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Kons, Rafael; Krabben, Kai; Mann, David L.; Detanico, Daniele

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Effect of vision impairment on match-related performance and technical variation in attacking moves in Paralympic judo

Rafael Kons^a, Kai Krabben^b, David L. Mann^b and Daniele Detanico^a

^aBiomechanics Laboratory, Sports Centre, Federal University of Santa Catarina, Florianópolis, Brazil; ^bDepartment of Human Movement Sciences, Faculty of Behavioral and Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam Movement Sciences, Amsterdam, The Netherlands

ABSTRACT

In Paralympic judo for athletes with vision impairment (VI judo) all eligible athletes (i.e. B1, B2 and B3 classes) compete against each other in the same competition. Evidence suggests that athletes with more impairment may be disadvantaged, but that more sensitive measures of performance are necessary to understand the impact of impairment on performance. The aim of this study was to investigate the relationship between Para sport class and technical variation, time-motion variables, and performance in Paralympic judo. All 175 judo matches from the Rio 2016 Paralympic Games were analysed across 129 competitors (82 male and 47 female). The main results indicated that athletes who demonstrated less technical variation also experienced less competitive success, with the functionally blind athletes (class B1) demonstrating less technical variation than partially sighted (class B2 and B3) athletes ($p < 0.05$). There was no difference in the time-motion variables between sport classes ($p > 0.05$). We conclude that measures of technical variation are sensitive to differences in impairment and are suitable for studies that investigate the impairment-performance relationship in VI judo. Results further confirm that some athletes with impairment are disadvantaged under the current rules of VI judo.

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Combat sports; Paralympic judo; time-motion; variability; classification

Introduction

Movement variability has traditionally been considered a source of noise which needs to be reduced, but is more recently recognized as a key element of expertise in sports (Bartlett et al., 2007; Davids et al., 2015; Seifert et al., 2012). Successful sports performance requires an optimal mix between stability and flexibility, which enables the performer to functionally adapt to dynamic (sport) environments (Fajen et al., 2009; Van Emmerik & van Wegen, 2000) and allows creative motor actions to emerge (Orth et al., 2017). This is especially clear in interactive sports, where athletes need to co-adapt their own behaviours to that of their opponent (Hristovski et al., 2012; Pinder et al., 2011). To outperform a direct opponent (e.g., pass a defender in soccer, or strike an opponent in boxing), athletes may need to operate in metastable performance regions, where multiple competing modes of action co-exist and small perturbations can shift the dynamics of the contest either way (Duarte et al., 2012; Hristovski et al., 2006; Kimmel & Rogler, 2018; Krabben et al., 2019b). The key implication for athletes in interactive sports is that a wider repertoire of movements will provide more options during a match and likely be associated with greater competitive success (Krabben et al., 2019b).

Judo is a highly dynamic and interactive sport which requires a variety of complex technical and tactical skills such as gripping, unbalancing, and throwing an opponent (Branco et al., 2013; Miarka, Fukuda, Del Vecchio, & Franchini, 2016). The behaviours of both athletes in a judo match are directly interdependent: action opportunities for one judo athlete continuously emerge and decay during a match depending on the behaviours of the other

combatant (Gutiérrez-Santiago et al., 2011; Krabben et al., 2019b; Miarka et al., 2012). Judo athletes thus need to constantly anticipate and (re)act to their opponent (Piras et al., 2014) to successfully execute offensive and defensive actions (Courel et al., 2014). Judo athletes are encouraged to develop a range of throwing techniques to increase the unpredictability of their actions and enhance their chance of winning (Calmet & Ahmaidi, 2004; Miarka et al., 2015). Technical variation might even distinguish good from excellent elite-level judokas. Judokas who repeatedly won medals at the World or Olympic level have been found to be able to apply a greater number of different throwing techniques in matches compared to athletes who also medalled at the elite level, but who were less consistent in their performance over time (Franchini, Sterkowicz, Meira, Gomes, & Tani, 2008).

