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Comparison between the KPNP and Daedo Protection Scoring Systems through a Technical-Tactical Analysis of Elite Taekwondo Athletes

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Abstract: Background: In the last two decades, the use of technology has been incorporated into taekwondo, changing the rules of the sport to employ a more objective scoring system. The current electronic Protection Scoring Systems (PSS) include sensors that register the number and power of the hits scored, but these may interfere with athlete's techniques and tactics. This study aimed to analyze the technical-tactical differences in elite taekwondoists using two different PSS. Methods: We systematically observed 112 combats involving 224 athletes, and their actions were registered and analyzed using contingency tables. Results: Eight hundred twenty-seven effective actions were tagged, and differences were found in the types of kicks performed using different PSS. For the total sample, there were differences between PSS in technical actions (X^2 = 36.08(10); $p < 0.01$; V = 0.21), tactical actions (X^2 = 10.73(3); $p < 0.05$; V = 0.11), and hitting side (X^2 = 30.97(1); $p < 0.01$; V = 0.19). In men, the differences in techniques and tactics between different PSS were found in technical actions (X^2 = 27.15(10); $p < 0.01$; V = 0.25), guard position (X^2 = 14.94(1); $p < 0.01$; V = 0.18), and hitting side (X^2 = 11.07(1); $p < 0.01$; V = 0.16), while in women, significant differences were found in technical actions (X^2 = 37.03(8); $p < 0.01$; V = 0.32), tactical actions (X^2 = 24.45(3); $p < 0.01$; V = 0.26), guard position (X^2 = 3.95(1); $p < 0.05$; V = 0.10), hitting side (X^2 = 19.27(1); $p < 0.01$; V = 0.23), and laterality (X^2 = 16.32(3); $p < 0.01$; V = 0.21). Conclusions: The present study evidenced a difference in the technical-tactical behavior of elite taekwondoists as a result of the PSS used in combat, with more marked differences in female athletes. These findings also suggest the need to adapt and review the PSS to effectively score in the same way.

Keywords: opposition sports; combat sports; mixed methods; tactics; protection; scoring system

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1. Introduction

In recent years, taekwondo has become one of the most rapidly updated combat sports [1], granting an important role to the use of technology within the sport. Scores in taekwondo had been traditionally determined by the agreement of three judges according to subjective criteria based on their perception of the technique and tactics performed by the athletes; thus, the scoring system depended on the referee's judgement. However, the World Taekwondo Federation (WT) integrated technology into the combat modality in 2009, leading to a more objective scoring system. This scoring is achieved using different sensors located in different areas of the chest protector and helmet, indicating the power and location of the hits [2,3].

After the 2004 Summer Olympic Games in Athens, the WT promoted the inclusion of electronic body protectors for its competitions [4]. Various PSS have been used since 2007,

and in 2009, they were included for the first time in a world championship (Copenhagen, Denmark) [5]. In 2012, PSS were introduced in the Olympics for the first time, and Electronic Protective Helmets (EPH) were later used in the 2016 Olympics [6]. These changes have led to the evolution of the athlete's technics and tactics depending on the security and scoring system used in competition, since the WT made some modifications to the rules along with the incorporation of these systems [7].

Such modifications were integrated for the first time in the 2012 Olympics and were mainly comprised of the use of an octagonal competition area and a revision of the scoring system. Since then, hits in the head are awarded three points, while the use of special abilities (i.e., a spinning kick) receives an extra point. Moreover, another changes were introduced in 2018, awarding two points for kicks on the chest protector, with an additional two points if the is performed while spinning [2]. These changes have promoted the performance of more technically complex kicks, along with with faster and more fluid fights, stimulating greater motivation for athletes in competitions and improved transparency in the scoring process [4,8,9].

PSS are intended to protect the athlete's trunk and head while allowing for a simultaneous, more reliable, and accurate score determination [4], since actions in taekwondo occur at high speed over short periods of time (0.12 to 0.31 s), increasing the difficulty of scoring by the judges [10]. This system, in which the intensity of the hit is adjusted according to the weight categories of the athletes, provides an objective evaluation and fair results [11–14].

