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OPTIMAL TIME OF THE ATTACKING ACTION IN KENDO

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ABSTRACT

The aim of this study was to investigate whether the time of an attacking action influenced the success rate of ippon (valid point) in international, elite level kendo. Selected videos of elite kendo competitors were viewed using Kinovea where the time of the attacking action could be analysed frame by frame. Movements were measured from the start of the forward or downward movement of the shinai until impact or until the point of the shinai had passed through the target area if the cut was a complete miss. There were 7.6% of attacks of 0.09s-0.12s and 6.5% of attacks of 0.13s-0.15s that led to ippon. This was a greater success rate than shorter or longer attacks. The timings of attacks performed by competitors who reached the quarter finals of tournaments were significantly faster ($p < 0.001$) and significantly more consistent ($p = 0.006$) than those performed by competitors eliminated prior to the quarter finals. These results suggest there is an optimal timing range in kendo that produces a winning strike. Mechanisms are needed to evaluate performance indicators where there are optimal values maximise the chance of success.

Key Words: kendo, performance analysis, optimal range, variability

RESUMEN

El objetivo de este estudio fue investigar en que medida el tiempo de una acción de ataque influía en el éxito del ippon (punto válido), en kendo, en una muestra competidores internacionales de élite. Los videos seleccionados de los competidores de élite en kendo se analizaron usando el programa Kinovea, que permitó analizar fotograma a fotograma la accion de ataque. Los movimientos fueros medidos desde el comieno del movimiento hacia adelante o hacia abajo del shinai hasta el impacto o el punto en el que el shinai habia pasado por el área objetivo si la accion era fallida. Hubo un 7.6% de ataques de entre 0.09 y 0.12 segundos y un 6.5% de ataques entre 0.13 y 15 segundos que acabaron en ippon, un éxito mucho mayor que el de los ataques más cortos o largos. Los tiempos de ataque ejecutados por los competidores que alcanzaron los cuartos de final en los torneos fueron significativamente más rápidos ($p < 0.001$) y signifiantemente más consitentes ($p = 0.006$) que aquellos ejecutados por los competidores que no alcanzaron los cuartos de final. Estos resultados sugieren que que existe un rango óptimo de tiempo que conduce a ataques ganadores. Se necesitan mecanismos para evaluar los indicadores de rendimiento en los que existen valores óptimos que maximizan las opciones de éxito.

Palabras clave: kendo, análisis del rendimiento, rango óptimo, variabilidad

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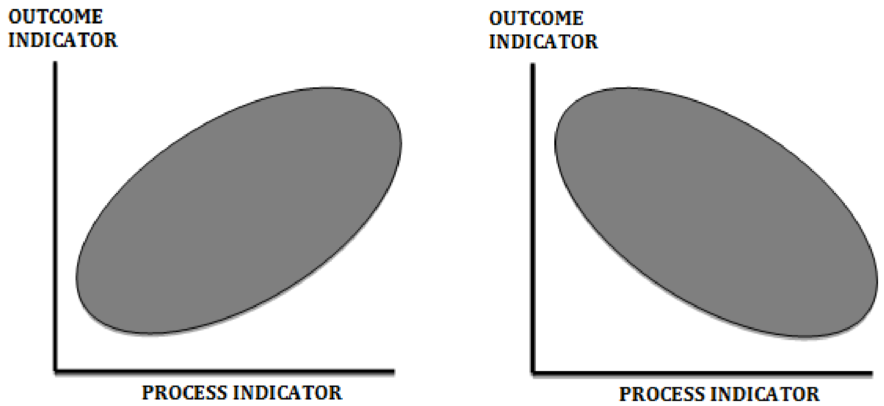
INTRODUCTION

The idea that some variables in performance analysis have optimal values that maximise the chance of success is not a new one. Early work described a continuum of risk in tennis serving whereby the combined probability of a serve being good and the point being won by the server is maximised at an optimal probability of the serve being good (Gale, 1971). Where the probability of the serve landing in is too low points will be lost due to a high number of serves landing out. Where the probability of the serve landing in is high, a high number of points will be lost because it is easier for the receiver to make a good return of serve. There are many other examples of optimal variables in sports performance. Consider the first lap of an 800m track race. If this is too fast, the athlete will run a slow overall time due to fatigue in the second half. If the first lap is too slow, the athlete will also run a slow overall 800m time. Therefore, there is an optimal time that the athlete should complete the first lap in to facilitate a fast overall 800m time.

