2022 · Retos Nº 46 / Págs. 833-842

Predominance of techniques analysis used in the final rounds of judo international competitions scoring for the Olympic ranking: A biomechanical approach

Análisis del predominio de las técnicas utilizadas en las rondas finales de competencias internacionales de judo puntuables para el ranking olímpico: un enfoque biomecánico

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Abstract. Judo is an Olympic combat sport that is divided into male and female weight categories. Each weight category implies significant differences in technical and strategic dimensions, as well as physiological, performance, and body composition among competitors. This individual variability can widely mark options and predominance of biomechanical actions inherent to its own movements. This study aimed to determine the technical actions predominance used by judokas in the international competitions final stages scoring for the Olympic ranking. We observed 285 judo matches, in several weight categories for men and women, played in the final stages of six scoring international competitions for the Olympic ranking in Tokyo 2021. An observation system was used according to the biomechanical classification of judo techniques proposed by Sacripanti. In Nage-Waza combat, there was a predominance of lever techniques over couple techniques. In Ne-Waza there was a predominance of pressure techniques, followed by venous breathing block and dislocation of the elbow joint. There were also differences between genders and significant associations by weight category in the technical options in combat, as well as according to the combat phase.

Keywords: Judo, Biomechanics, Lever techniques, Couple techniques, Competitive performance analysis.

Resumen. El judo es un deporte de combate olímpico que se divide en categorías de peso masculino y femenino. Cada categoría de peso implica diferencias significativas en las dimensiones técnicas y estratégicas, así como fisiológicas, de rendimiento y de composición corporal entre los competidores. Esta variabilidad individual puede marcar ampliamente opciones y predominio de acciones biomecánicas inherentes a sus propios movimientos.

Este estudio tuvo como objetivo determinar el predominio de las acciones técnicas utilizadas por los judokas en las etapas finales de las competencias internacionales puntuables para el ranking olímpico. Observamos 285 combates de judo, en varias categorías de peso para hombres y mujeres, disputados en las etapas finales de seis competencias internacionales puntuables para el ranking olímpico en Tokio 2021. Se utilizó un sistema de observación de acuerdo con la clasificación biomecánica de técnicas de judo propuesta por Sacripanti. En el combate Nage-Waza predominaban las técnicas de palanca sobre las técnicas de binario. En Ne-Waza predominaron las técnicas de presión, seguidas del bloqueo respiratorio venoso y la luxación de la articulación del codo. También hubo diferencias entre géneros y asociaciones significativas por categoría de peso en las opciones técnicas en combate, así como según la fase de combate.

Palabras clave: Judo, Biomecánica, Técnicas de palanca, Técnicas de binario, Análisis de rendimiento competitivo.

Introduction

Judo is an Olympic combat sport divided into male and female weight categories. Currently there are seven weight categories in the senior level, being the male categories -60kg, -66kg, -73kg, -81kg, -90kg, -100kg and +100kg and the female categories -48kg, -52kg, -57kg, -63kg, -70kg, -78kg and +78kg (Franchini, Del Vecchio, Matsushigue & Artioli, 2011).

Each weight category implies marked differences in technical and strategic dimensions, as well as physiological, performance, and body composition between different weight categories competitors (Franchini & Herrera-Valenzuela, 2017). This individual variability can broadly mark the options and predominance of biomechanical actions inherent to its own movements (Sterkowicz, Sacripanti, & Sterkowicz-Przybycien, 2013).

Given that judo is a dynamic and intermittent high-intensity sport it requires complex skills and tactical excellence for success (Degoutte, Jouanel, & Filaire, 2003; Franchini & Herrera-Valenzuela, 2017). In each combat the judokas have to perform a large number of motor actions of technical aspect, making the physical demand high in each combat and consequently in each competition. Usually, to compete in a judo competition final stages, the medal-winning athletes have five to seven combats during international competitions. The time limit for each fight is 4 minutes, but if the judoka gets ippon (maximum score), the fight ends with his victory. On the other hand, since 2003, when the combat allocated time

Fecha recepción: 05-05-22. Fecha de aceptación: 16-08-22
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ends and we are faced with a technical draw (scores and penalties are equal for both athletes), the combat result is decided by Golden Score (Franchini, Takito & Calmet, 2013). Currently, if none of the judokas get points in the gold scoring period, the fight continues indefinitely until a technical advantage emerges. Another way, it emphasizes on committing penalties during the combat by each judoka, that whenever it implies a sum of three light penalties (Shido), the third light penalty will give rise to a heavy penalty (Hansokumake) and consequent loss of the combat. Committing a heavy penalty implies immediate defeat in combat.

Today, a judo match can last from a few seconds to more than 12 minutes, depending on the score obtained by the competitors. However, a high-level judo match tends to last 3 minutes, with 20 to 30 seconds activity periods and 5 to 10 seconds of interruption. It is noted that a significant part of the matches last 3 to 4 minutes (Franchini & Herrera-Valenzuela, 2017).

