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Contribution of Nage-waza actions to the Olympic performance: an observational 2004-2016 medalists' study

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Abstract

Background: Winning an Olympic medal is a sporting accomplishment that rewards well-prepared judokas. Despite many studies devoted to understanding his performance, the elite judoka remained an attractive object of investigation. The study aimed to define the technical and tactical profile of the Olympic medalists. **Methods and material**: The observation of 575 matches determined 6,750 Nage-waza actions performed by 112 male medalists and their opponents in four consecutive Olympic Games (2004, 2008, 2012, and 2016). Anderson-Darling assessed the normal distribution of the data; one-way ANOVA used for inter and intra-Olympic comparisons, followed by the Post hoc Tukey test. Unbiased estimator ω^2 tested the effect size of the analysis of variance. **Results**: Medalists performed 6.4±2.4 attacks/match; opponents carried out 5.3±2.2 attacks/match. They have registered offensive effectiveness of 15.7±9.9% and defensive effectiveness of 95.7±4.2%. To achieve this performance, medalists executed 1.7±.6 attacks/min and their opponents' 1.4±.5 attack/min. Their technical repertoire of 10.8±3.9 techniques has shown the technical requirements at these Olympic competitions. Ashi-waza was the most preferred, but Te-waza was the most effective. **Conclusion**: These findings improve knowledge of the technical and tactical profile of Olympic medalists. Coaches could use them as references in judoka preparedness for future competitions.

Keywords: judo; technique; tactic; competition; high-level.

Introduction

Winning an Olympic medal is the dream for elite judokas. They value this moment because it affects their careers (McCann, 2008). This achievement becomes an obsession for many athletes (Crowther, 2004). By winning three Olympic gold medals in a row (Atlanta 1996, Sydney 2000, and Athens 2004), Tadahiro Nomura (Japan) performs the highest achievement. In comparison, no-one Athens 2004 champion keeps his title in Beijing; two gold medalists of Beijing 2008 reach a final in London. Only one London 2012 champion

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repeats his performance in Rio de Janeiro 2016. As for the silver and bronze places, four judokas of Athens 2004 are on the Beijing podium. Six medalists from Beijing 2008 are on the London podium, and five medalists from London 2012 are on the Rio de Janeiro podium. The complex and changing conditions of a judo match created by speed movements, high opposition, timing, and speed variation can explain this disaster (Sacripanti, 1987). The technical and tactical complexities of judo make up other reasons (Hoare, 2007). In London 2012, unfavorable judokas surprise by winning medals; about 16% of 80% of these new medalists have no sporting success (Lascau & Rosu, 2013). According to experts, the probability of winning a medal is 41.1% during London 2012 and 42.9% in Rio 2016. However, the chance for the judoka, ranked first by IJF, to win the gold medal is 19.5% in London 2012 and 36.8% in Rio 2016 (Marques Guilheiro & Franchini, 2017). On another side, the male lightweight division is the most homogeneous because the favorite has a lower chance of winning over the opponent (Krumer, 2017).

The performance in judo is multifactorial and systemic. Paillard (2010) identified individual judoka factors (biological, psychological, technical, and tactical) and environmental factors (family, material, technological, medical, institutional, economic, and media). Top-level European judo coaches consider physical fitness, technical, and tactical knowledge as the most fundamental factors (Krstulovic, 2012). Likewise, in an investigation, Spanish Olympic judokas add the individual psychological dimensions to these factors (Robles Rodriguez, 2019). Previous studies have reported the crucial role of technique and tactics (Bocioaca, 2014; Osipov et al., 2016). However, there are two possibilities to win in judo (Loizon et al., 2004). The first is to mobilize a technical-tactical knowledge modeled on the characteristics of the opponent. The second is to impose favor movement (Tokui-waza) to this opponent. Tactical intelligence is some principles of attack and defense to manipulate depending on adversity. Attack seeks to throw, turning down, or even immobilizing the opponent; judo defense aims to avoid being thrown or immobilized (Molina & Villammon, 2000). The offensive strategy purposes scoring points; the defensive strategy focuses on avoiding conceding. Judo is a technical sport because of the various skills composing its classifications (Dopico et al., 2014; Segedi & Sertic, 2014). This classification is a set of throwing techniques (Nage-waza) and ground techniques (Ne-waza). Judoka bases these strategies on throwing skills that include arm techniques (Te-waza), leg techniques (Ashi-waza), hip techniques (Koshi-waza), and sacrifice techniques (Sutemi-waza) (Daigo, 2005). Strategically, the attacker should adapt each skill to the opponents’ laterality (Santos et al., 2015). Yaneva and Lukanova (2019) argue the lack of development of physical qualities affects the learning process of judo techniques. Further, the repertoire is this technical variety, composed of a wide range of movements linked to specific and adequate grips (Kumi-kata). Its construction requires years of education and training. Official judo matches are the best way to test their mastery. This varied technical repertoire is essential to build a performance attack system; it could offer adequate solutions to beat the adversity (Roux, 2019).