PSS work with Bluetooth TM wireless technology and have several advantages, including: the possibility to record five hits per second, instant monitoring of the hit energy, the electronic definition of the minimum impact for a valid score, a high amplitude, and reliable transmission (from more than 100 m, encrypted to avoid interferences) [4]. Electronic sensors embedded in the footwear allow the scoring of points when PSS sensors are hit. Previous research studies have considered the use of PPS, focusing on their protective qualities [7,15,16]. According to a previous study [12], a kick in the chest can produce thoracic deflections of 3 to 5 cm, with maximum viscous tolerance values of 0.9 to 1.4 $m \cdot s^{-1}$ when body protection equipment is not used, regardless of the type of kick performed. For that reason, PSS are also interesting devices for athletes. Similarly, additional studies have investigated the protective role of PSS [7,15]. Chi et al. [11] reported the use of wireless force-sensing chest protectors and how they improve the evaluation of taekwondo competitions.

Currently, there are only two brands approved by the WT for such purposes, namely Daedo and KPNP [6,17]. Nevertheless, these two systems work in different ways, despite the fact that both are homologated. According to other authors [18], these two systems differ in that, while the Daedo PSS uses electromagnetic technology, KPNP uses radiofrequency identifiers (RFID). However, to the best of our knowledge, no previous study has analyzed the differences between both brands. Therefore, the objective of this study was to analyze the technical-tactical behavior of participants using either Daedo or KPNP, according to gender, to obtain the effective techniques validated using each PSS in two competitions using the same format. We would then compare the results to identify possible differences that lead to the alteration of the dominant technical-tactical profile of the elite taekwondo athlete depending on the PSS used.

2. Materials and Methods

2.1. Participants

One hundred taekwondo athletes who competed in the quarterfinal, semifinal, and finals of the Grand Prix II, celebrated in Chiba (Japan, 2019), using KPNP, and in the Grand Prix III, celebrated in Sofia (Bulgaria, 2019) using Daedo, participated in the study. Among them, 52 were men (M_{age} = 26.5 years ± SD = 3.7) and 48 were women (M_{age} = 25.6 years ± SD = 3.4). In total, 112 combats (56 male and 56 female) were analyzed, corresponding to 14 combats (7 with Daedo and 7 with KPNP) in each Olympic

senior category (men −58 kg, −68 kg, −80 kg, and +80 kg; and women −49 kg, −57 kg, −67 kg, and +67 kg). To avoid inconsistences, combats with extra periods (i.e., golden point) were excluded. Given that these combats are of public domain, no informed consent from the athletes was obtained [19].

2.2. Procedures

Data acquisition was accomplished through a systematic observation carried out by two observers [20] and was based on previous investigations using this methodology [7,21]. The observers had 10 years (3500 h) of previous experience in video analysis. Previous studies have considered this amount of experience as sufficient to ensure high objectivity and reproducibility in the analysis of taekwondo combats [22]. The observational tool was developed using an N/S/M observational design: nomothetic (100 athletes), with follow-up between sessions (112 bouts were recorded), and multidimensional (since the observational tool is a mixed tool based on a category system and field format that contemplates not only technical, but also tactical behaviors; see Table 1).

Table 1. A description of the technical-tactical variables analyzed.

