Demographic profile of combat sports athletes: A comparative analysis between genders and competitive achievement in London 2012

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Abstract

Background & Study Aim: Analysis of results in sports is essential in determination of the profile of a successful athlete. The aim of the study was the demographic profile of athletes who competed in combat sports at the last Olympic Games.

Material & Methods: The official documents of the XXX Olympic Games from tournaments of combat sports were analyzed. Age, height and body mass of 699 participants and five combat sports events (three events were considered in fencing) were considered. Body mass index (BMI), height–weight ratio (HWR) and ectomorphy somatotype component were calculated. Two-way ANOVA was used to compare combat sports and genders.

Results: The youngest subjects in the group of women were taekwondoists, who differed significantly in age from epeests, foilists and judoists. In the group of men, the taekwondoists differed significantly in age from the epeests, i.e., taekwondo representatives were younger than the epeests. The judoists were shorter than those who practised epee, sabre or taekwondo, whereas body mass in judoists was higher than in foilists and taekwondoists. Judoists presented significantly higher BMI than epeests, foilists and sabrists. Taekwondoists had higher HWR compared to judoists. Judoists presented lower scores in ectomorphy compared with epeests, foilists and taekwondo athletes.

Conclusions: Male and female combat sports Olympic athletes differed in terms of their age, height, body mass, HWR and proportionality. The characteristics of world elite female and male athletes can be adopted as model/optimal values and used when searching, in general population, young talents to be trained in combat sports.

Key words: olympic athletes • body mass • height • body mass index • anthropometry

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Background

Observation of elite athletes does not consist only in analyses of their results in sport; some researchers have made attempts to explain the results, using the indexes of physical, technical, tactical and psychological preparation [1,2]. These efforts, with different level of reliability and accuracy are conducted in small groups of elite athletes who practice a particular sport or event and focus only on certain indices of preparation. Although important, the characteristics such as age, height, body mass and weight-height ratio [3], are not discussed along with psychological analyses [4] or they are discussed as a less important information, with presentation of the results of the studies on anthropology [5], biomechanics [6] or fitness and profile of technical and tactical

Athlete – an individual who by virtue of special training or natural talent, is fit to compete in a physical demanding sports [48].

Combat sports – competitive contact sports where two athletes fight against each other under certain codified rules. In our study we focused on the Olympic combat sports.

Epee or **épée** (in French) – a fencing sword with a bowl-shaped guard and a long, narrow, fluted blade that has no cutting edge. The art or sport of fencing with this sword [49].

Demography – the scientific study of populations especially their age structure and other factors affecting the quality of life within populations [48].

Somatotype – a quantification of the present shape and composition of the human body. It is expressed in a three-number rating representing endomorphy, mesomorphy and ectomorphy respectively and always in the same order [5].

Sport science – the pursuit of objective knowledge gleaned from the observation of sports and those taking part in sport whether as performers, coaches, or spectators. It includes any discipline which uses the scientific method and relies on obseved information rather than biased judgement and vague impressions to explain and predict sports phenomena [48].

preparation [7]. Russian experts [8] suggested that their classification of combat sports allowed, at the stage of initial sports specialization, for choosing the best-suited sport for an athlete. Based on the analysis of competitive history of the athletes, these authors found that fencing and judo were dominated by the development of special endurance, which is based on optimum development of physical and technical/tactical preparation. Boxing was characterized by a dominant development of speed and strength motor abilities, which are based on an optimum level of special endurance. Furthermore, wrestling necessitates a relatively even development of all physical characteristics, with emphasis on the individual abilities of each athlete and high demands of movement technique. The theory that has been developed in recent years stresses, among other things, the criteria which determine the forms of direct encounters of the competitors, which include using weapons, hits, throws and grappling actions that restrict the opponent's movements. It is also essential to provide information about the effect of the somatic factor on the choice of a sport and future achievements in the sport. It is emphasized that the athletes with potential for success in sport should be found by means of "a careful elimination' in direct "back-up" groups in national teams [9]. The authors who classified combat sports did not sufficiently consider the age of starting regular training regimes and the somatic type [8,9], which, according to Carter and Heath [5], provides important information on the chances of success in a particular sport. Age and basic characteristics of physical development typical of elite athletes might be considered as a reference for achievement of success in a particular sport. Therefore, they are included in the characterization of a 'champion model' [3]. It can be assumed that there is an age range which is conducive to achievement of success in combat sports. The age characteristics of basic indices of many outstanding athletes have been provided in other studies. The comparative studies are very rare with respect to male elite athletes [7,11–14], and particularly female athletes that meet high requirements of competing in different combat sports [7,12,15–17].

