. Physique and body structure has generally been found to have a significant relation to physical performance (Gabbett & Georgieff, 2007). However, physique does not markedly influenced performance except at the extreme of the continuum. High degree of endomorph definitely limited physical performance capacity, while a high degree of mesomorphy are more adapted to motor performance. Nevertheless, correlations between physique, strength and performance are at best moderate and not sufficiently high for predictive purposes (Malina, 1975).

Correlations between skinfold thicknesses and performance are consistently negative suggesting the negative effect of fatness on motor performance (Vucetic, Matkovic, & Sentija, 2008). Body fatness influenced physical performance both mechanically and metabolically (Boileau & Lohman, 1997). Mechanically, excess fatness is detrimental to performance involving acceleration of body weight because it adds non-force producing mass to the body. Metabolically, excess fatness increases the metabolic cost of performing work in activities requiring movement of the total body mass. Thus, one would expect that in most type of performance involving translocation of the body mass a low relative fatness to be advantageous in both mechanical and metabolic sense. It should be noted that correlation type analyses relating a specific body dimension to and motor performance may has its limitation. Anthropometric factors influencing strength and performance are themselves related, thus, a set of selected anthropometric dimensions would account for a significant variation in physical performance (Slaughter, Lohman, & Boileau, 1982). Using the step-down regression procedure, height, upper arm circumference, abdominal and calf skinfolds were identified as significant predictors of physical performance. Analysis of canonical correlation on two sets of variables, anthropometric and physical performance also indicated that children with greater weight, thigh volume, and height will perform well on performance measures requiring high intensity work production (Docherty & Gaul, 1991).

Student athletes are different from their peers in that they are successful in sport. Moreover, they are also provided with regular physical training and more actively involved in sports activities than their peers. Regular physical training is known to speed up the rate of development of physical performance (Gabbett, Johns, & Riemann, 2008). Increased in physical performance, in turn, can be consistent with success in many sport activities. For example, competitive-level performance may require that high forces be generated rapidly in order to achieve sufficiently high velocity in movements such as throwing, jumping, kicking, or sprinting (Thorland, Johnson, Tharp, & Housh, 1988). Evidently, high performance athletes require specific biological profiles with outstanding biomotor ability and strong psychological traits. Biometric quality or anthropometric measurements of an individual are important asset for several sports, and therefore, considered among the main criteria for success in many sports (Bompa, 1999). However, which physique characteristics are important for success in different types of physical performance? Theoretically, it would be expected that those who are successful to have the appropriate structures commensurate with their physical performance task. Research showed overwhelming evidence showing differences in body size between athletes in different sports, whether measured by weight, height, lengths, breadths, girths, or skinfolds; between sports or within sports (Bayios, Bergeles, Apostolidis, Noutsos, & Koskolou, 2006; Gabbett & Georgieff, 2007; Ziv & Lidor, 2009).

Therefore, a study of the difference between body structure and motor task are important for better understanding of the important aspects of physique. The purpose of this study was to determine the anthropometric attributes and motor performance status of Malaysian universities based on gender and sport. Besides that, this research also determined the anthropometric characteristics that are the significant contributing factors to motor performance. This information can be used as guidelines for a more accurate selection, training and prediction for future success.

Methodology

Participants were Malaysian university student athletes who represented Malaysian universities in the ASEAN University Games 2008 held in Kuala Lumpur. A total of 225 male (n = 138) and female (n = 87) athletes, aged between 18 and 28 years (M = 22.1; SD = 1.8) participated in this study. Those involved were comprised of athletes from 18 different team related sports and also individual sports. **A**thletes' physical characteristics were determined through anthropometric measurements of the height, weight, body mass index (BMI), body fat percentage (%fat) and waist-hip ratio (WHR). A motor performance test battery was used to assess motor performance. The tests included in the battery were: grip strength (GS), back strength (BS), seven level sit-up (SU7), 10m sprint (S10), 30m sprint (S30), sit and reach (SR), trunk extension test (TE), SEMO agility test (SEMO), vertical jump (VJ), standing long jump (SLJ), reaction time (audio) (RTa), reaction time (visual)(RTv), bleep test (Bleep), leg strength (LS), stork test (ST) and push-ups (PU). All participants (N = 225) were involved in all anthropometric measurements. For the motor performance tests, participants were tested based on suitability and the requirement of each type of sport. Motor performance tests for each type of sports by gender are presented in Table 1.

Table 1: List of motor performance tests based gender and type of sports.

