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Article

Directions of attack and their effectiveness of male judo medalists at the Olympic competitions

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Abstract: Introduction: To perform a technical action, the elite judo athlete examines the direction of attack relative to the opponent's body position. This study aimed to analyze and compare the most frequent and effective attack directions carried out by male Olympic medalists. Materials and Methods: A sample of 112 male medalists performed 3,664 attacks in four Olympic tournaments (2004–2016). ANOVA (one factor) determined inter and intra-Olympic comparisons, followed by the post hoc Bonferroni test ($p < 0.05$). Eta squared η^2 and Cohen's d calculated the effect size, respectively. Results: Olympic medalists oriented their attacks principally in right forward (30.5 ±11.3%), left forward (29.9 ±10.5%), left backward (18.8 ±8.1%), and right backward (15.8 ±6.1%). The effectiveness of right forward (25.7 ±13.1%) and left forward (26.2 ±12.5%) dominates left backward (20.5 ±10.1%) and right backward (15.5 ±9.7%), respectively. In terms of frequencies and effectiveness, the contribution of secondary directions is negligible. Conclusions: Attacking in eight orientations made the defense vulnerable. Beside the uncertainty and unpredictability, they created more points of imbalance to overcome defensive issues.

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1. Introduction

The elite judo athlete relies on spatial perception to move favorably by assessing space and distance from his opponent. Accurate identification of spatial limits allows for strategic positioning within the combat area to focus on movement launched by the opponent [1]. Developing or improving several skills is necessary for an excellent visual assessment, which can predict and prepare for what is coming. As an illustration, Torbert [2] notes focus and attention, visual tracking of a person's or object's movements, reading and predicting the movement. He also adds the distinction between the visual image and the ground, the relationship and assessment of multiple visual stimuli, and the evaluation of speed and distance. In addition, judo techniques are complex, causing simultaneous execution of different movements, in all spatial directions, against a static or moving opponent [3]. The perfect achievement of this technique depends on spatial and temporal division, fluid motion, and good precision [4]. Also, the technique is one of the main factors influencing Olympic judo performance [5]. Perez Ramirez [6] defined the sport technique as sequences of movement or partial movements not aimed at achieving performance in competitive and non-competitive situations.

Tokui-waza (favored movement) is the essential element of a judoka's attack system. Frequency, efficiency, and stability are its principal criteria. To increase complexity considerably, an elite judo athlete must perfect it in different attack directions. From the offensive standpoint, the judo champion often directs his attack to the weakest side muscle of the opponent to reduce his defensive possibilities [7]. However, throwing effectively without *kuzuchi* (imbalance) is challenging. This imbalance allows the *tori* (attacker) to

position the opponent in a vulnerable position to select the most opportune time and place for an attack [8]. He may use the opponent's resistance as a direction for his attack [9] or target its weaker defensive side [10].

Defensive actions have proven effective in high-level judo events [11–13]. Also, building offensive activity in several directions can resolve defensive issues by increasing complexity and uncertainty. This approach also weakens the opponent's defense system by creating various points of unbalance. However, to better understand how the elite judo athlete masters his technical repertoire, researchers have investigated various throwing directions. According to the literature review, throwing space is organized in different ways. Gutierrez-Santiago et al. [14] and Ait Ali Yahia [15] analyzed eight directions, Segedi [16] studied five, while other authors explored four [17–20]. Other researchers have examined respectively three directions [21], two directions [22], and one direction [4]. For the present study, it would be interesting to determine how the elite athlete oriented his offensive activity. Hence, this study aims to analyze and compare the most frequent and effective directions of attack performed by Olympic male medalists in four successive Olympic Games (Athens 2004, Beijing 2008, London 2012, and Rio de Janeiro 2016). Avoiding defensive issues required these medalists to build their offensive activity in several orientations. Thus, we hypothesized that the tendencies of attack directions did not differ at these Olympic events.

2. Materials and Methods

2.1. Partcicipants

The research analyzed combats of 112 male medalists (28 gold, 28 silver, and 56 bronze) from seven weight classes. The research material is a video recording of four successive Olympic tournaments featuring 575 combats (gold = 138, silver = 141, and bronze = 296). Also, these medalists performed 3,664 attacks (gold = 878, silver = 957, and bronze = 1829) (Table 1). The data collection was possible thanks to the International Olympic Committee via the Olympic Multimedia Library (http://extranet.olympic.org). It is worth noting that these data have been previously analyzed in other studies [23, 24].

Table 1. Data Olympics Games

	Medalists			Combats			Attacks		
	Gold	Silver	Bronze	Gold	Silver	Bronze	Gold	Silver	Bronze
Athens	7	7	14	35	35	81	229	258	515
Beijing	7	7	14	34	35	74	211	285	497
London	7	7	14	35	36	71	211	202	473
Rio	7	7	14	34	35	70	227	212	344
Total	28	28	56	138	141	296	878	957	1829

2.2. Ethics

Examining primary data collected during sports competitions by structured observation does not raise any ethical problems. We proceeded without seeking permission because consent is challenging, and the advantages of the proposed study outweigh any potential drawbacks [25]. However, we did not collect sensitive data that third parties could misuse. The confidentiality and anonymity of all participants were guaranteed.