Identification of the body type in young athletes allows for matching them (by means of the method of discrimination) with the sport they show best natural aptitude for in terms of body build [18]. Therefore, body build should be taken into consideration during selection and coaching [19]. Somatotype is a synthetic information about body build and is related to motor fitness. Therefore, there are some differences between sports and disciplines [5]. Well-oriented and specialized training should develop the components of endo-, meso- and ectomorphy to the specific degree [20]. Gualdi–Russo and Graziani [21] demonstrated a relationship between the somatotypes and the level of achievement in combat sports, which was also confirmed lastly in fencing [22], karate [23], ju-jitsu [24] and wrestling [25,26].

Typical age of elite athletes represents the best period for achievement of best results in a sport. Having the information about the age and experience of elite athletes, one can define the optimum moment of starting regular training regimes in a particular sport. Furthermore, body build determines somatic aptitude for a sport. These aptitudes, which largely determine special physical fitness, can be developed through many-year training. Young athletes (including fencers, wrestlers and judoists) exhibit specific body build compared to the untrained subjects [27]. Height and body mass are positively correlated, so lightweight champions in these events are necessarily shorter [28]. The relationship between body mass and age, which suggests high stability of development of an individual in terms of a particular development is essential to the practice of training in sports since it allows for forecasting the future weight classes for adolescent sportsmen [29]. It might also be important to forecast the adult body height [30]. Physique of the athletes is developed through many years of training and also depends on the process of selection. Obtaining information on absolute body mass and body height and the relationships between each other is critical as these traits make it easier or more difficult to be successful in a particular sport. Norton and Olds [31], using the Bivariate Overlap Zone (BOZ), found significant differences between sporting groups compared to general population. The somatic characteristics typical of outstanding athletes compared with general population of a particular country provide information about the difficulty of searching young talents suitable for a particular discipline [31,32].

The system of Olympic qualifications causes that the international elite athletes are grouped at the same time and place. Undoubtedly, updating the data that allow for identification and classification of the somatic build of top elite athletes is important for development of champion models in professional sports. None of the previous publications have compared (in any aspect) athletes who participated in sports representative of the three groups of Olympic combat sports. Therefore, the goal of the present study was the demographic profile of women and men who compete in combat sports at the Olympic level.

Material and Methods

This study is of cross-sectional character. Directly after XXX Olympic Games (London 2012), the authors analysed the official documents from tournaments of combat sports [33–36]. Only the complete information concerning age, height and body mass in 314 women and 385 men were selected. Finally, the study group comprised of 699 participants and five combat sports events (three events were considered in fencing). Furthermore, body mass index (BMI), height-weight ratio (HWR) and ectomorphy somatotype component were calculated [5]. The focus of the study was on the characteristics of female and male athletes who participated in 10 Olympic tournaments in London 2012: (A) epee (n=66), sabre (n=69), foil (n=74), (B) taekwondo (n=127), (C) judo (n=363). In fencing (Group A), only the data from individual tournaments using different types of weapons were considered. Boxing and wrestling athletes were not included because the reports contained only information on meeting the weight criterion and there was not any exact data on weight. The data were collected from open-access sources and, thus, there are no ethical issues involved in the analysis and interpretation of the data used as these were obtained in secondary form and not generated by experimentation, and the athletes' personal identification was replaced by a code, ensuring anonymity and confidentiality.

Statistics

A group of dependent variables (age, height, body mass, BMI, HWR and ectomorphy somatotype component) were analysed in two–way classification:

1. Event (A – using weapon; B – using punches and kicks; C – using throws and grappling on the ground).
2. Gender (F – female; M – male)

STATGRAPHICS Centurion v. XVI.I software was employed. The completed data are presented as mean ± standard error. The hypotheses concerning differences between the mean values were tested by means of the 2-way ANOVA, after previous verification of the equality of variances in the subgroups (Levene's test). If the significant differences were found in ANOVA, Tukey's test of multiple comparisons was used. Effect size was calculated by means of eta squared (η^2), which describes the proportion of total variability attributable to the factor. The significance level was set at $P<0.05$.

The demographic characteristics were compared also according to the level of sports achievement between two groups ranked after each tournament: E group – the first eight placers; R group – the rest. Independent t–test was employed for comparison in each sport or event. Participants of Olympic Games are coming from international population, therefore the model of human "Phantom" average and SD for height and body mass [37] was used in our analysis. Furthermore, within the same sports, a proportionality and sexual dimorphism were calculated, using the Phantom stratagem developed by Ross and Marfell-Jones [37]: "Proportionality is the relationship of body parts to one another or to the whole body. Reported mean values for males and females were geometrically adjusted to the standard stature and the male and female averages ascribed as the Phantom P values. These values are distributed normally, unimodally, and symmetrically. The ascribed standard deviations, or s values, are used in the formula shown:

z-score = 1/s*(v*(170.18/h)^d–P) Equation 1.

where:
z is a proportionality score;
s is the Phantom standard deviation for variable (V);
v is obtained value for variable (V);
170.18 is the Phantom stature constant;
or, it can be any proposed Phantom value for use as a scaling constant;
h is the obtained stature;
or, the obtained value for the scaling constant;
d is a dimensional exponent;
for a geometrical similarity system, d=1 for lengths, breadths, girths, and skinfold thicknesses; 3 for all masses and volumes;

P are reported mean values for males and females were geometrically adjusted to the standard stature and the male and female averages ascribed as the Phantom P values."

