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**Original Article**

# Development of a reliable and valid kata performance analysis template

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**Abstract**
With the new kata evaluation procedure, examination of the underpinning features of successful kata performance appears warranted.The purposeof the study was to createa valid and reliable analysis template for the assessment of the movement characteristics of competitive kata.Following the creation, and scrutiny, of action variables and operational definitions, three observers were provided with the operational definitions of the performance indicators, example kata clips and instructions detailing the method of 'tagging' using a computerized analysis software.Intra- and inter-rater reliability assessment and median sign tests, and Cohen's Kappa coefficient were conducted. There were no significant differences ($p > 0.05$) between the observer's and analyst's test-retest observations for all the performance indicators. The intra-rater reliability was found to be "almost perfect" in all raters (LA K = 0.99 [95% CI: 0.98-0.99]; PA K = 0.94 [95% CI: 0.93-0.95]; KR K = 0.94 [95% CI: 0.93-0.95]) and the inter-rater Kappa coefficients were moderate (K = 0.55 ± 0.05). This study has demonstrated that a novel performance analysis template yields reliable observations of the key movements during kataand the procedures couldtherefore be used to objectively appraise features of successfulperformance.
**Key words: karate, technique, evaluation, difficulty, judging**

## Introduction

After the announcement that karate will be a part of Summer Olympic Games in 2021(International Olympic Committee, 2017), there has been an increase in the number of competitors registered in top-level karate tournaments(WKF News Center, 2018). The World Karate Federation (WKF) is the international governing body for Olympic style of karate. WKF is recognized by the International Olympic Committee and consist of more than 150 National Federations. The WKF World Karate Championships feature two events, kumite (combat with a real opponent) and kata (simulated combat with an imaginary opponent).
The word Kata means literally "form" and represents a detailed choreographed pattern of martial arts movements made.Traditional karate kata are performed at the competition as a specified series of moves such as strikes, blocks, stepping, kicks, and turning, while trying to accomplish perfect technique.It must adhere to the traditional values and principles and also be realistic in fighting terms demonstrating strength, power, and speed, as well as grace, rhythm and balance (WKF, 2019).The outcome of kata contests is determined using a subjective judging process, which is not typical only for combat sports.From 2000 to 2018, there was a repêchage elimination system used in kata competition. After the performance of a pair of competitors, the judges subjectively determined the winner of the match by raising blue or red flag. The WKF sought to reduce the subjectivity of the assessment by modifying the rules and introducing a point scoring system of competition in 2019 with twocrucial criteria (Table 1).In new karate kata competition procedure scores are given by panel of seven judges and the computer software eliminates the two highest and two lowest scores for both criteria; the total score is calculated following a breakdown of 70% for technical performance and 30% for athletic performance.

Table 1 Criteria of competitive kata evaluation ()

| Kata Performance | breakdown (factors) |
|---|---|
| 1.Technical performance | |
| a) Stances<br>b) Techniques<br>c) Transitional movements<br>d) Timing<br>e) Correct breathing<br>f) Focus (KIME)<br>g) Conformance: Consistence in the performance of the KIHON of the style (Ryu-ha) in the kata | 70 % |
| 2.Athletic performance | |
| a) Strength<br>b) Speed<br>c) Balance | 30 % |


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The duration of the individual kata performances is varying as well as technical composition whose difficulty is not well explained in the rule book, or handbook for coaches. In an effort to gain an advantage over opponents, the competitors choose katas which contain more number of technically challenging techniques, but the performances of kata are currently assessed by judges, according to the established dogma. To more effectively differentiate the kata in terms of the difficulty of the performances, an objective evaluation of the sport regarding the technical content and estimated energy cost would seem timely.

Unfortunately, there is a dearth of information describing the relative importance of the constituent features underpinning successful kata scores reinforcing the need for an objective quantification of kata performance. The WKF official competitions kata list includes 102 katas of the most expanded karate styles. Consequently, the same kata practiced by different competitors would appear almost identical in "choreography" and techniques applied, though the rules do not prescribe a mandatory duration for kata performances, nor speed of technique(s). The difficulty of the kata performance (stances, transitional movement, etc.) is not well described in the rules yet and so the ability to quantify the movements could enhance understanding of performance.