The projection and immobilization techniques in judo are described and classified by the maximum entity of Judo, the Kodokan (Daigo, 2005). Five groups of projection techniques are identified (arm, hip, leg, frontal sacrifice and lateral sacrifice techniques) and three of ground action (immobilizations, keys and chokes). There are several studies that explore the athletes' technical behavior in competition based on the Kodokan classification (e.g. Sterkowicz, & Franchini, 2000; Van Malderen et al., 2006; Boguszewski, 2016), which essentially explore trends by gender and weight categories.

To be effective, judo techniques must be applied with precision, within a good 'window of opportunity', with strength, speed and power (Franchini, Del Vecchio, Matsushigue, & Artioli, 2011). This movement precision implies biomechanical adaptations that can favor the coupling between athletes in their technical execution in competition.

For this purpose Sacripanti proposed a biomechanical techniques classification by classes (Sacripanti, 1987, 1989, 2010, 2012). According to this author, the projection techniques executions are classified as being of lever (medium arm lever; maximum arm lever; variable arm lever; minimum arm lever) or of couple (arm couple; arm leg couple; trunk leg couple; trunk and arms couple; leg couple). Ground level techniques are classified as pressure technique, respiratory venous block technique, and elbow joint dislocation technique.

Although there are a few scientific works that make the interpretation and description in biomechanical parameters of some projection techniques in judo (Sacripanti, 1989, Monteiro, 1992; Imamura & Johnson, 2003;), ground work (Sacripanti, 1989, Roquette, 1991a, 1991b) or falls (Koshida, Ishii, Matsuda, & Hashimot, 2017), the combat dynamics interpretation based on judo biomechanical techniques classification is reduced, pointing out the work of Sterkowicz, Sacripanti and Sterkowicz-Przybycien (2013), with an analysis of the most used techniques in the London Olympic Games and the work of Brito et al. (2017), where they present comparisons of technical-tactical character analysis by weight categories in elite judo athletes.

The evolution of how techniques are executed as a result of the rules changes since 2010 which conditioned the judokas' grips below the belt or in the pants, associated with the changes introduced in 2017 that aimed to make combat more dynamic, implied behavioral adaptations of biomechanical nature in judokas. Therefore, it is important to know in more detail the technical options and behaviors taken by athletes in combat today.

This work will allow us to explore current behavioral trends in high-level judo, exploring the most recent training trends in women's and men's judo, with a particular focus on the biomechanical classification of technical projection actions in judo.

Methodology

Objectives

In the technical actions analysis used in the fights in analysis, all judokas used the same rules in combat, regardless of whether they are male or female. It was assumed that the frequency found for a certain technical class could be related to gender, to a weight category, to the stage and to the combat time.

Therefore, the formulation of the following objectives is justified.

1 - Determine the techniques predominance used by judokas in the final phases of international competitions scoring for the Olympic ranking.
2 - Determine the techniques effectiveness predominance used by judokas in the final stages of international competitions scoring for the Olympic ranking.
3 - Determine the techniques predominance used by judokas according to the combat phase;
4 - Determine the techniques predominance used by judokas according to the combat time.

Sample

The study sample focused on 285 judo fights, in the various weight categories, 139 male (49%) and 146 female (51%), disputed in the final stages of six international competitions scoring for the Olympic ranking, specifically

the Grand Prix Zagreb 2019 and the Grand Slam Brasilia 2019, Baku 2019, Dusseldorf 2019, Budapest 2020, Doha 2021 and Tel Aviv 2021.

A total of 2101 technical actions in combat were categorized, of which 2025 actions in Nage-Waza (standing combat) and 76 actions in Ne-Waza (ground combat).

Instruments

We used an observation system created for this purpose, allowing registration and categorization of each technical action observed in combat, according to the following variables described.

The independent variables considered were gender (female and male sexual dimorphism), weight categories respectively female and male: (-48kg/-60kg) light weight; (-52kg/-66kg) middle light weight, (-57kg/-73kg) light weight; (-63kg/-81kg) middle middle weight; (-70kg/-90kg) middle weight; (-78kg/-100kg) middle heavy weight; (+78kg/+100kg) heavy weight, the combat mode which can be categorized into Nage-Waza (standing combat) and Ne-Waza (ground combat).

The combat phase that was categorized into combat time (combat time that goes from the first to the fourth minute of combat) and time in golden score (unlimited time after finishing the 4 minutes of combat).

The variable that assumes a characteristic as dependent is the technique class that can be categorized in Nage-Waza as either a lever technique (Medium arm lever; Maximum arm lever; Variable arm lever; Minimum arm lever); or a couple technique (Arm couple; Leg arm couple; Leg trunk couple; Trunk and arm couple; Leg couple). In Ne-Waza the technique is categorized into Pressure Technique - Immobilization; Venous Breathing Block technique and Dislocation technique to the elbow joint.

The scoring variable was categorized according to the technical actions effectiveness that were rated according to the judging validated by the referees, assuming a sub-maximum score of Wazari and the maximum score of Ippon.

Two researchers of this study were responsible for the categorization and recording of each technical action. The intra and inter observer reliability analyses were calculated through Cohen's Kappa, in the analysis of 50 technical actions, where we obtained K values of 0.98, for a significance level of $p \leq 0.05$, which gives us an almost perfect interpretation between the subjects (Marôco, 2018)

Procedures

For this research preparation, no ethical issues involved in the analysis and interpretation of the data used were considered, since they were obtained using publicly available and freely accessible International Judo Federation (IJF) online sources, and were not generated by any experimentation process.