2.3. Measures

The current study focused on how male Olympic medalists spatially oriented their *nage-waza* offensive activity. The throwing area encompasses four principal (backward, forward, left, and right) and four secondary (left backward, left forward, right backward, and right forward) directions (Figure 1). Each direction was defined by the direction of unbalancing the opponent. The direction of the left backward is breaking the balance in the left-back corner. Left forward is the direction of unbalancing in the left-front corner. Right backward is losing balance in the right-back corner. Right forward is when unbalancing the opponent in the right-front one. Frequencies and effectiveness of each direction of attack were presented in percentage values (%). A direction is effective if the attack scores points.

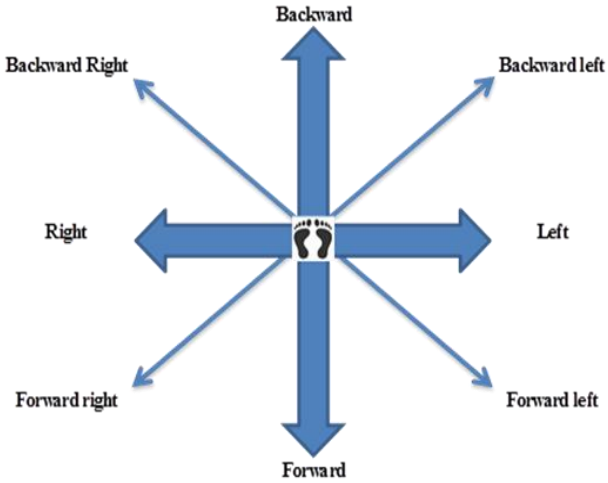

Figure 1. Directions of attack

2.4. Statistical Analysis

The Kolmogorov-Smirnov test assessed the normality of the collected data, while the Levene test showed equal variance. Descriptive data are presented as maximum, minimum, median (first quartile, third quartile), mean, and standard deviation with 95% confidence intervals (95% CI). One-way ANOVA was conducted for multiple comparisons, followed by the Bonferroni test. Eta squared η^2 calculated the effect size (small = 0.01, medium = 0.06, and large = 0.14) [26]. Cohen's d determined the effect size of t student. Hopkins et al. [27] recommended the following scale of magnitudes: trivial: 0.0–0.2, small: 0.2–0.6, medium: 0.6–1.2, large: 1.2–2.0, and very large: 2.0–4.0. Data were analyzed using IBM SPSS (version 27.0.1.0, SPSS, Inc., Chicago, IL, USA) predictive analytics software. The significance level was set at 5%.

3. Results

3.1. Directions of Attack by the Olympic Cycle

Attack direction frequencies (%) by the Olympic Games are presented in Table 2. There was an effect of directions of attack in Athens ($F_{2.052}$ = 34.766, p = 0.000, η^2 = 0.530, large), Beijing ($F_{2.052}$ = 41.693, p = 0.000, η^2 = 0.575, large), London ($F_{2.052}$ = 33.689, p = 0.000, η^2= 0.522, large), and Rio ($F_{2.052}$ = 26.396, p = 0.000, η^2 = 0.461, large).

Table 2. Directions of attack distribution (%)

		R.F	L.F	R.B	L.B	R	L	F	B
Athens	(Min; Max)	(0.0; 72.5)	(3.2; 64.1)	(0.0; 51.6)	(0.0; 45.5)	(0.0; 17.1)	(0.0; 18.2)	(0.0; 3.2)	(0.0; 4.8)
	Med (Q_1; Q_3)	26.1 (11.2; 41.0)	24.7 (16.2; 39.5)	16.0 (7.1; 19.4)	18.9 (11.9; 31.6)	0.0 (0.0; 3.9)	0.0 (0.0; 3.5)	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)
	M±SD	28.2±20.4	28.9±16.4	15.8±10.8	21.2±12.6	2.6±4.1	2.7±5.4	0.2±0.7	0.3±1.0
Beijing	(Min; Max)	(0.0; 69.2)	(0.0; 74.4)	(2.6; 31.3)	(0.0; 48.6)	(0.0; 28.6)	(0.0; 7.1)	(0.0; 10.5)	(0.0; 17.6)
	Med (Q_1; Q_3)	33.0 (19.4; 42.9)	28.6 (16.0; 37.1)	17.5 (7.6; 22.7)	12.5 (6.8; 22.8)	0.0 (0.0; 2.1)	0.0 (0.0; 2.1)	0.0 (0.0; 1.4)	0.0 (0.0; 3.0)
	M±SD	31.6±16.7	30.0±17.9	16.0±9.1	15.9±12.7	2.1±5.6	1.3±2.3	1.4±2.8	1.7±3.6
London	(Min; Max)	(0.0; 90.0)	(0.0; 73.1)	(0.0; 44.4)	(0.0; 56.4)	(0.0; 10.7)	(0.0; 19.2)	(0.0; 3.6)	(0.0; 7.4)
	Med (Q_1; Q_3)	35.3 (27.0; 50.5)	23.4 (13.3; 33.5)	10.6 (6.0; 20.6)	16.8 (6.0; 26.1)	0.0 (0.0; 2.1)	0.0 (0.0; 3.7)	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)
	M±SD	37.7±22.7	25.2±18.9	15.1±12.5	17.5±14.9	1.5±3.1	2.2±4.2	0.3±0.9	0.4±1.5
Rio	(Min; Max)	(0.0; 70.6)	(0.0; 91.3)	(0.0; 35.7)	(0.0; 66.7)	(0.0; 7.1)	(0.0; 12.2)	(0.0; 0.0)	(0.0; 0.0)
	Med (Q_1; Q_3)	23.0 (13.6; 39.7)	28.6 (15.0; 50.9)	12.2 (5.7; 19.2)	11.3 (5.3; 33.6)	0.0 (0.0; 2.3)	0.0 (0.0; 3.3)	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)
	M±SD	29.1±20.7	34.4±26.8	13.8±10.2	19.8±19.8	1.3±2.2	1.6±2.8	0.0±0.0	0.0±0.0