Effectiveness allows for appreciating sports performance. It provides information on the level and quality of motor efficiency (Hughes & Bartlett, 2004). This gestural effectiveness corresponds to expert knowledge, which is indispensable for triggering the decision, coinciding with the appropriate temporal conditions (Macquet & Fleurance, 2006). It is fundamental to study the activity of the judoka in the official competition. Its usefulness lies in the possibility of modeling it and integrating it into the training process as a support tool to prepare for competitions (Heinisch & Oswald, 2007). Recently, researchers have shown an increased interest in judo medalists. They analyzed temporal structure, technical variety, tactical choices, and other parameters of their accomplishment in high-level competitions (Table 1). Modeling the attack system is of interest only if the analysis covers several matches (Ait Ali Yahia, 2014; Kons et al., 2018; Ait Ali Yahia & Calmet, 2019; Ait Ali Yahia, 2020). To analyze only Olympic champions (Tabakov, 2009) or World champions (Adam & Smaruj, 2013; Pujszo et al., 2017) is questionable. Finals round matches' studies also do not determine the judokas model (Boguszewski & Boguszewska, 2006; Boscolo Del Vecchio et al., 2003; Martinez Moya & Tartabull, 2003; Boguszewski, 2006, 2010, 2011a, 2011b, 2014, 2016). This approach did not favor capturing the complexity of the judoka attack system through a single competition. To date, few studies have investigated technical and tactical variables of Olympic medalists. The analysis of all matches makes it possible to describe them with a great deal of precision. What are the principal features of Olympic medalists' performance? Comparing four successive Olympic Games (Athens 2004, Beijing 2008, London 2012, and Rio de Janeiro 2016) through some indexes allows defining these characteristics. The present study aimed to identify the technical-tactical profile of the male medalists. It considers their offensive activity, offensive and defensive effectiveness, attack frequency, and technical repertoire. Thus, we hypothesized the medalists could perform more attacks with better efficiency thanks to high technical variability than their opponents.

Table 1: Studies of medalists: E.CH (European Championships); W.CH (World Championships); OG (Olympics Games); IT (International Tournaments); Men (M); Woman (W).

Autor (s)	Year	Event (s)	Judokas	Sex	Match	Category
Ait Ali Yahia.A	2014	OG. 2012	Medalists	M	21	1
Kons et al.	2018	OG. 2016	Medalists	M&W	608	7
Ait Ali Yahia.A & Calmet.M	2019	OG. 2004-2012	Medalists	M	62	1
Ait Ali Yahia.A	2020	OG.2004-2016	Medalists	M	575	7
Tabakov.S	2009	OG. 2008	Olympic Champions	M	34	7
Adam.M & Smaruj.M	2013	W.CH. 2010	World Champions	M	50	8
Pujszo et al.	2017	W.CH.2015	World Champions	M	41	7
Boguszewski.D & Boguszewska.K	2006	E.CH. 2005	Finalists	M&W	14	7
Boscolo Del Vecchio et al.	2003	W.CH. 2003	Finalists	M	7	7
Martinez Moya.P & Tartabull.J	2003	OG. 2000	Finalists	M	1	1
Boguszewski.D	2006	OG. 88-92	Finalists	M	2	2
Boguszewski.D	2010	OG, W.CH, IT. 2005-2008	Finalists	M&W	54	7
Boguszewski.D	2011a	OG, W.CH, IT. 2005-2010	Finalists	M	40	7
Boguszewski.D	2011b	OG, W.CH, IT. 2005-2008	Finalists	M&W	56	7
Boguszewski.D	2014	OG, W.CH, IT. 2007-2010	Finalists	M	41	7
Boguszewski.D	2016	OG. 2016	Finalists	M&W	14	7

Methods and Material

Participants

The research material comprised video recording (52 hours, 9 minutes, and 25 seconds) of the four Olympic tournaments (Athens, Beijing, London, and Rio de Janeiro). We selected all the four medalists (gold, silver, and two bronze) and their opponents in all seven male weight categories of these competitions as subjects of this research. Their performances are a testament to the ability of each weight category. The current research analyzed 575 matches: extra-lightweight (-60 kg) = 82; half-lightweight (-66 kg) = 81; lightweight (-73 kg) = 85;

half-middleweight (-81 kg) = 82; middleweight (-90 kg) = 82; half-heavyweight (-100 kg) = 81, and heavyweight (+100 kg) = 82. Data collected from the eliminatory matches, quarter-final, semi-final, repechage, third place, and final. The sample included 112 male medalists and their opponents carrying out 3,664 and 3,086 throwing actions, respectively (Table 2).

Table 2: Olympic medalists' data

	Category	Medalist	Match	Medalists Actions	Opponents Actions
Athens	7	28	151	1002	822
Beijing	7	28	143	993	793
London	7	28	142	886	777
Rio	7	28	139	783	694
Mean	7.0	28.0	143.8	916.0	771.5
S.Deviation	0.0	0.0	5.1	103.1	54.9

Procedure

Dynamism has characterized the offensive judo activity. It symbolized the character of the medalists' engagement during their matches (Boguszewski, 2014). Top-level preparedness is a necessity for taking part in the IJF competition system. This dynamism expressed the progress reached by the various preparations required for elite judo. As a fundamental variable of the matches observed from a quantitative perspective, it reflected the performing quality. Delayed observation is the best means for collecting technical and tactical data. The International Olympic Committee (IOC) has provided renewable authorization to consult the Olympic Multimedia Library since 2014 (http://extranet.olympic.org). The study of medalists of Athens 2004, Beijing 2008, and London 2012 was a part of our Doctoral dissertation (Ait Ali Yahia, 2015). Two years later, we analyzed medalists Rio 2016 matches. We re-tested these data using the judo competition analysis sheet in Excel (Ait Ali Yahia, 2019, 2020).