Sport	Male (n)	Female (n)	Motor performance test
Taekwondo	7	7	Grip strength
Volleyball	11	8	Back strength
Beach volleyball	2	1	Sit-up
Squash	2	-	10m sprint
Karate do	6	3	30m sprint
Ping Pong	2	2	Sit and reach
Silat	13	9	Trunk extension
			Agility-SEMO
			Vertical jump
			Standing long jump
			Reaction time (A)
			Reaction time (V)
			Bleep test
Football	17	-	Grip strength
Futsal	11	-	Back strength
Badminton	5	3	Sit-up
Basketball	7	-	10m sprint
Sepak takraw	12	-	Sit and reach
Netball	-	12	Trunk extension
Track and field *	27	19	Vertical jump
			Reaction time (A)
			Reaction time (V)
*not tested for Agility			Bleep test
			Agility-SEMO
Archery	2	7	Grip strength
Tenpin bowling *	4	4**	Back strength
			Sit-up
			Sit and reach
			Trunk extension
			Stork test
* Not tested for push-up test			Push-up
** Not tested for strength tests			Bleep test

Descriptive statistics were used to determine the anthropometric characteristics and participants' motor performance status. The contribution of each anthropometric characteristic towards the motor performance components was determined using the multivariate analysis of covariance (MANCOVA) and multiple regressions.

Results

Separate means (M) and standard deviations (SD) for participants' anthropometric characteristics and motor performance status were computed for male and female student athletes. These measures are presented in Table 2. Difference in total number of participants in each motor performance test was due to the difference in type of motor performance test conducted on different type of sports.

Table 2: Descriptive analysis of anthropometry and motor performance components.

	Male (*n*=138)				**Female (*n*=87)**			
	M	***sd***	**Min**	**Max**	***M***	***sd***	**Min**	**Max**
Age (years)	22.2	1.8	18	27	21.9	1.7	18	28
Anthropometry *(n=225)*								
Height (cm)	172.5	7.4	158.0	192.0	161.8	7.9	146.0	181.0
Weight (kg)	70.2	14.1	47.4	146.7	58.5	10.9	41.7	99.4
BMI (kg/cm^2)	23.5	3.9	17.3	44.8	22.3	3.9	16.3	38.8
% fat (%)	15.8	7.4	3.9	48.4	23.4	8.5	7.4	44.6
Waist hip ratio (cm)	0.8	0.04	0.7	1.0	0.8	0.05	0.6	0.9
Motor performance								
Grip strength (kg) (n=225*)*	44.9	8.7	6.0	76.2	30.6	5.3	16.0	45.6
Back strength (kg) (n=217*)*	111.7	25.6	25.0	178.5	64.4	17.2	30.0	125.0
7 level sit-up (l) (n=225*)*	5.7	1.3	1.0	7.0	5.0	1.4	0.0	7.0
10m sprint (sec) (n=198*)*	1.8	0.1	1.5	2.3	2.1	0.1	1.7	2.3
30m sprint (sec) (n=92*)*	4.4	0.3	4.0	5.7	5.2	0.3	4.5	5.9
Sit and reach (cm) (n=225*)*	15.5	7.4	-7.0	28.3	16.2	7.1	-6.8	31.0
Trunk extension (cm) (n=225*)*	31.2	10.7	3.8	61.0	28.7	10.3	8.2	47.8
Agility-SEMO (sec) (n=140*)*	11.8	1.1	10.4	18.3	12.7	0.7	10.8	14.4
Vertical jump (cm) (n=186*)*	65.3	11.8	38.0	94.0	48.7	6.5	35.0	68.0
Standing long jump (cm)(n=162*)*	251.1	19.8	205.0	292.0	195.0	19.6	147.0	229.0
Reaction time (A)(sec) (n=186*)*	0.3	0.07	0.04	0.5	0.2	0.06	0.02	0.5
Reaction time (V)(sec) (n=186*)*	0.3	0.06	0.02	0.4	0.2	0.05	0.09	0.4
Bleep test (l) (n=215*)*	9.5	2.1	2.9	14.1	6.9	1.9	1.7	11.1
Leg strength (kg) (n=27*)*	110.0	40.4	45.0	170.0	82.5	14.7	70.0	120.0
Stork test (sec) (n=39*)*	31.3	17.2	8.7	60.9	24.1	19.9	1.1	60.2
Push-up (r) (n=31*)*	33.3	13.5	13.0	59.0	36.2	10.6	20.0	60.0

Based on the descriptive anthropometric characteristics of the athletes, it was found that male athletes were taller and heavier than female athletes. Male athletes were also found to have a higher BMI measurement than female athletes. However, both male and female athletes were still in the normal BMI category (Normal: 18.5 – 25). Female athletes had a higher body fat percentage than male athletes. For the waist hip ratio, male and female athletes had similar readings. Descriptive analyses for the athletes' motor performance showed that male athletes were better than female athletes in almost all motor performance components. However, female athlete scored better than male athletes in the sit and reach test, reaction time (audio and visual) and push-up test.

For a more accurate comparison, descriptive analysis was then conducted to determine the anthropometric characteristics and motor performance status of the subjects based on their sport for both genders. The analysis is presented in Table 3, Table 4 and Table 5.