Variable	Description
Techniques	
Bandal	Semicircular kick, hitting the chest protector with the instep.
Bituro	Semicircular kick from to the outside, striking the chest protector with the instep.
Double Bandal	Semicircular double kick in the air, hitting the chest protector with the instep.
Spinning Bandal	Semicircular kick with a 360° spin, hitting the chest protector with the instep.
Tuit	Spinning kick, hitting the chest protector with the heel or sole of the foot.
Yop	Side kick, hitting the chest protector with the heel or sole of the foot.
Dolyo	Circular kick, hitting the helmet with the instep.
Spinning Dolyo	Circular kick with a previous 360° turn, hitting the helmet area with the instep.
Mondolyo	Spinning kick, hitting the helmet with the heel or the sole of the foot.
Nako	Circular kick to outside, striking the chest protector or to the helmet with the heel or the sole of the foot.
Neryo	Downward kick, hitting the helmet the heel or sole of the foot.
Tactics	
Attack	Offensive action initiated by either of the two competitors without prior action from the opponent.
Counterattack	Offensive action in response to the opponent's attack.
Clinch	Offensive action started from a clinch or short distance where both opponents are close to each other, with hardly any space to execute the action.
Give and Take	Offensive action initiated in a chained manner by either of the two opponents after a previous situation of at least 1 attack—1 counterattack.
Hitting height	
Head	Kick directed at the head.
Trunk	Kick directed at the trunk or chest.
Hitting side	
Front	Kick directed to the front or ventral part of the trunk or head.
Back	Kick directed to the back or dorsal part of the trunk or head.
Laterality	
Front right	Kick performed with the front right leg.
Rear right	Kick performed with the rear right leg.
Front left	Kick performed with the front left leg.
Rear left	Kick performed with the rear left leg.
Technical Complexity	
Chest protector–2 points	Effective kick to the chest protector.
Helmet–3 points	Effective kick to the helmet.
Spinning chest protector–4 points	Effective spinning kick to the chest protector.
Spinning helmet 5 points	Effective spinning kick to the helmet.

One video camera (Sony HDR-CX405) was utilized in each of the three competition areas to simultaneously record all the combats. The cameras were installed at the referees' control table in such a way that they registered the entire combat, allowing an optimal view for observational analysis [23]. The variables included are shown in Table 1. Dartfish ConnectPlus 7.0 (Dartfish Limited, Switzerland) was used as the observation instrument. This software allows for the analysis and tagging of combat actions with a specific record sheet for taekwondo, and the data can be easily exported to statistical packages.

A total of 1429 effective offensive actions were tagged. For the analysis, only the points validated by the PSS through kicks (n = 827, valid points = 1923) were included. Neither points validated through punches (n = 256, valid points = 256) nor banns (n = 346, valid points = 346) were included. These actions were discarded because they depend on a referee's judgement and are not controlled by PSS.

2.3. Statistical Analysis

Prior to data collection, the observational tool (Table 2) was validated. To validate and test the reliability of the observational tool, five bouts were rated by two observers. To determine the observers' agreement, the intraclass correlation coefficient (ICC) was also computed. Additionally, the reliability between the observations made (interobserver agreement) was tested using a generalizability analysis which was also used to test the validity and accuracy of the observational tool using the SAGT software [24] with multi-faceted designs that included two facets: observers (O) and categories (C). Therefore, a prior variance component was calculated which generated errors in design and the relative weights of these components (Table 2). In this sense, the C/O model evaluates interobserver agreement in the categories observed in the bouts selected, determining—when results are close to one—that the observations made are reliable. In this case, the G coefficient of 0.97 revealed nearly perfect agreement. This result was supported by an $ICC_{intraobserver}$ and $ICC_{interobserver}$ of 0.99. The O/C model tests the goodness of fit of the categories, that is, whether they are exhaustive and mutually exclusive (E/ME) if the results tend toward zero. The G coefficient of 0 indicates the well-fitting and heterogeneous categories of the observational tool created.

Table 2. The variance component analysis results.

Source of Variance	ANOVA Type III	Degrees of Freedom
Observer	0.325	1
Categories	2142.955	7
Observer*Categories	66.050	7

The data analysis was performed using the software JASP 0.14 (JASP Team, University of Amsterdam, Amsterdam, The Netherlands). The descriptive statistical parameters were calculated for continuous variables (mean and standard deviation) and categorical variables (frequency and percentages). Comparisons between the categorical variables were performed using the Chi-Square test through a contingency table. Cramer's V effect size was used to measure how strongly two categorical fields were associated. ES $\leq$ 0.2 means a weak association, 0.2 < ES $\leq$ 0.6 means a moderate association, and ES > 0.6 means a strong association [25]. Z-tests were also used to compare column proportions with a Bonferroni adjustment for the p-values when significant differences were found.