A recent development in sports performance analysis has been using norms to interpret performance variables. These work in a similar way to the use of norms in other areas such as anthropometry. Percentile norms can be determined for sports performance variables if there are data available from a population of relevant performances. For example vigintile norms have been determined for variables in women's and men's tennis singles at Grand Slam tournaments (O'Donoghue, 2005) and decile norms have been produced for possession conversions in British National Superleague netball (O'Donoghue et al., 2008). These allow future performances to be interpreted by determining the percentile band that performance indicator values fit into for the relevant population. This approach works well with two types of variables that are illustrated in Figure 1. Figure 1(a) represents where the chance of success increases where the value of some process variable increases. For example we might expect there to be a positive relationship between the percentage of possessions that are converted into goals in a team game and the margin of victory. Figure 1(b) represents where the chance of success decreases where the value of some process variable increases. For example we might expect there to be a negative relationship between the percentage of opposition possessions that are converted into goals in a team game and the margin of victory. Figures 1(a) and 1(b) intentionally use ellipse shapes to represent the variability about a theoretical line of best fit between such process indicators and outcome indicators. There are many factors that influence the value of an outcome indicator and single process indicators rarely have perfect correlations with outcome variables.



(a) Positive relationship (b) Negative relationship

FIGURE 1: Two relationships between process indicators and outcome indicators in sports performance.

Returning to the idea that some process indicators have optimal values that maximise the chance of success, let us consider Figure 2. Gale's (1971) model represents the risk of losing a point in tennis for a range of probabilities of a serve being good from 0 (it is certain to be played out) to 1 (it is certain to be played in). Figure 2 represents how data for a series of events might be plotted where optimal values of some process indicator maximise the chance of success. High level performers who achieve high values for outcome indicators may be expected to have optimal values of some process indicator that facilitates this success; there is a low degree of variability about this optimal sub-range of values. An inverted-U relationship is not feasible because it suggests that lower level performers have process indicator values that are too low or too high to yield success without being able to produce process indicator values in between. Figure 2 is a conceptual model of process indicator values that assumes that lower level performers will exhibit a range of values that includes values that are too low and too high to achieve success. They may even have similar average values for the process indicator to high level performers. It is the variability in process indicator values that is the main difference between high level and lower level performers according to this conceptual model.

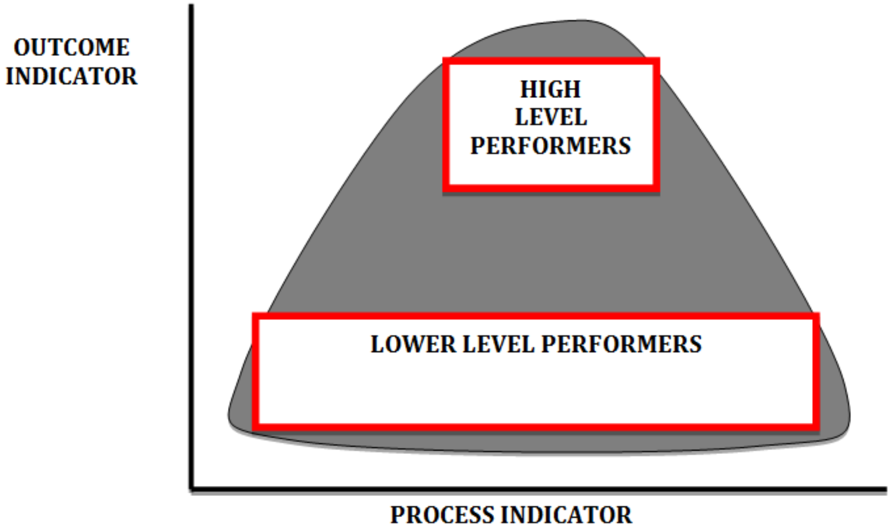


FIGURE 2: The relationship between a process indicator and outcome indicators where optimal values of the process indicator are preferable.