The difficulty of the kata performance (techniques, transitional movement, stances, etc.) is not very well described in the WKF Competition Rules yet and so the ability to quantify the movements could enhance understanding of kata performance. Performance analysis is common in sport games research, including volleyball, rugby (Vaz, Mouchet, Carreras, & Morente, 2011) soccer (Castellano, Blanco-Villaseñor, & Álvarez, 2011), and also martial arts such as boxing (El Ashker, 2011), taekwondo (Bridge, Jones, & Drust, 2011; Haddad, 2014), kickboxing (Ouergui et al., 2014), and judo (Miarka, Fukuda, Del Vecchio, & Franchini, 2016). In these sports, expert practitioners and scientists have established relevant performance indicators and created reliable templates for video analysis(Hughes et al., 2012; Thomson, Lamb, & Nicholas, 2013).Studies covering the analysis of kata performance have focused upon the physical response(s)during competition(Arriaza & Leyes, 2005)and training sessions with maximal effort(Doria et al., 2009; Milanez, Vinicius, Dantas, Destro, & Araujo, 2012). However, those studies did not determine the content of kata thatproduce the physical responses and so developing a reliable tool for such analysis that could be usedby a range of individuals involved in the sport (e.g. analysts, coaches, judges), appears necessary.

This tool should include number and type of performed techniques. Current sources describe katas in a traditional way: used techniques, their sequence and their application in a real fight. Further clarification of the kata performance may contribute to the distribution of katas to individual age categories according to the technical difficulty, discernthe difficulty of particular kata and reveal the salient features underpinning success. Such measures may improve the kata evaluation system, secure Adherence preferable to the long-term athlete development model in terms of multilateral development and consequently prevent early specialisation, which causes a number of issues such as premature drop-out and unnecessary overuse injuries(Augustovicova, Dusana, Stefanovsky & Argajova, 2019).Therefore, the aim of this study was to devise a kata performance analysis system for the assessment of the movement characteristics of competition and assess its reliability using analysts of varying experience of the sport and performance analysis methods.

**Methods**

*The Development of a Kata Analysis Template*

In the context of this study, performance was scrutinised visually during post-competition video analysis of the kata known as “Anan”. The kata was performed by the World champion at the WKF Championships 2016 during the final match. The video of the final match was available online, so no informed consent was needed and the study was approved by the Ethics Committee of the Faculty of Physical Education and Sports, Comenius University, Bratislava, Slovakia (reference number 4/2019).

The template was developed by three karate experts, the senior author (coach with an international license, member of Technical Commission of European Karate Federation - LA) and two coaches (coach A:>30 years of experience; coach B: >20 years of experience). All individuals were asked to review a list of techniques(initially created by LA)and provide their opinions as to whether the variables and categories would allow the collection of objective data. Following discussion and written feedback, the adapted list comprised 24 action variables placed into 7 categorieswith total kata duration also recorded.

The kata was ‘tagged’ via the bespoke template (Figure 1) in a sequential manner, commencing with the transition from the beginning of the katato the end of the kata (from reito rei).The performance was viewed four times – each time focusing on one of the indicators (transitions, stances, upper limb techniques, kicks) to avoid misinterpretation and slow-motion playback(x0.1, x0.25, or x0.50 normal speed, selected as the analysts saw fit)was used during the parts of kata where necessary.

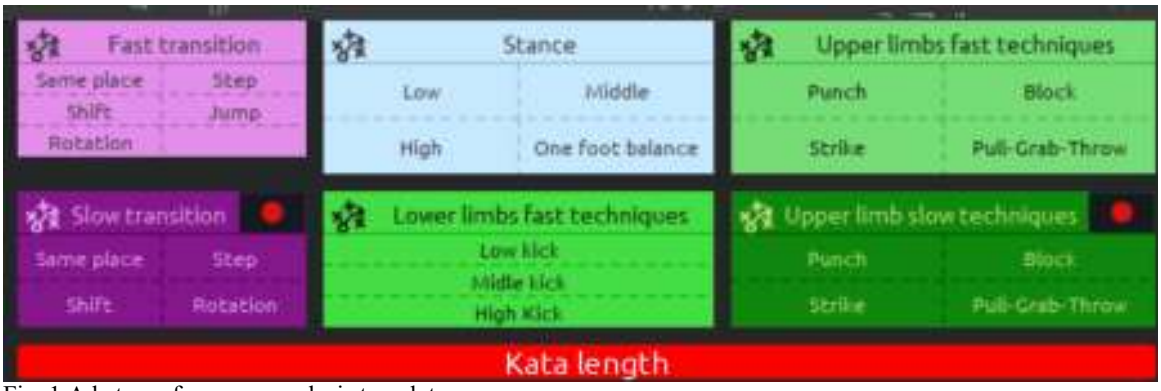


Fig. 1 A kata performance analysis template

*Classification of techniques (appendix 1)*

*Transitions*

If athletes moved with what appeared to be maximum effort and speed, these transitions were considered 'fast' whereas when athletes did not appear to move with maximum effort and speed, these transitions were considered 'slow'.By a transition, we mean any change from one karate stance to another. All body transitions and changes of stances like steps, shifts, jumps and rotations (more than 180°) were subsequently registered as well as transitions wherethe position of the legs changedwhilst thecentre of gravity (COG) remained in the same place (shift).