3. Results

Table 3 presents the results regarding techniques and tactics for the total sample and for both genders (men and women) for the PSS used. The distribution of frequencies of the 827 tagged kicks as a function of gender and PSS has been analyzed using a Chi-Square test (X^2). For the total sample, the Chi-Square test showed significant differences in the technical (X^2 = 36.18(10); p < 0.01; V = 0.21) and tactical (X^2 = 10.82(3); p < 0.05; V = 0.11) actions, respectively. Concretely, the z-test used to compare the column proportions showed that

Bituro and Nako were the techniques that scored higher with KPNP while Dolyo and Yop received higher scores with Daedo., Results also showed that, with KPNP, more points were obtained using Give and Take than with Daedo.

Table 3. The frequency (N) and percentages (%) of the technical-tactical actions observed (data presented in N (%)).

	Men		**Women**		**Total**	
	KPNP	**DAEDO**	**KPNP**	**DAEDO**	**KPNP**	**DAEDO**
Technical	$X^2 = 27.15(10)$; $p < 0.01$; V = 0.25		$X^2 = 37.03(8)$; $p < 0.01$; V = 0.32		$X^2 = 36.08(10)$; $p < 0.01$; V = 0.21	
Bandal	100(47.4) ^{a}	121(50) ^{a}	56(47.1) ^{a}	131(51.6) ^{a}	156(47.3) ^{a}	252(50.8) ^{a}
Bituro	9(4.3) ^{a}	9(3.7) ^{a}	6(5) ^{a}	0(0) ^{b}	15(4.5) ^{a}	9(1.8) ^{b}
Double Bandal	1(0.5) ^{a}	2(0.8) ^{a}	1(0.8) ^{a}	3(1.2) ^{a}	2(0.6) ^{a}	5(1) ^{a}
Dolyo	10(4.7) ^{a}	40(16.5) ^{b}	17(14.3) ^{a}	32(12.6) ^{a}	28(8.2) ^{a}	72(14.5) ^{b}
Spinning Bandal	1(0.5) ^{a}	1(0.4) ^{a}	-	-	1(0.3) ^{a}	1(0.2) ^{a}
Spinning Dolyo	0(0) ^{a}	2(0.8) ^{a}	-	-	0(0) ^{a}	2(0.4) ^{a}
Mondolyo	1(0.5) ^{a}	0(0) ^{a}	1(0.8) ^{a}	1(0.4) ^{a}	2(0.6) ^{a}	1(0.2) ^{a}
Nako	18(8.5) ^{a}	8(3.3) ^{b}	20(16.8) ^{a}	12(4.7) ^{b}	38(11.5) ^{a}	20(4) ^{b}
Neryo	35(16.6) ^{a}	23(9.5) ^{b}	5(4.2) ^{a}	22(8.7) ^{a}	40(12.1) ^{a}	45(9.1) ^{a}
Tuit	9(4.3) ^{a}	9(3.7) ^{a}	3(2.5) ^{a}	3(1.2) ^{a}	12(3.6) ^{a}	12(2.4) ^{a}
Yop	27(12.8) ^{a}	27(11.2) ^{a}	10(8.4) ^{a}	50(19.7) ^{b}	37(11.2) ^{a}	77(15.5) ^{b}
Tactical	$X^2 = 2.27(3)$; $p = 0.52$; V = 0.07		$X^2 = 24.45(3)$; $p < 0.01$; V = 0.26		$X^2 = 10.73(3)$; $p < 0.05$; V = 0.11	
Attack	83(39.2)	101(41.7)	31(26.1) ^{a}	97(38.2) ^{b}	114(34.4) ^{a}	198(39.9) ^{a}
Clinch	50(23.6)	49(20.2)	20(16.8) ^{a}	78(30.7) ^{b}	70(21.1) ^{a}	127(25.6) ^{a}
Counterattack	39(18.4)	54(22.3)	29(24.4) ^{a}	40(15.7) ^{b}	68(20.5) ^{a}	94(19) ^{a}
Give and Take	40(18.9)	38(15.7)	39(32.8) ^{a}	39(15.4) ^{b}	79(23.9) ^{a}	77(15.5) ^{b}

Each subscript letter denotes a subset of system categories whose column proportions do not differ significantly from each other at the 0.05 level.