The athletes' personal identification was not done since the observation was not individualized. The identification of each observed combat was replaced by a code, which guaranteed anonymity and confidentiality.

Each technique was categorized according to the biomechanical classification system proposed by Sacripanti (1987, 1989, 2010, 2012). Data analysis was performed to identify each technique serving nine categorization classes for Nage-Waza and three categorization classes for Ne-Waza (Sacripanti, 1987, 1989, 2010, 2012).

The techniques count distribution frequency was compared using the software IBM SPSS 21.0 software. For this purpose, cross-frequency tables were produced, where the association degree between variables was analyzed using the Chi Square test, where the significance level was set at $p \leq 0.05$. We complemented the association analysis between variables by calculating the adjusted standardized residuals, taking as reference positive values equal to or greater than 1.96, assuming that the higher the residual, the more significant the trend is (Marôco, 2018).

To determine differences between groups in the frequencies recorded proportions, the Z test was applied, where the significance level was set at $p \leq 0.05$.

Results

In the present part of the study we will describe the main findings in relation to the established objectives. According to Table 1 we observed that the technical actions hierarchy used globally in the combats analyzed in the Nage-Waza combat form were, variable arm lever techniques (29.5%), maximum arm (22.4%), leg arm couple (20.4%), leg trunk couple (17.6%), minimum arm lever (7.4%) and medium arm lever (2.7%).

We observed that the most used techniques by the female gender are those of the maximum arm lever class, unlike the male gender that are the variable arm lever and minimum arm lever techniques. There were significant differences between genders in the quoted classes. It should be noted a high use of techniques of maximum arm lever by the male categories, but without statistical significance evidence, as well as a reduced use of techniques of medium arm by both genders.

When we focus the observation taking into account the weight categories we verify that there is a predominance of the use of techniques of maximum arm lever and variable arm lever. However, in the male categories, there is a significant association in the use of minimum arm lever techniques by the -60kg and -73kg categories, as well as in

the use of variable arm lever techniques by the -100kg and +100kg categories.

In the female categories we observed a significant association for maximum arm lever techniques by the -48kg, -52kg, -57kg and -63kg categories, as well as for minimum arm lever techniques in the +78kg category.

As for the Couple techniques, they were less used globally during combat (38%) compared to the lever techniques (62%) by both genders. However, the Couple techniques predominantly used were arm-leg couple, with the exception of the male categories -60kg, -73kg, +100kg and female -78kg that predominantly used torso-leg Couple techniques. There were no significant associations or differences between groups in the use of these classes of techniques.

In the Ne-Waza combat form, the predominant techniques used by both genders were pressure (51.3%) and venous and respiratory blocking (28.9%), although with statistical significance in favor of the female weight categories. The elbow joint dislocation was less frequently requested as a technical resource (19.7%).

Of the 2025 projection techniques attempted by judokas in the evaluated fights, only 221 (11%) of the total technical actions were scored with a technical advantage of Wazari (60.2%) or Ippon (39.8%), with male athletes recording an effectiveness of 11.2% and female athletes 10.6%.

In Table 2 we observe an application predominance in the male categories of variable arm lever techniques and arm/leg couple. The female categories showed a predominance of the use of maximum arm lever and variable arm lever techniques, as well as leg-arm couple. There is a significant association of minimum arm lever techniques scored with Wazari in the male categories, as well as a significantly higher use of medium arm techniques scored with Ippon. In the female categories there was a significant association of maximum arm techniques in the -63kg category, and minimum arm techniques in the -52kg category scored with Ippon.

In Table 3 data, we observe that in the combat phase the most used techniques by the female gender are the maximum arm lever class, unlike the male gender that are the variable arm lever and minimum arm lever techniques. There were significant differences between genders in this phase in the mentioned classes. It should be noted a high use of techniques of maximum arm lever by the male categories, but without evidence of statistical significance, as well as a reduced use of medium arm techniques by both genders.

When we focus the observation taking into account the weight categories we verify that there is a predominance of the use of techniques of maximum arm lever and variable arm lever. However, in the male categories there is a significant association in the use of minimum arm lever techniques by the -60kg and -73kg categories, as well as in the use of variable arm lever techniques by the -81kg, -100kg and +100kg categories.

In the female categories we observed a significant association for maximum arm lever techniques by the -48kg, -52kg, -57kg and -63kg categories, as well as for medium arm lever techniques in -70kg and minimum arm in the +78kg category.

As for the couple techniques, they were less used globally during the combat phase (37.5%) compared to the lever techniques (62.5%) by both genders. However, the couple- type techniques predominantly used were arm-leg couple, with the exception of the male categories -60kg, -73kg, +100kg and female -70kg that predominantly used

Table 1.
Cross frequency table between technique class and weight category by gender and by form of combat.