Variability in sports performance has been recognised in individual sports (O'Donoghue, 2005; Montelpare *et al*., 2013) as well as team games (James *et al*., 2005; Gregson *et al*., 2010). Sports performance variables are not as stable as anthropometric variables and fitness test results. There are various factors that influence variability in sports performance, but the largest source of variability is thought to be opposition quality (McGarry and Franks, 1994). Despite this, there is a lack of statistical analysis of timing variability comparing successful and less successful athletes. The analysis of variability may give a deeper understanding of optimal performance in sport.

Gale's (1971) model was a theoretical model and the conceptual model proposed in Figure 2 has not been tested using real sports performance data. Therefore, the purpose of the current investigation was to consider the success of sports performance where values of some process variable are low, average and high to determine whether or not there is evidence to support the notion of optimal values in sports performance. The current investigation uses the example of attack speed in Kendo, considering the outcomes of attacks.

Kendo literally translates as 'The Way of The Sword' and is the art of Japanese Fencing. It has evolved over the years into a sport, where Kendoka (kendo practitioners) have two basic forms of practice; one involves the use of a *bokken* or wooden sword, where the practitioner does not need to wear full protective armour. A *bokken* is a hardwood replica sword and training with the *bokken* is based on technique. Kendo has 'patterns' called '*Kata*'. By practising *kata*, trainees learn to wield a weapon much more like a real sword. The other form of practice in kendo involves the use of *bōgu* (armour) and the *shinai* (Bamboo sword).

Kendo competitions, referred to internationally as taikai, consist of monitored bouts of free sparring, with the competitors aiming to get the best of three cuts. The four target areas are the *Men* (the head), *Do* (either side of the body), *Kote* (the right wrist) and *Tsuki* (Throat) (Sasamori & Warner, 1964). Valid points scored on these targets are judged by three referees and the point is given by majority decision. Standard competition bouts are five minutes in duration with extra time (if no point is scored) lasting three minutes or for an unlimited time until *ippon* is scored. All points scored in kendo competition fall into two attacking categories which are: *shikake-waza* (attacking movements) and *oji-waza* (counter-attacks). The *shikake-waza* are attacks where the kendoka executing the strike has moved into his attacking distance and initiated the attacking movement. *Oji-waza* are attacks where the kendoka executing the technique has invited their opponent to attack by making them believe they can score a *shikake-waza* and then capitalising on the moment of their strike to execute their counter-attack.

Competitive kendo requires specific criteria to be met before a referee will award a point to either competitor. This valid point is called *ippon* and the criteria include an accurate strike with high spirits, where the attacker has committed themselves to the attack while using a strong *kiai* (shout) and correct posture. The physical attacking actions and movements in kendo lend themselves well to biomechanical analysis as they are easily measured. All attacking movements in kendo are generated from the left leg (which can be shown by whether or not the knee is bent or the legs are far apart as a good kendo position is considered for the left leg to be almost straight and for the feet to be up to about six inches apart from anterior to posterior and shoulder width apart laterally) and the body is kept in as much of an upright position as possible when attacking so that the basic posture is not broken. This comes under 'correct posture' in the definition of ippon provided by the International Kendo Federation. The striking power in kendo is also generated from the left side, so the hand position for a good, accurate and strong strike is also important as the left hand should not be above the right at the point of impact. All of these criteria for scoring *ippon* mean that kendo is not just about hitting the opponent but also about the technique of the strike and the timing of the movement along with posture while executing the strike.

Ippon in competition is only awarded when 2 or more of the 3 referees (usually higher graded, more experienced and senior individuals) on the court agree that it is a valid point. The awarding of *ippon* has a subjective element as there are no video replays or appeals against points awarded.

