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Muscle Strength and Power of Elite Female and Male Swimmers

Author's Conrtibution
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
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G – Funds Collection

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Abstract

Background: *The aim of the study was to examine gender differences in the maximal power and height of rise of the body mass centre, measured in ACMJ (akimbo counter movement jump), BCMJ (bounce counter movement jump) and CMJ (counter movement jump) and maximal muscle torque in elite swimmers who have a similar training load during the season.*

Materials and methods: *Eight male and eight female elite swimmers competing at the international level took part in the study. The maximal power and height of rise of the body mass center were measured at ACMJ, BCMJ and CMJ jumps performed on a dynamometric platform. Maximal muscle torques of elbow, shoulder, knee, hip and trunk flexors and extensors were measured under static conditions on a special stand.*

Results: *Only differences in relative muscle torque of flexors of the left and the right hip, flexors and extensors of the right knee and flexors and extensors of the trunk, the sum of relative muscle torque of the trunk and relative maximal power output measured during BCMJ were not significant between the female and male competitors, while statistically significant differences were observed between the groups in all the remaining variables of physical performances.*

Conclusions: *The results of the present study demonstrate that the male swimmers had much better performance than the female swimmers of comparable physical conditions, but when the results were calculated per body mass, gender differences in some the values were insignificant.*

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Introduction

Physical performance capacity of males and females has been a subject of various investigations. It is a commonly accepted finding that males have higher physical performance capacity than females [1,2]. In different performance tests for maximal strength and muscle elasticity, females have reached 54-82% of the values obtained by males [1,3,4,5,6]. As reported by Patterson et al. [7], men displayed significantly higher values for relative average power and jump height in squat jump (SJ) than women. A statistically significant gender difference was found in SJ and countermovement jump (CMJ) (25% and 19% respectively) in Bosco's et al. [8] study. Female subjects attained significantly lower values than men in relative power outputs in both tests – six maximal exercises of lower extremities on a cycle ergometer (18%) and 6 bouts of 10 push-offs each on an inclined plane device (48%) [9]. Malina et al. [10] reported that grip strength, 2 kg ball throw and 20 m sprint do not differ between male and female jumpers. In swimmers, relative power outputs in the Wingate test for upper extremities and swimming force in semi-tethered swimming test were significantly higher (54.9 and 74.7% respectively) in males than in females [11]. Less is known about sex differences in static muscle torques and power of lower extremities in elite swimmers. On the other hand, comparisons between the sexes should be made only if the two groups have comparable duration and intensity of the training, coaching and competition.

The aim of the study was to examine gender differences in the maximal power and height of rise of the body mass centre, measured in ACMJ (akimbo counter movement jump), BCMJ (bounce counter movement jump) and CMJ (counter movement jump) and maximal muscle torque in elite swimmers who have a similar training load during the season.

Material and Methods

The study was approved by the Ethics Committee of Institute of Sport in Warsaw, Poland. All participants were informed about the study aim and methodology as well as about the possibility of immediate resignation at any time of the experiment. Subjects agreed to the above conditions in writing. Eight male and eight female elite swimmers competing at the international level took part in the study. Their mean (±SD) age, body height, body mass and training experience were 21.9±3.2 years, 188.8±6.0 cm, 82.5±3.8 kg 11.3±3.5 years in men and 19.4±3.7 years 175.9±9.0 cm, 66.4±8.9 kg, 10.3±4.6 years in women, respectively. Body mass and body height were significantly different between males and females.

The maximal muscle torques of ten groups of muscles: flexors and extensors of the elbow, shoulder, hip, knee and trunk were measured in static conditions [12]. During the measurement of the muscle torque of elbow flexors and extensors the subject was sitting, with his/her arm bent at the right angle and placed on an armrest, and with the trunk stabilized. The muscle torque of shoulder flexors and extensors was measured in a sitting position. The joint angles during measurements were set at 70° and 50° during extension and flexion actions, respectively. The trunk was stabilized and the chest pressed against the testing station. The measurements of muscle torque of knee flexors and extensors were carried out on subjects in a sitting position. The hip and knee joints were bent at 90°. The subjects were stabilized at the level of anterior iliac spines and thighs, with the upper limbs crossed on his chest. The subjects were lying face down during the measurement of the muscle torque of hip extensors, and face up during the measurement of the muscle torque of hip flexors. The hip joint angle remained at 90° during both measurements. The maximal extension of the elbow, knee and hip joints was accepted as 0°. For the shoulder joint, the positioning of the arm along the trunk's side was taken as 0°. The axis of rotation during the muscle torque measurement corresponded to the axis of rotation of the torque meter.