The bivariate scaling of sporting groups for Phantom stature (170.18±6.29 cm) and body mass (64.58±8.60 kg) were used. Sample mean ± standard errors were calculated from individually obtained z-values for body mass and stature. A z-value equal to 0.00 indicated that subject or group mean is proportionally the same as Phantom. Higher or lower z-values are interpreted as proportionally higher or lower values compared to Phantom reference, respectively. Location of mean z-values for 28 sport groups (events and weight categories) were pictured on a bivariate chart (proportional body mass and proportional stature). In addition, proportionality dimorphism/difference between female and male z-scores in the same event was also presented. Sexual dimorphism was compared between the representatives of the three Olympic combat sports: (A) fencers (an average from 3 events: epee, saber, foil), (B) taekwondoists (an average from gender matched in 4 consecutive weight categories) and (C) judoists (an average from gender matched in 7 successive weight categories).

Results

Age, height and weight

Table 1 presents age, height and body mass in the athletes who participated in Olympic combat sports.

Table1. Age, height and body mass of 699 Olympians who participated in combat sports tournaments.

Level	Count	Age (years)		Height (cm)		Body mass (kg)	
		Mean	Std. error	Mean	Std. error	Mean	Std. error
Total	699	25.97		176.0		70.53	
Event		Signif.		Signif.		Signif.	
Epee	66	27.57*	0.50	178.7†	1.0	71.73	2.27
Foil	74	26.21*	0.46	175.1	1.0	66.62†	2.13
Judo	363	26.10*	0.21	172.5	0.5	76.15	0.98
Sabre	69	25.74	0.48	177.0†	1.0	70.63	2.21
Taekwondo	127	24.21	0.35	177.0†	0.7	67.50†	1.63
Gender		N.S.		Signif.		Signif.	
Female (F)	314	25.62	0.26	169.9	0.5	62.56	1.20
Male (M)	385	26.32	0.26	182.2	0.6	78.49	1.21
Interaction event × gender		Signif.		Insignif.		Insignif.	
Epee. F	37	27.00‡	0.66	173.0	1.4	63.32	3.02
Epee. M	29	28.14§	0.74	184.4	1.5	80.14	3.41
Foil. F	38	27.11‡	0.65	168.4	1.4	58.82	2.98
Foil. M	36	25.31	0.67	181.8	1.4	74.42	3.06
Judo. F	144	26.04‡	0.33	167.2	0.7	67.54	1.53
Judo. M	219	26.16	0.27	177.8	0.6	84.77	1.24
Sabre. F	32	24.53ǁ	0.71	169.9	1.5	62.31	3.24
Sabre. M	37	26.95	0.66	184.0	1.4	78.95	3.02
Taekwondo. F	63	23.40	0.50	171.0	1.1	60.83	2.31
Taekwondo. M	64	25.03	0.50	182.8	1.0	74.18	2.29

* Significant different from taekwondo athletes; † significant different from judo athletes; ‡ significant different from taekwondo female athletes; § significant different from taekwondo male athletes; ǁ significant different from epee male group; F – female, M – male.

Age differed significantly between athletes from the different events ($F=8.85$, $P<0.001$, $\eta^2=0.05$). The representatives of epee, foil and judo were older compared to the taekwondoists ($P=0.001$, $P=0.01$ and $P=0.001$, respectively). There was a significant interaction between event and gender factors ($F=3.46$, $P=0.009$, $\eta^2=0.02$). The youngest subjects in the group of women were taekwondoists, who differed significantly ($F=7.70$; $P=0.001$; $\eta^2=0.091$) from epeests ($P=0.001$), foilists ($P=0.001$) and judoists ($P=0.001$). In the group of men, the taekwondoists differed significantly ($F=4.07$; $P=0.003$; $\eta^2=0.041$) from the epeests, with taekwondo representatives being younger than the epeests ($P=0.05$). Female taekwondo were younger compared to male athletes from epee ($P=0.001$), sabre ($P=0.001$) and judo ($P=0.003$).

The event factor significantly affected height ($F=14.16$, $P<0.001$, $\eta^2=0.05$) and body mass ($F=8.22$, $P<0.001$, $\eta^2=0.04$). Judo athletes were shorter than epee ($P=0.001$), sabre ($P=0.001$) and taekwondo athletes ($P=0.001$) and heavier than foilists ($P=0.001$) and taekwondoists ($P=0.001$). There was an effect of the gender on height ($F=330.82$, $P<0.001$, $\eta^2=0.31$) and body mass ($F=134.07$, $P=0.001$, $\eta^2=0.15$), with male being taller ($P=0.001$) and heavier ($P=0.001$) than female athletes. No interaction was observed between the event and gender factor.