*Stances/ Positions*

We separated all positions (stances) into four groups (high, middle, low stances and one-foot balances), based on the depth of the stance. In the group of high stances,the legs were generally straight but not necessarily fully extended at the knee (e.g. Heiko daci) and the COG was determined to be practically at the same height as in a regular standing position. With middle stances,the knees were slightlyflexed (e.g. moto daci, sanchin daci) and COG height was approximately 75% of regular standing position. In low stances (shiko daci, nekoashi daci) knees were flexed moreconsiderably and the COG was determined to be below 70% of regular standing position.

*Upper Limb Techniques*

This group contained all attacks(punches e.g. tzuky, strikes - uči, pull – grab - throw techniques) and defensive techniques - blocks (kake uke). If performed with maximum effort and speed, these techniqueswere classified as 'fast' whereas when athletes did not appear to perform with maximum effort and speed, they were classified as 'slow'.

*Lower Limb Techniques*

All types of kicksand sweepswere included in this group of techniques and were classified as high (kicks to the head), middle (kicks to the abdomen) and low (kicks to the knee and lower leg)and like upper limb techniques, also 'fast' or'slow'.

*Intra- and Inter-observer Reliability Analysis*

The three observers were a professional kata athlete (PA) who had no prior experience of performance analysis, an experienced international kata referee (KR), and professional coach and experienced performance analyst (LA, the lead author). The inclusion of all raters was to determine whether an individual requires specialist knowledge of the sports actions or performance analysis per se, to use the template reliably. The kata was analysed on two occasions, one week apart by the observers (LA, KR, and PA), and subjected to intra-observer reliability analysis. Subsequently, the initial analysis by LA was used as a reference against which the initial analyses of two other observers were compared to examine inter-observer reliability. Each individual observer was given the operational definitions of the performance indicators to read and theninstructions and kata example clips were provided to the observers detailing the method of 'tagging' using LongoMatch analysis software. Familiarisation took less than 30 minutes.

*Statistical Analyses*

A median sign test was computed to assess the null hypothesis of no significant systematic bias between the test and retest scores (frequency counts) of each action. An alpha of 0.05 was used throughout the analysis.Data were subjected to intra-rater reliability assessment using Cohen's Kappa coefficient (± 95% CI). For inter-rater reliability of all rater pairs (LA-PA, LA-KR, KR-PA) the arithmetic mean of Kappa (± 95% CI) was used (Light, 1971). The Kappa coefficient was interpreted as: 0.01–0.20 "none to slight", 0.21–0.40 "fair", 0.41– 0.60 "moderate", 0.61–0.80 "substantial", and 0.81–1.00 "almost perfect" agreement (Cohen, 1960).

**Results**

*Intra-observer Agreement*

There were no significant differences ($p > 0.05$) between the analyst's test and retest observations for all the performance indicators. Moreover, a sign test revealed no differences between the two test-retest medians for

all other analysts (LA:$p$ = 1.00;PA:$p$ = 0.73; KR:$p$ = 1.0).Using the Kappa coefficient, the intra-rater reliability was found to be "almost perfect" in all raters (LA $K$ = 0.99 [95% CI: 0.98-0.99]; PA$K$ = 0.94 [95% CI: 0.93-0.95]; KR $K$ = 0.94 [95% CI: 0.93-0.95]).

Table 2 illustrates the descriptive appraisal of the intra-observer test-retest data for performance indicators. The agreement was perfect in LA for 17 of 24 indicators (67%) with all other indicators falling within +/-1 of the original test frequencies. Although LA failed to record the exact same frequency in the test and retest conditions for eight indicators, all such instances were accompanied by margins of error of a single frequency count and overall, there were 135 notations recorded on both occasions. Exact agreement for PA was evidenced for 63% of indicators (16/24) thoughall but one (slow shift) of the indicators were within a single frequency count and overall, the total frequency count was also within ± 1 (test = 130; retest = 129).Lastly, perfect agreement for KR was evidenced for 79% of indicators (20/24). Of the five indicators in which KR failed to record the same frequency in the test and retest conditions, threeindicators were accompanied by margins of error of a single frequency count and overall, the frequency of indicators was identical (126 in both conditions). Where the kata length was concerned, the agreement was deemed acceptable with LA, PA, and KR all recording durations of 121 s.