Regarding technique, men ($X^2 = 27.67(10)$; $p < 0.01$; V = 0.25) and women ($X^2 = 37.03(8)$; $p < 0.01$; V = 0.32) showed significant differences between the use of KPNP and Daedo. Concretely, the z-test used to compare the column proportions showed that, in men, the scoring of a point with the use of Nako and Neryo was significantly higher with KPNP, while the use of Dolyo yielded significantly greater scores with Daedo. On the contrary, women scored significantly more points for Bituro and Nako with the use of KPNP while the use of Yop showed significantly higher scoring with Daedo.

Regarding tactics, no differences were found in men ($X^2 = 2.27(3)$; $p = 0.52$; V = 0.07) wearing either KPNP or Daedo. In women, the results in relation to tactics showed significant differences ($X^2 = 24.45(3)$; $p < 0.01$; V = 0.26). Concretely, the z-test used to compare the column proportions showed a significant higher scoring with the use of KPNP in Counterattacks and Give and Take, while a with Daedo, there was a significantly higher scoring with the use of Attack and Clinch.

Table 4 presents the results regarding guard, hitting height, hitting side, laterality, and technical complexity. For the total sample, Chi-Square (X^2) analyses showed statistically significant differences for hitting side ($X^2 = 30.97(1)$; $p < 0.01$; V = 0.19) while no differences were found for guard, hitting height, laterality, and technical complexity ($p > 0.05$). Concretely, the z-test used to compare the column proportions showed significantly higher scoring with the use of KPNP when kicking in the front side of the body protector, while with Daedo, higher scoring occurred with kicks to the back side.

Table 4. The results observed regarding guard, hitting height, hitting side, laterality, and technical complexity.

	Male		**Female**		**Total**	
	KPNP N (%)	**DAEDO N (%)**	**KPNP N (%)**	**DAEDO N (%)**	**KPNP N (%)**	**DAEDO N (%)**
Guard	$X^2 = 14.94(1)$; $p < 0.01$; V = 0.18		$X^2 = 3.95(1)$; $p < 0.05$; V = 0.10		$X^2 = 2.31(1)$; $p = 0.12$; V = 0.05	
Open	145 (68.7) [a]	123 (50.8) [b]	66(55.5) [a]	168(66.1) [b]	212(64)	291(58.7)
Closed	66 (31.1) [a]	119 (49.2) [b]	53(44.5) [a]	86(33.9) [b]	119(36)	205(41.3)
Hitting height	$X^2 = 0.56(1)$; $p = 0.46$ V = 0.04		$X^2 = 0.59(1)$; $p = 0.44$ V = 0.04		$X^2 = 0.59(1)$; $p = 0.44$ V = 0.04	
Helmet	53(25.1)	68(28.1)	31(26.1)	57(22.4)	84(25.4)	125(25.2)
Body protector	159(74.9)	174(71.9)	88(73.9)	197(77.6)	247(76.6)	371(74.8)
Hitting side	$X^2 = 11.07(1)$; $p < 0.01$; V = 0.16		$X^2 = 19.27(1)$; $p < 0.01$; V = 0.23		$X^2 = 30.97(1)$; $p < 0.01$; V = 0.19	
Front	156(73.9) [a]	143(59.1) [b]	92(77.3) [a]	136(53.5) [b]	249(75.2) [a]	279(56.2) [b]
Back	55(26.1) [a]	99(40.9) [b]	27(22.7) [a]	118(46.5) [b]	82(24.8) [a]	217(43.8) [b]
Laterality	$X^2 = {}^0.13(3)$; $p = 0.98$; V = 0.16		$X^2 = 16.32(3)$; $p < 0.01$; V = 0.21		$X^2 = 6.33(3)$; $p = 0.09$; V = 0.09	
Right front	60(28.4)	68(28.1)	57(47.9) [a]	70(27.6) [b]	117(35.3)	138(27.8)
Right rear	45(21.3)	49(20.2)	20(16.8) [a]	55(21.7) [a]	65(19.6)	104(21.0)
Left front	44(20.9)	53(21.9)	15(12.6) [a]	60(23.6) [b]	59(17.8)	113(22.8)
Left rear	62(29.4)	72(29.8)	27(22.7) [a]	69(27.2) [a]	90(27.2)	141(28.4)
Technical Complexity	$X^2 = 0.69(3)$; $p = 0.88$; V = 0.04		$X^2 = 1.82(3)$; $p = 0.61$; V = 0.07		$X^2 = 0.73(3)$; $p = 0.87$; V = 0.03	
Chest protector—2 points	150(70.6)	164(67.8)	85(71.4)	194(76.4)	235(71)	358(72.2)
Helmet—3 points	52(24.6)	66(27.3)	30(25.2)	56(22.0)	82(24.8)	122(24.6)
Spinning chest protector—4 points	9(4.3)	10(4.1)	3(2.5)	3(1.2)	12(3.6)	13(2.6)
Spinning helmet—5 points	1(0.5)	2(0.8)	1(0.8)	1(0.4)	2(0.6)	3(0.6)
Total	212(100)	242(100)	119(100)	254(100)	331(100)	496(100)

