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# DEVELOPMENT OF A SPORTS SPECIFIC AEROBIC CAPACITY TEST FOR KARATE – A PILOT STUDY

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**ABSTRACT**
The purpose of the study was to develop an aerobic fitness assessment test for competitive Karate practitioners and describe the preliminary findings. Five well-trained, competitive Karate practitioners participated in this study. A protocol simulating common attack strikes used in competition Karate sparring was developed from video analysis. In addition, pilot testing established a specific sequence of strikes and timings to be used in the test. The time to perform the strike sequence remained the same, whilst the time between strike sequence performances was progressively reduced. The aim of the test was to increase intensity of exercise through a decrease in recovery. On two separate occasions, absolute and relative peak oxygen uptake ($VO_{2peak}$), peak ventilation ($VE_{peak}$), maximum heart rate (HRM), and time to exhaustion (TE) obtained during the test were recorded. Subjective feedback provided by the participants was positive in that participants felt the test accurately simulated actions of a competitive sparring situation, and as a result athletes felt more motivated to perform well on this test. There was no significant between test difference in absolute $VO_{2peak}$, relative $VO_{2peak}$, HRM and TE ($p > 0.05$), indicating a potentially high reproducibility with the new test for these variables (test 1-test 2 difference of 0.04 $L·min^{-1}$, 1 $ml·kg^{-1}·min^{-1}$, -3 $beats·min^{-1}$, and 28 s; respectively). However, $VE_{peak}$ displayed potentially less reproducibility due to a significant difference observed between tests (test 1-test 2 difference of -2.8 $L·min^{-1}$, $p < 0.05$). There was a significant relationship between TE and relative $VO_{2peak}$ ($R^2 = 0.77$, $p < 0.001$). Further developments to the test will need to address issues with work rate/force output assessment/monitoring. The new test accurately simulates the actions of competitive Karate sparring.

**KEY WORDS**: Maximal test, oxygen consumption, Karate, motivation.

## INTRODUCTION

In recent years, training and physiological testing have become progressively tailored to the specific demands of the sport. For example, in cycling, the Kingcycle$^{TM}$ ergometer allows the cyclist to use his or her own bicycle as the ergometer, making for a more sports specific and therefore, arguably, valid test (Palmer et al., 1996).

There are numerous direct (i.e. laboratory) maximal oxygen uptake ($VO_{2max}$) tests developed for the treadmill and cycle ergometers (Åstrand and Rodhal, 1986; McArdel et al., 1973). Several methods of predicting $VO_{2max}$ have also been developed in an effort again to be more sports specific and allow measurements to take place whilst accurately simulating the activity in which the athlete participates (Cooper, 1968; Shephard, 1979). An example of such a test is the 20m multistage fitness test developed by Léger et al. (1988) used for predicting $VO_{2max}$ in multidirectional, stop – start type activities (e.g. soccer, rugby).

For participants of high-intensity intermittent activity, direct $VO_{2max}$ assessment tests are limited to exhaustive continuous or discontinuous protocols with the use of a treadmill or cycle ergometer

(McArdel et al., 1973). For participants of activity that does not involve running or cycling, these tests are not specific to the nature of their activity. Competitive Karate is one of these high-intensity intermittent activities (Lewis, 1996). Sparring in the competitive Karate environment involves the use of systematic attack and defence techniques against an opponent. Competition matches last 3 continuous mins for senior men, with intermittent pauses when fighters commit an offence (e.g. illegal strike), step out of a marked fighting area, or when an injury is sustained. Competitive sparring is very intermittent in nature, divided into periods of very high intensity activity (when attacking or blocking/parrying an attack) and low intensity activity when the fighter is preparing for an attack or just moving around ('dancing on their toes'). Much of the research available on Karate has focused on the nature of the activity in stressing the cardiovascular system and the potential health benefits this may elicit to the practitioner (Francescato et al. 1995; Shaw et al. 1982; Zher et al. 1993). This theme is continued in what little literature exists in competition Karate and Karate type sparring (Imamura et al. 1996; Schmidt et al. 1985). These studies have collectively shown Karate and Karate type sparring to be of intensity to stress the cardiovascular system and improve cardiovascular fitness.