The anthropometric characteristics of male athletes based on their sport showed volleyball, beach volleyball and basketball athletes were generally taller than athletes in other sports (Table 3). Basketball athletes also were heavier than athletes of other sports. The BMI of most male athletes for all sports was within the normal range, except for archery and tenpin bowling, which recorded a value higher than normal (Normal: 18.5 – 25). Male volleyball athletes recorded the lowest body fat percentage, whereas the highest were those of archery and tenpin bowling athletes. All male athletes had similar waist hip ratio reading except for archery and tenpin bowling.

The anthropometric characteristics for female athletes show that basketball and beach volleyball athletes were heavier than athletes of other sports. Female tenpin bowling athletes, however, were heavier and had a higher BMI value than other sports. Female athletes of other sports recorded a normal BMI status. Track and field athletes recorded the lowest body fat percentage while female athletes of four sports, which are archery, shooting, lawn bowl, and tenpin bowling had a higher body fat percentage than other sports. The waist hip ratio measurements were almost similar for all sports except for volleyball, beach volleyball and silat. For both genders, tenpin bowling recorded the highest BMI and fat percentage reading.

Table 3: Descriptive analysis of anthropometric based on gender and sports.

	Height		**Weight**		**BMI**		**% Fat**		**WHR**	
	M	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***
Male (n = 138)										
Taekwondo (14)	170.4	4.8	69.0	12.2	23.6	3.1	12.9	5.8	0.8	0.05
Football (17)	169.0	5.9	65.2	5.5	22.8	1.5	14.9	4.4	0.8	0.02
Archery (9)	165.0	2.8	68.7	9.1	25.2	2.5	24.3	0.9	0.9	0.01
Shooting (10)	165.7	4.7	65.4	12.9	24.0	6.0	21.5	12.6	0.8	0.05
Tenpin bowling (8)	172.2	6.3	75.5	21.5	25.6	6.0	25.6	8.9	0.9	0.07
Futsal (11)	169.8	5.3	68.8	8.0	23.8	1.6	19.2	4.6	0.8	0.02
Badminton (8)	174.2	3.7	68.9	3.4	22.7	0.9	14.6	1.7	0.8	0.01
Lawn bowl (12)	167.0	2.2	61.4	3.1	22.0	1.3	19.5	5.4	0.8	0.02
Volleyball (19)	182.6	6.2	69.4	10.1	20.7	2.4	8.9	4.1	0.8	0.04
Beach volleyball (3)	184.5	6.4	76.5	3.5	22.4	0.5	22.1	0.8	0.8	0.01
Squash (2)	172.5	9.2	67.5	4.9	22.7	0.7	22.4	0.6	0.8	0.02
Karate do (9)	174.2	6.7	70.8	15.1	23.2	4.0	16.6	7.5	0.8	0.04
Basketball (7)	182.4	6.2	82.1	18.5	24.4	3.9	14.8	7.4	0.8	0.04
Sepak takraw (12)	171.8	6.9	70.0	12.8	23.6	3.3	14.9	8.3	0.8	0.04
Ping pong (4)	172.0	5.6	64.5	4.6	21.8	0.1	17.1	0.1	0.8	0.01
Track and field (46)	173.6	6.6	75.3	22.0	24.8	6.2	14.5	9.5	0.8	0.06
Silat (22)	167.5	3.9	66.6	9.8	23.7	3.2	15.9	5.8	0.8	0.04
Female (n = 87)										
Taekwondo (14)	163.9	3.8	65.4	13.1	24.4	5.3	26.0	7.9	0.8	0.07
Archery (9)	161.6	5.4	61.7	7.6	23.5	1.6	30.7	2.5	0.8	0.03
Shooting (10)	154.8	3.5	52.0	6.9	21.6	2.4	33.1	3.6	0.8	0.02
Tenpin bowling (8)	162.0	6.5	71.0	20.0	27.3	8.5	34.0	8.4	0.8	0.09
Netball (12)	170.9	5.6	60.6	6.5	20.8	2.3	15.3	.6	0.8	0.03
Badminton (8)	160.3	8.1	59.9	5.9	23.5	4.7	25.4	1.5	0.8	0.09
Lawn bowl (12)	152.7	4.3	54.5	8.8	23.5	4.3	33.5	7.4	0.8	0.06
Volleyball (19)	169.6	3.7	61.8	3.9	21.5	1.2	21.5	2.8	0.7	0.04
Beach volleyball (3)	173.0		68.0		22.7		20.4		0.7	
Karate do (9)	158.7	3.5	51.0	2.5	20.3	0.7	20.7	1.6	0.8	0.01
Ping pong (4)	151.0	0.0	49.4	2.0	21.7	0.8	23.8	0.9	0.8	0.02
Track and field (46)	162.6	6.3	59.1	13.3	22.3	.8	17.8	8.7	0.8	0.06
Silat (22)	153.2	3.3	48.2	4.7	20.5	1.5	23.1	4.7	0.7	0.02

BMI-body mass index; %fat-body fat percentage; WHR-waist-hip ratio

Table 4 showed the motor performance status for male athletes based on their sport. Male squash players recorded the highest grip strength, whereas male shooters recorded the lowest. Karate athletes recorded the strongest back strength compared to other sports. Four sports that recorded the lowest back strength were archery, shooting, lawn bowling and ping pong. Shooting, lawn bowl and ping pong also recorded the lowest push-up count.