Table 2. Body mass index (BMI), height-weight ratio (HWR) and ectomorphy somatotype component (EC) for 699 Olympians.

Level	Count	BMI ($kg \cdot m^{-2}$)		HWR ($cm/kg^{e0.3333}$)		EC (somatotype unit)	
		Mean	Std. error	Mean	Std. error	Mean	Std. error
Total	699	22.57		42.88		2.86	
Event		Signif.		Signif.		Signif.	
Epee	66	22.34¶	0.54	43.14¶	0.23	3.00¶	0.13
Foil	74	21.61¶	0.50	43.33¶	0.22	3.14¶	0.12
Judo	363	25.11	0.23	41.29	0.10	1.90	0.06
Sabre	69	22.42¶	0.52	42.96¶	0.23	2.86¶	0.13
Taekwondo	127	21.38¶	0.38	43.70¶	0.17	3.41¶**	0.09
Gender		Signif.		Signif.		Signif.	
Female (F)	314	21.58	0.28	43.01	0.12	2.96	0.07
Male (M)	385	23.56††	0.29	42.75††	0.12	2.77††	0.07
Interaction event × gender		Insignif.		Insignif.		Insignif.	
Epee. F	37	21.13	0.71	43.47	0.31	3.24	0.17
Epee. M	29	23.55	0.81	42.81	0.35	2.76	0.20
Foil. F	38	20.72	0.70	43.38	0.30	3.17	0.17
Foil. M	36	22.50	0.72	43.29	0.31	3.11	0.18
Judo. F	144	23.81	0.36	41.61	0.16	2.14	0.09
Judo. M	219	26.42	0.29	40.96	0.13	1.67	0.07
Sabre. F	32	21.55	0.77	42.95	0.33	2.86	0.19
Sabre. M	37	23.29	0.71	42.97	0.31	2.87	0.17
Taekwondo. F	63	20.71	0.55	43.65	0.24	3.37	0.13
Taekwondo. M	64	22.06	0.54	43.74	0.23	3.44	0.13

¶ Significant different from judo group; ** significant difference between taekwondo from sabre groups; †† significant difference between males and females; F – females, M – Males.

Body build indices

Weight-height ratios and ectomorphy somatotype component are presented in Table 2.

There was an effect of sport on BMI ($F=26.43$, $p<0.001$, $\eta^2=0.12$), HWR ($F=55.98$, $P<0.001$, $\eta^2=0.24$) and ectomorphy ($F=66.64$; $P<0.0001$, $\eta^2=0.27$). There was also an effect of gender on BMI ($F=43.13$, $P<0.001$, $\eta^2=0.05$), HWR ($F=7.02$, $P=0.008$, $\eta^2=0.01$) and ectomorphy ($F=12.06$, $P<0.005$, $\eta^2=0.01$).

The judoists were distinguished by a significantly higher BMI compared to those who practised epee ($P=0.001$), foil ($P=0.001$), sabre ($P=0.001$) and taekwondo ($P=0.001$). Furthermore, taekwondo athletes had higher HWR ratios compared to judo athletes ($P=0.001$). Consequently, the judo athletes presented lower scores of ectomorphy compared to epee ($P=0.001$), foil ($P=0.001$) and taekwondo athletes ($P=0.001$). Moreover, the ectomorphy score from the taekwondo group was higher than in the sabre group ($P=0.01$). The females were characterized by considerably lower value of BMI ($P=0.001$), higher HWR ratios ($P=0.01$) and ectomorphy ($P=0.001$) compared to males.

Level of sport achievements within sporting groups

No significant differences ($P<0.05$) were found between placers and the other athletes who competed in each event. Only in the TKD M58 group, medallists were younger than the other athletes (19.75±0.85 years *vs.* 24.17±1.10 years, $t=2.206$, $P=0.045$). The first eight winners (E) in male epee tournament differed significantly from the rest of the group (R) in height (188.9±2.7 cm *vs.* 182.6±1.3 cm, $P=0.025$) and body mass (85.63±2.12 kg *vs.* 78.05±1.62 kg, $P=0.016$).