It is well established that short and intense bouts of exercise, similar to that seen in competition Karate, rely predominately on the immediate (ATP-PCr) and short-term (anaerobic glycolysis) systems for the resynthesis of ATP. However, there is evidence to suggest aerobic processes are also involved in ATP resynthesis during all-out, high-intensity exercise (Medb∅ et al. 1989; Serresse et al. 1988). Medb∅ et al. (1989) have shown the contribution of energy from aerobic pathways to be as high as 40% during 30 s maximal work, and 50% during 1 min of maximal work. These findings indicate that even for activities considered to be 'anaerobic' in nature, there is significant involvement of the aerobic system to energy production. For activities that are highly intermittent in nature, such as competitive Karate, the relative contribution of oxidative pathways to the resynthesis of ATP could be even higher. Indeed, a recent study highlights the importance of aerobic pathways during Karate type sparring. Heller et al. (1998) assessed the physical characteristics of male and female Taekwondo (Korean equivalent of Karate) black belts performing in competition sparring. The study observed the actual fighting time (periods of attack/defence) compared to non-fighting time (pauses between scores, 'ring-outs' and injuries) in competition. The authors reported that the maximal (fighting time) to low intensity (pauses) activity ratio was 1:3 to 1:4. They concluded that competitive Taekwondo practitioners demonstrated high anaerobic and aerobic abilities. Furthermore, the authors also state 'it would be useful to detail more sport-specific tests to evaluate Taekwondo black belts during the training season'.

Evidence exists to suggest that competitive sparring, of which Karate is included, stresses the aerobic energy pathways to produce energy for the resynthesis of ATP (Francescato et al., 1995; Imamura et al., 1996; Shaw et al., 1982). As with any sport, the assessment of the physiological processes important to success in that sport is, especially at the elite level, compulsory. A number of sports specific protocols to assess aerobic capacity exist for sports highly dependent on the aerobic system (Léger et al., 1988; Palmer et al., 1996). To date, no protocol exists to assess the aerobic capacity of competitive Karate practitioners whilst simulating the nature of the activity. The aim of the present study was to develop such a test protocol.

## METHODS

### *Participants*

Five male competitive Karate practitioners participated in this study. All participants were highly competent in Karate kumite (sparring) to at least England National Squad level; Age (M = 31, SD = 9 years), height (M = 1.80, SD = 0.05 m), body mass (M = 78.9, SD = 13.2 kg) and experience (M = 15.4, SD = 8.6 years). All participants were informed of the procedures of the investigation and completed a pre-test health-screening questionnaire and provided written consent, according to ACSM guidelines (ACSM, 1995) prior to participation. The University Research Ethics Committee approved all experimental procedures.

### *Sport specific protocol development*

Pilot testing took place over a 1-month period. Figure 1 (a-d) illustrates the techniques performed in the test with gas analysis equipment attached. These techniques were selected from video analysis of competition Karate and the most common techniques observed were selected. These included the straight punch and the roundhouse kick.

The test protocol itself involved a sequential set of straight punch and roundhouse kick combinations on a heavy punch/kick bag suspended from a wall mounted bracket. The combination consisted of a leading straight punch (Figure 1a), followed by a rear leg roundhouse kick (Figure 1b), a rear straight punch (Figure 1c), and a leading roundhouse kick (Figure 1d), repeated twice. The time to complete this set of movements accurately and without haste was set at 7 seconds. This allowed sufficient time to execute and prepare each strike in a controlled manner.

a) b) c) d)

**Figure 1.** Techniques and correct sequence utilised for the new test. a) Lead straight punch, b) Rear roundhouse kick, c) Rear straight punch, d) Lead roundhouse kick.

The progression in intensity of the exercise during the test was based on a similar sequence of emitted audio beeps as the multistage fitness test (Léger et al, 1988). The test was designed with 2 auditory signals, the first to let the participant know when to begin the bout of exercise and a second sound to indicate when they should rest (7 seconds later).

The time to complete the exercise bout remained the same, 7 seconds, whilst the recovery time between bouts would be progressively decreased. Participants had to perform each strike and kick with as maximum force as possible. The aim here was to maintain maximal exercise intensity whilst progressively making the test more demanding by reducing the recovery between exercise bouts. One additional participant performed 3 experimental trials to obtain sets of recovery periods and subsequent decrements in time allotted for each particular set of recovery periods. This participant was not included in the actual experimental trials due to the imbalance in familiarity with the test. Once the data from these trials was analysed, a final test protocol was developed.