Table 4: Descriptive analysis of motor performance for male athletes based on sports.

n = 138	GS		BS		SU7		S10		S30		SR	
	M	*sd*	*M*	*sd*	*M*	*sd*	*M*	*sd*	*M*	*sd*	*M*	*sd*
Taekwondo (7)	44.6	10.2	110.7	24.2	6.4	1.1	1.6	0.1	4.1	0.1	20.3	4.1
Football (17)	43.7	5.2	119.4	30.9	5.9	0.9	1.8	0.1			18.3	5.8
Archery(2)	47.0	2.8	80.0	21.2	5.5	2.1					14.0	8.5
Shooting (4)	27.5	14.7	75.0	33.9	4.5	1.0					14.7	2.2
Tenpin bowling (4)	46.0	9.5	103.7	32.5	4.7	1.5					5.7	9.9
Futsal (11)	42.3	6.4	114.0	13.4	5.6	1.5	1.8	0.1			15.7	6.0
Badminton (5)	44.3	5.2	106.0	18.9	6.4	0.5	1.8	0.1			6.7	5.2
Lawn bowl (6)	44.3	7.1	86.7	8.7	4.0	1.4					12.4	3.1
Volleyball (11)	47.3	6.6	114.5	21.6	6.0	0.8	1.8	0.1	4.4	0.2	10.4	10.8
Beach volleyball (2)	48.5	3.5	117.5	24.7	5.5	2.1	1.6	0.1	4.0	0.1	15.0	0.0
Squash(2)	56.5	10.6	120.0	14.1	6.0	1.4	1.8	0.1	4.4	0.2	20.0	0.0
Karate do (6)	40.5	6.9	128.0	19.2	5.3	0.5	1.9	0.1	4.6	0.2	11.7	8.8
Basketball (7)	44.0	8.3	106.2	22.2	5.4	2.0	1.9	0.1			16.3	8.0
Sepak takraw (12)	40.9	5.5	110.0	16.7	5.9	1.8	1.8	0.1			20.0	4.0
Ping pong (2)	44.5	16.3	70.0	42.4	4.5	2.1	2.0	0.3	5.0	0.9	7.0	2.8
Track and field (27)	48.8	9.3	125.5	23.8	6.0	1.3	1.7	0.1			15.0	6.8
Silat (13)	48.0	8.6	102.6	20.4	5.8	0.9	1.9	0.1	4.6	0.1	20.7	5.0

( ) number of athletes

GS - Grip strength; BS - Back strength; SU7 - 7 level sit-up; S10 - 10m sprint; S30 - 30m sprint; SR - Sit and reach.

Continued on next page

Table 4 (continued)

	TE		SEMO		VJ		SLJ		RTa		RTv	
	M	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***
Taekwondo (7)	15.5	6.8	11.1	0.4	72.7	11.4	246.0	8.5	0.2	0.07	0.2	0.1
Football (17)	26.9	7.3	11.9	0.6	57.1	6.5			0.3	0.07	0.3	0.06
Archery(2)	38.1	7.0										
Shooting (4)	33.5	4.3										
Tenpin bowling (4)	16.9	11.7										
Futsal (11)	31.5	11.9	11.9	0.4	60.4	5.3			0.3	0.08	0.3	0.09
Badminton (5)	23.9	7.5	11.3	0.2	55.6	4.1			0.3	0.07	0.3	0.06
Lawn bowl (6)	31.9	7.5										
Volleyball (11)	18.3	8.6	11.6	0.5	80.6	8.2	264.0	22.4	0.2	0.04	0.2	0.03
Beach volleyball (2)	37.3	2.7	11.8	0.4	85.5	4.9	283.5	3.5	0.3	0.0	0.3	0.03
Squash(2)	40.8	15.5	12.2	0.5	63.0	4.2	229.0	18.4	0.2	0.09	0.2	0.03
Karate do (6)	39.7	6.6	11.5	0.4	60.0	1.8	244.8	13.4	0.3	0.04	0.2	0.03
Basketball (7)	39.7	3.4	11.4	0.2	56.0	5.2			0.3	0.04	0.3	0.05
Sepak takraw (12)	33.9	4.2	12.7	2.0	58.3	9.6			0.3	0.08	0.3	0.06
Ping pong (2)	41.0	2.3	15.2	0.2	63.5	7.8	226.5	4.9	0.3	0.01	0.3	0.06
Track and field (27)	38.1	9.3			70.5	12.6			0.3	0.05	0.3	0.04
Silat (13)	31.5	7.1	11.6	0.5	68.0	9.7	247.6	14.9	0.2	0.0	0.2	0.03

( ) number of athletes,

TE - Trunk extension; SEMO - SEMO test; VJ - Vertical jump; SLJ - Standing long jump; RTa - Reaction time (audio); RTv - Reaction time (visual).