Takahashi et al. (2005) describe three phases composing each throwing action. First, breaking the balance of the opponent (Kuzushi); second, positioning the body (Tsukuri); and third, throwing the opponent (Kake). Unsuccessful action was an attempted skill, which respected these three phases without scoring points. However, a successful one was a performed skill that scored points awarded by the referee. The offensive activity was the sum of unsuccessful and successful actions. The current research considered the following parameters: total match duration, offensive volume, technical groups, and overall efficient actions. Intra-Olympic (cross-sectional study) and inter-Olympic (longitudinal study) comparisons measured their effect on the medalists' offensive activity.

Measures

The Reviewing literature on judo has highlighted different indexes used, in recent years, to analyze the judokas' performance. The effectiveness index gives relevant information on the character of the actions performed by the athlete. But it cannot explain his performance (Nadeau & Martel, 2006). The present study determined the technical-tactical profile of medalists through the offensive activity index and effectiveness index (Adam et al., 2011b), combativeness index (Tabakov, 2009), and variability index. Table 3 shows these indexes.

Table 3: Technical and tactical indexes.

Index	Parameter	Calculation
Offensive activity	Medalists' attack activity / match	Am = Medalists' total actions / observed matches
	Medalists' defense activity / match	Ao = Opponents' total actions / observed matches
	Activity index	A = Am-Ao
Effectiveness	Medalists' offensive effectiveness	Em = Effective actions / total actions * 100
	Medalists' defensive effectiveness	Ed = Defense before match (100%) - opponents' offensive effectiveness (Eo)
	Overall effectiveness	Eg = Em+Ed
Combativeness	Medalists' attack frequency	Fm = Medalists' total actions / matches' total duration
	Opponents' attack frequency	Fo = Opponents' total actions / matches' total duration
	Attack frequency index	F = Fm / Fo
Variability	Technical repertoire	Total techniques mastered by medalists

Statistical analysis

Anderson-Darling test assessed the normality of the data. The descriptive analysis determined the minimum, the maximum, the mean, the standard deviation, the median, the first quartile, and the third quartile of all these variables. One way analysis of variance made multiple inters and intra-Olympic comparisons to measure any differences followed by the post hoc Tukey test. Unbiased estimator ω^2 (strong effect =.15; moderate effect =.06; small effect =.01) measured the effect size of the analysis of variance (Keppel, 1991). We set the significance level at .05. The XLSTAT 2019.1.2 software carried out all analyses.

Results

Medalists' offensive activity

Table 4 presents the attack activity, defense activity, attack activity per match, defensive activity per match, and their difference of the medalists. No difference was found on the medalists' attack activity (F (2.689) =2.331; p=.078; ω^2=.000 [small effect]), defense activity (F (2.689) =0.796; p=.499; ω^2=.000 [small effect]), attack activity per match (F (2.689) =1.498; p=.219; ω^2=.000 [small effect]), defense activity per match (F (2.689) =.366; p= .777; ω^2=.000 [small effect]), and their difference (F (2.689) =.541; p=.655; ω^2=.000 [small effect]). Means of these variables were homogeneous.

Table 4: Comparison of medalists offensive activity: Ma: Medalists' attack activity; Md: Medalists' defense activity; Am: Medalists attack activity/match; Ao: Medalists defense activity/match; A: Difference between attack and defense activities; Min: Minimum; Max: Maximum; Med: Median; Q_1: first quartile; Q_3: third quartile; *: No difference; (P<.05).

		Athens	Beijing	London	Rio	M±SD	F	P	ω²
Ma	(Min; Max)	(19.0; 60.0)	(16.0; 81.0)	(10.0; 61.0)	(6.0; 53.0)	32.7±13.0	2.331*	0.078	0.000
	Med (Q_1; Q_3)	33.0 (25.5; 44.5)	37.5 (24.0; 42.3)	29.0 (22.5; 41.5)	27.0 (21.5; 35.3)				
	M±SD	35.8±12.8	35.5±14.6	31.6±12.9	28.0±10.4				
Md	(Min; Max)	(8.0; 51.0)	(6.0; 57.0)	(9.0; 55.0)	(5.0; 42.0)	27.6±11.6	0.796*	0.499	0.000
	Med (Q_1; Q_3)	27.0 (22.8; 35.3)	28.5 (14.0; 38.5)	23.0 (20.0; 35.3)	24.0 (21.0; 30.3)				
	M±SD	29.4±10.0	28.3±14.2	27.8±13.0	24.8±8.4				
Am	(Min; Max)	(3.5; 11.4)	(3.2; 16.2)	(2.0; 12.2)	(1.2; 10.6)	6.4±2.4	1.498*	0.219	0.000
	Med (Q_1; Q_3)	6.2 (5.1; 8.1)	6.8 (4.9; 8.1)	5.8 (4.4; 7.9)	5.4 (4.3; 7.1)				
	M±SD	6.6±2.3	6.9±2.8	6.2±2.6	5.6±2.1				
Ao	(Min; Max)	(1.6; 8.6)	(1.2; 9.6)	(1.8; 11.0)	(1.3; 8.4)	5.3±2.2	0.366*	0.777	0.000
	Med (Q_1; Q_3)	5.3 (4.2; 6.6)	5.6 (2.8; 7.7)	4.6 (4.0; 7.1)	4.8 (4.2; 6.1)				
	M±SD	5.4±1.7	5.5±2.6	5.5±2.5	5.0±1.7				
A	(Min; Max)	(4.4; 5.8)	(5.2; 9.2)	(4.0; 5.0)	(3.0; 5.6)	2.2±1.7	0.541*	0.655	0.000
	Med (Q_1; Q_3)	1.7 (0.4; 2.7)	1.7 (0.6; 2.5)	0.9 (0.7; 2.4)	0.6 (1.2; 2.4)				
	M±SD	1.2±2.3	1.4±3.2	0.8±2.5	0.6±2.4				

