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Effect of body length, body weight, and sport achievement on points scored by male judo athletes in the Olympic tournament 2012

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Stanisław Sterkowicz[1ABDE], Hans-Dieter Heinisch[2ABDE], Katarzyna Sterkowicz-Przybycień[3BCD]

[1] Department of Theory of Sport and Kinesiology, Institute of Sport Sciences, Faculty of Physical Education and Sport, University of Physical Education in Cracow, Poland
[2] Institute for Applied Training Science in Leipzig, Germany
[3] Department of Gymnastics and Dance, Institute of Sport Sciences, Faculty of Physical Education and Sport, University of Physical Education in Cracow, Poland

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Abstract

Background & Study Aim: High technical preparation is important for judoka. The aim of this study is knowledge about the association between effects of relative body height, weight category and sport achievement on points scored by judo athletes who use different techniques during their fights.

Material & Method: The study is based on an analysis of video recordings and a notational analysis of the Olympic men's tournament 2012 in London. Altogether 252 fights were analysed with the judo specific version (4.5.2) of the video analyse system *utilius vs*®. Fights of 28 medallists and 28 judo players ranked 5th to 7th were selected for detailed expert video and notational analysis. Three independent values were analysed: relative body height; weight categories combined; level of sport achievement. Dependent value in MANOVA was the efficiency quotient of all relative numbers of own score points collected by each competitor during his fights. Biomechanical classification of techniques was employed. Descriptive statistics were counted and compared between all levels for each factor (statistical significance $p<0.05$).

Results: A downward tendency of the relative number of all scored points per time (EQ) across consecutive height categories was noticed, but any of pair wise difference between EQ was significant. EQ depended on weight category. Physical lever sub-group techniques were distinguished by higher efficiency when performed by short participants to tall participants, who in place of better scored using "C" techniques (couple of forces throws type).

Conclusion: The top judo athletes adapt techniques to their physique and motor preparation. So, coaches of top athletes and also on lower competitive level could use revealed statistical regularities for their individual development.

Keywords: efficiency • elite judo athletes • judo technique • performance • video analyse

Author's address: Stanislaw Sterkowicz, Department of Theory of Sport and Kinesiology, Institute of Sport Sciences, Faculty of Physical Education and Sport, University of Physical Education, Al. Jana Pawla II 78, 31-571 Cracow, Poland, e-mail: stanislaw.sterkowicz@awf.krakow.pl

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Throwing techniques *(nage-waza)* – hand techniques (sub classification: *te-waza*); hip techniques (sub classification: *goshi-waza*); leg techniques (sub classification: *ashi-waza*); rear-fall and side-fall judo throws, synonym: "dedication throws" (sub classification: *sutemi-waza*).

Grappling techniques *(katame-waza)* – **pinning techniques** (*osae-waza*); **strangle technique** (*shime-waza*); **joint holds** (*kansetsu-waza*).

Tori – the person who applies a technique in *judo* training. The receiver of the technique is referred to as ***uke*** [26].

Ippon – one point. Achieved through the execution of a valid technique on the opponent [26].

Waza-ari – a *judo* term for a technique that cannot be regarded as a full *ippon*, but is very close [26].

Yuko – a score in judo competition.

Introduction

In Olympic judo seven weight divisions exist [1]. High competitive judokas have selected both throws and gripping techniques during groundwork (*ne-waza*) phase to take advantage during their fights or finished the bout ahead of time by *ippon*.

The attraction of judo defines itself first of all by the efficacy of technical-tactical actions. These are dynamic throwing actions (*nage-waza*) by which the opponent is thrown with power and momentum (preferably) on his back. Also, the fight can be transferred from the vertical (*tachi-waza*) into the horizontal (*ne-waza*) posture – in judo jargon: from standing to ground position – and points can be scored by grappling techniques (*katame-waza*) [2].

Parallel to the achieved technical advantages, the fighting behaviour and the match result are influenced by the officiating team assessing the bout by giving penalties for infraction of the rules. These rules are constantly being adjusted to the current demands of a modern Olympic sport by the International Judo Federation (IJF) refereeing commission [2-5].

A longitudinal study during the period 2004-2013 about the relevance of throwing technique groups shows an increasing dominance of inward turn techniques as well as foot and leg techniques in summary of all men weight categories [6].