Each subscript letter denotes a subset of system categories whose column proportions do not differ significantly from each other at the 0.05 level.

Regarding guard, there were significant differences for men ($X^2 = 15.23(1)$; $p < 0.01$; V = 0.18) and women ($X^2 = 3.95(1)$; $p < 0.05$; V = 0.10) when using both PSS methods. Concretely, in men, the z-test used to compare the column proportions showed a significantly higher scoring with the use of KPNP in open guard position, while with Daedo showed higher scoring with the close guard position. In women, there was a significantly higher scoring with the use of KPNP in the close guard position, while with Daedo, the scoring was higher using the open guard position.

For hitting height, no significant differences were found in either men ($X^2 = 0.56(1)$; $p = 0.46$ V = 0.04) or women ($X^2 = 0.59(1)$; $p = 0.44$ V = 0.04) regarding the PSS used.

For hitting side, the results showed significant differences between both systems in men ($X^2 = 11.29(1)$; $p < 0.01$; V = 0.16) and women ($X^2 = 19.27(1)$; $p < 0.01$; V = 0.23). Concretely, for both sexes, the z-test used to compare the column proportions showed significantly higher scoring with the use of KPNP when kicking in the front side of the body protector, while with Daedo, a higher score was obtained when kicking to the back side.

For laterality, the results showed significant differences between the systems in women ($X^2 = 16.32(3)$; $p < 0.01$; V = 0.21), but not in men. Concretely, the z-test used to compare the column proportions showed a significantly higher scoring with the use of KPNP when kicking with right foot in the front, while with Daedo, a higher scoring was obtained when kicking with the left foot in the front.

Regarding technical complexity, no differences were found neither in men or in women ($p > 0.05$).

4. Discussion

The objective of this study was to analyze the technical-tactical behavior of taekwondo athletes to score effective techniques registered with Daedo and KPNP and to determine whether results observed with both systems differ according to gender in order to identify possible differences that translate into alterations of the dominant technical-tactical profile of elite taekwondoists depending on the PSS used. The main findings show: (i) taekwondo athletes show different techniques and tactics when using different PSS; and (ii) these differences are independent of gender. These results are a matter of interest for trainers, since they reveal which techniques and tactics to practice ahead of a tournament depending on the PSS that will be used, Daedo or KPNP.

To the best of our knowledge, this is the first study to compare the technical-tactical behavior of elite taekwondoists regarding the PSS used in official competitions. The results show that the total number of points earned was higher with Daedo than with KPNP. This suggests that it is easier to score points with Daedo than with KPNP. This is in contrast with a previous study that analyzed the valid points of the two e-trunk protectors on an adjustable humanoid target with a sample of elite college taekwondo athletes and found a higher number of valid points scored with KPNP than with Daedo [26]. The authors concluded that it was easier to obtain valid points using the KNPN chest protector. However, [27] examined the validity and reliability of the Daedo electronic body protector when tested on two separated days. They found significant differences in 9 of the 12 areas tested on each day. These differences compromised the reliability and validity of the Daedo PSS, which can explain the discrepancies in the results found.