Continued on next page

Table 4 (continued)

	Bleep		**LS**		**ST**		**PU**	
	M	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***
Taekwondo (7)	11.0	2.0						
Football (17)	10.4	1.5						
Archery (2)	7.5.	0.1	100.0	0.0	17.6	5.4	43.5	13.4
Shooting (4)			100.0	39.4	49.6	13.0	37.2	16.6
Tenpin bowling (4)	4.0	1.0	125.0	53.4	16.6	5.4		
Futsal (11)	9.9	1.6						
Badminton (5)	11.3	0.8						
Lawn bowl (6)	6.1	0.9			33.4	15.6	27.3	10.2
Volleyball (11)	8.9	1.3						
Beach volleyball (2)	10.4	0.3						
Squash (2)	11.5	0.5						
Karate do (6)	10.8	2.1						
Basketball (7)	9.7	0.9						
Sepak takraw (12)	8.6	1.8						
Ping pong (2)	10.7	1.1						
Track and field (27)	10.1	2.0						
Silat (13)	9.2	1.3						

( ) number of athletes,

Bleep - Bleep test; LS - Leg strength; ST - Stork test; PU - Push-up.

The highest sit-up count was displayed by taekwondo and badminton athletes. Taekwondo also recorded the best times for 10-metre and 30-metre sprints, besides beach volleyball. Among the sports that recorded the highest score for sit and reach were taekwondo, squash and silat while the lowest were tenpin bowling, badminton and ping pong. Badminton recorded the best for trunk extension, while taekwondo, tenpin bowling and volleyball recorded the lowest. For the SEMO test, the best score were performed by taekwondo while the lowest was exhibited by the ping pong athletes.

Volleyball and beach volleyball recorded the best results for vertical jump and standing long jump compared to other sports. Reaction times (audio and visual) for all sports were almost the same. Sports that recorded the best results for the Bleep test were taekwondo, badminton and squash, whereas the worst was tenpin bowling. However, tenpin bowling recorded the best stork test results compared to the four types of sports that conducted the same test.

Table 5 showed the motor performance status for female athletes based on the sport. Motor performance status for female athletes showed that beach volleyball players recorded the highest grip strength and back strength. Lowest score was recorded in shooting, alongside ping pong and silat. Ping pong also recorded the lowest back strength. For sit-ups, taekwondo recorded the highest count while tenpin bowling recorded the lowest. Taekwondo recorded the best times for 10-metre and 30-metre sprints. Taekwondo also had the highest sit and reach results, but yielded the lowest results for back arch. Highest score for back arch was attained by beach volleyball, which was also highest in the SEMO test, vertical jump and standing long jump. Badminton recorded the lowest for vertical jump, while ping pong recorded the lowest for standing long jump. In the reaction time tests (audio and visual), all female athletes had almost similar scores. Sports that recorded high bleep test results were ping pong, taekwondo and beach volleyball. Archery yielded the best results for the stork test.

Table 5: Descriptive analysis of motor performance for female athletes based on sports.

n=87	GS		BS		SU7		S10		S30		SR	
	M	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***
Taekwondo (7)	33.1	5.6	67.5	30.4	6.4	0.9	1.9	0.2	5.0	0.4	23.8	4.2
Archery (7)	33.1	4.3	68.3	6.8	4.4	0.9					15.0	3.
Shooting (6)	22.8	5.8	52.5	2.7	4.0	1.5					11.3	4.1
Tenpin bowling (4)	31.0	2.7			3.3	1.1					4.7	2.3
Netball (12)	31.1	4.8	63.4	14.9	5.6	1.2	2.1	0.1			16.4	6.8
Badminton (3)	30.6	2.5	69.7	7.8	5.7	0.6	2.0	0.1			14.8	9.0
Lawn bowl (6)	28.7	3.0	62.0	14.4	4.0	0.6					14.4	5.2
Volleyball (8)	30.1	4.8	62.8	9.0	5.0	1.1	2.2	0.1	5.3	0.1	22.3	5.0
Beach volleyball (1)	36.0		80.0		6.0		1.8		4.6		6.0	
Karate do (3)	32.3	2.1	61.7	10.4	6.0	1.0	2.1	0.04	5.1	0.2	13.3	4.2
Ping pong (2)	28.0	9.9	30.0		5.0	0.0	2.2	0.07	5.5	0.1	15.0	9.9
Track and field(19)	32.6	5.9	70.3	23.3	5.3	1.9	2.0	0.1			15.6	7.9
Silat (9)	27.9	3.2	60.5	9.2	4.8	0.9	2.1	0.07	5.3	0.3	18.1	6.8