We suppose that these techniques will probably be associated with weight categories. But it is also justified that relative body height has an impact on effective technique selection by individuals. In addition, we expect that level of sport achievements will depend mainly on techniques scored by performers. We suppose that:

- physical lever throw techniques/PL will be applied by judo athletes with lower body length often than by opponents with higher body length;
- there will be dependence of technique on weight division,
- the medallists will be able to score mainly from both physical lever throw techniques and couple of forces throwing techniques.

Therefore, the aim of this study is knowledge about the association between effects of relative body height, weight category and sport achievement on points scored by judo athletes who use different techniques during their fights.

Material and methods

Participants and protocol

There are no ethical issues involved in the analysis and interpretation of the data used as these were obtained from other sources and were not generated by experimentation. The athletes' personal identification was replaced by a code, which ensured anonymity and confidentiality [1, 5]. The study is based on an analysis of video recordings and a notational analysis of the Olympic men's tournament 2012 in London. Altogether 252 fights were analysed with the judo specific version (4.5.2) of the video analyse system *utilius vs*® [7] in context with aspects and analyses strategies named in Table 1.

All actions were evaluated by judo experts via reviewing digital records of all fights using classical classification of the IJF [8]. The observer reliability of three experts was assessed by calculation of the median of Cohen's Kappa [9] respectively for two observers [10]. In context with Landis and Koch [11] we found a perfect accordance for classification the kind of technique as well as the score quality ($\varkappa$ =0.84).

Table 1. Data basis (aspects, indicator, calculation).

Qualitative and quantitative data	Technical-tactical indicator	Algorithm of calculation
Registration of all scored actions and the combat time (CT)	Relative number of own scores (S_{own})	$S_{own} = n_{own} / CT\ [n \cdot min^{-1}]$
	Relative number of opponent's scores (S_{opp})	$S_{opp} = n_{Opp} / CT\ [n \cdot min^{-1}]$
Registration of all scored points	Efficiency quotient (EQ_{own}) relative number of own score points* (SP_{Own})	$EQ_{own} = \sum SP_{own} / CT\ [SP_{own} \cdot min^{-1}]$
	Efficiency quotient of the opponent (EQ_{Opp}) relative number of opponent's score points (SP_{Opp})	$EQ_{opp} = \sum SP_{opp} / CT\ [SP_{opp} \cdot min^{-1}]$
	Efficiency Index (EI)	$EI_T = EQ_{own} - EQ_{opp}$

*score points: 5 *(yuko)*; 7 *(waza-ari)*; 10 *(ippon)*

General characteristics of the 56 top judo athletes: 28 medallists (ME) and 28 (non-medallists NME) ranked 5th to 7th (best eight in each weight limit). Their time exposures during they fought and scored techniques performed are grouped in the three combined weight divisions were selected:

(1) 60 and 66 kg, i.e. extra lightweight and half lightweight;

(2) 73 and 90 kg, i.e. lightweight, half middleweight and middleweight;

(3) 100 kg and over 100 kg, i.e. half heavyweight and heavy weight.

The quality of techniques performed during the tournament was expressed as point score gained by 55 participants (one athlete won his fights by another tactic). Scored points were summarized in each bout and for all individual competitors. So, we focused our attention on the efficiency quotient (EQ_{own}) relative number of own score points (SP_{own}) using formula:

$EQ_{own} = \sum SP_{own} / CT\ [SP_{own} \cdot min^{-1}]$ (Table 1).

Table 2. Legend of recorded techniques and classification in dependence of Sacripanti [12, 13].