Inter-Olympic technical groups' offensive activity

Table 5 shows technical groups' offensive activity of medalists. In Athens, technical groups' offensive activity of medalists differed (F (2.689) =11.594; p=.000; ω^2=.221 [strong effect]). Post hoc Tukey test revealed that Te-waza was more attempted than Sutemi-waza and Koshi-waza; Ashi-waza more than Koshi-waza. Concerning medalists of Beijing, ANOVA corroborated a difference for the technical groups' offensive activity (F (2.689) =15.191; p=.000; ω^2=.275 [strong effect]). In this competition, Te-waza was more carried out than Ashi-waza, Sutemi-waza, and Koshi-waza; Ashi-waza more than Koshi-waza; Sutemi-waza more than Koshi-waza. Also, technical groups' offensive activity of London medalists differed significantly (F (2.689) =17.119; p=.000; ω^2=.302 [strong effect]). Post hoc Tukey test confirmed that Te-waza was more used than Sutemi-waza and Koshi-waza; Ashi-waza more than Sutemi-waza and Koshi-waza. Statistical analysis showed a significant difference in Rio (F (2.689) =18.283; p=.000; ω^2=.316 [strong effect]). However, Te-waza was more executed than Ashi-waza and Koshi-waza; Ashi-waza more than Sutemi-waza and Koshi-waza. Regarding the descriptive analysis, Te-waza showed the highest values in Athens and Beijing, Te-waza and Ashi-waza in London, and Ashi-waza in Rio.

Table 5: Technical groups' offensive activity: TW (Te-Waza), AW (Ashi-Waza), SW (Sutemi-Waza), KW (Koshi-Waza); Min: Minimum; Max: Maximum; Med: Median; Q_1: first quartile; Q_3: third quartile; **: Significant difference; (P<.05).

		TW	AW	SW	KW	F	P	ω²
Athens	(Min; Max)	(0.0; 48.0)	(2.0; 42.0)	(0.0; 35.0)	(0.0; 10.0)	11.594**	0.000	0.221
	Med (Q_1; Q_3)	12.5 (6.8; 20.5)	9.5 (4.0; 14.3)	6.5 (2.0; 9.3)	1.0 (0.0; 2.5)			
	M±SD	14.9±12.5	11.2±8.7	7.8±7.6	1.9±2.6			
Beijing	(Min; Max)	(0.0; 39.0)	(1.0; 26.0)	(0.0; 37.0)	(0.0; 8.0)	15.191**	0.000	0.275
	Med (Q_1; Q_3)	13.0 (8.0; 22.3)	5.5 (2.0; 10.3)	9.5 (3.8; 13.3)	1.0 (0.0; 2.0)			
	M±SD	16.1±11.2	8.0±7.4	9.9±8.9	1.5±2.2			
London	(Min; Max)	(0.0; 41.0)	(0.0; 40.0)	(0.0; 15.0)	(0.0; 4.0)	17.119**	0.000	0.302
	Med (Q_1; Q_3)	9.0 (3.8; 18.5)	12.0 (6.8; 17.0)	5.0 (0.8; 6.5)	0.5 (0.0; 2.0)			
	M±SD	12.3±10.5	13.6±10.3	4.8±4.2	1.0±1.3			
Rio	(Min; Max)	(0.0; 30.0)	(0.0; 35.0)	(0.0; 18.0)	(0.0; 10.0)	18.283**	0.000	0.316
	Med (Q_1; Q_3)	6.0 (1.0; 12.5)	12.5 (6.0; 21.3)	4.5 (1.0; 10.0)	0.0 (0.0; 1.0)			
	M±SD	7.6±8.3	13.9±9.0	5.6±5.0	0.9±1.9			

Medalists' offensive and defensive effectiveness

Table 6 presents the comparison of medalists' offensive, defensive, and overall effectiveness. The analysis of variance revealed a significant difference in the medalists' offensive effectiveness (F (2.689) =4.270; p=.007; ω^2=.081 [moderate effect]). The post hoc Tukey test affirmed that medalists of Athens were more effective than medalists of London. Concerning the descriptive analysis, the medalists in Athens presented the highest values. Also, there was a significant difference among the medalists' defensive effectiveness (F (2.689) =3.642; p=.015; ω^2=.066 [moderate effect]). The medalists of Athens were more defensive than the medalists of Beijing and London. The medalists of London showed the highest values. No difference in overall effectiveness was found (F (2.689) =1.668; p=.178; ω^2=.000 [small effect]). The means of this variable were identical.