Continued on next page

Table 5 (continued)

	TE		**SEMO**		**VJ**		**SLJ**		**RTa**		**RTv**	
	M	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***	***M***	***sd***
Taekwondo (7)	12.6	2.3	12.5	0.9	50.4	3.1	194.6	25.5	0.2	0.08	0.2	0.01
Archery (7)	32.3	4.8										
Shooting (6)	16.8	5.2										
Tenpin bowling (4)	17.1	6.2										
Netball (12)	30.7	4.7	12.7	0.7	45.7	4.8			0.3	0.03	0.2	0.05
Badminton (3)	23.8	2.5	12.4	0.2	40.7	5.5			0.2	0.01	0.2	0.04
Lawn bowl (6)	27.6	5.6										
Volleyball (8)	17.9	6.3	12.4	0.4	50.2	2.8	205.1	11.3	0.2	0.06	0.2	0.05
Beach volleyball (1)	43.2		11.6		59.0		229.0		0.3		0.2	
Karate do (3)	37.3	6.9	12.3	0.2	46.7	2.5	195.7	17.2	0.2	0.03	0.2	0.0
Ping pong (2)	41.4	8.9	14.2	0.4	46.0	1.4	166.0	26.9	0.3	0.01	0.3	0.02
Track and field(19)	39.7	4.3			51.9	8.4			0.3	0.07	0.3	0.05
Silat (9)	28.2	4.7	13.0	0.5	46.7	6.1	189.1	11.6	0.2	0.04	0.2	0.04

	Bleep		**LS**		**ST**		**PU**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Taekwondo (7)	8.2	2.0						
Archery (7)	5.5	0.7	90.0	17.6	10.7	3.6	46.6	8.5
Shooting (6)			75.0	5.5	37.6	22.8	33.5	6.5
Tenpin bowling (4)	2.9	1.1			33.9	25.2		
Netball (12)	7.3	1.6						
Badminton (3)	6.7	1.2						
Lawn bowl (6)	4.9	1.2			19.9	15.9	27.0	3.9
Volleyball (8)	6.5	1.6						
Beach volleyball (1)	8.4							
Karate do (3)	7.3	1.9						
Ping pong (2)	9.4	0.5						
Track and field (19)	7.8	1.7						
Silat (9)	6.8	1.2						

( ) Number of athletes

Multivariate analysis of covariance (MANCOVA) and multiple regression analysis were used to determine anthropometric characteristics that contributed to the athlete's motor performance components. According to Table 6, MANCOVA and multiple regression analyses showed that anthropometric characteristics significantly contribute to male's motor performance. Based on these results, the reported anthropometric characteristics that contributed to the male's motor performance were height [F (10, 84) = 2.57, $p < 0.01$, *eta squared* = 0.23], weight [F (10, 84) = 1.99, $p < 0.05$, *eta squared* = 0.19], BMI [F (10, 84) = 2.92, $p < 0.01$, *eta squared* = 0.26], % fat [F (10,84) = 2.47, $p < 0.05$, *eta squared* = 0.23] and WHR [F (10,84) = 2.23, $p < 0.05$, *eta squared* = 0.21].

Table 6: MANCOVA and multiple regression analysis for influence of anthropometric characteristics on the male's motor performance.

		Anthropometry				
	Motor performance	**Height**	**Weight**	**BMI**	**% fat**	**WHR**
	Grip strength	1.46*	-1.56*	7.57**	-0.29	-133.83**
	Back strength	3.00	-3.53	18.13**	-1.12*	-92.84
	7 level sit-up	0.00	0.02	0.06	-0.05	-3.92
β coefficient	10m sprint	0.42	-1.07	4.80	-0.45	-23.92
	Sit and reach	-0.76	0.85	-1.42	-0.10	-85.23*
	Trunk extension	-1.40	1.76	-5.82	0.12	58.57
	Vertical jump	3.27**	-3.53**	12.17**	-0.78**	-77.77
	Reaction time (A)	-0.01	0.01	-0.03	0.00	0.59
	Reaction time (V)	-0.00	0.00	-0.01	0.00	0.11
	Bleep test	-0.44**	0.49**	-1.55**	0.04	-11.75
	MANCOVA F	2.57**	1.99*	2.92**	2.47*	2.23*
	Eta squared	0.23	0.19	0.26	0.23	0.21