Despite the assumed benefit of technical variation in Olympic judo athletes, it remains unclear whether the relationship remains in Paralympic judo for athletes with vision impairment (VI judo), and therefore, whether technical variation is a marker of success in the sport. Although there are technical and tactical similarities between VI Judo and its Olympic counterpart, there is one key adaptation to the sport that alters the nature of competition. In VI judo, athletes must start the match with a two-handed grip on the jacket of the opponent already in place to decrease the visual demands of the sport (Gutiérrez-Santiago et al., 2011; Kons et al., 2018). This is in contrast to able-sighted judo, where athletes start the bout a few metres apart, after which they first must fight to engage and grip their opponent before they can attempt to throw him/her (Gutiérrez-Santiago et al., 2011). The adaptation in VI judo

constrains the initial position of the athletes and might alter the type of throwing techniques they are capable of using. Accordingly, technical variation might not be a marker of success in the sport.

In VI judo, athletes with different degrees of vision impairment (ranging from partially sighted to fully blind) are allocated to one of three different sport classes commonly used across almost all VI sports (B1, B2 and B3 for athletes with the most to the least severe degree of impairment, see Table 1). However, during competition all judokas compete against each other in the same competitive class. This is unlike most other VI sports, where competition is divided into different sport classes to ensure athletes compete against others with a similar degree of activity limitation (Mann & Ravensbergen, 2018; Tweedy & Vanlandewijck, 2011). The assumption has been that the adaptations made to the sport ensure that the most severely impaired athletes who are functionally blind (in particular the B1 athletes) must be able to compete fairly even against those with the least impairment (i.e., B3 athletes) when competing together in the same competition.

Previous studies have already raised doubt that functionally blind athletes are able to compete equitably in elite level VI judo competitions against those with some residual visual function (Krabben et al., *in press*, 2018; Kons et al., 2019; Mashkovskiy et al., 2019). For instance, Kons et al. (2019) reported that the odds ratio for winning a gold medal at the 2012 and 2016 Paralympic Games was up to seven-times lower for functionally blind athletes (class B1) compared to partially sighted athletes (class B2 and B3). However, it is less clear which aspects of judo performance are mostly limited in athletes with full loss of vision. Kons et al. (2019) explored some technical-tactical and time-motion parameters that might explain the differences in performance through an analysis of the final throwing technique used that resulted in wins at the 2012 and 2016 Paralympic Games. The authors verified that both time-motion variables (e.g., time to lose) and the winning technique were different between functionally blind (B1) and partially sighted (B2 and B3) athletes. This is useful from the perspective of evidence-based classification research, because it provides additional measures of performance that could be used to better understand the relationship between vision impairment and performance in VI judo (i.e., to address Step 3b in Tweedy et al.'s (2016) five-step model for evidence-based classification research to develop sport-specific measures of determinants of performance). Yet although the aforementioned study analysed the winning technique, the degree of variability of techniques that athletes use in VI judo remains

unclear. Considering that judo performance in able-sighted judo is related to a judoka's degree of technical variation (Calmet & Ahmaidi, 2004; Franchini et al., 2008; Miarka et al., 2015), technical variation might also be a relevant determinant of performance in Paralympic judo. If so, it could be used as an additional measure of performance when establishing the impairment-performance relationship to establish new evidence-based sport classes in VI judo.

The aim of this study was to investigate the relationship between Para sport class and technical variation, time-motion variables, and performance in Paralympic judo. We analysed the performance of all Paralympic judo athletes who participated in the Rio 2016 Paralympic Games (PG) to determine differences in technical variation, match-related performance, and competitive success across the different sport classes. We hypothesized that functionally blind (B1) athletes would show lower levels of technical variation and competitive success (e.g., win ratio) than partially sighted (B2 and B3) athletes. In particular, we expected that judokas who showed higher levels of technical variation would be more successful during competition. The results were expected to be useful in uncovering potentially new measures of performance for establishing the impairment-performance relationship in VI judo.

Method

Data sample

Data for this study were extracted from the Official Result Books of the Rio de Janeiro 2016 PG, documented by a judo expert referee from the International Judo Federation (IJF). The results book includes detailed match information including the temporal structure and technical aspects of each match (e.g., type of judo techniques applied). The lead author, who is a judo black belt as well as a VI judo coach, tabulated the data and performed the statistical analyses.