According to Ogle (2008), *Dan* grades (the equivalent of black belt or higher) have faster movements during attacking actions and better accuracy than *Kyu* grades (those yet to reach *Dan* level). Significant differences were exhibited in all of the variables measured between the two groups, but the time of the cutting movement had no significant effect on the accuracy of the strike in either group. This study however, did not look at competitive kendoka or even a competitive situation. Consistency of striking technique is considered to be important in Kendo (Stodden *et al.,* 2005). Miyamoto and Yamagami (1997) investigated the relationship between the weight of the *Shinai* and cutting movement, and of particular interest is Tsuboi and Imai's (1986) investigation of cutting speed as an indicator of successful strikes in Kendo.

The current investigation is concerned with attacking time and attack outcome at the elite level of competitive kendo. The investigation will focus on the elite level of Kendo in Europe and the world. A range of participants is used due to the availability of video footage being higher for European championships and world championships. The scope of the current investigation is restricted to fighters who have reached the last 16 of the individuals' tournament or higher.

METHOD

Data Collection

Video footage was taken from international taikai (competitions) where all participants were selected by their home nation to be an international representative (World Kendo Championships, European Kendo Championships, 5 Nations Kendo Championships). Matches where the recording or viewpoint did not show the point of impact for strikes were excluded and the videos used were only selected from the men's individual matches from the last 16 through to the final. The rationale for this decision was that many countries with national teams who are less experienced or only newly formed will not perform at the same level as other well established teams. Selection of videos was dependant on their public availability on the internet provided by the event organisers.

The selected videos were viewed using Kinovea where the time of the attacking action could be viewed frame by frame. Due to the video quality, the time between each frame differed slightly (from 0.01s to 0.02s). The video was paused each time an attack was made by either competitor and the attacking movement was measured and timed using the synchronised stopwatch in Kinovea and noted down in Microsoft Excel 2010. Each movement was measured from the start of the forward or downward movement of the shinai until the point of impact with the target, the opponents' shinai if they blocked, a non-valid target area or until the point of the shinai had passed through the target area if the cut was a complete miss. Each cutting action from the start of the downward or forward motion to the point of impact (See Figure 3) was measured with one of the following outcomes being recorded:

- Ippon - if the point was awarded
- 1 flag – if one referee awarded the point but the other two disagreed
- Hit – if the cut hit the target but no referee awarded the point
- Blocked – if the cut was stopped from hitting the target by the opponents body or shinai
- Missed – if the cut landed away from a target area or missed the opponent completely

Start of forward/downward motion	Point of impact with target

FIGURE 3: Striking action for an attack that results in Ippon.

The duration of the attacking time was recorded for each attack together with whether the attack was made by the winning or losing competitor, the outcome of the attack and the round of the competition where the match took place.

Data Analysis

The mean and standard deviation of attack durations were calculated for each round, for winners and losers as well as for attacks of different outcomes. The unit of analysis was individual strikes with winning and losing competitors within matches having different numbers of strikes. Therefore, a direct matched comparison between winning and losing kendo competitors within matches using a paired samples t-test was not possible. Therefore, an independent samples t-test was used to compare the timings of strikes performed by the winners and losers of matches. There are five classes of strike outcome; not all performances involved all classes of outcome and some involved multiple occurrences of the same outcome type. Therefore, a one-way ANOVA test was used to compare timings of strikes leading to different outcomes. Strikes performed within different rounds of competitions were also compared using a one-way ANOVA test. The strikes performed within the semi-finals and finals were grouped together for the purpose of the one-way ANOVA test. Where a one-way ANOVA test revealed a significant effect, Bonferroni adjusted post hoc tests were used to compare individual pairs of outcomes or individual pairs of rounds.

Variability between strikes performed by winning and losing competitors, strikes of different outcomes and strikes performed indifferent rounds of tournaments were compared using Levene's test of equality of variances. The Levene's tests were important to find if successfully performed strikes or strikes performed by more successful performers were within an optimal timing range.