Table 2 Intra-rater reliability data for the kata "Annan"

| | LA | | | PA | | | KR | | |
|---|---|---|---|---|---|---|---|---|---|
| Technique | Test | Re-test | Identical | Test | Re-test | Identical | Test | Re-test | Identical |
| **Fast upper limbs techniques** | | | | | | | | | |
| Punch | 14 | 14 | YES | 13 | 12 | NO | 12 | 12 | YES |
| Strike | 6 | 6 | YES | 5 | 5 | YES | 7 | 7 | YES |
| Block | 18 | 19 | NO | 18 | 18 | YES | 17 | 16 | NO |
| Pull-Grab_Throw | 6 | 6 | YES | 7 | 8 | NO | 6 | 6 | YES |
| **Slow upper limb techniques** | | | | | | | | | |
| Slow block | 14 | 13 | NO | 11 | 11 | YES | 12 | 12 | YES |
| Punch | 0 | 0 | YES | 0 | 0 | YES | 0 | 0 | YES |
| Strike | 0 | 0 | YES | 0 | 0 | YES | 0 | 0 | YES |
| Pull-Grab_Throw | 0 | 0 | YES | 0 | 0 | YES | 0 | 0 | YES |
| **Lower limb techniques** | | | | | | | | | |
| Low kick | 3 | 3 | YES | 2 | 2 | YES | 2 | 2 | YES |
| Middle kick | 6 | 6 | YES | 7 | 7 | YES | 6 | 6 | YES |
| High kick | 0 | 0 | YES | 0 | 0 | YES | 0 | 0 | YES |
| **Stances** | | | | | | | | | |
| High stance | 8 | 7 | NO | 5 | 5 | YES | 3 | 6 | NO |
| Middle stance | 25 | 25 | YES | 24 | 25 | NO | 25 | 23 | NO |
| Low stance | 7 | 8 | NO | 9 | 8 | NO | 8 | 8 | YES |
| One foot balance | 0 | 0 | YES | 0 | 0 | YES | 0 | 0 | YES |
| **Fast transitions** | | | | | | | | | |
| Jump | 4 | 5 | NO | 0 | 0 | YES | 4 | 4 | YES |
| Rotation | 4 | 4 | YES | 4 | 3 | NO | 3 | 4 | NO |
| Shift | 12 | 11 | NO | 6 | 5 | NO | 11 | 11 | YES |
| Step | 15 | 14 | NO | 24 | 24 | YES | 15 | 14 | NO |
| Same place | 0 | 0 | YES | 0 | 0 | YES | 0 | 0 | YES |
| **Slow transitions** | | | | | | | | | |
| Slow Rotation | 2 | 3 | NO | 3 | 3 | YES | 2 | 2 | YES |
| Slow Same Place | 1 | 1 | YES | 4 | 3 | NO | 1 | 1 | YES |
| Slow Shift | 5 | 5 | YES | 4 | 6 | NO | 4 | 4 | YES |
| Slow Step | 5 | 5 | YES | 2 | 1 | NO | 7 | 7 | YES |
| **Total** | **135** | **135** | **16 YES 8 NO** | **130** | **129** | **15 YES 9 NO** | **126** | **126** | **19 YES 5 NO** |

*Inter-observer agreement*

There were no significant differences between the observers for all performance indicator frequenciesrecorded in the test and re-test conditions (all $p$ >0.05) and the inter-rater reliability for all pairs of comparisons was $K$ = 0.55 ± 0.05 ("moderate" agreement; LA vs PA= 0.58; PAvs KR = 0.46; and LA vs KR= 0.60).

The agreement between the analyses of the LA and the KR was impressive (Table 3). There was no systematic bias between the observers for any performance indicator.Total agreement occurred for 54% of indicators, and for 29% indicators, where the ±1 range was considered. Only 17% of indicators had a range higher than ±2. The biggest error between the LA and KR was in high stances whereby, it appears as though the KR did not consider the kata from rei to rei and missed high stances at the beginning and the end of the kata.KR recorded a smaller number of techniques compared to the LA. These inconsistencies were ±2 across seven indicators (table 3). The biggest error between the LA and PA was in fast transitions whereby the PA considered all jumps to be shifts. Errors in recording stances also occurred between PA and KR.