	Code	Total	Mal	Fem	Male Group / Weight Category							Female Group / Weight Category						
					Lig	Mlev	Lev	MM	M	Mpes	Pes	Lig	Mlev	Lev	MM	M	Mpes	Pes
Nage Waza	ABmed	54	25	29	3	1	3	6	4	5	3	7	0	5	7	6	2	2
	ABmax	454	195	**#259***	46	36	33	25	21	25	9	**63***	**45***	**45***	**49***	27	27	3
	ABvar	598	**#382***	216	48	62	42	60	36	**75***	**59***	24	27	33	43	38	36	15
	ABmin	150	**#112***	38	**23***	17	**18***	16	14	10	14	2	2	4	2	4	5	**19***
	TotalA	1256	714	542	120	116	96	107	75	115	85	96	74	87	101	75	70	39
	BBrpr	412	207	205	19	25	40	30	35	38	20	43	29	25	17	21	59	11
	BTrpr	357	171	186	24	17	41	21	15	29	24	33	18	20	17	18	60	10
	TotalB	769	378	391	43	42	81	51	50	67	44	76	47	45	34	39	119	21
	Total	2025	1092	933	163	158	177	158	125	182	129	172	121	132	135	114	189	60
	Code	Total	Mal	Fem	Male Group / Weight Category							Female Group / Weight Category						
					Lig	Mlev	Lev	MM	M	Mpes	Pes	Lig	Mlev	Lev	MM	M	Mpes	Pes
NeWaza	Tpres	39	7	**#32**	1	1	0	1	1	2	1	3	4	2	6	8	5	4
	BloqVR	22	10	**#12**	0	1	0	4	2	1	2	0	2	2	3	3	2	0
	Acot	15	5	10	1	0	1	1	1	1	0	2	2	3	0	3	0	0
	Total	76	22	54	2	2	1	6	4	4	3	5	8	7	9	14	7	4

Key: * (technical group shows a significant residue); # (technical group differs by gender); Mal (Male); Fem (Female); Lig (light weight); Mlev (medium light weight); Lev (light weight); MM (medium middle weight); M (medium weight); Mpes (medium heavy weight); Pes (heavy weight); ABmed (Average arm lever); ABmax (Maximum arm lever); ABvar (Variable arm lever); ABmin (Minimum arm lever); BBrpr (Arm/leg Couple); BTrpr (trunk/ leg Couple); Tpres (Pressure Technique- Immobilization); BloqVR (Respiratory venous block); Acot (dislocation elbow joint); TotalA (Total lever techniques); TotalB (Total Couple techniques).

Table 2.
Cross frequency table between technique class and weight category as a result of the score obtained and by gender.

	Code	Total	Wazari	Ippon	Wazari							Ippon						
					Lig	Mlev	Lev	MM	M	Mpes	Pes	Lig	Mlev	Lev	MM	M	Mpes	Pes
Male	ABmed	3	0	**#3**	0	0	0	0	0	0	0	1	0	1	1	0	0	0
	ABmax	15	7	8	4	1	0	0	0	1	1	2	2	2	1	1	0	0
	ABvar	38	22	16	5	6	4	1	2	4	0	3	3	1	3	1	3	2
	ABmin	21	**14***	7	4	1	5	2	1	0	1	2	1	0	3	1	0	0
	TotalA	77	43	34	13	8	9	3	3	5	2	8	6	4	8	3	3	2
	BBrpr	29	16	13	2	1	5	1	2	4	1	1	0	3	3	1	3	2
	BTrpr	16	10	6	2	0	2	0	1	2	3	1	0	0	0	2	1	2
	TotalB	45	26	19	4	1	7	1	3	6	4	2	0	3	3	3	4	4
	Total	122	69	53	17	9	16	4	6	11	6	10	6	7	11	6	7	6
	Code	Total	Wazari	Ippon	Wazari							Ippon						
					Lig	Mlev	Lev	MM	M	Mpes	Pes	Lig	Mlev	Lev	MM	M	Mpes	Pes
Female	ABmed	5	3	2	2	0	0	0	1	0	0	0	0	1	0	1	0	0
	ABmax	22	15	7	4	1	1	4	2	3	0	2	0	1	**2***	0	1	1
	ABvar	24	15	9	1	2	2	3	4	2	1	1	0	2	0	2	4	0
	ABmin	4	3	1	0	0	0	0	0	1	2	0	**1***	0	0	0	0	0
	TotalA	55	36	19	7	3	3	7	7	6	3	3	1	4	2	3	5	1
	BBrpr	29	18	11	3	2	2	2	1	8	0	2	2	3	2	0	2	0
	BTrpr	15	10	5	1	0	1	2	3	2	1	1	0	1	0	0	3	0
	TotalB	44	28	16	4	2	3	4	4	10	1	3	2	4	2	0	5	0
	Total	99	64	35	11	5	6	11	11	16	4	6	3	8	4	3	10	1

Key: * (technical group shows a significant residual); # (technical group differs depending on the obtained score); Lig (light weight); Mlev (medium light weight); Lev (light weight); MM (medium medium weight); M (medium weight); Mpes (medium heavy weight); Pes (heavy weight); ABmed (Average arm lever); ABmax (Maximum arm lever); ABvar (Variable arm lever); ABmin (Minimum arm lever); BBrpr (Arm leg couple); BTrpr (trunk leg couple); TotalA (Total lever techniques); TotalB (Total couple techniques).

torso-leg couple techniques. There were no reported differences between groups, but there were significant associations between the leg couple class and the male -90kg and female -52kg categories, as well as torso leg couple techniques in the -70kg category.