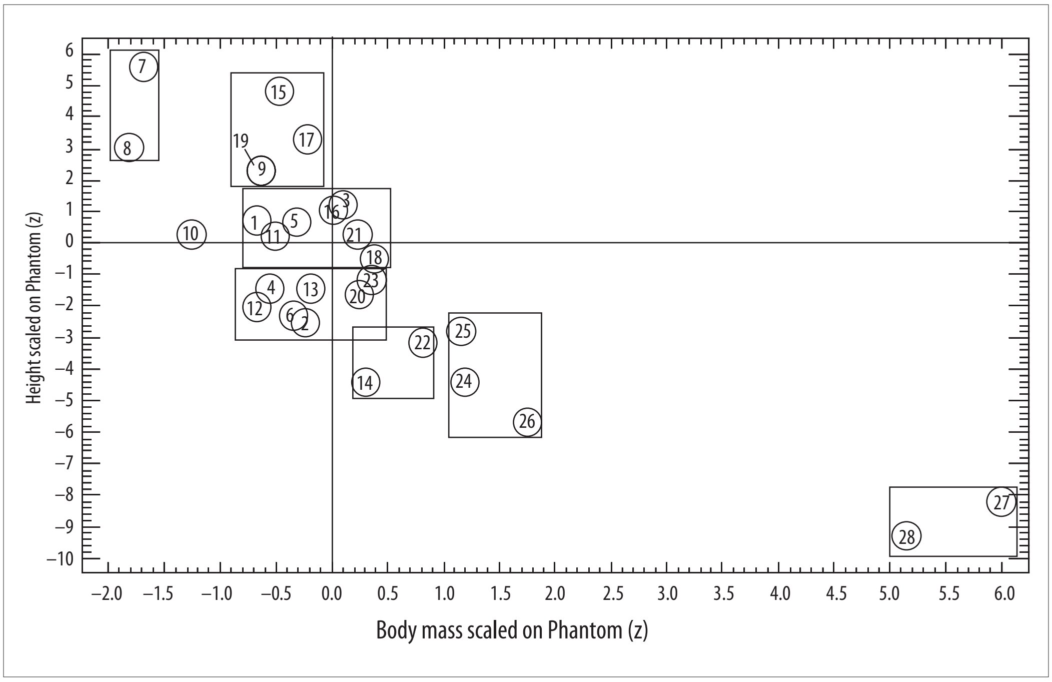

Figure 1. Bivariate location chart of female and male Olympians from combat sports: 1 – epee F, 2 – epee M, 3 – foil F, 4 – foil M, 5 – sabre F, 6 – sabre M; 7-TKD F 49 kg, 8 – TKD M 58 kg, 9 – TKD F 57 kg, 10 –TKD M 68 kg, 11 – TKD F 67 kg, 12 – TKD M 80 kg, 13 – TKD F over 67 kg, 14 – TKD M over 80 kg; 15 – judo F 48 kg, 16 – judo M 60 kg, 17 – judo F 52 kg, 18 – judoM 66 kg, 19 – judo F 57 kg, 20 – judo M 73 kg, 21 – judo F 63 kg, 22 – judo M 81 kg, 23 – judo F 70 kg, 24 – judo M 90 kg, 25 – judo F 78 kg, 26 – judo M less 100 kg, 27 – judo F over 78 kg, 28 –judo M over 100 kg. 7-TKD F 49 kg – group 7th taekwondo females weight category to 49 kg.

The analysis of the female group did not confirm such differences. Among female sabrists, a significant difference was observed between E and R groups in body mass (69.13±2.45 kg *vs.* 60.04±1.14 kg, P<0.001), BMI (23.14±0.63 kg·m^{-2} *vs.* 21.02±0.33 kg·m^{-2}, P=0.004), HWR (42.16±0.39 *vs.* 43.21±0.26, P=0.043) and ectomorphy (2.28±0.29 *vs.* 3.05±0.19, P=0.043). Similar tendencies were found in females and males. Male E group of sabrists had advantage over R group in BMI (24.37±0.28 kg·m^{-2} *vs.* 22.19±0.37 kg·m^{-2}, P=0.065), HWR (42.28±0.26 *vs.* 43.16±0.24, P=0.07) and ectomorphy (2.37±0.19 *vs.* 3.01±0.19, P=0.07). In judo, with 7 weight categories, only the group of 90 kg category males (E group) differed significantly from R group in height (179.3±1.2 cm *vs.* 184.1±0.9 cm. P=0.006), BMI (27.85±0.36 kg·m^{-2} *vs.* 26.41±0.27 kg·m^{-2}, P=0.007), HWR (40.09±0.27 *vs.* 41.17±0.20) and ectomorphy (0.99±0.16 *vs.* 1.62±0.13, p=0.006).

Proportionality and sexual dimorphism in combat sports athletes

The proportionalities of the athletes from Olympic combat sports differ considerably (Figure 1). The athletes who competed in group 10, that was comprised of taekwondo males from 68 kg weight category (10-TKD M68kg) are similar to Phantom in height (0.25z), but they are a little lighter than the general population (–1.3z).