We analysed all 175 matches from seven male weight categories (111 matches) and six female weight categories (64 matches).¹ A total of 129 athletes took part (82 men and 47 women), representing 36 different national federations. Twenty-four athletes were classified as B1, 58 as B2 and 47 as B3. The B1 athletes competed on average in 2.3 ± 1.2 matches (mean $\pm$ SD), B2 athletes competed in 2.9 ± 0.8 matches, and B3 athletes in 2.7 ± 2.9 matches. The structure of Paralympic judo takes the form of a "knock-out" competition, similar to Olympic judo, where judokas who win continue to the next round, and those defeated are "knocked out" of the competition. At the Rio Paralympic

Table 1. Classification criteria for VI athletes according to International Blind Sports Federation (IBSA) regulation.

Class	Visual acuity (LogMAR)	Visual field (radius)	Description
B3	1.0 to 1.4	Less than 20 degrees	Limited visual acuity and/or visual field in both eyes
B2	1.5 to 2.6	Less than 5 degrees	Severely limited visual acuity and/or visual field in both eyes.
B1	Poorer than 2.6	Cannot be B1 with only loss of visual field	An athlete can distinguish only light from dark, or is not able to perceive light.

¹A total of 175 matches were played during the RIO 2016 PG according to the official Results Book of the event. However, detailed match data were missing from that same Results Book for eight matches. We are not aware why these data are missing from the Results Book but could not include these matches for some of our analyses. Since all match-related variables were normalised by number of matches, we did not expect the omission of these eight fights to have a significant impact on our results and conclusions.

Games, judokas each competed in a minimum of one and a maximum of four matches. No ethical committee was consulted prior to conducting this study because data were obtained in secondary form from a publicly available source and were not generated by experimentation (Morley & Thomas, 2005).

Description of variables

In judo, scores are awarded for successfully executed techniques, subdivided into *ippon* (highest score, which immediately ends the match), *waza-ari* (medium score), and *yuko* (small score) according to the rules applied during the PG Rio 2016. For each score in each match, we extracted who made the score, what time in the match the score was made, and which type of judo throwing technique was used to obtain the score. Throwing techniques were subdivided into leg throws, hip throws, hand throws, and sacrifice throws. Leg, hip, and hand techniques refer to the main body part used to throw the opponent. Sacrifice techniques are throws whereby the attacking judoka drops him/herself on his back first (i.e., “sacrifices” oneself) to execute the throw (Daigo, 2005). The time-motion analysis was based on the time that each action occurred during the match, expressed in seconds of playing time (Gutiérrez-Santiago et al., 2012, 2020, 2011).

For each athlete (winner or loser), we analysed the match outcome, technical variation, and time-motion using the following variables:

- (a) Win ratio: the ratio between matches won and matches competed;
- (b) Throws per match: each judoka’s total number of throws throughout the competition awarded with a score divided by the number of matches they competed in;
- (c) Technical variability ratio: each athlete’s total number of different types of throwing techniques awarded with a score (i.e. leg, hip, hand or sacrifice throws) throughout the competition divided by the number of matches they competed in;
- (d) Index of Qualitative Variation (IQV): the IQV is a measure to assess how much spread there is within a nominal variable. It expresses the ratio between the total number of different values to the maximum number of different values in the distribution (Frankfort-Nachmias & Leon-Guerrero, 2016):

$$IQV = \frac{K(100^2 - \sum Pct^2)}{100^2(K - 1)}$$

Where:

K = the number of categories (in this study 4: leg, hip, hand, and sacrifice throws)

$\sum Pct^2$ = the sum of the squared percentages for all categories in the distribution

When all cases in the distribution are in a single group, there is no variation (or diversity) and the IQV is 0. In contrast, when the cases in the distribution are distributed evenly across the groups, there is maximum variation and the IQV is 1. For example, an athlete who scores three times using three different type of techniques (e.g., one hand throw, one leg throw and

one sacrifice throw) will show a higher technical variability ratio, and a higher IQV, than another athletes who also scored three times, but each time using the same type of technique (e.g., all leg throws). For example, for actual scores for the technical variability ratio and the IQV if the athlete had, for instance, taken part in four matches and used in total six scoring throws (hand throws ($n=2$), hip throws ($n=1$) and sacrifice throws ($n=3$)), their technical variability ratio would be 0.75 and their IQV would be 0.81.