In the golden score phase we observed that the techniques significantly more used by the female gender are the medium arm lever class, unlike the male gender who use the variable arm lever techniques. In this phase there were significant differences between genders in the mentioned classes. There is to point out a high use of maximum arm lever techniques, as well as a reduced use of minimum arm lever techniques by both genders, but without statistical significance evidence.

When we focus the observation attending to the weight categories we verify that there is a predominance of the use of maximum arm and variable arm lever techniques. However, there is a significant association in the use of minimum arm lever techniques by the -90kg categories.

In the female categories we observed a significant association for medium arm lever techniques by the -48kg category, maximum arm by the -48kg, -52kg categories, as well as for minimum arm lever techniques in the +78kg category.

Regarding the couple techniques, they were also less used globally during the golden score phase (40.4%), although with an increase compared to the lever techniques (59.6%) by both genders. In this phase, the predominant couple techniques used was arm-leg couple, with the exception of the male categories -90kg and +100kg and the female categories -52kg, -78kg and +78kg that predominantly used leg-arm couple techniques. There were no differences between groups and no significant associations between classes of couple techniques and weight categories.

In the data shown in Table 4 we observe that in the male categories as the combat progresses in time, the total attempts of both lever and couple technical actions increase in the 2nd and 3rd minutes. In the female categories we observe totals, in both classes of techniques, decreasing from the 1st to the 4th minute.

We also observe that at combat time the male categories preferentially opt for variable arm lever techniques, followed by maximum arm, maintaining this tendency at golden score time. The female categories opted in combat time for maximum arm lever techniques followed by variable arm and in the golden score they invert the described tendency, presenting significant differences in their options from combat time to golden score. Both genders show less use of minimum arm techniques and even less of medium arm techniques.

However, in the male categories, there is a significant association in the use of minimum and medium arm leverage techniques in the 3rd minute of combat, as well as the variable arm in the 4th minute. In the female categories we observed a significant association by maximum arm lever techniques at the 3rd combat minute, as well as by medium arm and variable arm techniques in the golden score. Overall, we observed a significant association in the use of variable arm lever techniques in the golden score.

Table 3.
Cross-frequency table between technique class and weight category, according to gender and by combat phase.

	Code	Total	Mal	Fem	Male Group / Weight Category							Female Group / Weight Category						
					Lig	Mlev	Lev	MM	M	Mpes	Pes	Lig	Mlev	Lev	MM	M	Mpes	Pes
Combat	ABmed	44	23	21	3	1	3	6	4	4	2	3	0	3	5	**6***	2	2
	ABmax	393	170	**#223***	44	31	28	19	21	21	6	**52***	**36***	**43***	**41***	25	24	2
	ABvar	491	**#320***	171	45	47	34	**53***	36	**59***	**46***	22	21	26	35	31	24	12
	ABmin	133	**#102***	31	**23***	**15**	**17***	13	13	9	12	2	0	2	2	4	4	**17***
	TotalA	1061	615	446	115	94	82	91	74	93	66	79	57	74	83	66	54	33
	BBrpr	341	177	164	18	20	33	28	**32***	30	16	33	**26***	17	15	14	49	10
	BTrpr	296	147	149	23	14	37	19	11	25	18	26	12	17	15	**28***	43	8
	TotalB	637	324	313	41	34	70	47	43	55	34	59	38	34	30	42	92	18
	Total	1698	939	759	156	128	152	138	117	148	100	138	95	108	113	108	146	51
	Code	Total	Mal	Fem	Male Group / Weight Category							Female Group / Weight Category						
					Lig	Mlev	Lev	MM	M	Mpes	Pes	Lig	Mlev	Lev	MM	M	Mpes	Pes
Golden Score	ABmed	10	2	**#8***	0	0	0	0	0	1	1	**4***	0	2	2	0	0	0
	ABmax	61	25	36	2	5	5	6	0	4	3	**11***	**9***	2	8	2	3	1
	ABvar	107	**#62***	45	3	15	8	7	0	16	13	2	6	7	8	7	12	3
	ABmin	17	10	7	0	2	1	3	**1***	1	2	0	2	2	0	0	1	**2***
	TotalA	195	99	96	5	22	14	16	1	22	19	17	17	13	18	9	16	6
	BBrpr	71	30	41	1	5	7	2	3	8	4	10	3	8	2	7	10	1
	BTrpr	61	24	37	1	3	4	2	4	4	6	7	6	3	2	0	17	2
	TotalB	132	54	78	2	8	11	4	7	12	10	17	9	11	4	7	27	3
	Total	327	153	174	7	30	25	20	8	34	29	34	26	24	22	16	43	9

Key: * (technical group shows a significant residual); # (technical group differs depending on the obtained score); Lig (light weight); Mlev (medium light weight); Lev (light weight); MM (medium medium weight); M (medium weight); Mpes (medium heavy weight); Pes (heavy weight); ABmed (Average arm lever); ABmax (Maximum arm lever); ABvar (Variable arm lever); ABmin (Minimum arm lever); BBrpr (Arm leg couple); BTrpr (trunk leg couple); TotalA (Total lever techniques); TotalB (Total couple techniques).