The right arm and the left arm muscles were measured separately, always in the flexion–extension sequence. Each subject was supposed to achieve the maximal strength during measurement. The results were related to the subject's body mass and as percentage topography to the sum of muscle torque of the ten muscle groups.

The power output of lower extremities and the height of rise of the body mass center during vertical jumps were measured on a dynamometric platform with a Kistler amplifier for counter-movement jumps (CMJ), akimbo counter-movement jumps (ACMJ) and bounce counter-movement jumps (BCMJ). The amplifier was connected to a PC via an a/d converter. The MVJ v. 3.4. software package was used for measurement. In the applied physical model the subject's body mass bouncing on the platform was reduced to a particle affected by the vertical components of external forces: the body's gravity force and the vertical component of the platform's reactive force. The maximal power and maximal height of rise of the body mass center (h) were calculated from the registered reactive force of the platform [13]. Each subject performed nine vertical jumps with maximal force on the dynamometric platform: three counter-movement jumps (CMJ), three akimbo counter-movement jumps (ACMJ) and three bounce counter-movement jumps (BCMJ). There were 5 s breaks between the CMJs and ACMJs, and 1 min breaks between the BCMJ. The jump with the highest elevation of the body's center of mass was chosen for statistical analysis.

All measurements were performed in the morning. The subjects were informed about the aims and methodology of the tests prior to the measurements.

The gender differences were calculated by formula:

Gender differences [%] = ((Male * 100)/Female) – 100

ANOVA/MANOVA procedures with post-hoc Scheffé test were employed for comparison of means. The level of statistical significance was set at $p < 0.05$. All calculations were made with the aid of Statistica (v. 5.5, StatSoft) software package.

Results

Mean (±SD) values of absolute and relative maximal muscle torques of elbow, shoulder, knee, hip and trunk flexors and extensors are presented in Tables 1-4. Female swimmers exhibited significantly lower torque values than male swimmers in all variables. When the values of muscle torque were calculated per unit of the body weight the gender, the difference was insignificant in flexors of the left and right hip, flexors and extensors of the right knee and flexors and extensors of the trunk. Female swimmers had a similar muscle percent topography as men with the exception of the left (2.09±0.22, 2.57±0.28 $N \cdot m \cdot kg^{-1}$ respectively) and the right (2.19±0.26, 2.63±0.39

Tab. 1. Mean values (±SD) of the maximal muscle torques [N•m] of the flexors (F) and extensors (E) of the elbow, shoulder, hip, knee and trunk

		Female	Male	Diff.	Female	Male	Diff.
Variables		Left	Left	[%]	Right	Right	[%]
Elbow	F	45.9±5.5	76.6±7.7 [a]	66.9	46.0±5.0	75.9±11.2 [a]	65.0
	E	30.1±4.9	54.6±5.2 [a]	81.4	30.9±2.6	54.5±5.9 [a]	76.4
Shoulder	F	38.0±7.5	62.8±4.1 [a]	65.3	43.4±10.5	65.9±6.9 [a]	51.8
	E	45.5±7.7	83.3±5.1 [a]	83.1	48.1±10.8	85.5±11.6 [a]	77.8
Hip	F	78.1±12.1	103.1±6.0 [a]	32.0	73.3±11.3	103.6±9.8 [a]	41.3
	E	335.6±73.3	494.4±60.8 [a]	47.3	332.6±71.0	479.5±51.4 [a]	44.2
Knee	F	97.0±20.5	139.3±12.2 [a]	43.6	99.4±21.0	140.8±32.2 [a]	41.7
	E	179.6±46.9	299.1±82.8 [a]	66.5	188.1±54.6	291.8±72.7 [a]	55.1
Trunk	F	137.0±29.8	199.8±32.8 [a]	45.8			
	E	347.1±90.9	459.3±64.3 [a]	32.3			

Diff. – percent gender differences, [%]; [a] - significantly different from the female, p<0.05.