The seven from 28 groups of Olympic athletes presented similar proportionality in the main dimension of body size and met the general population standards defined in Phantom stratagem for both mass and height: 1 – epee F (–0.7z; 0.7z,), 3 – foil F (0.1; 1.0), 5 – sabre F (–0.3; 0.7), 11 – TKD F67kg (–0.5; 0.2), 16 – judo M 60 kg (0.0; 1.2), 18-judo M 66 kg (0.4; –0.5), 21 – judo F 63 kg (0.2;0,3). Probability of meeting the requirements of proportionality in body size dimensions in the general population was more difficult in the other combat sport groups. The 2 – epee M (–0.2; –2.5), 4 – foil M (–0,6; –1.4), 6 – sabre M (–0,3; –2.3), 12–TKD M 80 kg (–0.7; –2.0), 13 – TKD F over 67 kg (–0,2; 1.4), 20 – judo M 73 kg (0.2; –1.6), 23 – judo F 70 kg (0.3; –1.2), were placed within ±1z of the phantom score area for their proportional body mass, but they were proportionally shorter, especially those from 14 – TKD M over 80 kg (0.3; –4.4) and 22 – judo M 81 kg (0.8; –3.1). Three judoist groups ascribed as 24 – judo M 90 kg (1.2; –4.4), 25 – judo F 78 kg (1.2; –2.8), 26 – judo M less 100 kg (1.8; –5.7) were still heavier and shorter compared to previous athlete's groups. Judo representatives who were recognized as 27 – judo F over 78 kg (6.0; –8.2) and 28 – judo M over 100 kg (5.1; –9.3) contrast with other groups, showing the highest difference from Phantom stratagem in their body mass and height. Their body mass were by 5z greater than the phantom standard and, in terms of the proportionality of height,

Table 3. Proportional weight of sporting groups (count, mean, z-score, SE, 95% Tukey HSD intervals).

Group	Count	Mean	Std. error (pooled s)	Tukey HSD lower limit	Tukey HSD upper limit
Epee F	37	–0.69	0.19	–1.18	–0.19
Epee M	29	–0.25	0.21	–0.80	0.31
Foil F	38	–0.60	0.19	–1.09	–0.11
Foil M	36	–0.55	0.19	–1.05	–0.05
Sabre F	32	–0.32	0.20	–0.86	0.21
Sabre M	37	–0.34	0.19	–0.83	0.15
TKD F 49	16	–1.66	0.29	–2.41	–0.90
TKD M 58	16	–1.72	0.29	–2.47	–0.97
TKD F 57	15	–0.77	0.29	–1.55	0.01
TKD M 68	16	–1.24	0.29	–1.99	–0.49
TKD F 67	16	–0.50	0.29	–1.26	0.25
TKD M 80	16	–0.63	0.29	–1.38	0.13
TKD Fover 67	16	–0.16	0.29	–0.91	0.59
TKD Mover 80	16	0.33	0.29	–0.42	1.09
Judo F 48	18	–0.45	0.27	–1.16	0.26
Judo M 60	34	0.04	0.20	–0.47	0.56
Judo F 52	22	–0.20	0.24	–0.84	0.45
Judo M 66	34	0.44	0.20	–0.08	0.95
Judo F 57	24	–0.40	0.23	–1.02	0.21
Judo M 73	33	0.30	0.20	–0.22	0.83
Judo F 63	22	0.26	0.24	–0.38	0.90
Judo M 81	32	0.89	0.20	0.32	1.38
Judo F 70	20	0.39	0.26	–0.28	1.07
Judo M 90	30	1.24	0.21	0.69	1.79
Judo F 78	20	1.22	0.26	0.55	1.89
Judo Mless 100	27	1.81	0.22	1.23	2.39
Judo Fover 78	18	5.96	0.27	5.25	6.67
Judo Mover 100	29	5.31	0.21	4.76	5.87

Group code: HSD – Tukey's honestly significant difference procedure. TKD F49 – taekwondo female weight category to 49 kg.

they were shorter by more than 8z than the normal population pattern, while groups 7 – TKD F 49 kg and 8 – TKD M 58 kg, were proportionally lighter and taller.

When evaluating the proportionality dimorphism, the weights obtained individually in 28 sport groups were transformed to z-values (Table 3 and Figure 1).

The displacement between female and male epeeists means was 0.44z and indicated proportionality dimorphism degree. Differences between the three sports classified as group A, B and C were significant ($F=9.45$, $P=0.004$, $\eta^2=0.63$). Proportional sexual dimorphism in judo (0.64±0.04z) was significantly higher ($P=0.01$) than in fencing (0.17±0.14z), and higher than in taekwondo (0.29±0.11z).