Min: Minimum; Max: Maximum; Med: Median; Q1: first quartile; Q3: third quartile; M: Mean; SD: Standard Deviation; Right Forward: R.F; Left Forward: L.F; Right Backward: R.B; Left Backward: L.B; Right: R; Left: L; Forward: F; Backward: B.

The statistical analysis showed differences between directions of attack that occurred in Athens. Right forward produced a higher ratio compared with right backward (p = 0.001, 95% CI [2.9, 21.9], d = 0.757, medium), right (p = 0.000, 95% CI [16.1, 35.1], d = 1.736, large), left (p = 0.000, 95% CI [16.0, 35.0], d = 1.707, large), forward (p = 0.000, 95% CI [18.5, 37.5], d = 1.937, large), and backward (p = 0.000, 95% CI [18.4, 37.4], d = 1.927, large). Also, left forward reached a higher ratio than right backward (p = 0.001, 95% CI [3.5, 22.5], d = 0.939, medium), right (p = 0.000, 95% CI [16.8, 35.7], d = 2.196, very large), left (p = 0.000, 95% CI [16.7, 35.7], d = 2.144, very large), forward (p = 0.000, 95% CI [19.2, 38.2], d = 2.469, very large), and backward (p = 0.000, 95% CI [19.1, 38.0], d = 2.455, very large). In addition, right backward revealed a higher ratio compared with right (p = 0.000, 95% CI [3.7, 22.7], d = 1.621, large), left (p = 0.001, 95% CI [3.7, 22.6], d = 1.542, large), forward (p = 0.000, 95% CI [6.2, 25.1], d = 2.046, very large), and backward (p = 0.000, 95% CI [6.0, 25.0], d = 2.024, very large). However, left backward displayed a higher ratio than right (p = 0.000, 95% CI [9.1, 28.1], d = 1.993, large), left (p = 0.000, 95% CI [9.0, 28.0], d = 1.918, large), forward (p = 0.000, 95% CI [11.5, 30.5], d = 2.364, very large), and backward (p = 0.000, 95% CI [11.4, 30.4], d = 2.345, very large).

For Beijing medalists, the post hoc test revealed differences between directions of attack. Right forward presented a higher ratio compared with right backward (p = 0.000, 95% CI [6.7, 24.6], d = 1.168, medium), left backward (p = 0.000, 95% CI [6.8, 24.7], d = 1.062, medium), right (p = 0.000, 95% CI [20.6, 38.5], d = 2.382, very large), left (p = 0.000, 95% CI [21.4, 39.3], d = 2.552, very large), forward (p = 0.000, 95% CI [21.2, 39.2], d = 2.529, very large), and backward (p = 0.000, 95% CI [21.0, 38.9], d = 2.487, very large). In addition, left forward showed a higher ratio than right backward (p = 0.000, 95% CI [5.0, 23.0], d = 0.987, medium), left backward (p = 0.001, 95% CI [5.1, 23.0], d = 0.906, medium), right (p = 0.000, 95% CI [19.0, 36.9], d = 2.107, very large), left (p = 0.000, 95% CI [19.7, 37.6], d = 2.248, very large), forward (p = 0.000, 95% CI [19.6, 37.5], d = 2.228, very large), and backward (p = 0.000, 95% CI [19.4, 37.3], d = 2.193, very large). Also, right backward produced a higher ratio compared with right (p = 0.000, 95% CI [5.0, 22.9], d = 1.849, large), left (p = 0.000, 95% CI [5.7, 23.6], d = 2.220, very large), forward (p = 0.000, 95% CI [5.6, 23.5], d = 2.166, very large), and backward (p = 0.000, 95% CI [5.4, 23.3], d = 2.073, very large). In contrast, left backward displayed a higher ratio than right (p = 0.000, 95% CI [4.9, 22.8], d = 1.416, large), left (p = 0.000, 95% CI [5.7, 23.6], d = 1.605, large), forward (p = 0.000, 95% CI [5.5, 23.4], d = 1.578, large), and backward (p = 0.000, 95% CI [5.3, 23.2], d = 1.530, large).