Table 4.
Cross-frequency table between technique class as a function of gender and combat time and phase.

Code	Total	TCs	TGS	Male Group / Combat Time						Female Group / Combat Time					
				1° m	2° m	3° m	4° m	TC	GS	1° m	2° m	3° m	4° m	TC	GS
ABmed	54	44	10	4	6	**10***	3	23	2	6	6	6	3	21	**8***
ABmax	452	414	**# 38**	47	52	36	34	169	26	70	56	**69***	50	245	**#12**
ABvar	596	500	**96***	72	86	71	**93***	322	60	52	52	37	37	178	**#36***
ABmin	150	135	15	27	22	**33***	21	103	9	10	9	7	6	32	6
TotalA	1252	1093	159	150	166	150	151	617	97	138	123	119	96	476	62
BBrpr	409	349	60	40	51	46	39	176	31	51	48	40	34	173	29
BTrpr	356	310	46	38	33	40	35	146	25	55	47	32	30	164	21
TotalB	765	659	106	78	84	86	74	322	56	106	95	72	64	337	50
Total	2017	1752	265	228	250	236	225	939	153	244	218	191	160	813	112

Key: * (technical group shows a significant residual); # (technical group differs depending on the obtained score); Lig (light weight); Mlev (medium light weight); Lev (light weight); MM (medium medium weight); M (medium weight); Mpes (medium heavy weight); Pes (heavy weight); ABmed (Average arm lever); ABmax (Maximum arm lever); ABvar (Variable arm lever); ABmin (Minimum arm lever); BBrpr (Arm leg couple); BTrpr (trunk leg couple); TotalA (Total lever techniques); TotalB (Total couple techniques).

The couple techniques were less used globally during the combat time (37.6%) and golden score (40%) than the lever techniques in combat time (62.4%) and golden score (60%) by both genders. In the couple techniques there was a predominance for both genders throughout the fights for the use of arm/leg couple techniques, even though very near to the registered frequencies in the trunk/leg techniques. There were no differences between groups nor significant associations between classes of couple techniques and fight minutes.

Discussion

In this section we expose the main evidence found in our study, confronting it with the theoretical findings of the main works in this study field.

The methods evolution for the execution techniques due to the changes in the rules since 2010, which conditioned the judokas' grips below the belt or in the pants, had implications on the athletes' options and use of technical actions.

The arm couple techniques almost disappeared with the exception of the Uchi-mata-sukashi use which was not reported in any matches in the final stages of the competitions observed in this study. The techniques of trunk and arm couple and leg couple are forbidden in competition, so there was no report in our study. This was not an observed tendency as numerous athletes attempted their application, and in large numbers with high effectiveness, as shown in the studies of Sterkowicz and Franchini (2000) or Van Malderen et al. (2006), contrary to the studies of Sterkowicz, Sacripanti and Sterkowicz-Przybycien (2013) or Boguszewski (2016) regarding present-day judo.

It is important to refer that the rule changes introduced by the IJF did not achieve the set goal of increasing scores

and decreasing penalties (Franchini, Takito, & Calmet, 2013).

In 2017 there were already changes in the rules that aimed to turn the combat more dynamic again, aiming a more positive judo, which implied behavioral adaptations in the judokas, particularly in the male categories, which saw the combat time reduced from 5 to 4 minutes.

The study by Calmet, Pierantozzi, Sterkowicz, Takito, & Franchini (2017), in a first analysis suggest that these new rules partially met the proposed goal by showing a slightly more dynamic judo partially increasing scores and with fewer fouls.

Our findings globally indicate a greater use of lever techniques and less use of couple techniques, which is in accordance with what was referred by Sterkowicz, Sacripanti and Sterkowicz-Przybycien (2013) in the London Olympic Games. In our study this trend was observed in the different weight categories for men and women, both in a global analysis perspective and according to the combat phase, respecting this same trend during the combat time and in the golden score phase, when it exists.

The technical actions hierarchy used globally in the analyzed combats in Nage-Waza were: variable arm lever techniques, maximum arm, leg/arm couple, leg/trunk couple, minimum arm lever, and medium arm lever. In Ne-Waza the hierarchy was technical and pressure, from respiratory venous block and dislocation to the elbow joint. These evidences are not in accordance with the trends evidenced by Sterkowicz, Sacripanti and Sterkowicz-Przybycien (2013), where in Nage-Waza the technical hierarchy was led by maximum arm lever techniques, followed by variable arm, and the remaining classes remained the same. In Ne-Waza the highest use was also in immobilization techniques, followed by dislocations to the elbow joint, and lastly the respiratory venous block.