PL (physical lever-type throwing techniques)		C (couple of forces-type throwing techniques)		GRAP	
Technique	**Code**	**Technique**	**Code**	**Technique**	**Code**
Ashi-guruma	AGU	*De-ashi-barai*	DAB	*Juji-gatame*	JGT
Eri-seoi-nage	ESN	*Harai-goshi*	HRG	*Kami-shiho-gatame*	KSH
Eri-seoi-otoshi	ESO	*Harai-goshi-gaeshi*	HRA	*Kesa-gatame*	KEG
Hiza-guruma	HIZ	*Harai-maki-komi*	HRM	*Koshi-jime*	KOJ
Ippon-seoi-nage	ISN	*Kata-ashi-dori*	KAD	*Kuzure-kesa-gatame*	KKG
Koshi-guruma	KOG	*Ko-soto-gake*	KSK	*Mune-gatame*	MGT
Morote-seoi-nage	MSN	*Ko-soto-gari*	KSG	*Okuri-eri-jime*	OEJ
Sasae-tsuri-komi-ashi	STA	*Ko-uchi-gake*	KUK	*O-soto-gari*	OSG
Seoi-otoshi	SOO	*Ko-uchi-gari*	KUG	*Ryo-te-jime*	RTJ
Sode-tsuri-komi-goshi	STG	*Ko-uchi-maki-komi*	KUM	*Tate-shiho-gatame*	TSG
Soto-maki-komi	SMK	*Kuchiki-taoshi*	KTA	*Yoko-shiho-gatame*	YSG
Sumi-gaeshi	SUG	*O-soto-gari*	OSG		
Sumi-otoshi	SOT	*O-soto-maki-komi*	OSM		
Tai-otoshi	TOS	*O-soto-otoshi*	OSO		
Tani-otoshi	TNO	*O-uchi-gari*	OUG		
Tomoe-nage	TNG	*Te-guruma*	TGU		
Tsuri-goshi	TGO	*Uchi-mata*	UMA		
Uki-goshi	UGO	*Uchi-mata-gaeshi*	UMG		
Uki-waza	UWA	*Uchi-mata-maki-komi*	UMK		
Ura-nage	UNA	*Uchi-mata-sukashi*	UMS		
Utsuri-goshi	UTS				
Yoko-otoshi	YOT				
Yoko-tomoe-nage	YTN				

In our opinion the classification of throwing techniques in judo according to biomechanical aspects is more suitable than the classical classification [8] because it considers the physique of the athletes. Therefore the following-described biomechanical criteria for classification of techniques recommended by Sacripanti [12, 13] were used in our study (Table 2):

1. physical lever-type throwing techniques (PL). From the biomechanical point of view, the force with the same magnitude and direction that acts on the greater lever causes greater effect (moment of force). Moreover, with equal resistance, when the arm of the lever used in a lever technique increases, the applied force decreases on the same maximal muscle torque. This means that lever techniques of maximum arm are energetically the most effective among lever techniques group;
2. couple of forces-type throwing techniques (C). Normally, it is well known that couple techniques are energetically more convenient compared to lever techniques;
3. grappling (GRAP) during mat work, pinning techniques, joint techniques of the bending and pressing against elbow joint type, and vascular chocking techniques are allowed [5].

Age, body height and mass were collected from the *Official Olympic Book* [1]. Body mass index (BMI) was calculated [14]. Relative body height category of each competitor within each of seven weight divisions was determined on the basis of mean and ½ standard deviation (½ SD):

short (S) < mean – ½SD of body height

Table 3. General characteristics of the 56 top judo athletes including their time exposures during their fights.

Group of variables	Count	Mean	SD	Minimum	Maximum	
Age (years)	**56**	**26.09**	**3.49**	**20.0**	**34.0**	
1	16	25.13	2.89	20.0	31.0	
2	24	25.79	3.25	21.0	33.0	
3	16	27.50	4.12	21.0	34.0	
Body length (cm)	**56**	**177.75**	**10.27**	**160.0**	**204.0**	
1	16	167.94	5.62	160.0	181.0	
2	24	176.88	5.01	168.0	190.0	
3	16	188.88	8.00	175.0	204.0	
Body weight (kg)	**56**	**85.63**	**23.92**	**59.60**	**169.4**	
1	16	62.84	3.09	59.60	66.00	
2	24	80.86	6.98	72.20	89.90	
3	16	115.59	21.60	97.70	169.40	
BMI (kg/m^2)	**56**	**26.68**	**4.80**	**20.05**	**41.11**	
1	16	22.31	1.26	20.05	24.24	
2	24	25.84	1.81	22.33	28.93	
3	16	32.30	4.75	25.38	41.11	
Total combat time (minute)	**56**	**22.28**	**5.7919**	**8.25**	**38.64**	**1247.4**
1	16	23.278	4.14	17.03	32.4	**372.35**
2	24	23.13	6.45	10.70	38.64	**555.02**
3	16	20.00	5.89	8.25	29.4	**320.02**

Note: 1, 2, 3 are Weight combined categories

middle (M) = mean ± ½SD of body height
tall (T) > mean + ½SD of body height.

Total combat time was also counted for the best eight, in each of the seven weight division combined next into the three weight categories (Table 3).