ANOVA showed differences between directions of attack in London. Right forward presented a higher ratio compared with the left forward (p = 0.008, 95% CI [1.7, 23.1], d = 0.596, small), right backward (p = 0.000, 95% CI [11.9, 33.3], d = 1.232, large), left backward

(p = 0.000, 95% CI [9.4, 30.8], d = 1.049, medium), right (p = 0.000, 95% CI [25.4, 46.8], d = 2.233, very large), left (p = 0.000, 95% CI [24.7, 46.1]; d = 2.174, very large), forward (p = 0.000, 95% CI [26.7, 48.1], d = 2.330, very large), and backward (p = 0.000, 95% CI [26.6, 48.0], d = 2.323, very large). Furthermore, left forward showed a higher ratio than right (p = 0.000, 95% CI [13.0, 34.4], d = 1.748, large), left (p = 0.000, 95% CI [12.3, 33.7], d = 1.678, large), forward (p = 0.000, 95% CI [14.2, 35.6], d = 1.862, large), and backward (p = 0.000, 95% CI [14.2, 35.6], d = 1.855, large). In contrast, right backward reached a higher ratio compared with right (p = 0.002, 95% CI [2.9, 24.3], d = 1.486, large), left (p = 0.005, 95% CI [2.2, 23.6], d = 1.377, large), forward (p = 0.001, 95% CI [4.1, 25.5], d = 1.667, large), and backward (p = 0.001, 95% CI [4.1, 25.5], d = 1.653, large). However, left backward produced a higher ratio than right (p = 0.000, 95% CI [5.3, 26.7], d = 1.482, large), left (p = 0.000, 95% CI [4.6, 26.0], d = 1.394, large), forward (p = 0.000, 95% CI [6.5, 27.9], d = 1.628, large), and backward (p = 0.000, 95% CI [6.5, 27.9], d = 1.618, large).

Finally, regarding Rio medalists, the post hoc test revealed differences. Right forward presented a higher ratio compared with right backward (p = 0.003, 95% CI [3.2, 27.5], d = 0.942, medium), right (p = 0.000, 95% CI [15.6, 40.0], d = 1.888, large), left (p = 0.000, 95% CI [15.3, 39.7], d = 1.863, large), forward (p = 0.000, 95% CI [16.9, 41.3], d = 1.988, large), and backward (p = 0.000, 95% CI [16.9, 41.3], d = 1.988, large). Left forward showed a higher ratio than right backward (p = 0.000, 95% CI [8.5, 32.8], d = 1.018, medium), left backward (p = 0.005, 95% CI [2.5, 26.8], d = 0.620, medium), right (p = 0.000, 95% CI [20.9, 45.3], d = 1.738, large), left (p = 0.000, 95% CI [20.6, 45.0], d = 1.720, large), forward (p = 0.000, 95% CI [22.3, 46.6], d = 1.813, large), and backward (p = 0.000, 95% CI [22.3, 46.6], d = 1.813, large). Right backward displayed a higher ratio compared with right (p = 0.040, 95% CI [0.3, 24.6], d = 1.688, large), forward (p = 0.012, 95% CI [1.6, 25.9], d = 1.909, large), and backward (p = 0.012, 95% CI [1.6, 25.9], d = 1.909, large). Left backward reached a higher ratio than right (p = 0.000, 95% CI [6.3, 30.7], d = 1.311, large), left (p = 0.000, 95% CI [6.0, 30.4], d = 1.286, large), forward (p = 0.000, 95% CI [7.6, 32.0], d = 1.413, large), and backward (p = 0.000, 95% CI [7.6, 32.0], d = 1.413, large).

3.2. Inter-Analysis of Medalists' Directions of Attack

No effect of right forward ($F_{2.689}$ = 1.242, p = 0.298, η^2 = 0.033, small), left forward ($F_{2.689}$ = 0.963, p = 0.413, η^2 = 0.026, small), right backward ($F_{2.689}$ = 0.253, p = 0.859, η^2 = 0.007, small), left backward ($F_{2.689}$ = 0.662, p = 0.577, η^2 = 0.018, small), right ($F_{2.689}$= 0.613, p = 0.608, η^2 = 0.017, small), and left ($F_{2.689}$ = 0.742, p = 0.529, η^2 = 0.020, small). However, there was an effect of forward ($F_{2.689}$ = 5.256, p = 0.002, η^2 = 0.127, medium) and backward ($F_{2.689}$ = 3.768, p = 0.013, η^2 = 0.095, medium). Forward of Beijing medalists presented a higher ratio than of Athens medalists (p = 0.015, 95% CI [0.2, 2.3], d = 0.615, medium), of London medalists (p = 0.031, 95% CI [0.1, 2.2], d = 0.556, small), and of Rio medalists (p = 0.003, 95% CI [0.4, 2.5], d = 0.736, medium). Backward of Beijing medalists showed a higher ratio than of Rio medalists (p = 0.017, 95% CI [0.3, 3.0], d = 0.655, medium).