Women using Daedo achieved more than two times the number of effective kicks scored with Daedo than with KPNP, while the number in men was nearly equivalent. These results are in line with a previous study in which the authors highlighted various difficulties observed for effective scoring when using KPNP in several weight and gender categories, especially in heavier taekwondoists [15]. The current study supports these findings, evidencing that there is a gap found between the difficulty of scoring when using KPNP or Daedo. There is an increased difficulty to score when using KPNP in both the chest protector and the helmet, which is more noticeable in female participants. This evidence suggests the need to decrease the power thresholds in KPNP, at least in female combats.

Regarding the technical actions, for the total sample, Bituro and Nako were scored significantly higher with KPNP than with Daedo, while Dolyo scored more points with Daedo than KPNP. Men showed higher scoring when using Nako and Neryo with KPNP than with Daedo, while Dolyo was scored significantly higher using Daedo. On the contrary, women scored significantly more points with Bituro and Nako when using KPNP, while Yop yielded higher scores with Daedo. It seems that with KPNP, it is easier to score with using circular actions (i.e., Nako and Bituro) while with Daedo, it is easier to score using linear actions (Yop). This is in line with previous studies [26] that found that with the KNPN protector, the effectiveness of the scoring rate was higher for a roundhouse kick (a circular kick) that for a side kick (a linear kick).

Nevertheless, it is important to highlight that, in men, with the use of KPNP, the technique with a higher percentage of scoring was for Bandal, followed by Neryo. With the use of Daedo, the higher percentage scored was for Bandal, followed by Dolyo. In women, the higher percentage of scored technique wearing KPNP was for Bandal, followed by Nako, while those using Daedo scored higher using Bandal, followed by Yop. Previous investigations have focused on Bandal [28–30] and agree that this kicking technique is the easiest kick to perform due to its short trajectory, great efficacy, and high speed, together with a low associated risk during combats. Other studies [31] have shown that in men, the second most-used technique was Yop, while in women, Yop was the most-used technique and Bandal was the second.

Regarding tactics, for the total sample, more points were obtained when using Give and Take with KPNP than with Daedo. No difference between either PSS was shown for

men. However, women showed higher scoring in Counterattacks and Give and Take with KPNP than with Daedo, while the use of Attack and Clinch scored higher with Daedo than with KPNP. It seems that with KPNP (especially for women), it is more rewarding to wait for the attack of the opponent, profiting from the inertia of the other athlete (and reaching the minimum threshold of the system) to score in a counterattack or in an exchange situation (Give and Take). With Daedo, it is suggested to initiate the attack, either in the long distance or in body-to-body situations (i.e., clinch). With KPNP, men showed the higher percentage of points for Attacks, followed by Clinch. With Daedo, Attack and Counterattack showed the higher percentages of scoring. For women, Give and Take and Attack showed the higher percentages of scoring with KPNP, while with Daedo, it was Attack and Clinch. This shows that even though there are no differences between the systems, the Attack is still the best way to score and win the match. This is in line with previous studies [23] showing that taekwondo athletes performed more Attacks than Counterattacks. However, winners performed more Counterattacks than non-winners. In males, previous studies [32] showed a higher proportion of scores from Counterattacks in the 2008 Summer Olympic Games in Beijing. In women, a similar percentage was found regarding attacks and counterattacks [32]. It will be interesting to see the evolution of the Give and Take and the Clinch in future studies, since the results showed an increase in these types of tactical actions and no previous studies have reported on these.

Regarding guard position, there were no significant differences for the total sample. However, men showed significantly higher scoring in the open guard position with the use of KPNP than with Daedo, while with Daedo, higher scoring was obtained using the close guard position than with KPNP. In women, there was significantly higher scoring with the use of KPNP in the close guard position, while with Daedo, higher scoring was obtained with the open guard position. When using KPNP, men showed a higher percentage of scoring with the open guard position, while with Daedo, the percentage was similar in both guard positions. On the contrary, women showed a similar percentage of scoring with KPNP with both guard positions, while with Daedo, the higher percentage was found in the open guard position. This can be explained by the fact that there is movement by the opponent when being kicked, and the kicks are defended by hand. In any case, in a taekwondo match, lower scoring may lead to lower interest, so further discussion about the reference impact force used in scoring is needed [17].