The study by Sterkowicz, Sacripanti and Sterkowicz-Przybycien (2013) refers as resource percentages 60.5% lever techniques and 39.5% couple techniques. This trend was approximately observed in our study, respectively 62% and 38%, with significant differences between genders, in the application of maximum arm lever techniques favorable to female categories and medium and minimum arm lever favorable to male categories.

As in the quoted study we did not identify differences in frequencies within gender, with the use percentage in the male classes being 65.4% and 34.6%, and for the female classes 58.1% and 41.9%.

Variable arm lever techniques were the most commonly used regardless of gender (29.5%), in contrast to the study by Sterkowicz, Sacripanti, and Sterkowicz-Przybycien (2013), who pointed out that it was the maximum arm techniques (25.1%). We noted significant associations in the use of maximum arm lever techniques in the female gender (27%) and variable arm lever techniques in the male gender (35%). Sterkowicz, Sacripanti, and Sterkowicz-Przybycien (2013) observed significant associations in both genders in the use of variable arm lever techniques. Sacripanti (1989, 2010, 2012) refers that from a biomechanical point of view, a force of the same magnitude and direction that acts on a larger lever causes a greater effect (force moment), giving its performers some advantage in effort management at trunk and arms level, essential elements and necessary management for a judoka in competition. In general, when faced with identical resistance, when the arm lever used in a lever technique increases, the applied force decreases. This evidence from physics means that arm lever techniques are more energetically efficient than others in the lever techniques class.

In Ne-Waza combat form, as stated by Sterkowicz, Sacripanti and Sterkowicz-Przybycien (2013) no significant associations between technical actions and female weight category were evident, however the authors identified in Olympic athletes an association towards the use of four-holds pressure techniques (Shio-Gatame) by athletes in the lighter categories (-60kg and -66kg). Analogously to the mentioned study, it was found that female athletes lost more fights by strangulation, as well as in the remaining classes of technical actions on the ground than male athletes, with differences between genders in the classes of pressure technique and venous breathing block techniques. The fact that female athletes have less developed neck muscles, particularly the sternocleidomastoid muscles, than men, can be considered as an explanation for the higher number of chokes in females, generating less protection of the carotid arteries and airways in women than in men. Sterkowicz, Sacripanti and Sterkowicz-Przybycien (2013) had already pointed out this evidence and the need for more detailed biomechanical research in the future.

When we focused our observation on the techniques applied effectiveness, we observed that 11% of all technical actions were scored with a technical advantage of Wazari (60.2%) or Ippon (39.8%). There was a significant association of minimum arm lever techniques scored with Wazari in the male categories, as well as a significantly higher use of medium arm techniques scored with Ippon. In the female categories a significant association of maximum arm techniques in the -63kg category, and minimum arm techniques in the -52kg category, scored with Ippon, was identified.

It is important to note that with the introduction of new rules in 2017 by the IJF, according to the study by Calmet, Pierantozzi, Sterkowicz, Takito, & Franchini (2017), there was a significant increase in techniques scored with Wazari.

However, unlike what was observed by Sterkowicz, Sacripanti and Sterkowicz-Przybycien (2013) in the London Games, in the present study, even though it was in the final stages, the female effectiveness percentage was lower compared to the male, suggesting an evolution in the defensive ability of women, which may contradict the one that had been pointed out by the authors as a justification for the higher female effectiveness.

Apparently, in the analyzed competitions there was also an evolution in the preparation and training methods in the female gender, regarding the increment of strength, since Sterkowicz, Sacripanti and Sterkowicz-Przybycien (2013) in their study, justified the lower effectiveness frequency resulting from the application of maximum arm lever techniques used by women, probably attributing it to the lower strength indicators reflected in the supine and rowing tests recorded by Monteiro, Garcia and Carratalá (2011).

In the golden score combat phase, although the hierarchical tendency of technique application remained identical compared to the combat phase, significant associations were identifiable between variable arm lever techniques and male gender, and variable arm lever and medium arm techniques with female gender. This observation suggests a behavioral change in the female gender regarding technical options in the combat phase, which had a significant association with maximum arm lever techniques as exposed by Sterkowicz, Sacripanti, and Sterkowicz-Przybycien (2013), apparently changing those options for the golden score phase.

It should be noted that the body proportionality of an athlete should be related to their favorite techniques (Detanico & Santos, 2007), making it essential to the performance in judo, a commitment of the judoka to maintain the ideal weight and body composition so that the physiological and motor efficiency is obtained (Almansba et al., 2010; Calvo Rico et al., 2018).

The body composition factor may interact with the preference for a particular technique performed by heavy or light weights, as relative strength often tends to be lower in heavy weights than in light weights (Sacripanti, 2010, 2012, 2013), with lighter weights generating more explosive technical actions, and heavier weights, more comfortable performing technical actions.