3.3. Directions Effectiveness of Attack by the Olympic Cycle

Effectiveness directions of attack values (%) by the Olympic Games are presented in Table 3. There was an effect of directions of attack effectiveness resulted in Athens ($F_{2.052}$ = 14.865, p = 0.000, η^2 = 0.325, large), Beijing ($F_{2.052}$ = 5.941, p = 0.000, η^2 = 0.161, large), London ($F_{2.052}$ = 11.441, p = 0.000, η^2= 0.270, large), and Rio ($F_{2.052}$ = 10.779, p = 0.000, η^2 = 0.259, large).

Table 3. Distribution (%) of directions of attack effectiveness

		R.F	L.F	R.B	L.B	R	L	F	B
Athens	(Min; Max)	(0.0; 83.3)	(0.0; 80.0)	(0.0; 50.0)	(0.0; 57.1)	(0.0; 30.0)	(0.0; 28.6)	(0.0; 0.0)	(0.0; 20.0)
	Med (Q_1; Q_3)	18.3 (0.0; 60.0)	18.3 (7.5; 40.0)	0.0 (0.0; 17.5)	25.0 (13.2; 40.0)	0.0 (0.0; 15.7)	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)
	M±SD	28.9±29.1	24.8±22.6	10.2±15.1	24.3±16.4	7.1±11.2	3.9±8.8	0.0±0.0	0.7±3.8
Beijing	(Min; Max)	(0.0; 66.7)	(0.0; 75.0)	(0.0; 100.0)	(0.0; 75.0)	(0.0; 50.0)	(0.0; 33.3)	(0.0; 50.0)	(0.0; 50.0)
	Med (Q_1; Q_3)	22.5 (0.0; 33.3)	25.0 (0.0; 38.1)	13.4 (0.0; 27.1)	12.5 (0.0; 21.3)	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)	0.0 (0.0; 14.3)
	M±SD	20.8±19.8	24.2±25.3	19.0±24.6	15.1±19.3	3.9±11.4	3.8±8.9	6.1±12.9	7.1±13.0
London	(Min; Max)	(0.0; 100.0)	(0.0; 100.0)	(0.0; 66.7)	(0.0; 100.0)	(0.0; 20.0)	(0.0; 50.0)	(0.0; 0.0)	(0.0; 33.3)
	Med (Q_1; Q_3)	33.3(0.0; 50.0)	10.0(0.0; 50.0)	0.0(0.0; 25.0)	0.0(0.0; 33.0)	0.0(0.0; 0.0)	0.0(0.0; 0.0)	0.0(0.0; 0.0)	0.0(0.0; 0.0)
	M±SD	35.0±33.2	23.9±29.1	14.1±20.3	17.2±25.5	0.7±3.8	3.4±11.2	0.0±0.0	2.1±7.7
Rio	(Min; Max)	(0.0; 100.0)	(0.0; 100.0)	(0.0; 75.0)	(0.0; 100.0)	(0.0; 0.0)	(0.0; 50.0)	(0.0; 0.0)	(0.0; 0.0)
	Med (Q_1; Q_3)	25.0(0.0; 50.0)	25.0(0.0; 33.3)	25.0(0.0; 35.0)	0.0(0.0; 33.3)	0.0(0.0; 0.0)	0.0(0.0; 0.0)	0.0(0.0; 0.0)	0.0(0.0; 0.0)
	M±SD	28.1±27.7	28.0±33.2	21.4±22.5	17.6±27.9	0.0±0.0	4.9±12.8	0.0±0.0	0.0±0.0

Min: Minimum; Max: Maximum; Med: Median; Q1: first quartile; Q3: third quartile; M: Mean; SD: Standard Deviation; Right Forward: R.F; Left Forward: L.F; Right Backward: R.B; Left Backward: L.B; Right: R; Left: L; Forward: F; Backward: B.

For Athens medalists, the post hoc Bonferroni test showed differences. Right forward presented a higher ratio of effectiveness compared with right backward (p = 0.001, 95% CI [5.0, 32.2], d = 0.804, medium), right (p = 0.000, 95% CI [8.1, 35.3], d = 0.987, medium), left (p = 0.000, 95% CI [11.3, 38.5], d = 1.160, medium), forward (p = 0.000, 95% CI [15.3, 42.5], d = 1.403, large), and backward (p = 0.000, 95% CI [14.5, 41.8], d = 1.356, large). Also, left forward established a higher ratio than right backward (p = 0.023, 95% CI [1.0, 28.2], d = 0.760, medium), right (p = 0.002, 95% CI [4.1, 31.3], d = 0.995, medium), left (p = 0.000, 95% CI [7.3, 34.5], d = 1.220, large), forward (p = 0.000, 95% CI [11.2, 38.4], d = 1.555, large), and backward (p = 0.000, 95% CI [10.5, 37.7], d = 1.490, large). In addition, left backward produced a higher ratio than right backward (p = 0.034, 95% CI [0.5, 27.5], d = 0.893, medium), right (p = 0.002, 95% CI [3.6, 30.8], d = 1.226, large), left (p = 0.000, 95% CI [6.8, 34.0], d = 1.550, large), forward (p = 0.000, 95% CI [10.7, 37.9], d = 2.098, very large), and backward (p = 0.000, 95% CI [10.0, 37.2], d = 1.985, large).