* $p < 0.05$ ** $p < 0.01$

Further analysis using multiple regression analysis determined the direction and magnitude of contribution of anthropometric characteristics to motor performance components. Results showed that, height has a significant contribution to grip strength (β = 1.46, $p < 0.05$), vertical jump (β = 3.27, $p < 0.01$) and the bleep test (β = -0.44, $p < 0.01$). Height has a positive effect to combine strength of the arm muscles and foot muscle power, but a negative effect to the cardiovascular endurance. Weight also contributed significantly to grip strength (β = -1.56, $p < 0.05$), vertical jump (β = -3.27, $p < 0.01$) and bleep test (β = 0.49, $p < 0.01$). However, weight contributed negatively to the combined strength of the arm muscles and leg muscle power, but positively to cardiovascular endurance. BMI contributed to four motor performance components, which were grip strength (β = 7.57, $p < 0.01$), back strength (β = 18.13, $p < 0.01$), vertical jump (β = 12.17, $p < 0.01$) and bleep test (β = -1.55, $p < 0.05$). Body Mass Index contributed positively to combined arm muscle strength, back and leg muscle strength and leg muscle power, but negatively to cardiovascular endurance. Body fat percentage contributed to back strength (β = -1.12, $p < 0.05$) and vertical jump (β = -0.78, $p < 0.01$). Waist hip ratio contributed to grip strength (β = -133.83, $p < 0.01$) and sit and reach (β = -85.23, $p < 0.05$). Body fat percentage and waist hip ratio each contributed negatively to back and leg muscle strength, leg power, combined arm strength and the flexibility of the back muscle and hamstring.

Results of MANCOVA and regression analysis for female athletes revealed that only body fat percentage has a significant contribution toward the motor performance of female athletes as shown in Table 7. However, body fat percentage only contributed to certain motor performance components. Based on the following multiple regression analysis, it showed that body fat percentage has a negative effect to the sit-up test (β = -0.10, $p < 0.05$), trunk extension (β = -0.61, $p < 0.05$) and vertical jump (β = -0.53, $p < 0.01$). However, waist hip ratio did not contribute significantly to female's motor performance, and contributed negatively on vertical jump (β = -73.08, $p < 0.01$).

Table 7: MANCOVA and multiple regression analysis for anthropometric influence on the motor performance of female athletes.

		Anthropometry				
Motor performance		**Height**	**Weight**	**BMI**	**% fat**	**WHR**
β coefficient	Grip strength	-0.87	1.57	-.294	-0.011	-.15.73
	Back strength	2.43	-2.90	11.22	-0.19	-52.07
	7 level sit-up	-0.27	0.44	-11.05	-0.10*	4.99
	10m sprint	-0.02	0.02	-0.08	0.01	1.07
	Sit and reach	-0.14	0.48	-0.45	-0.12	-40.04
	Trunk extension	-0.33	-.40	0.97	-0.61*	-37.74
	Vertical jump	-0.26	0.25	0.81	-0.53**	-73.08**
	Reaction time (A)	-0.00	0.01	-0.02	0.00	0.16
	Reaction time (V)	0.01	-0.02	0.05	0.00	-0.23
	Bleep test	0.06	-0.17	0.43	-0.04	-3.94
	MANCOVA *F*	0.76	0.72	0.72	0.66*	0.64
	Eta squared	0.24	0.29	0.28	0.34	0.36

* $p < 0.05$ ** $p < 0.01$

Conclusion and Discussion

Overall, descriptive analysis indicated that male athletes have a higher anthropometric measurement compared to female athletes. Motor performance ability of male athletes was higher than female athletes in most motor performance components. Descriptive analysis of anthropometric characteristics for both male and female athletes were based on sport showed that athletes for volleyball, beach volleyball and basketball possess advantage in height compared to other sports. Anthropometric feature difference between athletes, either in the same sport or different sports, not only regards height but also athlete's weight, length, width, diameter and skinfolds (Bayios et al., 2006). This advantage showed that height is among the factors that need focusing to athletes who are involved in sports that require height. Such findings demonstrated that some physical qualities can discriminate athletes of different sports. Therefore, differences between body structure and motor tasks either in the same sport or different sports are important to raise the understanding of importance of the body physique aspect in their type of sport.

Some male athletes in archery and tenpin bowling have a BMI value above normal (> 25), which indicated athletes in these sports may have excess body weight. However, BMI of athletes may not be an accurate indicator of fatness since weight among athletes may largely due to muscles' weight. Nevertheless, further investigation on this issue revealed that these male athletes were also found to have a higher fat percentage and hip waist ratio than male athletes in other sports. Similar problem is faced by female tenpin bowling athletes. They have a higher fat percentage compared to female athletes in other sports. This problem in athletes needs to be given the appropriate attention. This is because obesity has a negative influence on motor performance (Vucetic, Matkovic, & Sentija, 2008). Although the body physique does not affect motor performance directly, but on an extreme continuum which is too thin or too fat, it can affect an athlete's motor performance.

Descriptive analysis for the motor performance status of male athletes showed that certain sports have better performance in certain motor performance components. Apparently, these motor performance components are the components needed by the sport. Volleyball and beach volleyball athletes (male and female) that recorded the best performance for the vertical jump test and standing long jump test shows that the athletes of these sports have better foot muscle power than other sports. Besides that, squash has one of the best arm muscle strength and cardiovascular endurance compared to other sports based on the grip strength test and bleep test. Badminton has one of the best scores for the trunk extension and the bleep test. This shows that badminton athletes have good flexibility, back muscle strength and cardiovascular endurance.