Statistics analyses

We have considered the following factors:

- length (height) category within each of the seven weight categories (S short, M middle, T tall);
- combined weight limits (1-lighter, 2-middle, 3-heavier);
- sport achievements (ME medallists, NME non-medallists).

Dependent variables were the sum of point's scores for PL, C and GRAP techniques in relation to total match time. For multifactor ANOVA results performed in GLM module a significance level of $p<0.05$ was adopted and the effect size of eta^2 (η^2) was counted and interpreted according to Cohen's guidelines [15]: 0.01 = small, 0.06 = medium, 0.14 = large.

Comparison between levels of each factor was done using on Bonferroni multiple comparison procedure. Statgraphic Centurion XVII software was employed for all counting.

Results

The analysis of variance for scored points per time (Table 4) revealed a significant effect on all scored points per time for weight juxtaposed factor ($F=3.70$, $p=0.032$, $\eta^2=0.12$ /medium effect/) and sport achievements level factor ($F=4.77$, $p=0.034$, $\eta^2=0.08$ / medium effect/); but not for length category ($F=1.07$, $p=0.351$, $\eta^2=0.04$ /small effect/). All F-ratios are based on the residual mean square error.

Table 5 presents ANOVA results of length category, weight category and sport achievements factors for PL per time, C per time and GRAP per time. There is a significant effect of body length factor on points scored using physical lever throws type ($F_{2, 49}=3.54$, $p=0.037$, $\eta^2=0.12$ /medium/). Multiple comparisons Bonferroni test shows a significant difference between short and tall participants for disadvantage of the second group.

Weight category factor has a significant effect on physical lever throws type ($F_{2, 49} = 4.09$, $p=0.023$, $\eta^2=0.14$ /large/). Competitors from lighter category (1) scored better using PL throws type than those representing middle category (2). Means between medallists (ME) and non-medallists (NME) did not differ significantly ($F_{1, 49} = 0.08$, $p=0.779$, $\eta^2=0.001$) in this aspect.

Couple of strength throw type scores per time did not differ between levels of length category ($F_{2, 49} = 1.26$, $p=0.292$, $\eta^2=0.05$ /small/) and weight category ($F_{2, 49} = 0.10$, $p=0.909$, $\eta^2=0.003$ /small/). ANOVA of Sport achievements revealed the tendency that medallists scored better than non-medallists using C throws type ($F_{1, 49} = 3.35$, $p=0.073$, $\eta^2=0.06$ /medium/).

Table 4. Least squares means and standard error (SE) for all scored points per time (EQ_{own}).

Level	Special aspect	Count	Mean	SE
GRAND MEAN		55	1.22	
Length category	S	21	1.37	0.14
	M	21	1.26	0.14
	T	13	1.03	0.18
Weight combined	1	16	1.44	0.16
	2	23	0.90	0.14
	3	16	1.31	0.16
Level of sport achievements	ME	28	1.41	0.12
	NME	27	1.03	0.12

Note: S – short; M – medium; T – tall; 1 – lighter, 2 – medium, 3 – heavy; ME – medallists, NME – non-medallists

Table 5. Least squares means and standard error (SE) for PL per time, C per time and GRAP per time.

Special aspect	Count	PL per time				C per time				GRAP per time			
		Mean	SE	Lower limit	Upper limit	Mean	SE	Lower limit	Upper limit	Mean	SE	Lower limit	Upper limit
GRAND MEAN	**55**	**0.51**	**0.06**	**0.38**	**0.64**	**0.47**	**0.07**	**0.34**	**0.60**	**0.24**	**0.05**	**0.14**	**0.34**
Length category													
S	21	0.73	0.11	0.52	0.95	0.39	0.11	0.18	0.61	0.25	0.08	0.08	0.41
M	21	0.53	0.10	0.32	0.74	0.39	0.10	0.18	0.60	0.35	0.08	0.18	0.51
T	13	0.27	0.13	0.00	0.53	0.64	0.13	0.38	0.90	0.12	0.10	–0.09	0.33
Weight category combined													
1	16	0.74	0.12	0.51	0.98	0.45	0.12	0.22	0.69	0.25	0.09	0.06	0.43
2	23	0.29	0.11	0.08	0.50	0.51	0.11	0.30	0.72	0.10	0.08	–0.07	0.26
3	16	0.49	0.12	0.26	0.73	0.45	0.12	0.22	0.69	0.37	0.09	0.19	0.56
Sport achievements level													
ME	28	0.53	0.09	0.35	0.71	0.59	0.09	0.41	0.77	0.29	0.07	0.15	0.43
NME	27	0.49	0.09	0.31	0.68	0.36	0.09	0.17	0.54	0.19	0.07	0.04	0.33

Level: S, M, T – length categories; 1, 2, 3 – successive weight categories; ME – medallists, NME – non-medallists

Table 6. Summary statistics for scores.