- (a) Total match time: average time from start to end of the match, including the pauses (i.e. *mate*) (measured in seconds);
- (b) Time to reach score: average time taken to obtain each scoring throw (measured in seconds);
- (c) Time to receive penalty: average time taken to receive each penalty (measured in seconds).

Statistical analysis

The normal distribution of the variables was confirmed using the Kolmogorov-Smirnov test. The relationship between the win ratio and throws per match, and between the win ratio and the measures of technical variation (technical variability ratio and IQV) were assessed using Pearson correlation coefficients, adopting the criteria proposed by Hopkins (2002): $r = 0 - 0.1$ (trivial), $0.1 - 0.29$ (small), $0.3 - 0.49$ (moderate), $0.5 - 0.69$ (large), $0.7 - 0.89$ (very large) and $0.9 - 1.0$ (almost perfect). One-way analysis of variance (ANOVA) and Tukey post-hoc tests were used to compare the win ratio, throws per match, measures of technical variation (technical variability ratio and IQV) and time-motion variables (total match time, time to reach score, and time to receive penalties) between athletes from the different sport classes (B1, B2 and B3). Effect sizes for ANOVAs were calculated using partial eta squared (η_p^2), using 0.01, 0.06, and 0.14 as small, medium, and large effects (Cohen, 1988). Significant associations were followed-up using post-hoc analysis of the adjusted residuals using Tukey corrections (MacDonald & Gardner, 2000). The significance level was set at 0.05.

Results

In the matches between B1 and B2 athletes, B1 athletes won 30.8% of matches and B2 won 69.2% of matches. In the matches between B1 and B3 athletes, B1 won 40.9% and B3 won 59.1%. Finally, in the matches between B2 and B3 athletes, B2 won 48.3% and B3 won 51.7%. A Chi squared analysis showed there to be no significant association between B2 and B3 athletes in the distribution of the matches won and lost against B1 athletes ($\chi^2(1) = 0.54$, $p = 0.46$), i.e. there is no significant difference between B2 and B3 in percentage of matches won and lost when fighting B1.

Very large positive correlations were found between the win ratio and throws per match ($r = 0.73$, CI: 0.64–0.80, $p < 0.001$) and between the win ratio and technical variability ratio ($r = 0.76$, CI: 0.68–0.83, $p < 0.001$), in addition to a large correlation between the win ratio and IQV ($r = 0.57$, CI: 0.45–0.68, $p < 0.001$).

(Figure 1) shows the comparison of the win ratio, throws per match, technical variability ratio, and index of qualitative variation (IQV) among athletes allocated to the three sport classes. Significant differences between classes were found for the win ratio ($F_{(2,126)} = 4.40$, $p = 0.01$, $\eta_p^2 = 0.07$ [medium effect]), throws per match ($F_{(2,126)} = 3.61$; $p = 0.03$; $\eta_p^2 = 0.05$ [medium effect]) and technical variability ratio ($F_{(2,126)} = 5.44$, $p = 0.005$, $\eta_p^2 = 0.08$ [medium effect]). Post-hoc testing revealed that the win ratio, throws per match, and technical variability ratio were significantly higher for the B2 athletes compared to the B1 athletes (win ratio: $p = 0.01$; throws per match: $p = 0.03$; technical variability ratio: $p = 0.007$). A similar pattern was observed for the B3 athletes when competing against B1, however only the technical variability ratio was significantly higher for the B3 athletes ($p = 0.01$), while the differences for win ratio ($p = 0.06$) and throws per match ($p = 0.09$) were not significant. No significant differences were identified for the win ratio, throws per match and technical variability ratio between the B3 and B2 athletes when competing against each other (win ratio: $p = 0.78$; throws per match, $p = 0.85$; technical variability ratio, $p > 0.99$). A similar pattern for IQV was found, with higher values for B2 and B3 compared to B1, but these differences were not significant ($F_{(2,126)} = 1.97$, $p = 0.14$, $\eta_p^2 = 0.03$ [small effect]).