The post hoc Bonferroni test confirmed differences between the effectiveness of directions of attack chosen in Beijing. However, right forward presented a higher ratio compared with right (p = 0.013, 95% CI [1.8, 32.1], d = 1.048, medium), left (p = 0.013, 95% CI [1.8, 32.1], d = 1.104, medium). Left forward showed a higher ratio than right (p = 0.001, 95% CI [5.2, 35.4], d = 1.036, medium), left (p = 0.001, 95% CI [5.2, 35.4]; d = 1.073, medium), forward (p = 0.005, 95% CI [3.0, 33.2], d = 0.902, medium), and backward (p = 0.012, 95% CI [2.0, 32.2], d = 0.851, medium). In addition, right backward revealed a higher ratio compared with right (p = 0.050, 95% CI [0.0, 30.2], d = 0.787, medium) and left (p = 0.049, 95% CI [0.0, 30.3], d = 0.817, medium).

Regarding London medalists, the post hoc Bonferroni test revealed differences. Right forward presented a higher ratio of effectiveness compared with the right backward (p = 0.003, 95% CI [4.0, 37.9], d = 0.761, medium), left backward (p = 0.028, 95% CI [0.9, 34.8], d = 0.603, medium), right (p = 0.000, 95% CI [17.4, 51.3], d = 1.453, large), left (p = 0.000, 95% CI [14.7, 48.6], d = 1.278, large), forward (p = 0.000, 95% CI [18.1, 52.0], d = 1.493, large), and backward (p = 0.000, 95% CI [16.0, 49.9], d = 1.367, large). Also, left forward showed a higher ratio than right (p = 0.001, 95% CI [6.3, 40.2], d = 1.119, medium), left (p = 0.005, 95% CI [3.6, 37.5], d = 0.932, medium), forward (p = 0.000, 95% CI [7.0, 40.9], d = 1.163, medium), and backward (p = 0.002, 95% CI [4.9, 38.8], d = 1.027, medium). Left backward produced a higher ratio than forward (p = 0.043, 95% CI [0.2, 34.1], d = 0.952, medium).

Finally, the post hoc Bonferroni test confirmed differences between the effectiveness of directions of the attack in Rio. Right forward presented a higher ratio of effectiveness

compared with right (p = 0.000, 95% CI [10.9, 45.3], d = 1.437, large), left (p = 0.001, 95% CI [6.0, 40.5], d = 1.078, medium), forward (p = 0.000, 95% CI [10.9, 45.3], d = 1.437, large), and backward (p = 0.000, 95% CI [10.9, 45.3], d = 1.437, large). Left forward showed a higher ratio than right (p = 0.000, 95% CI [10.8, 45.2], d = 1.194, medium), left (p = 0.001, 95% CI [5.9, 40.3], d = 0.920, medium), forward (p = 0.000, 95% CI [10.8, 45.2], d = 1.194, medium), and backward (p = 0.000, 95% CI [10.8, 45.2], d = 1.194, medium). In contrast, right backward revealed a higher ratio compared with right (p = 0.003, 95% CI [4.2, 38.6], d = 1.346, large), forward (p = 0.003, 95% CI [4.2, 38.6], d = 1.346, large), and backward (p = 0.003, 95% CI [4.2, 38.6], d = 1.346, large). Left backward displayed a higher ratio than right (p = 0.040, 95% CI [0.3, 34.8], d = 0.890, medium), forward (p = 0.040, 95% CI [0.3, 34.8], d = 0.890, medium), and backward (p = 0.040; 95% CI [0.3; 34.8]; d = 0.890, medium).

3.4. Inter-Analysis of Medalists' Directions of Attack Effectiveness

No effect of effectiveness' of right forward ($F_{2.689}$ = 1.222, p = 0.305, η^2 = 0.033, small), left forward ($F_{2.689}$ = 0.128, p = 0.943, η^2 = 0.004, small), right backward ($F_{2.689}$ = 1.596, p = 0.195, η^2 = 0.042, small), left backward ($F_{2.689}$ = 0.859, p = 0.465, η^2 = 0.023, small), and left ($F_{2.689}$ = 0.100, p = 0.960, η^2 = 0.003, small). In contrast, there was an effect of effectiveness of right ($F_{2.689}$ = 4.436, p = 0.006, η^2 = 0.110, medium), forward ($F_{2.689}$ = 6.184, p = 0.001, η^2 = 0.147, large), and backward ($F_{2.689}$ = 4.732, p = 0.004, η^2 = 0.116, medium). Right of Athens' medalists presented a higher ratio of effectiveness than of medalists London (p = 0.025, 95% CI [0.5, 12.3], d = 0.769, medium) and of Rio medalists (p = 0.009, 95% CI [1.2, 13.0], d = 0.902, medium). In addition, the forward of Beijing medalists displayed a higher ratio of effectiveness than of Athens medalists (p = 0.004, 95% CI [1.4, 10.7], d = 0.665, medium), London (p = 0.004, 95% CI [1.4, 10.7], d = 0.665, medium), and of Rio medalists (p = 0.004, 95% CI [1.4, 10.7], d = 0.665, medium). Backward of Beijing medalists revealed a higher ratio of effectiveness than of Athens medalists (p = 0.016, 95% CI [0.8, 12.0], d = 0.668, medium) and of Rio medalists (p = 0.005, 95% CI [1.5, 12.7], d = 0.774, medium).