Techniques	Count	Average	SD	Minimum	Maximum	Range
C	12	14.7	9.3	5.0	36.0	31.0
C+PL	9	26.8	16.6	15.0	68.0	53.0
PL	13	15.0	8.3	5.0	34.0	29.0
PL+C	15	30.3	9.4	15.0	46.0	31.0
PL = C	7	9.6	7.6	0.0	20.0	20.0
Total	56	20.3	12.8	0.0	68.0	68.0

Grappling techniques scored per minute was similar between levels of length category ($F_{2, 49} = 1.42$, $p=0.253$, $\eta^2=0.050$ /small/), and sports achievement factors ($F_{1, 49} = 1.06$, $p=0.309$, $\eta^2=0.018$ /small/). However there was a tendency to score higher among heavier groups (3) than middle (2) and lighter (1) weight categories ($F_{2, 49} = 2.46$, $p=0.096$, $\eta^2=0.09$ / medium/).

Scores gained by competitors performed different types of throw techniques are presented in Table 6.

ANOVA results show that points scored depend on the judo athlete's technical preference ($F_{4, 51} = 7.90$, $p<0.001$, $\eta^2= 0.38$ /large/). Judo athletes who preferred PL + C throws or C + PL throws have collected more scores and build homogenous group. They differed significantly from those who were able to collect PL = C scores in equal (Figure 1).

Discussion

The decrement tendency in EQ for the relative number of all scored points per time in consecutive height categories were noticed, but any of pair–wise difference was significant. Biomechanical classification [12, 13] conducted by us revealed that physical lever group techniques were distinguished by higher

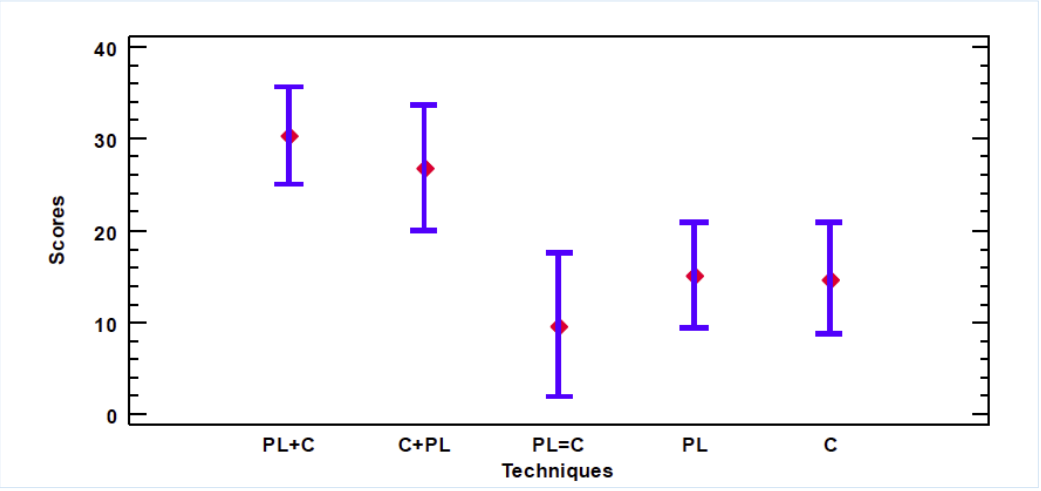

Figure 1. Dependence of different throwing combinations on effectiveness (95% Bonferroni test intervals).

efficiency when performed by short participants than in tall participants, who in place of better score using C techniques.

Among PL techniques dominated *seoi-nage* and *sode-tsurikomi goshi* (using variable arm, i.e. variable fulcrum from *uke's* waist to his knees), *tai-otoshi*, *tani-otoshi*, *sumi-gaeshi* (maximum arm lever, i.e. fulcrum under *uke's* malleolus).

Among C techniques dominated *ko-soto-gake* (couple of forces applied by arms and leg), and *uchi-mata*, *harai-makikomi*, *uchi-mata gaeshi*, *ouchi-gari* (where couple of forces were applied by trunk and legs) and *te-guruma* (arms).