RESULTS

An independent samples t-test revealed that the mean attack time of 0.14$\pm$0.05s for the winning competitors was not significantly shorter than the 0.16$\pm$0.11s for the losing competitors (t_{791} = 1.9, p = 0.059). Furthermore, Levene's test did not reveal a significant difference between the standard deviation of attack times between winning and losing competitors (p = 0.255). Figure 4 shows the distribution of attacking time for attacks made by the winners and losers of the matches analysed. The winners of the matches present a noticeably higher frequency of attacks between 0.09s and 0.12s and attacks with a duration of ≥0.24s.

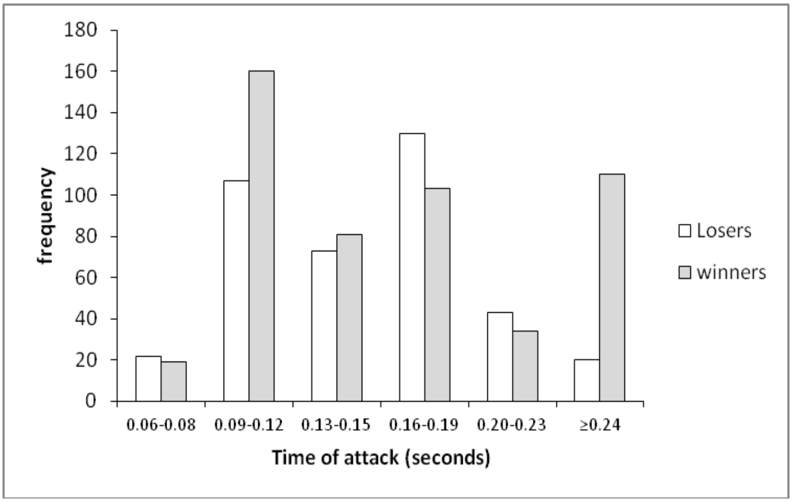


FIGURE 4: Frequency of attacks of different times.

Figure 5 shows the proportion of attacks of different outcomes when attacks were of different timings. The highest proportion of ippons were 7.6%

of 0.09-0.12s attempts and 6.5% of 0.13-0.15s attacks suggesting that there is an optimal range of timings that maximise the chance of an ippon.

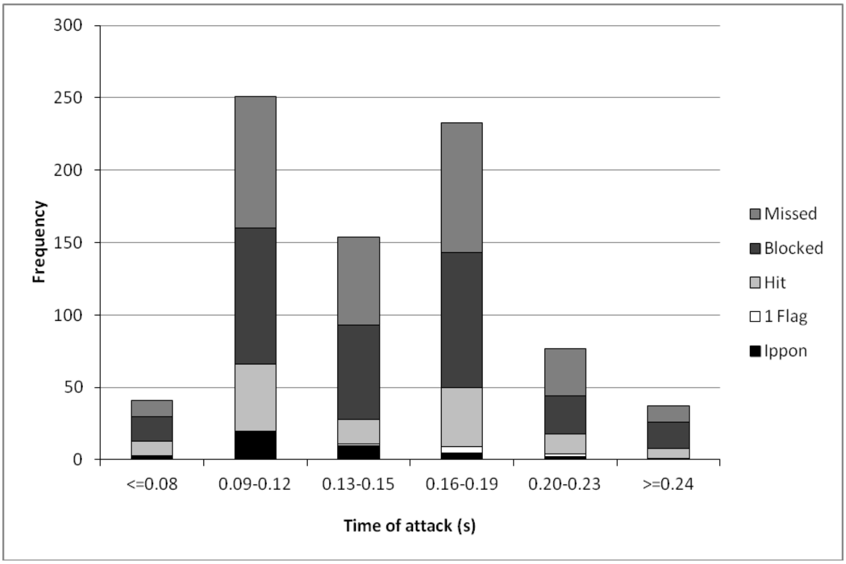


FIGURE 5: Number of outcomes per time zone.