Table 6: Medalists' offensive and defensive effectiveness: Em: Offensive effectiveness; Ed: Defensive effectiveness; Min: Minimum; Max: Maximum; Med: Median; Q_1: first quartile; Q_3: third quartile; *: No difference; **: Significant difference; (P<.05).

		Athens	Beijing	London	Rio	M±SD	F	P	ω²
Em	(Min; Max)	(7.1; 40.0)	(2.5; 42.1)	(0.0; 31.3)	(4.3; 66.7)	15.7±9.9	4.270**	0.007	0.081
	Med (Q_1; Q_3)	18.8 (11.9; 27.3)	13.4 (9.5; 20.2)	10.5 (6.5; 13.9)	15.0 (9.6; 18.8)				
	M±SD	20.0±9.9	15.6±8.8	11.0±6.8	16.3±11.8				
Ed	(Min; Max)	(72.4; 100.0)	(88.9; 100.0)	(90.5; 100.0)	(85.7; 100.0)	95.7±4.2	3.642**	0.015	0.066
	Med (Q_1; Q_3)	94.4 (92.1; 96.1)	97.2 (92.8; 100.0)	96.4 (95.2; 100.0)	96.6 (93.6; 100.0)				
	M±SD	93.5±5.3	96.4±3.7	96.8±2.8	95.9±4.0				
Eg	(Min; Max)	(87.6; 135.8)	(99.6; 133.2)	(97.4; 126.7)	(94.3; 161.9)	111.4±10.5	1.668*	0.178	0.000
	Med (Q_1; Q_3)	111.2 (105.2; 124.3)	110.1 (105.2; 117.7)	108.7 (101.0; 111.1)	110.6 (105.7; 115.2)				
	M±SD	113.5±12.1	112.1±8.8	107.7±6.9	112.3±12.7				

Intra-Olympic technical groups' effectiveness

Table 7 shows the comparison of technical groups' effectiveness. In Athens, the medalists technical groups' effectiveness differed (F (2.689) =8.444; p=.000; ω^2=.166 [strong effect]). The Post hoc Tukey test confirmed that Te-waza, Ashi-waza, and Sutemi-waza were more effective than Koshi-waza. Regarding the technical groups of Beijing medalists, their effectiveness differed significantly (F (2.689) =7.146; p=.000; ω^2=.141 [moderate effect]). Also, Te-waza, Ashi-waza, and Sutemi-waza were more effective than Koshi-waza. As for the technical groups of London medalists, their effectiveness differed (F (2.689) =7.914; p=.000; ω^2=.156 [strong effect]). Te-waza was more effective than Sutemi-waza and Koshi-waza; Ashi-waza more than Koshi-waza. There was a significant difference in Rio (F (2.689) = 8.097; p=.000; ω^2=.160 [strong effect]). Te-waza, Ashi-waza, and Sutemi-waza were more effective than Koshi-waza. From the descriptive analysis, it is apparent that Te-waza presented the highest values of effectiveness in Athens, Beijing, and London. In Rio, Ashi-waza was the most effective.

Table 7: Technical groups' effectiveness: TW (Te-Waza), AW (Ashi-Waza), SW (Sutemi-Waza), KW (Koshi-Waza); Min: Minimum; Max: Maximum; Med: Median; Q_1: first quartile; Q_3: third quartile; **: Significant difference; (P<.05).

		TW	AW	SW	KW	F	P	ω^2
Athens	(Min; Max)	(0.0; 9.0)	(0.0; 5.0)	(0.0; 6.0)	(0.0; 4.0)	8.444**	0.000	0.166
	Med (Q_1; Q_3)	2.0 (1.0; 4.0)	1.0 (1.0; 2.3)	1.0 (0.8; 2.3)	0.0 (0.0; 0.0)			
	M±SD	2.7±2.6	1.7±1.4	1.7±1.6	0.4±0.9			
Beijing	(Min; Max)	(0.0; 5.0)	(0.0; 4.0)	(0.0; 5.0)	(0.0; 2.0)	7.146**	0.000	0.141
	Med (Q_1; Q_3)	1.5 (0.0; 3.0)	1.0 (0.0; 2.0)	1.0 (0.0; 2.3)	0.0 (0.0; 0.0)			
	M±SD	1.8±1.7	1.2±1.4	1.4±1.4	0.3±0.5			
London	(Min; Max)	(0.0; 5.0)	(0.0; 4.0)	(0.0; 2.0)	(0.0; 2.0)	7.914**	0.000	0.156
	Med (Q_1; Q_3)	1.0 (0.0; 2.0)	1.0 (0.0; 2.0)	0.0 (0.0; 1.0)	0.0 (0.0; 0.0)			
	M±SD	1.4±1.4	1.1±1.3	0.5±0.7	0.2±0.6			
Rio	(Min; Max)	(0.0; 6.0)	(0.0; 5.0)	(0.0; 3.0)	(0.0; 2.0)	8.097**	0.000	0.160
	Med (Q_1; Q_3)	1.0 (0.0; 1.0)	1.5 (1.0; 2.0)	1.0 (0.0; 2.0)	0.0 (0.0; 0.0)			
	M±SD	1.1±1.6	1.6±1.4	1.0±0.9	0.1±0.4			

Inter-Olympic technical groups' effectiveness

No significant difference of effectiveness of the technical groups was found in Athens (F (2.689) =1.276; p=.286; ω^2=.000 [small effect]), Beijing (F (2.689) =0.334; p=.801; ω^2=.000 [small effect]), London (F (2.689) =0.768; p=.514; ω^2=.000 [small effect]), and Rio (F (2.689) =1.446; p=.233; ω^2=.000 [small effect]). Regarding these technical groups, their means were homogeneous.