N·m·kg[-1] respectively) extensors of the shoulder, left extensors of the elbow (1.40±0.28, 1.69± 0.23 N·m·kg[-1] respectively) and sum of relative muscle torque of the left upper extremities (Table 4).

Mean (±SD) values of the maximal power (Pmax) and height of rise of the body mass center measured at ACMJ, BCMJ and CMJ jumps performed on a dynamometric platform are presented in Table 5. Female swimmers generated significantly lower absolute and relative power than men with the exception of the relative maximal power measured during BCMJ. The gender difference was observed in height of all jumps, too.

Tab. 2. Mean values (±SD) of the relative maximal muscle torques [N•m•kg[-1]] of the flexors (F) and extensors (E) of the elbow, shoulder, hip, knee and trunk

Variables		Female	Male	Diff.	Female	Male	Diff.
		Left	Left	[%]	Right	Right	[%]
Elbow	F	0.69±0.05	0.93±0.11 [a]	34.8	0.70±0.03	0.92±0.17 [a]	31.4
	E	0.46±0.08	0.66±0.08 [a]	43.5	0.47±0.08	0.66±0.09 [a]	40.4
Shoulder	F	0.58±0.10	0.76±0.07 [a]	31.0	0.66±0.15	0.80±0.10 [a]	21.2
	E	0.69±0.07	1.01±0.08 [a]	46.4	0.73±0.13	1.04±0.18 [a]	42.5
Hip	F	1.19±0.18	1.25±0.12	5.0	1.11±0.16	1.26±0.14	13.5
	E	5.03±0.70	6.0±0.80 [a]	19.3	5.0±0.73	5.82±0.65 [a]	16.4
Knee	F	1.46±0.24	1.69±0.16[a]	15.8	1.50±0.28	1.70±0.36	13.3
	E	2.67±0.46	3.63±1.0[a]	36.0	2.81±0.65	3.53±0.86	25.6
Trunk	F	2.06±0.33	2.42±0.34	17.5			
	E	5.21±1.16	5.57±0.79	6.9			

Diff. – percent gender differences, [%]; [a] - significantly different from the female, p<0.05.

Tab. 3. Mean values (±SD) of the sums of the maximal muscle torque of the right (R) and left (L) upper extremity (SUE), lower extremity (SLE), trunk (ST) and all ten muscle groups (TOTAL)

Variables	Muscle torque [N·m]		Diff.
	Female	Male	[%]
SUER	168.4±24.1	281.8±26.2 [a]	67.3
SUEL	159.5±20.7	277.3±13.6 [a]	73.8
SLER	693.4±134.8	1015.6±138.4 [a]	46.5
SLEL	690.4±136.4	1035.9±149.6 [a]	50.0
ST	484.1±113.8	659.0±90.2 [a]	36.1
TOTAL	2195.8±408.0	3269.5±329.5 [a]	48.9

Diff. – percent gender differences, [%]; [a] - significantly different from the female, p<0.05

Tab. 4. Mean values (±SD) of the sums of the relative maximal muscle torque and topography of the maximal muscle torque of the right (R) and left (L) upper extremity (SUE), lower extremity (SLE), trunk (ST) and all ten muscle groups (TOTAL)

	Muscle torque [N·m·kg[-1]]		Diff.	Muscle topography [%]	
Variables	Female	Male	[%]	Female	Male
SUER	2.55±0.31	3.43±0.44 [a]	34.5	7.77±0.89	8.68±1.07
SUEL	2.42±0.22	3.37±0.27 [a]	39.3	7.38±0.91	8.54±0.84 [a]
SLER	10.42±1.28	12.31±1.60 [a]	18.1	31.54±0.77	30.99±1.56
SLEL	10.35±1.12	12.57±1.88 [a]	21.5	31.40±1.22	31.60±2.26
ST	7.27±1.37	7.99±1.04	9.9	21.92±2.27	20.18±2.30
TOTAL	33.0±3.80	39.67±4.1 [a]	20.2		