Table 1 shows the mean and standard deviation of attack times for attacks of different outcomes. Attacks leading to ippons were faster than other attacks on average but also had the lowest variability in timing. However, a one-way ANOVA did not reveal a significant difference in timings between attacks of different outcomes ($p = 0.285$) and Levene's test did not reveal a significant difference between the standard deviations of attacks of different outcomes ($p = 0.216$).

TABLE 1
Mean and SD for the time (s) of attack in relation to the outcome.

Outcome	Mean	SD
Missed	0.15	0.05
Blocked	0.16	0.12
Hit	0.15	0.05
1 Flag	0.17	0.07
Ippon	0.13	0.03

Figure 6 shows the attack times of competitors reaching different stages of tournaments. A one-way ANOVA test revealed significant differences between these groups of competitors ($p < 0.01$) with Bonferroni adjusted post hoc tests showing that the attacks of those eliminated in the last 16 round were significantly longer than the attacks of the quarter-finalists ($F_{2,663} = 6.6$, $p = 0.001$) and the semi-finalists and finalists ($p < 0.01$). Levene's test found that the standard deviation of attack times was significantly greater for those eliminated in the last 16 round than it was for those eliminated in other rounds ($p = 0.006$).

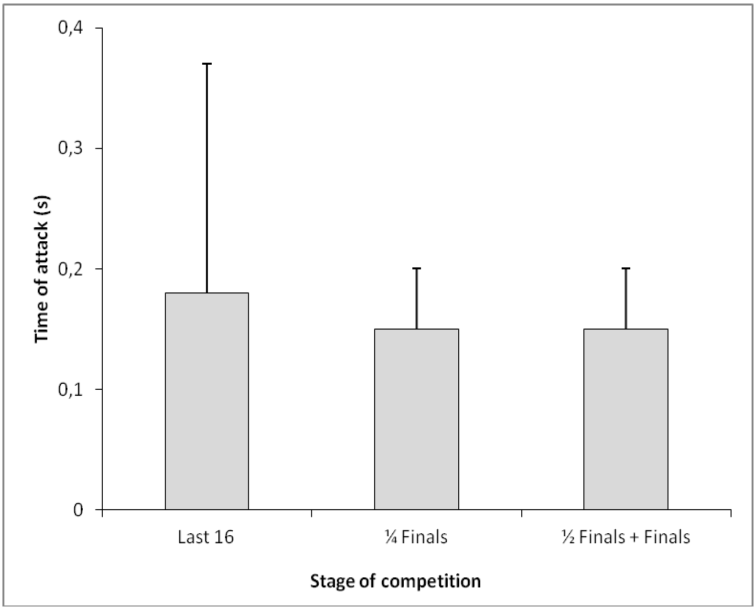


FIGURE 6: Attack times for the final round reached by the individual.

DISCUSSION

These results show that the attacks of durations between 0.09s and 0.15s have a higher chance of ippon than attacks of longer or shorter durations. The range of attack times for those eliminated from tournaments prior to the quarter finals was significantly greater than the range for those reaching later stages. This suggests that there is an optimal timing range in kendo that maximises the chance of a winning strike. The more consistent timings used by competitors reaching the quarter finals reflects similar findings for variables in other sports. For example, it has been suggested that baseball pitchers should focus on consistent mechanics to produce the highest pitching speeds (Stodden *et al.*, 2005). These consistent mechanics allow the athlete to produce their optimum performance, speed and action for longer and produce it when required rather than intermittently. Another example is advanced swimmers who produce stroke technique is significantly closer to the suggested optimum than intermediate swimmers (Andrews *et al.*, 2011). Seifert and Chollet (2005) also showed that top elite level swimmers showed greater continuity of the actions performed than other swimmers. A third example is the optimal range for the percentage of points where the first serve is good in women's singles tennis (O'Donoghue, 2014). The percentage of points won by serving players were in those performances where 70-80 % of first serves were in rather than when fewer or more of the first serves were in.