Combativeness of medalists and their opponents

Table 8 presents the medalists' attack frequency, opponents' attack frequency, and their ratio. There was a significant difference between the medalists' combativeness (F (2.689) =12.164; p=.000; ω^2=.230 [strong effect]). Regarding the Post hoc Tukey test, medalists of Athens were more offensives than medalists of London and Rio; medalists of Beijing more than medalists of London. The medalists of Athens presented the highest values. Also, their opponents showed a significant difference of combativeness (F (2.689) =6.652; p=.000; ω^2=.131[moderate effect]). Opponents of Athens were more offensives than opponents of Beijing, London, and Rio. Opponents of Athens proved the highest values. However, no significant difference was found in the ratio of medalists and their opponents (F (2.689)

=1.133; p=.339; ω^2=.000 [small effect]). During these four competitions, medalists led a mean of 1.7±.6 attacks/min, while their opponents' 1.4±.5 attacks/min.

Table 8: Attacks frequencies of medalists and their opponents: Fm: Medalists' attack frequencies, Fo: Opponents' attack frequencies; F: ratio of medalists and opponents attack frequencies; Min: Minimum; Max: Maximum; Med: Median; Q_1: first quartile; Q_3: third quartile; *: No difference; **: Significant difference; (P<.05).

		Athens	Beijing	London	Rio	M±SD	F	P	ω^2
Fm	(Min; Max)	(1.0; 3.3)	(1.0; 2.8)	(0.5; 2.2)	(0.5; 3.0)	1.7±0.6	12.164**	0.000	0.230
	Med (Q_1; Q_3)	2.1 (1.8; 2.5)	1.8 (1.3; 2.1)	1.4 (0.9; 1.7)	1.5 (1.1; 1.8)				
	M±SD	2.1±0.6	1.8±0.5	1.3±0.5	1.5±0.6				
Fo	(Min; Max)	(1.0; 3.3)	(0.4; 2.6)	(0.4; 2.1)	(0.3; 1.8)	1.4±0.5	6.652**	0.000	0.131
	Med (Q_1; Q_3)	1.6 (1.3; 1.9)	1.4 (0.9; 1.7)	1.1 (0.9; 1.5)	1.4 (1.1; 1.6)				
	M±SD	1.7±0.5	1.4±0.6	1.2±0.5	1.3±0.4				
F	(Min; Max)	(0.5; 2.6)	(0.4; 5.8)	(0.5; 2.6)	(0.3; 5.0)	1.4±0.8	1.133*	0.339	0.000
	Med (Q_1; Q_3)	1.4 (0.9; 1.5)	1.2 (0.9; 2.2)	1.2 (0.9; 1.7)	1.1 (0.8; 1.7)				
	M±SD	1.3±0.5	1.6±1.1	1.3±0.5	1.3±0.9				

Inter-Olympic medalists' technical repertoire

The technical repertoire produced by the medalists during their contests did not show any difference (F (2.689) =1.534; p=.210; ω^2=.000 [small effect]). The means of these technical repertoires in Athens (11.6±3.4 techniques), Beijing (11.4±4.0 techniques), London (10.2±3.1 techniques), and Rio (9.8±4.6 techniques) were similar.

Intra-Olympic technical groups' repertoire

Table 9 shows the technical groups' repertoires. In Athens, technical groups' repertoires presented a significant difference (F (2.689) =25.400; p=.000; ω^2=.395 [strong effect]). Post hoc Tukey test confirmed that Te-waza was more preferred than Sutemi-waza and Koshi-waza; Ashi-waza more than Sutemi-waza and Koshi-waza; Sutemi-waza more than Koshi-waza. Also, there was a significant difference in Beijing (F (2.689) =20.220; p=.000; ω^2=.340 [strong effect]). Te-waza was more preferred than Sutemi-waza and Koshi-waza; Ashi-waza and Sutemi-waza more than Koshi-waza. Concerning London, ANOVA revealed a significant difference of the technical groups' repertoires (F (2.689) =24.296; p=.000; ω^2=.384 [strong effect]). For the Post hoc Tukey test, Te-waza was more preferred than Ashi-waza and Koshi-waza; Ashi-waza more than Sutemi-waza and Koshi-waza; Sutemi-waza more than Koshi-waza. Statistical analysis corroborated a difference for the technical groups' repertoires in Rio (F (2.689) =28.609; p=.000; ω^2=.425 [strong effect]). Te-waza was more preferred than Ashi-waza, which was more than Sutemi-waza and Koshi-waza. Medalists chose Sutemi-waza more than Koshi-waza. From the descriptive analysis, it is apparent that Ashi-waza is the most preferred/d technical group in Athens, London, and Rio. In Beijing, Te-waza is the most executed.

Table 9: Technical groups' repertoire: TW (Te-Waza), AW (Ashi-Waza), SW (Sutemi-Waza), KW (Koshi-Waza); Min: Minimum; Max: Maximum; Med: Median; Q_1: first quartile; Q_3: third quartile; **: Significant difference; (P<.05).