(Figure 2) presents a comparison of the time-motion variables (total time, time to reach score and time to receive penalties) between the sport classes. No significant differences were found between classes for any of the time-motion variables (time to reach score: $F_{(2,126)} = 0.97$, $p = 0.38$, $\eta_p^2 = 0.01$ [small effect]; total time: $F_{(2,126)} = 1.15$, $p = 0.89$, $\eta_p^2 = 0.02$ [small effect]; time to receive penalties: $F_{(2,126)} = 0.80$, $p = 0.45$, $\eta_p^2 = 0.01$ [small effect]).

Discussion

The aim of this study was to investigate the relationship between Para sport class and technical variation, time-motion variables, and performance in Paralympic judo. We found that functionally blind athletes (in the B1 class) demonstrated less technical variation in the Rio 2016 Paralympic Games than their partially sighted counterparts (class B2/B3), and that athletes who showed less technical variation were also less successful in competition. The results suggest that measures of technical variation hold promise as a means of evaluating performance in VI judo, particularly for evaluating the relationship between impairment and performance in evidence-based classification research.

It has been previously established that functionally blind athletes are less successful in Paralympic judo compared to those with some residual visual function (Krabben et al., in press, 2018; Mashkovskiy et al., 2019). However, little was known about the relationship between the technical variation in their performance and the competitive success of athletes with more severe vision impairment (Krabben et al., 2019a, 2018). The current results show that athletes who are functionally blind perform less throws per match, and demonstrate less variation in their throwing techniques. The technical variability ratio appears to be a particularly suitable determinant of performance, with an effect size across classes similar in magnitude to that of the win ratio (both a “medium” effect size) and larger in magnitude of that for the index of qualitative variation (IQV; small effect size). From a performance perspective, the identification of these match-derived variables is important for understanding the competitive profile of Paralympic judo athletes with different degrees of vision impairment and their strategies for achieving scores during the matches.

Figure 1. Technical variation among athletes of different sport classes. (a) Win ratio; (b) throws per match; (c) technical variability ratio; and (d) Index of Qualitative Variation across different sport classes in Rio 2016 PG. *Significant difference from B1 class.

Figure 2. Time-motion analysis among athletes of different sport classes. (a) Total time; (b) time to reach score; and (c) time to receive penalties.

Even though the overall patterns of results were similar for all performance and technical variation variables when comparing the partially sighted (class B2 and B3) athletes to the functionally blind (class B1) athletes, not all differences were statistically significant (Figure 1). In particular, the current study did not find statistically significant differences in the competitive success (i.e.,

win ratio [$p = 0.06$] and throws per match [$p = 0.09$] of B3 athletes when competing against B1 athletes that have been reported in previous research (e.g., Krabben et al., *in press*; Kons et al., 2019), although we did find differences between B2 and B1 athletes. Given that we found no significant differences in performance between the best (B3) and the worst sighted (B1) athletes, this study might offer support for the current one-class system used in VI judo. However, taking into account that (i) the current study was only based on a single competition, with less B3 athletes than B2 athletes (47 vs 58), (ii) B1 athletes lost the majority (59.1%) of their fights against B3 athletes, and (iii) taking into account the similarity in the overall patterns of performance between B3 and B2 compared to B1 athletes (Figure 1), we consider it unlikely that there is no difference in performance between the B3 and B1 athletes.