Male taekwondo athletes were found to have a top score in back strength, sit-up, 10m and 30m sprint, sit and reach, SEMO and bleep test. This shows that taekwondo athletes have better back muscle strength, abdominal muscle strength, speed, flexibility, agility and cardiovascular endurance than athletes from other sports. The performance is almost the same for female taekwondo athletes that show the best results for abdominal strength, speed, flexibility, and cardiovascular endurance.

Besides that, it is also found that there are some sports have a lower score for certain motor performance compared to other sports. Four sports have recorded the lowest performance score for back strength are archery, shooting, lawn bowl and ping pong. Shooting, lawn bowl and ping pong also recorded the lowest score for sit-up shows that this sport has lower back muscle strength and abdominal muscle strength than other sports. The low scores for certain motor performance components can also be due to the anthropometric feature of the athlete's self. Male and female tenpin bowling athletes have the lowest score for the sit and reach and bleep test, which shows that these athletes have low flexibility and cardiovascular endurance. Female tenpin bowling athletes were found to have low abdominal muscle strength. This could possibly be linked to the overweight and high body fat percentage problem. As explained by Boileau & Lohman (1997), the negative influences of fat towards motor performance are both mechanical and metabolic. Mechanically, excess fat disrupts acceleration-related performance because of the addition of non-working mass. Metabolically, excess fat can increase the metabolic cost for doing tasks which involved moving the whole body mass. Therefore, most types of motor performances that include movement of body mass, low relative fat gives an advantage in both mechanical and metabolic aspects. Although the components are not dominant in the sport, but an international athlete must have good physical abilities without making the sport type an excuse.

Table 8 summarise the influence of anthropometric characteristics on the athletes' motor performance. The anthropometric characteristics that contribute to the male athletes' motor performance are height, weight, BMI, fat percentage and WHR. However, each of these anthropometric characteristics has a negative or positive contribution to a certain motor performance component. For male athletes, height has a significant effect on grip strength, vertical jump, and bleep test. Height has a positive effect on combined arm muscle strength, and leg muscle power but a negative effect on cardiovascular endurance. Weight also affects significantly to grip strength, vertical jump, and bleep test. However, weight contributes negatively to arm muscle strength and leg muscle power but positively to cardiovascular endurance. Consequently, BMI which takes the weight and height factor into account is found to contribute to performance of four motor components which are grip strength, back strength, vertical jump and bleep test. BMI promotes combined arm muscle strength, back and leg muscle strength, and foot muscle power but hinders cardiovascular endurance. This means that a high BMI score will increase the combined arm muscle strength, back and foot muscle strength; oppositely, a high BMI score will lower cardiovascular endurance. The situation goes for the body fat percentage which has a negative effect on back strength and vertical jumping while the waist hip ratio negatively affects grip strength and sit and reach. An increase in body fat percentage and hip waist ratio will inhibit back and leg muscle strength, leg muscle power, the combined strength of arm muscle and a male athlete's back and hamstring flexibility. This explains the negative influence of obesity towards motor performance (Boileau & Lohman, 1997).

Table 8: Anthropometric characteristics that contributes to the motor performance of male and female athletes.

Anthropometry				
Height	**Weight**	**BMI**	**% fat**	**WHR**
Male				
Grip strength Vertical jump Bleep test	Grip strength Vertical jump Bleep test	Grip strength Back strength Vertical jump Bleep test	Back strength Vertical jump	Grip strength Sit and reach
Female				
			Sit-ups Trunk extension Vertical jump	Vertical jump

For the anthropometric characteristics of female athletes, which are body fat percentage and waist hip ratio, they contribute to certain motor performance components. The body fat percentage was found to affect the sit-up, trunk extension and vertical jump while the waist hip ratio contributes to vertical jump. The body fat percentage and waist hip ratio both affects the abdominal muscle strength, the strength and flexibility of body extensions and leg muscle power negatively. This shows an increase in body fat percentage and waist hip ratio will disrupt the abdominal muscle strength, the strength and flexibility of body extensions and leg muscle power. As for male athletes, the matter also describes the negative influence of an athlete's motor performance. Excess fat will inhibit the motor performance because of the addition of non-working mass to the body and will increase the metabolic cost for tasks that require the movement of the whole body mass. These aspects must be considered because low relative fat can give an advantage to the mechanical and metabolic aspect of athletes.

Findings of this study suggested that anthropometric characteristics that significantly contributed to athletes' motor performance need to be given special attention in selections and training. Evidently, high performance athletes need a special biology profile with outstanding biometric abilities and a strong psychological trait. Moreover, the individual anthropometric and performance qualities are important features in some types of sports and are considered as the main criteria for success in most types of sport.

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