		TW	AW	SW	KW	F	P	ω^2
Athens	(Min; Max)	(0.0; 9.0)	(1.0; 8.0)	(1.0; 7.0)	(0.0; 3.0)	25.400**	0.000	0.395
	Med (Q_1; Q_3)	3.5 (2.0; 6.0)	4.0 (3.0; 5.3)	2.0 (1.8; 3.0)	0.5 (0.0; 1.0)			
	M±SD	4.0±2.4	4.3±1.8	2.6±1.5	0.7±0.8			
Beijing	(Min; Max)	(0.0; 9.0)	(1.0; 8.0)	(0.0; 7.0)	(0.0; 3.0)	20.220**	0.000	0.340
	Med (Q_1; Q_3)	4.0 (3.0; 6.0)	3.0 (2.0; 5.0)	3.0 (1.8; 4.0)	1.0 (0.0; 1.0)			
	M±SD	4.4±2.2	3.3±2.0	2.9±1.9	0.8±0.8			
London	(Min; Max)	(0.0; 6.0)	(0.0; 11.0)	(0.0; 6.0)	(0.0; 3.0)	24.296**	0.000	0.384
	Med (Q_1; Q_3)	2.0 (1.8; 3.0)	5.0 (3.0; 6.0)	2.5 (0.8; 3.0)	0.5 (0.0; 1.0)			
	M±SD	2.6±1.5	4.6±2.3	2.3±1.7	0.8±0.9			
Rio	(Min; Max)	(0.0; 4.0)	(0.0; 10.0)	(0.0; 7.0)	(0.0; 3.0)	28.609**	0.000	0.425
	Med (Q_1; Q_3)	1.0 (1.0; 3.0)	5.0 (3.0; 6.3)	2.0 (1.0; 5.0)	0.0 (0.0; 1.0)			
	M±SD	1.6±1.3	5.0±2.6	2.7±2.3	0.5±0.7			

Discussion

This study set out four purposes: i) to assess the offensive activity; ii) to identify offensive and defensive effectiveness; iii) to compare attack frequencies; and iv) to determine the technical repertoire. The main findings of the present study provide evidence of the offensive particularity of Olympic medalists. They carried out 6.4±2.4 attacks/match, while their opponents performed 5.3±2.2 attacks/match. Their frequency of attacks remains stable over the four Olympic Games. These outcomes are contrary to previous studies. As a comparison, high-level judo athletes performed 4.4 actions in London 2012 (European Judo Union, 2012); 5.5 in the World championships 2011 (Stankovic et al., 2015); 6.6 in finals and semi-finals of 12 tournaments (Courel et al., 2014), 7.2 in World, European, and Olympics competitions (Bocioaca, 2014). Also, World champion 2010 and 2015 performed 10.6 actions (Adam & Smaruj, 2013), while the heaviest category carried out 10.7 actions in London 2012 (Pujszo et al., 2017). A high frequency of offensive activities does not always ensure outstanding performance (Ait Ali Yahia, 2019). The temporal meticulousness in preparing each attack is the principal characteristic of these medalists (Miarka et al., 2018). Precision, accuracy, and speed of the action are essential elements of their offensive strategy (Lech et al., 2007). Strategic mastery and tactical components, ensuring a better combat quality, show this precision (Scurati et al., 2006). The index of offensive activity does not discriminate at this competition level between the medalists and their opponents. Regarding the technical groups, medalists produced a typical configuration for each competition. However, Te-waza was the most solicited in Athens and Beijing, which it shared first place with Ashi-waza in London; in Rio, Ashi-waza was the most performed. It is interesting to note that the offensive activity of medalists changed progressively from using Te-waza to Ashi-waza. Because less often attempted, Koshi-waza remains negligible in the medalists' attack system. Boguszewski (2011a, 2016) has confirmed a similar tendency. The opponents' defense can be the element that affects its contribution. Sertic et al. (2007) argued that Koshi-waza techniques raise a significant risk of counter-attacking when the Kuzushi and Tsukuri phases are not adequate. The level of physical maturity influences the judokas' technical choices. Seniors privileged complex technique as Te-waza and Sutemi-waza, while juniors gave more importance to Koshi-waza and Ashi-waza (Segedi & Sertic, 2012). Even Jagiello et al. (2014) noticed that 17-19-year-old judokas preferred first Koshi-waza, then Te-waza, Sutemi-waza, and Ashi-waza.