Table 3 The agreement between the analyses of the LA and the KR

| | LA ↓ | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **KR** | **Fast punch** | **Fast strike** | **Fast block** | **P-G-T** | **Slow block** | **Low kick** | **Middle kick** | **High stance** | **Middle stance** | **Low stance** | **Jump** | **Fast rotation** | **Fast shift** | **Fast step** | **Slow rotation** | **Slow same** | **Slow shift** | **Slow step** | **No event recorde** | **Grand Total** | **Total %** |
| Fast punch | 12 | | | | | | | | | | | | | | | | | | | 12 | 7.6 |
| Fast strike | | 6 | | | | | | | | | | | | | | | | | 1 | 7 | 4.4 |
| Fast block | | | 17 | | | | | | | | | | | | | | | | | 17 | 11.0 |
| P-G-T | | | | 6 | | | | | | | | | | | | | | | | 6 | 3.8 |
| Slow block | | | | | 12 | | | | | | | | | | | | | | | 12 | 7.6 |
| Low kick | | | | | | 2 | | | | | | | | | | | | | | 2 | 1.3 |
| Middle kick | | | | | | | 6 | | | | | | | | | | | | | 6 | 3.8 |
| High stance | | | | | | | | 3 | | | | | | | | | | | | 3 | 2.0 |
| Middle stance | | | | | | | | | 25 | | | | | | | | | | | 25 | 15.7 |
| Low stance | | | | | | | | | | 7 | | | | | | | | | 1 | 8 | 5.0 |
| Jump | | | | | | | | | | | 4 | | | | | | | | | 4 | 2.5 |
| Fast rotation | | | | | | | | | | | | 3 | | | | | | | | 3 | 2.0 |
| Fast shift | | | | | | | | | | | | | 11 | | | | | | | 11 | 6.9 |
| Fast step | | | | | | | | | | | | | | 15 | | | | | | 15 | 9.4 |
| Slow rotation | | | | | | | | | | | | | | | 2 | | | | | 2 | 1.3 |
| Slow same place | | | | | | | | | | | | | | | | 1 | | | | 1 | 0.6 |
| Slow shift | | | | | | | | | | | | | | | | | 4 | | | 4 | 2.5 |
| Slow step | | | | | | | | | | | | | | | | | | 5 | 2 | 7 | 4.4 |
| No event recorded | **2** | | 1 | | 2 | 1 | | 5 | | | | 1 | 1 | | | | 1 | | | 14 | 8.8 |
| **Grand Total** | **14** | **6** | **18** | **6** | **14** | **3** | **6** | **8** | **25** | **7** | **4** | **4** | **12** | **15** | **2** | **1** | **5** | **5** | **4** | **159** | |
| **Total %** | **8.8** | **3.8** | **11.3** | **3.8** | **8.8** | **2.0** | **3.8** | **5.0** | **15.7** | **4.4** | **2.5** | **2.5** | **7.6** | **9.4** | **1.3** | **0.6** | **3.1** | **3.1** | **2.5** | | |

*Zero indicators are omitted, P-G-T – Pull-Grab-Throw

**Discussion**

This article has presented a unique performance analysis model (template) for the karate discipline of kata and reported on its reliability through intra- and inter- observer comparisons. The template was established through content validity procedures by three karate experts. This yielded the identification of 25 performance indicators (karate techniques/movements). In its current form, the template is designed to be used post-competition to appraise the technical features of performance which should facilitate objective appraisals of the sport.

Following a comprehensive appraisal of its reliability, it emerged that the level of intra-observer reliability was excellent for the notation of the karate techniques (indicators) giventhe test-retest frequency scores for most indicators demonstrated almost perfect agreement across all indicators.For the inter-observer analysis, the degree of perfect agreement for the frequency of actions was lower than that for intra-observer, but was nevertheless satisfactory for all analysts, the LA, the PA and the KR given the agreement was often perfect or within a single frequency count.Clearly, with adequate familiarisation with the performance template, kata performance (filmed from one camera angle) can be reliably notated by individuals who are not particularly

experienced with computerized analysis. Such findings indicate those involved in the sport could apply an objective post-competition appraisal of performance to explicate the nature of the effort rather than relying upon subjective and qualitative appraisals.