When it comes to the hitting height, no significant differences were found between either PSS for either men or women in the total sample. With both PSS, the ratio of scoring was about one to three, for the helmet and the body protector, in both males and females. This is in line with other studies that have shown a greater use of kicks to the body protector rather than the helmet, due to less difficulty in scoring [22,33–35].

Regarding the hitting side, for the total sample, as well as for both sexes, higher scoring was noted when kicking in the front side of the body protector with the use of KPNP compared to Daedo, while there was a higher scoring when kicking to the back side with Daedo compared to KPNP. For both sexes, the ratio of actions scored when using KPNP were one to three, with kicks to the back and front side of the protector, respectively, while with Daedo, the ratio was quite similar. This can explain why with KPNP, there is a higher scoring with the open guard position, while the scoring is higher in Clinch with Daedo. Future studies should confirm this.

No significant differences were found regarding laterality for the total sample of men. In women, significantly higher scoring was found with the use of the right foot on the front comparing KPNP and Daedo, while with the left foot in the front, there was a higher scoring with Daedo than with KPNP. With both systems, men and women performed their kicks with both legs, revealing the bilateral capacity of taekwondoists to hit their opponents [22,30]. These results support the proposal of [33,36], who stated that training both sides of the body uniformly and not only the dominant side, can provide taekwondoists with competitive advantages in combat. Nevertheless, women using KPNP evidenced a preference for the effective use of the front side leg, what differs from data

presented in the aforementioned investigations. This suggests that women had to use their dominant leg more frequently to reach the minimum power threshold established for each weight category. These findings are in agreement with those of Cho et al. [7] who stated that the taekwondoists' technical-tactical performance during a competition can be substantially influenced by the PSS used.

In terms of technical complexity, no differences were found in either PSS for the total sample for either men or women. Previous studies [23,28,37] coincide in showing the preference for scoring with kicks on the chest protector and helmet than by hitting with spinning kicks. This evidence highlights that the two extra points rewarded for spinning techniques do not influence their utilization; moreover, athletes more often choose simpler and safer kicks [7]. This is in line with previous studies [31] that analyzed the techniques used in the 2017 World Cup finals where KPNP was used and spinning kicks accounted for 2.5% of kicks in men and 1.5% in women.

The present study has two main limitations. The first limitation is that even though the athletes analyzed are the best 32, not all of them participated in both competitions, which can vary the results. The second limitation is the fact that we did not analyze performance regarding the weight category, which has shown that not all categories compete in the same manner. Future investigations should analyze these differences with regard to the different weight categories in both men and women. Moreover, it is important to address this topic in different performance levels to extrapolate the results to other areas of the population.

5. Conclusions

This study confirms the technical-tactical differences found in taekwondo combats depending on the PSS used (Daedo or KPNP). Moreover, these differences are independent of gender. That is: (1) With KPNP, men obtain more effective points with Nako and Neryo, while women obtain more effective points with Bituro and Nako. On the contrary, with Daedo, men obtain more effective points with Dolyo, while women obtain more effective points with Yop. (2) With KPNP, women achieve better results with Give and Take and Counterattacks, while with Daedo, they are more effective with Attack and Clinch. (3) Men score more using the open guard position with KPNP and with the close guard position with Daedo, while for women, the opposite occurs. (4) Regarding hitting side, with the use of KPNP, men and women show a higher effectivity with techniques towards the front, while with Daedo, they show a higher effectivity with techniques towards the back. (5) With KPNP, women show higher effectivity with the front right leg, while with Daedo, they show more effectivity with the front left leg. These findings show the need to adapt technical-tactical techniques considering the PSS that the athlete will use in the competition, optimizing previous trainings and achieving better results with the techniques employed for each protection system. The need to adapt and review the PSS to be used in competition in order to score effectively is also suggested.

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