Medalists can carry out technical actions in a complex and defensively organized competitive context. Technical effectiveness depends on the strategy implemented by the medalists following regulations in force. IJF refereeing rules revisions undermine attack system and effectiveness, which reached the lowest level in the London Olympic Games (IJF, 2010). In these four competitions, medalists registered an effectiveness of 15.7±9.9%. Precision, timing, strength, speed, and power are factors that can explain the quality of their technical mastery (Adam & Smaruj, 2013). This finding is contrary to earlier studies. Top judo athletes produced an effectiveness of 7.4% in 40 finals held between 2005-2010 (Boguszewski, 2011a); 8.0±1.5% by male judokas in Rio 2016 (Kons et al., 2018); 8.7% by Olympic male champions of London 2012 (Adam et al., 2013); 8.7% in 150 matches organized between 2010-2012 (Bocioaca, 2014); 8.9% by the World champion 2010 (Adam & Smaruj, 2013); 11.9% by World champion 2015 (Pujszo et al., 2017); 17% in London 2012 (EJU, 2012); 18.6% in World Championships 2011 (Stankovic et al., 2015); and 28.4±4.2% by Olympic champions 2008 (Tabakov, 2009). The particular context of major sporting events, the status of athletes taking part in these competitions, and their level of technical-tactical preparations are among the factors affecting these efficiencies. Deterioration of one or more phases of the technical action may explain its lack of effectiveness. Also, gesture quality, technical precision, speed execution, technical variety, sequencing capacity, and movement quality are principal elements of this technical production. Perfect technique execution depends on spatial and temporal division, fluid movement, and good accuracy (Perez Ramirez, 2010). The development of postural strategies is a fundamental element to consider for achieving performance (Paillard, 2019). The elite judokas index effectiveness decreases from the eliminatory round to the finals (Ceylan, 2020). Concerning the technical groups, Te-waza still the most effective for medalists' attack systems during the first three Olympic Games. Adam et al. (2013) confirmed this Te-waza effectiveness tendency. Ashi-waza takes first place in Rio. Previous studies have reported this Ashi-waza increasing effectiveness (Adam et al., 2012, 2016; Miller et al., 2015). Losing Te-waza leading place is a direct consequence of IJF referee injunctions (IJF, 2013). Takahashi et al. (2005) defined excellent defense as "strong stand-up judo and not overly defensive or negative judo". The quality of the defensive effectiveness of 95.7±4.2% is a forceful point of these medalists. The London medalists recorded the best score on defensive activity. This defense does not equal that established by other analyses (Adam et al., 2011a; Boguszewski, 2014). It remains efficient in neutralizing the offensive potential of the opponents. The effective defense should neutralize the approach and handgrip that may limit the opponent's attacking possibility (Mota Barreto et al., 2019). In combat sports, for defense or attack, the combatant positioned his body to the opponent according to various approaches (Krabben et al., 2019). The perfect judoka is that possesses active attacks and solid defense (Takahashi et al., 2005). Medalists performed a combativeness of 1.7±.6 attack/min. However, this outcome contradicts 2.9 attacks/min of the World champions 2010 (Adam & Smaruj, 2013) and 2.0 attacks/min of the Beijing Olympic champions (Tabakov, 2009). A high combativeness allows medalists to avoid being sanctioned by referees. This offensive approach aims, in addition, the referee to punish opponents for their impossibility of attacking (Escobar-Molina et al., 2014). Increasing the number of attacks can exhaust the opponent while weakening his defense system. The dominated opponent becomes more passive and undergoes the fight (Riguidel, 2010). Sanctions given by the referee, resulting from a high rhythm of attacks, are also a tactical means of winning judo matches.

The technical profile is among the factors contributing to success. However, the elite judoka cannot assert himself in the competition through a limited technique number. Also, the technical variability increases the chance of scoring. Medalists mastered 10.8±3.9 techniques during these four events. It is a scathing response to coaches suggesting a repertoire of 5 to 7 techniques (Santos et al., 2015). IJF referee rules revisions affected the repertoire of medalists, which declined between the first and fourth competition. This repertoire remains very indicative compared to earlier studies: 6 techniques for Weers (1997); 10±3 for Franchini et al. (2008); 7±1 for Tabakov (2009); and 4 to 5 for Inman (2009). Likewise, Adam et al. (2014) recommend three fundamental techniques and many supporting techniques. An extensive repertoire could defeat any defensive system. It increases the opportunities for attacking in different directions. In addition, it disrupts defense possibilities while increasing the spatial and temporal uncertainty of the opponent. Combining technical groups in the repertoire is fundamental for an effective attack system. Medalists choose Ashi-waza as the principal group in Athens, London, and Rio de Janeiro, while Te-waza in Beijing. Various studies showed this dominant tendency of Ashi-waza (Miller et al., 2015; Sacripanti, 2019; Pereira Martins et al., 2019). From the strategic standpoint, the Ashi-waza use allows the judoka not to get too close to the opponent because of a specific safety distance. Counter-attacks are difficult for the ban of hand grips below the belt. Compared to others, it is also the least risky group to attack the opponent. Sacripanti (2019) corroborated the difficulty of opponents to defend against Ashi-waza techniques. These arguments justify the choice of medalists for this group. The suggested diagnosis has shown the value of the technical-tactical indices of medalists. Coaches could use them in preparing their judokas for eventual competitions (Adam et al., 2013).

Conclusion

This study has shown that the offensive activity observed during these Olympic Games was not great. Careful preparation of attacks may be the principal reason. The offensive and defensive effectiveness is the basis of their winning. Their repertoire attested to the know-how necessary for their technical and tactical approaches for this competition level. Given its advantages, Ashi-waza became the most preferred group. Although the IJF rules affected Te-waza frequencies, its efficiency still high. However, despite the relatively limited sample, the present research adds to our understanding of judo matches of the medalists in elite competitions, providing a better discernment of their technical-tactical profile. Coaches could use these findings as references in preparedness their judokas for planned competitions. Further researches are therefore imperative to explore the impact of Ne-waza's actions and other variables as grips types and attack directions.

Disclosure statement

The author declares that there is no conflict of interest.

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