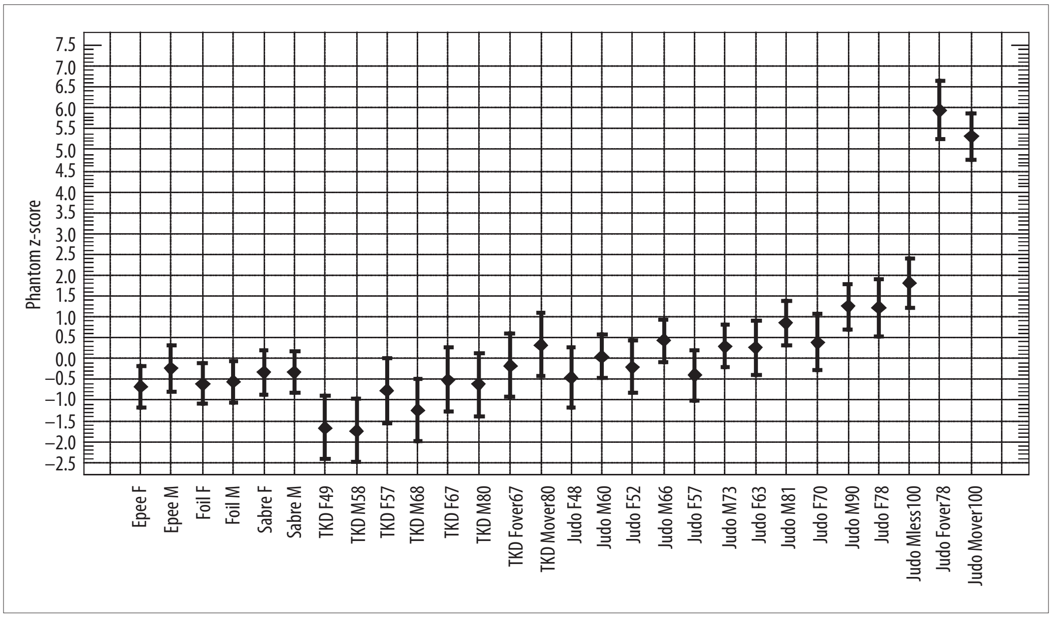

Figure 2. Means with 95.0 percent Tukey HSD intervals for combat sports groups.

Discussion

Age of combat sports Olympic athletes

Age of the subjects involved in Olympic combat sports differed significantly depending on the sport or event. However, the representatives of fencing events formed a homogeneous group (25.74 to 27.57 years, on average). Women were younger than men, with the exception of foil event. An interaction was found in gender and event factors; it was determined by considerably older age of male epeest with respect to women who fought in foil. It can be expected that older participants of Olympic tournaments in fencing (London, 2012) had longer training experience. Other studies [38] have demonstrated that the elite fencers were younger than the Olympians with training experience of 8.8±3.1 years. This group [39] was created without consideration of gender factor. Therefore, male/female ratio also remains unknown. Thirty Polish male contestants were also examined according to weapon. They took part in epee (n=10), foil (n=10) and sabre (n=10). They were aged 23.3±2.9 years; their training experience was 12.6±2.5 years, with the training load of 15.9±3.1 hours per week, and were similar in these respects [22].

This study showed that Olympic taekwondo athletes were the youngest representatives of combat sports that competed in London Olympic Games. The only difference we found was in age between the best 8 placers (younger) and the others (older) in TKD M58. Kazemi et al. [7] provided a characterization of Olympic Taekwondo athletes who participated in the 2008 tournaments and did not find significant differences between winners and non-winners with regard to average age. These values were close to average age specified in this study concerning participants of the Taekwondo Olympic tournaments in London 2012. Slightly lower age was observed in males selected to national team from Turkish elite taekwondo athletes, where sub-elite athletes were significantly younger [39]. Fritzsche and Raschka [40] did not find this relationship in male and female top taekwondo German competitors *versus* nonprofessional taekwondoka groups, respectively. Kostka et al. [41] formulated the criteria for qualifying children and young people for particular sports according to the biological (developmental) age. Chronological (calendar) age is not always a good indicator of the development of a young human body. Therefore, developmental age (as determined by skeletal age, Tanner staging of puberty, body size, motor skill or psychological function) should rather be used whenever possible, especially when an important drawback in developmental age compared with chronological age is suspected. According to doctors, optimal age for starting regular training regimes differs between individual combat sports e.g.: fencing – older than 8 years; judo – older than 10 years, taekwondo (with limited contact) older than 12 years [41]. The authors did not differentiate between age of qualification for sports between boys and girls, although the phase of peak height velocity (PHV) observed by parents and trainers generally occurs in girls earlier than in boys. This problem is complicated and needs to be further investigated.

In the present study, both female and male judoists were at a similar age, but they were older than those who competed in the Olympic Games in Atlanta (1996), when the females were, on average, younger by one year than the men [17]. As results from other studies on judo, the competitors at the age range between 23 to 29 are the most successful in the sport [42]. The individual data on the competitors from the lighter and heavier weight categories suggest repeatability of sport result depending on their body mass. According to Jagiełło [43], who conducted a long-term observation of this phenomenon, five competitors from Barcelona tournament (1992) entered the medal zone for the second time during the Olympic Games in Atlanta (1996). Based on the figures released by the International Judo Federation (Atlanta 1996), it was found that the oldest contestants fought in the heaviest weight categories [17]. We did not find this scenario in current judo Olympic athletes.