Previous research in able-bodied judo suggests that judokas who show more variation in their throwing techniques and, therefore, are less predictable, are more successful in elite judo competitions than judokas who show less technical variation (Calmet & Ahmaidi, 2004; Franchini et al., 2008; Miarka et al., 2015). Our results extend those findings to Paralympic judo and help to explain the disadvantage that functionally blind (B1) judokas appear to experience during international competitions. The ability to functionally adapt to an opponent by switching between different coordination solutions may be considered a crucial element of expertise (Fajen et al., 2009; Kimmel & Rogler, 2018; Krabben et al., 2019b; Orth et al., 2017; Seifert et al., 2012), and one for which the partially sighted judokas in the B3 and B2 classes have an advantage. An interesting question that is not directly answered by the current study is why functionally blind judokas might be more limited in their technical variation than partially sighted judokas. It might be that some throwing techniques are more visually demanding than others, thereby limiting the range of techniques that blind judokas can execute. Indeed, previous work found that B1 judokas generally favour different types of throwing techniques to B2/B3 judokas (Kons et al., 2019). An alternative (or complementary) explanation might be that blind judokas may require more time and effort to acquire new skills (Krabben et al., 2019a), and that the athletes may therefore be more limited in developing proficiency in different throwing techniques.

We found no significant differences in the time-motion variables (total time, time to reach score and time to receive penalties) between athletes of different sport classes in the Rio 2016 PG. These findings suggest that the time-motion variables analysed in our study do not discriminate Paralympic judo athletes of different classes, or at least that those measures are less sensitive than others which were significant. Thus, the time-motion variables analysed in this study seem less suitable as measures of performance in VI judo.

Some limitations are inherent in the current study, as only a single competition was investigated and we did not control for the level of vision impairment of each player's opponent. Although we don't expect any bias in the quality of the opponents in early rounds, there may be a bias in the latter rounds because B1 athletes are less likely to progress to those rounds. Accordingly, if anything, the magnitude of any effects we found may be underestimated because the B2 and B3 athletes may be, on average, more likely to compete against other B2 and B3 athletes who make it past the initial rounds. Perhaps most importantly, it was not

possible to quantify the relationship between performance and the exact measure of vision impairment (e.g., visual acuity and visual field) because detailed information about each athlete's visual acuity and visual field were not publicly available. Instead, we compared measures of performance among the three sports classes (B1, B2 and B3) as a proxy for their level of impairment because all athletes were classified according to their visual acuity or visual field by International classifiers leading up to the competition.

This approach of comparing classes allows us to verify which measures of performance might be suitable as candidate measures of performance for further research; however, the approach does not allow us to make conclusions about the future class structure of competition (Tweedy et al., 2016). While our results are consistent with existing research which suggests that VI judo should be split into (at least) two classes, it remains possible that there is a subset of athletes in the B2 class who are disadvantaged, or even that the B1 class should be further subdivided into separate classes. Studies that specifically compare measures of impairment with performance will be required to provide definitive evidence about the most appropriate number of classes for VI judo and their class structure. Recently, Krabben et al. (in press) related measurements of VA and VF obtained in classification to the competitive success (i.e., win ratio) of elite VI judokas over a period of 8 years. The results of that study also supported a two class system, and suggested a cut-off between classes in the range of 2.0 to 3.5 logMAR. To further narrow down to a specific cut-off point between classes, measures of technical variation appear to be suitable determinants of performance. Another potential limitation of both the current work, as well as the study by Krabben et al. (in press), is that these studies are based on measures of visual function currently used in classification (i.e., VA and VF), whereas a panel of experts in VI judo expressed the opinion that other or additional measures of visual function, such as contrast sensitivity or motion perception, might be required to more appropriately classify VI judokas (Krabben et al., 2019a). However, recent research comparing different measures of visual function in VI judo suggests that VA remains the most important predictor of performance (Krabben et al., 2021).

Conclusion

We conclude that the main match-derived variables that differentiate Paralympic judo athletes with different degrees of vision impairment degrees are throws per match, technical variability ratio and win ratio, which tend to be better in B2 and B3 athletes than B1 athletes. Paralympic judo athletes who had higher levels of technical variation in their throws during competition were more successful during the Rio 2016 PG.

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ORCID

Rafael Kons <http://orcid.org/0000-0003-1615-5464>

Kai Krabben <http://orcid.org/0000-0001-5843-8898>

David L. Mann <http://orcid.org/0000-0001-7476-6939>

Daniele Detanico <http://orcid.org/0000-0001-6127-437X>

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