3.5. Frequencies and Effectiveness of Directions of Attack in Four Olympic Games

Table 4 shows frequencies and effectiveness of directions of attack in four Olympics Games. ANOVA showed significant differences in frequencies ($F_{2.052}$ = 108.885, p = 0.000, η^2 = 0.779, large) and effectiveness ($F_{2.052}$ = 42.493, p = 0.000, η^2 = 0.579, large) of directions of attack in four Olympics Games.

Table 4. Frequencies and effectiveness of directions of attack in four Olympic

		R.F	L.F	R.B	L.B	R	L	F	B
Frequencies	(Min; Max)	(9.6; 53.7)	(5.9; 47.6)	(5.7; 32.4)	(6.1; 39.5)	(0.0; 7.4)	(0.0; 7.9)	(0.0; 2.9)	(0.0; 2.9)
	Med (Q_1; Q_3)	31.9 (22.4; 38.3)	31.4 (21.8; 36.9)	14.2 (12.0; 19.5)	18.4 (13.2; 22.5)	1.8 (0.6; 2.8)	1.2 (0.8; 2.5)	0.0 (0.0; 0.6)	0.0 (0.0; 0.9)
	M±SD	30.5±11.3	29.9±10.5	15.8±6.1	18.8±8.1	2.0±1.9	1.9±2.0	0.5±0.8	0.5±0.8
Effectiveness	(Min; Max)	(5.0; 48.0)	(0.0; 55.6)	(0.0; 36.8)	(0.0; 38.9)	(0.0; 15.8)	(0.0; 15.8)	(0.0; 10.0)	(0.0; 11.1)
	Med (Q_1; Q_3)	24.3 (16.4; 35.9)	24.0 (16.7; 32.0)	16.7 (8.4; 20.3)	18.9 (13.1; 27.6)	0.0 (0.0; 5.9)	1.9 (0.0; 8.8)	0.0 (0.0; 0.0)	0.0 (0.0; 5.1)
	M±SD	25.7±13.1	26.2±12.5	15.5±9.7	20.5±10.1	3.6±5.3	4.7±5.4	1.5±3.1	2.3±3.4

Min: Minimum; Max: Maximum; Med: Median; Q1: first quartile; Q3: third quartile; M: Mean; SD: Standard Deviation; Right Forward: R.F; Left Forward: L.F; Right Backward: R.B; Left Backward: L.B; Right: R; Left: L; Forward: F; Backward: B.

The post hoc Bonferroni test confirmed differences between frequencies of directions of attack. Right forward presented a higher ratio compared with right backward (p = 0.000, 95% CI [9.3, 20.1], d = 1.619, large), left backward (p = 0.000, 95% CI [6.3, 17.1], d = 1.190, medium), right (p = 0.000, 95% CI [23.1, 33.9], d = 3.517, very large), left (p = 0.000, 95% CI [23.1, 34.0], d = 3.525, very large), forward (p = 0.000, 95% CI [24.6, 35.4], d = 3.745, very large), and backward (p = 0.000, 95% CI [24.6, 35.4], d = 3.745, very large). Also, left forward showed

a higher ratio than right backward (p = 0.000, 95% CI [8.7, 19.5], d = 1.642, large), left backward (p = 0.000, 95% CI [5.7, 16.5], d = 1.184, medium), right (p = 0.000, 95% CI [22.5, 33.3], d = 3.698, very large), left (p = 0.000, 95% CI [22.5, 33.3], d = 3.705, very large), forward (p = 0.000, 95% CI [24.0, 34.8], d = 3.948, very large), and backward (p = 0.000, 95% CI [24.0, 34.8], d = 3.948, very large). Right backward displayed a higher ratio compared with right (p = 0.000, 95% CI [8.4, 19.2], d = 3.055, very large), left (p = 0.000, 95% CI [8.5, 19.3], d = 3.062, very large), forward (p = 0.000, 95% CI [9.9, 20.7], d = 3.517, very large), and backward (p = 0.000, 95% CI [9.9, 20.7], d = 3.517, very large). In addition, left backward produced a higher ratio than right (p = 0.000, 95% CI [11.4, 22.2], d = 2.856, very large), left (p = 0.000, 95% CI [11.5, 22.3], d = 2.865, very large), forward (p = 0.000, 95% CI [12.9, 23.7], d = 3.180, very large), and backward (p = 0.000, 95% CI [12.9, 23.7], d = 3.180, very large).