Frequently used in groundwork were *ude-hishigi-juji-gatme* (from joint manipulation techniques sub-group), *yoko-shiho-gatame* (represents pinning techniques) and *koshi-jime* (from strangle techniques sub-group).

EQ depended on weight category when representatives of 1st group demonstrated advantage over those from 2nd group, but did not differ from 3rd group. Weight categories 2nd and 3rd formed homogenous group. Competitors presented different somatotypes across weight categories [16] and in consequence differ in their physical fitness level [17]. Therefore we considered the three combined weight categories. The lighter category scored better using PL throws-type than those representing middle category. In addition, middle and heavier categories were homogenous in this aspect.

Expected relationship between the efficiency quotient of all techniques performed during fight and the level of sport achievements was confirmed. Olympic medallists were characterized by substantially higher variability and efficiency of techniques used. Particularly, analysis of technique type and a level of sports achievement were unclear. The relative number of all scored points per time depends on technique type (PL or C), but performers who won using throws from both classification groups (PL + C and C + PL) gained higher scores quality.

This phenomenon shows the importance of attack variability for scored points during fight. Heinisch et al. [2] proved that efficacy of technical-tactical actions index during Beijing (2008) and London (2012) Olympic Games was similar, but specifically lower than during successive World Judo Championships 2009, 2010, 2011. Also the authors originally divided techniques between groups: inward turn throwing techniques (two-legged, i.e. *seoi-nage* or one-legged, e.g. *uchi-mata*) and techniques turning vertical axis of a performer's body, for example *ashi-waza* (e.g. *osoto-gari*), lifting throws (e.g. *ura-nage*), circle and corner reversal throws (like *tomoe-nage*) and grips in ground work used (pinning, joint manipulation, strangles). Inward turn techniques with rotation about transverse of longitudinal axis of thrower's body were highest scored [2].

A judoka has to perfect complementary throws with a single grip in order to use attacks in three to four directions and to be effective during a bout [18, 19]. Results of many years' observation concerning a double Olympic medallist show that his technical

variability is much broader than can be observed during single bout or single competition. Since he was champion, he used efficient throws from all Kodokan classification groups: arm techniques, hip techniques, foot and leg techniques, sacrifice techniques) and ground-work techniques (pinning, strangles, joint manipulations techniques [20].

In Kodokan IJF classification a criterion of exclusion *uchi mata* (foot and leg subgroup) from arm techniques sub-group was justified by its different biomechanics (couple-force type throw) in comparison to *seoi-nage* throw (arm technique). Another justification to separate those techniques which are very efficient in judo fights are not only their different kinematics, but also different energy expenditure. A much higher energy amount for execution of *seoi-nage* throw than for *uchi-mata* throw is needed [21].

In another throws classification both mentioned above techniques are classified as inward turn techniques [6]. Relative muscle torques, used in kinetic method analysis, optimal for each athlete with a particular technical preparation seems to be more important than their total, since it was demonstrated that it is connected with the effectiveness of utilized techniques [22]. It can be an additional argument for using classification basing not only on kinematic but also on dynamometry measurement results [13].

Also the lateralization of technical-tactical actions is important, because the actions performed by high-skilled and well-trained judoists, especially the left-sided, are less predictable and are conducive to medal winning [23, 24]. We not focused our attention on lateralization and gripping combination, but latest research confirmed hypotheses that attacking on the same side of the *kumi-kata* increases the chance of scoring and winning the combat. Performed same-side attacks by *kenka-yotsu* (adversaries using reverse grip, right versus left) were the most effective, especially for lightest weight judo fighters. Performed same-side attacks by *ai-yotsu* (both opponents using right or left grip at the same time; and only one athlete is gripping (only the attacking athlete performing the grip; increased the likelihood of winning the combat) [25].

A limitation of the present work is that the biomechanical classification of throwing techniques (PL and C) used is rough. In reality, there are four sub-groups within PL group and three sub-groups within C group [11, 12], which have application in previous analysis of frequently used techniques by all men and women participating in the London Olympic judo tournaments [5].

Conclusions

On the basis of our findings we can formulate the general conclusion that the top judo athletes adapt techniques to their physique and motor preparation. So, coaches of top athletes and also on lower competitive level could use statistical regularities for their individual development.

Competing interests

Authors have declared that no competing interest exists.

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