It was not unexpected that the level of inter-observer reliability was somewhat inferior to the intra-observer reliability as this has been observed previously (Hughes et al., 2012; Thomson et al., 2013). It is plausible that this could be due to the observer's lack of familiarity with the analysis template and/or the kata, a degree of imprecision in the operational definitions of the performance indicators, or possibly computer issues.James et al. ( 2007)suggest involving method using freeze frame and replay functions to discuss events between analysts and experts. In this way a 'gold standard' coding for the match would be available and hence deemed as correct as possible. Even though the participants were probably very knowledgeable, there might still be one or two actions they are not so perfectly able to identify the actions via analysis. Indeed, kata is performed very dynamically, and despite the slow-motion playback, it is probable that any bias between the numbers of observations was a result of misclassification, not of failure to detect them. For instance, the PA recorded jumps as fast shifts whereas LA coded them as jumps,and the PA recorded some fast shifts as fast steps whereas LA coded them as shifts.Even though the definitions of these two movementsvary, there aremany similarcharacteristics to them, therefore it is understandable that there may occur some issues with distinguishing between them.Similar issues have occurred repeatedly in performance analysis(M. Hughes, Cooper, Nevill, & Brown, 2003) though it provides useful information for future use of the template whereby misclassification is possible.

It seems that neither the expertise in performance analysis nor the expert knowledge of the karate styles, or Ryu-ha,is necessary to use the template. This may be a consequence of the fact karate techniquescan be classified as fundamental movements, and so are generally observed with reasonable ease.PA was less proficient in identification of the movements than LA and KR which couldbe the result of them having more experience observing kata performance when compared to LA. Still, with only a single 30-minute familiarisation, participants were effectively able to notate performance suggesting the template holds promise in adding objectivity to appraisals of performance. Moreover, the analysis template could be expanded to incorporate other aspects of performance, such as the direction ofmovements or transition difficulty (e.g. change from Shiko daci to another one), to provide a more comprehensive profile of a kata performance. The outcome of such a comprehensive analysis could help create the difficulty coefficient of the kata based on a number and type of techniques (movements) rather than rely upon subjectivity as is currently the case.

Currently, the kata score awarded to athletes post-performance depends only on the judges' subjective evaluation, and the decision does not consider the length of the kata, the number, difficulty, or the frequency of the individual kata techniques. In this way, each kata on the official WKF kata list could be evaluated and could be consideredin the manner gymnastics is judged. Kata judges could thus be divided into groups appraising difficulty (D) and execution (E). E judges would award a score for the execution of individual techniques and D judges for difficulty of individual kata techniques (taking into account specific factors such as the number of techniques in each kata). Each kata from the WKF list could be described by its D score. Before the beginning of performance, the display would show a D score of the kata (as is the case in high diving). In the interest of transparency, this way the audience would know beforehand the scores to expect of D. The result would be the sum of scores D and E.

Indeed, the proposed D score would also help to divide kata performances into difficulty groups andeach performance indicator could have a value; when summed together the total would be a "D-score". This would allow the other judges to focus on the E component alone, defining the differences in demonstrating individual karate techniques (kicks, punches, transitions, etc.) by points subtraction, thus potentially creating a comparatively accurate ranking between competitors. Given the difficulty and the high dynamics of individual punches, kicks and transitions, it would be difficult for judges to evaluate the technical correctness of each individual move, so it might be more feasible to apply a global subtraction after the entire kata has been performed.In the manner of previous research scrutinising combat sports judging (Myers, Nevill, & Al-Nakeeb, 2010), the above recommendations infer an improved and comparatively objective appraisal of performance might be possible.

The errors produced by the observers were typically no larger than six (LA vs KR for total) and approximatelywithin one or two events for most indicators across La vs PA/KR, and so we consider the template consistent enough for effective practical use. The system has not only the potential to elucidate the movement characteristics and demands of karate kata and inform the coaches what to address during the training process but also enhance the transparency and objectivity of the judging process.

**Conclusions**

Intra-rater agreement was almost perfect whereas inter-rater concordance was moderate.Based on results,this study has demonstrated that a novel performance analysis template can yield consistent observations of the key movement characteristics occurring during kata. Moreover, the template can be used reliably by different operators with varying experiences of performance analysis, and the sport itself, to determine the features of a kata though clearly there remains scope to enhance the agreement across observers.Future work is

now underway to identify specific traits associated with a successful performance which might streamline analysis of kata performance.

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