Regarding effectiveness of directions of attack, the post hoc Bonferroni test revealed differences. However, right forward presented a higher ratio of effectiveness compared with right backward (p = 0.000, 95% CI [3.1, 17.3], d = 0.885, medium), right (p = 0.000, 95% CI [15.0, 29.2], d = 2.212, very large), left (p = 0.000, 95% CI [14.0, 28.2], d = 2.096, very large), forward (p = 0.000, 95% CI [17.1, 31.3], d = 2.542, very large), and backward (p = 0.000, 95% CI [16.4, 30.6], d = 2.445, very large). Left forward showed a higher ratio than right backward (p = 0.000, 95% CI [3.6, 17.8], d = 0.956, medium), right (p = 0.000, 95% CI [15.4, 29.6], d = 2.354, very large), left (p = 0.000, 95% CI [14.4, 28.6], d = 2.233, very large), forward (p = 0.000, 95% CI [17.6, 31.8], d = 2.712, very large), and backward (p = 0.000, 95% CI [16.8, 31.0], d = 2.609, very large). In contrast, right backward revealed a higher ratio compared with right (p = 0.000, 95% CI [4.8, 19.0], d = 1.523, large), left (p = 0.000, 95% CI [3.8, 18.0], d = 1.376, large), forward (p = 0.000, 95% CI [6.9, 21.1], d = 1.944, large), and backward (p = 0.000, 95% CI [6.1, 20.4], d = 1.816, large). Left backward displayed a higher ratio than right (p = 0.000, 95% CI [9.8, 24.0], d = 2.095, very large), left (p = 0.000, 95% CI [8.8, 23.0], d = 1.951, large), forward (p = 0.000, 95% CI [11.9, 26.1], d = 2.543, very large), and backward (p = 0.000; 95% CI [11.2; 25.4]; d = 2.415, very large).

4. Discussion

Based on the inter-analysis of the four Olympic Games, the study found no significant difference in attack directions, except for right forward and backward. However, Olympic medalists perform attacks predominantly in right forward, left forward, left backward, and right backward. The other directions are inconsequential. This study also identified three different attack configurations. Medalists of Athens and Rio preferred right forward, left forward, and left backward over right backward. In Beijing, medalists chose right forward and left forward in front of right backward and left backward. Medalists of London preferred right forward first, followed by left forward, right backward, and left backward. These results are consistent with a previous study that corroborated similarities between the Olympic medalists and medalists of the 2019 World Championships and international tournaments. Kashiwagura et al. [20] observed 34.9% right forward, 34.8% left forward, 15.6% left backward, and 14.6% right backward. From the tactical point of view, diagonally forward and sideward are relevant for attacking judo, while backward and diagonally backward are appropriate for defensive judo [16].

The inter-analysis of the four main directions revealed no statistical difference in their effectiveness, signifying the constancy of choices throughout these four Olympic Games. It would appear that the International Judo Federation (IJF) refereeing rules change observed within these events did not affect these directions [28, 29]. In contrast, right, forward, and backward showed differences. Olympic medalists are more efficient in right forward, left forward, left backward, and right backward than others. These results reflect the 2017 World Championships' tendency, with 30.9% left forward, 27.3% right forward, 20.5% right backward, and 21.4% left backward [18]. Furthermore, gold medalists of the 2015 World Championships achieved 77% forward attacks, 21.2% backward attacks, and

1.9% situational attacks [21]. In comparison, the Olympic results are contrary to those of medalists from the 2019 World Championships and international tournaments, which displayed 12.2% right forward, 11.8% left forward, 13.1% left backward, and 9.7% right backward [20]. Adam et al. [17] confirmed the dominance of the left forward effectiveness in front of left backward, right backward, and right forward at all Japan Championships held between 2003 and 2012. In addition, at the 2013 Judo World Championship, both women and men scored a higher percentage of actions in the forward throw area (57.5%) than in the backward throw area (42.4%) [30]. However, left 4.0±10.5%, right 2.9±8.6%, backward 2.5±8.2%, and forward 1.5±6.9% as secondary directions scored a negligible efficiency. The present research revealed the variability of attacks produced during these four competitions. Attacking in eight throwing areas enhanced the unpredictability of these Olympic medalists. It is a way to create uncertainty, making it difficult for opponents to organize their defense.

Despite its limitations, the study helps to know more about the offensive system of these outstanding judokas. Combat duration may impact judo technical activity of all categories [31]; therefore, it is complicated to generalize these findings. Recently, some Olympic medalists' weight classes presented a difference in attack volume per match [12]. Thus, further studies are required to determine the attack directions of each weight class.

5. Conclusions

The present research has identified the prevailing trend of directions of attacks chosen during these four competitions. Specifically, right forward, left forward, left backward, and right backward are the favorite main directions for the Olympic medalists' attacking activity. Although the remaining orientations had statistically low frequencies, they are still crucial at this level of competition as they provide opportunities to increase more points of unbalance. Having eight orientations allows a range of possibilities for combining techniques, which could effectively disrupt even the most sophisticated defense. Coaches should consider attack directions among capital variables of the achievement in judo.

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