Diff. – percent gender differences, [%]; [a] - significantly different from the female, p<0.05

Tab. 5. Mean values (±SD) of the height of rise of the body's center of mass (h), maximal power output (Pmax), relative maximal power output (Pmax/mass) during akimbo counter-movement jumps (ACMJ), counter-movement jumps (CMJ) and bounce counter-movement jumps (BCMJ) on a dynamometric platform

Variables		P_{max} [W]	$P_{max}\cdot mass^{-1}$ [$W\cdot kg^{-1}$]	h [m]
ACMJ	Female	1146.5±209.29	16.80±2.31	0.27±0.04
	Male	1948.0± 420.9 [a]	23.16±5.22 [a]	0.38±0.05 [a]
	Diff.	69.9	37.9	40.7
CMJ	Female	1408.1±285.9	20.70±3.43	0.32±0.04
	Male	2318.3±464.0 [a]	27.68±5.47 [a]	0.42±0.05 [a]
	Diff.	64.6	33.7	31.3
BCMJ	Female	1945.4±718.8	29.31±12.35	0.36±0.03
	Male	3226.0±824.1 [a]	38.36±9.53	0.51±0.07 [a]
	Diff.	65.8	30.9	41.7

Diff. – percent gender differences, [%]; [a] - significantly different from the female, $p<0.05$.

Discussion

The results of the present study demonstrate clearly that the male subjects had much better performance than the female subjects of comparable physical conditions. As has been pointed out by Komi and Karlsson [5] the strength performance of female subjects is 20-30% lower than that of males. A similar gender difference was found by Trzaskoma and Trzaskoma [14] for relative muscle torque of the flexors and extensors of the knee and hip joints in elite athletes. On the other hand, the major contributing factor taking into account sex differences in force production is the greater muscle mass in males. When Komi and Karlsson [5] calculated the total leg force per unit of body weight, they observed very similar values for males (34.0) and females (33.8). In the present data of muscle torque, differences between the sexes were big (32.3-83.1%). The differences were smaller (6.9-46.4%) when the muscle torque was then related to the body mass, but there was a significant difference of the data, too, with the exception of the sum of relative muscle torque of the trunk, relative muscle torque of flexors of the left and right hip, flexors and extensors of the right knee and flexors and extensors of the trunk. Fidelus and Skorupski [15] suggested that in senior athletes there are specific sport-related topographies of muscle torques. On the other hand, in Buśko's [16] study absolute and relative muscle torque and percent muscle topography were significantly different between female and male elite basketball players of comparable physical conditions. In the present investigation, female swimmers had a similar muscle percent topography as men with the only exception of the left and right extensors of the shoulder, and left extensors of the elbow.

In different performance tests for maximal strength and muscle elasticity, females have reached 54-82% of values obtained by males [1,4,5,9,11]. Sienkiewicz-Dianzenza et al. [9] reported female-to-male ratio for 6 bouts of 10 push-offs each on an inclined plane device equal 48%. Komi and Bosco [1], Hudson and Owen [4] and Nelson and Martin [17] reported female-to-male ratio for height of CMJ equal 58%, 82% and 68%, respectively. In Hudson and Owen's [4] paper, the difference data of height of rise of the body mass centre, velocity and use of stored elastic energy were not statistically significant between females and males of comparable physical conditions. In our study female-to-male ratio in CMJ was 31.3%. We observed significant gender differences for the value of absolute and relative power and height of jumps. Only relative power generated in BCMJ was not statistically significant between female and male swimmers of comparable physical conditions. The female-to-male ratio for all variables were not statistically significant between three different jumps.

Conclusions

The results of the present study demonstrate that male swimmers had much better performance than female swimmers of comparable physical conditions, but when the results were calculated per body mass, the gender difference in some of the values were insignificant.

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