The attack times of competitors reaching the quarter finals were significantly faster than those eliminated prior to the quarter finals. Thus, the attack times of the more successful competitors were faster and more consistent. The higher consistency of shorter attacking times produced by the winners may be explained by the work of Pinto Neto *et al*., (2007) where martial-arts trained practitioners exhibited higher hand speed during striking. Though the difference in this investigation is not between trained and untrained, the level between those reaching different stages of tournaments can reflect a difference in years of training or experience. This pattern of being faster and more consistent has also been found in elite swimmers who exhibit a shorter recovery phase between actions and therefore forward propulsion is more effective (Seifert and Chollet, 2005).

The only unexpected figure from the frequency of attacking time is the much higher frequency of attacks of 0.24s or longer for the winners. This could be due to a number of different factors, the most likely being a tactical manoeuver to change their cutting time so that their opponent is thrown off guard or taken by surprise or the use of 'renzoku-waza' or repeated attacks; these attacks take longer to execute in terms of time as they require multiple actions in the same attacking movement but can be used to change the pace or position of a bout. However, none of the attacks of 0.24s or longer resulted in an ippon being scored.

Schemes based on percentile norms have been proposed to evaluate performance variables in netball (O'Donoghue, 2006) and tennis (O'Donoghue, 2008). However, the variables used in these studies were variables that were either positively or negatively associated with success (like the variables types described in Figure 1). The evaluations give higher marks for high values of performance indicators that are positively associated with success and for low values of performance indicators that are negatively associated with success. Where a performance variable, such as attack time in kendo, has an optimal range of values that maximise the chance of success, higher marks should be given for values of such performance indicators within this optimal sub-range. Table 2 is an example of how this could be done in kendo. The points awarded for strikes of different timings are derived from the percentage of such strikes that result in ippon (illustrated in Figure 5). These percentages are used can be used as scores for individual strikes allowing an overall performance score to be calculated for. The table shows the strikes made by an elite competitor during 6 matches. Consider the first match; there were 6 strikes within an optimal range of 0.09s to 0.12s awarded 7.57 points each and there were 2 strikes of 0.16s to 0.19s that were awarded 2.15 marks each. This comes to a total of 49.72 for match 1. However, some matches are longer than other with the number of strikes ranging from 6 to 18 within these performances. Therefore, the total score is divided by the number of strikes to get an average score per strike (6.22 in the case of match 1). This score can be seen as the average chance of achieving ippon using the strikes made during the match. This suggests that match 3 was the athlete's best performance with 15 out of 18 strikes being within an optimal range. However, it is notable that the two matches where the competitor achieved 2 ippon were actually those with the lowest evaluation scores. In the case of match 6, this could be explained by a high variability in timings making the performance successful as the opponent would have difficulty predicting the speed of attacks being made. This is supported by evidence from other sports where variability can be associated with success. For example, elite soccer players have been found to have more within-player variability in work-rate that the amount of between-player variability seen in the sport (O'Donoghue, 2004).

TABLE 2
Evaluation of 6 performances of an elite Kendo competitor.

	Timing of strike							Score	Ippons
Time	<=0.08s	0.09-0.12s	0.13-0.15s	0.16-0.19s	0.20-0.23s	>=0.24s	All		
Points	4.88	7.57	6.49	2.15	2.60	0.00			
Match									
1	0	6	0	2	0	0	8	6.22	1
2	0	3	8	1	0	0	12	6.40	1
3	2	15	0	1	0	0	18	6.97	1
4	0	0	5	1	0	0	6	5.77	2
5	1	9	0	4	0	0	14	5.83	1
6	1	5	0	3	2	0	11	4.94	2

In conclusion, the successful athletes performed faster and more consistent attacks then less successful athletes. This suggest that there is an optimal range of attack times in kendo and that if an attack is too slow then it is easily dodged or blocked and if an attack is too fast then it may not have the accuracy required to score the point. The study has provided evidence of a more general concept in sport that there are variables where an optimal range of values is preferable. Further research is needed to provide evidence of this general concept using variables in other sports. There is also a need to devise evaluation schemes for such variables that recognise the potential for success of optimal values of relevant performance indicators.

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