Sport skill level

No significant differences were found between the best 8 athletes and the other athletes who competed in each event. Only in the TKD M58 group, the best 8 athletes were younger than the other athletes. The first eight winners (E) in male epee tournament were significantly higher and heavier from the rest of the group (R), but this difference was not found in females. Female E sabrists were significantly heavier than those in R group, had higher BMI, lower HWR and ectomorphy. Similar tendencies were observed in females and males. Male E group sabrists had advantage over R group in BMI, and had lower HWR and ectomorphy. In judo, with 7 weight categories, only the group of 90 kg category males (E group) was significantly higher from R group, more massive (BMI), which was confirmed by lesser values of HWR and ectomorphy. Few differences that depend on sport skill level are connected with the fact that the sporting groups compared differ in the type of motor activities accepted in sports regulations. Therefore, assuming that the age requirements and body dimensions are met, technique and tactics of the fight and psychological preparation become critical [1,2]. The injury is an additional factor causing trouble in achieving a win. The injuries risk (#injuries / # athletes) was highest in TKD males (51.6%) and TKD females (26.6%) and a middle in male (10.9%) and female (12.4%) judo athletes. The rates of injuries in fencing were 13.1% and 5.6% in males and females, respectively [50].

Height, body mass, weight-height ratios, proportionality and sexual dimorphism

Our findings show that the likelihood of selection and success in Olympic combat sports for each individual from the general population varies considerably. The probability of finding candidates suitable for a sport in the general population depends on how different their body size characteristics are from the typical/central part of bivariate chart. Norton and Olds [31] argued that 'in open-ended sports, more massive players have an advantage.' Those authors made a simulation of the quest somatically talented candidates to basketball, indicating that about 5% of the population of young adult males have the appropriate size for NBA selection. We confirmed this phenomenon in the heaviest weight categories of male and female judoists who exhibited untypical proportional height (low) and body mass (high). These heavy individuals are not observed in the heaviest, open-ended weight categories in taekwondo. The heaviest ones (TKD males above 80 kg) are similar to judo males from 81 kg weight category. Female foilist's proportional characteristics are located near male judoists from 60 kg. Finding the candidates in general population for both groups mentioned is available to higher extent than in the taekwondoists suitable for subgroups of 7 – TKD F 49 kg and 8 – TKD M 58 kg.

Body mass and body composition largely depend on nutrition and training, which does not concern body height and frame. The differences in body height observed between events are important indices only if body mass is also taken into consideration. Much higher effect size of event factor on body mass was found: it was higher in judoists compared to foilists and taekwondoists. There is an official recognition in so-called closed events that the heavier weights have an advantage over the lighter weights and the contestants are matched within rigid weight groupings [44]. It was demonstrated in this study that judoists were shorter than those trained for fighting in epee, sabre or taekwondo. The division into weight categories in taekwondo (4) and judo (7) caused that the athletes from heavier weight categories are usually taller than those from lower weight categories. Therefore, being a fighter of medium height in a given weight category and fighting in a heavier weight category, one will probably be classified as a short fighter in this category. The relative height of a competitor with respect to their opponents from the same weight category can be an important factor in selection of technique and/or tactics. Body height in contestants was moderately related to the level of achievements in sport. The athletes with medium body height were more seldom medal winners [45]. Khosla and McBroom [44] argued that 'Caution is necessary in interpreting the body mass index because it does not account for frame size. Moreover, obesity and extra weight are often dissimilar. Extra weight may be muscle in an athlete but adipose tissue in a more typical person. The body mass index alone cannot distinguish between these possibilities.' The somatotype provides total information which is more useful than calculating particular measurements from predicting equations [5]. Claessens et al. [10]

discovered increased values of endomorphy and mesomorphy with low levels values of ectomorphy. In addition, male judo athletes were heavier, taller, had lower body fat and higher muscle mass percentage and absolute values, higher circumferences and bone diameters, lower endomorphic and higher mesomorphic components than females [12]. There is an importance of anthropometric profiling in judo. In addition, there is possibility to reduce the sexual dimorphism in body build in judoists compared to the untrained subjects [46]. Sexual dimorphism for proportional body mass scaled on phantom height in taekwondo and judo was insignificant in successive weight categories. Similarly to Keogh et al. [47], our findings support the importance of anthropometric profiling and suggest that successful males or females should exhibit similar proportional characteristics in weight in both open (fencing weapons) and closed events (weight categories in taekwondo and judo). Proportional sexual dimorphism in judo was significantly higher than in fencing, and higher than in taekwondo. An explanation of this phenomenon can be found in higher resistance load demands from judo athletes than in fencing and taekwondo athletes.

Finally, one should emphasize weaker points of this study, such as small number of variables that form the demographic profile of an athlete. However, those analysed concerned the elite female and male athletes.

Conclusions

In conclusion, athletes from the events within Olympic combat sports tournaments exhibited different demands among male and female athletes in terms of their age, height, body mass, weight-height ratio and proportionality. The highest proportional sexual dimorphism in body mass was observed in judoists. The characteristics of world elite female and male athletes can be adopted as model/optimal values and used when searching, in general population, young talents to be trained in combat sports.

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