It is also worth mentioning the evidence of Brito et al. (2017) who analyzed technical-tactical actions of elite judokas according to weight category and respective heights, regarding approach, grip, attack, ground fighting, and defense, and concluded that the technical-tactical actions by weight category interfere in the biomechanical patterns during the combat phases. More recently, Kashiwagura et al. (2021) analyzed the high-level, demonstrating that the effectiveness of the attack depends on the technical-tactical dynamics, with emphasis on the grip configuration. Gripping the dorsal region was shown to be decisive in differentiating the effectiveness of attacking systems. Of the main grip configurations evidenced by the athletes that resulted in specific score rates, there was a dependence of these on the direction of the attack and the posture. Athletes should perform actions that increase the distance from their opponents to avoid being grabbed at the dorsal area. The authors also point out that when attacking, grips performed with one hand should be avoided, as they are unlikely to result in a score. Therefore, specific technical training, appealing to the variability and complexity of the task is important to improve the performance capacity and effectiveness of the judoka's technical options, as demonstrated by Hurel Tola et al. (2020), always contemplating a complete and strong physical performance (Norambuena, 2021), also playing a prophylactic role regarding the prevalence of injuries in sport (Colonna et al. 2022).

It should also be noted that the application of lever techniques demands from judokas a greater coordination of the body and kinematic chains in the application of force, compared to couple techniques, in addition to the fact of a greater energy consumption, as already demonstrated by Inman (2007), Franchini et al. (2008) or Sacripanti (2012, 2013).

Apparently, the training standardization worldwide tends to shape the technical options and their application frequency in modern judo, with innovative technical actions even appearing in chaotic forms that escape the technical classicism observed in the recent past. Inclusively, probably derived from the training methods, Sacripanti (2012) refers to a progressive approach of female judo tending to be more classical, to the more explosive and innovative male judo.

Conclusions

Considering the objectives set for the present study, we present the main conclusions.

The first objective aimed to determine the techniques predominance used by judokas in the final stages of international competitions scoring for the Olympic ranking. We observed globally a greater predominance of lever techniques over the use of couple techniques. The technical actions hierarchy used globally in the combats analyzed in Nage-Waza were, variable arm lever techniques, maximum arm, leg arm couple, leg trunk couple, minimum arm lever and medium arm lever. In Ne-Waza the hierarchy was pressure technique, venous breathing block and dislocation to the elbow joint.

By gender, the techniques most used by male athletes were variable arm lever techniques, followed by arm leg couple techniques and on the ground venous breathing block techniques predominated. Female athletes used more maximal arm lever techniques, followed by variable arm, and on the ground pressure techniques predominated.

The second objective, to determine the techniques effectiveness predominance used by judokas in the final stages of international competitions scoring for the Olympic ranking, the technical actions effectiveness predominance were specifically, in the application of maximum arm lever and leg-arm couple techniques for male athletes, and of leg-arm couple, variable arm lever and maximum arm for female athletes.

It was also evidenced a significant association of minimum arm lever techniques scored with Wazari in the male categories, as well as a significantly higher use of medium arm techniques scored with Ippon. In the women's categories, a significant association of maximum arm techniques in the -63kg category, and minimum arm techniques in the -52kg category, scored with Ippon, was identified.

Regarding the third objective, to determine the techniques predominance used by the judokas according to the combat phase, the technical actions hierarchical trend used in the combat phase were, variable arm lever techniques, maximum arm, leg/arm couple, leg/trunk couple, minimum arm lever, and medium arm lever. In the golden score phase the technique hierarchy of use were variable arm lever techniques, arm leg couple, maximum arm techniques equal to trunk leg couple, minimum arm lever and medium arm lever techniques. At this stage, significant associations were also identifiable between variable arm lever techniques and male gender and variable arm lever and medium arm lever techniques with female gender.

The fourth objective, which aimed to determine the techniques predominance used by judokas as a combat time function, the male categories preferentially opt for variable arm lever techniques, followed by maximum arm, and this trend is maintained in golden score time. The female categories opted in combat time for maximum arm lever techniques followed by variable arm lever and in the golden score reversed the described trend, showing significant differences in their choices from combat time to golden score. In the couple techniques there was a predominance for both genders throughout the combats for the use of arm-leg couple techniques, although very close to the frequencies registered in the trunk-leg techniques, without differences between groups or significant associations between classes of couple techniques and fight minutes.

This work, despite presenting a method of classifying the technique different from the conventionality of technical analysis works in judo, presents an interpretative limitation based on the absence of other technical-tactical indicators before the technical execution by the competitors.

It is suggested that in future studies that consider the technical interpretation from this biomechanical perspective, information regarding the direction of imbalance and attack should also be integrated, as they are essential to identify an athlete's attack system and its effectiveness.

As practical applications of the results obtained in the present study, we present our proposals below.

Given that some associations in technical options in combat were evidenced in terms of judokas' gender and weight category, the connections found in this study, which can be justified by the biomechanics projection techniques, should be taken into consideration in the technical and tactical training of the competitors.

The somatotype must be considered when choosing the techniques that make up the technical-tactical system for the competition, always taking into account the opponent's height and the type of grips used.

The quantity and quality of technical and tactical actions performed by the competitors must be monitored during training and competitions, allowing a detailed analysis by combat phases and providing feedback, in order to best select the physical preparation means and stimulate technical and tactical preparation regarding the execution of counter-attack or combination techniques.

The systematic methods development of technical and tactical observation can and should be a reference for coaches and analysts to identify judokas' optimal performances, allowing them more specific, precise, and facilitated comparative analyses.

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