The protocol was again similar to that of Léger et al. (1988), in that stages and levels were adopted to correspond to certain periods of the recovery time. The outcome of pilot testing and the final test protocol is presented in Table 1. The final test protocol was placed onto a laptop PC.

***Procedures***

30 minutes before the onset of the experiment, participants were allowed to warm-up and stretched for 15 minutes. 10 minutes prior to test commencement participants were allowed a trial, with the portable gas analysis system and heart rate monitor attached, to practice the techniques used on the heavy bag and familiarise themselves with the test procedure. 5 minutes before the test all systems were checked again and the computer programme was put to ready. The test began after a pre-recorded 5 second auditory countdown. Expired air was analysed continuously throughout the test (Cosmed K4b2, Cosmed™ S.r.l, Italy). Often peak oxygen uptake ($VO_{2peak}$) is used to express the highest oxygen uptake obtained when the criteria for achieving a $VO_{2max}$ are not strictly met (BASES, 1997). Both relative ($ml \cdot kg^{-1} \cdot min^{-1}$) and absolute ($L \cdot min^{-1}$) peak oxygen uptake ($VO_{2peak}$) were defined as the highest 30 second average $VO_2$. The K4b2 is an upgraded version of the K2 gas analyser (Vacumetrics Inc., Ventura, CA), which has been shown to be both a valid (Lothian et al. 1993) and reliable (Bigard et al. 1995; Crandall et al. 1994) system for analysing $VO_2$ uptake. The heart rate (HR) was recorded every 5 seconds during the test via short wave telemetry (Polar Vantage, Polar Electro OY, Kempele, Finland). During the test, one of the researchers held the heavy bag in place to avoid unwanted movement. The test ended when the participant achieved volitional exhaustion at which point time to exhaustion (TE), exercise level and the cycle number obtained on the test were recorded. A

**Table 1.** Final test protocol exercises, cycles, activity periods, rest periods, exercise times and the cumulative time of the test protocol.

| Exercise | Cycles | Activity (s) | Rest (s) | Exercise Total (s) | Cumulative (s) |
|---|---|---|---|---|---|
| 1 | 10 | 7 | 20 | 270 | 0 |
| 2 | 6 | 7 | 15 | 132 | 270 |
| 3 | 6 | 7 | 13 | 120 | 402 |
| 4 | 6 | 7 | 11 | 108 | 522 |
| 5 | 6 | 7 | 9 | 96 | 630 |
| 6 | 6 | 7 | 7 | 84 | 726 |
| 7 | 6 | 7 | 5 | 72 | 810 |
| 8 | 6 | 7 | 4 | 66 | 882 |
| 9 | 6 | 7 | 3 | 60 | 948 |
| 10 | 6 | 7 | 2 | 54 | 1008 |
| 11 | 15 | 7 | 1 | 120 | 1062 |
| *Total* | | | | *1182* | |

second performance of the test was carried out 1 week after the initial test. Following both trials subjective feedback was noted, however this was not formally standardised.

***Data handling and statistics***

All results are presented as mean ± S.D. Due to the small sample size, a non-parametric differences test (Wilcoxin signed-rank) was carried out on all dependant variables. In addition, relative and absolute $VO_{2peak}$ values obtained from the two tests were individually plotted against TE to examine possible relationships via linear regression. Where a significant correlation was observed, the coefficient of determination (variance) was determined. A significance level of $p < 0.05$ was established prior to analysis. Statistical tests were run using SPSS version 12.1 for windows.

## RESULTS

There was no significant difference in $VO_{2peak}$, HRM and TE between test 1 and test 2 ($p > 0.05$). However, a significant difference in $VE_{peak}$ between test 1 and test 2 was observed ($p < 0.05$). Figure 2 illustrates a significant relationship ($R^2 = 0.77$, $p < 0.001$) between time to exhaustion and relative $VO_{2peak}$. The calculated coefficient of determination was 0.593 (0.77 x 0.77). Therefore, 59.3% (0.593 x 100) of the variance in TE is accounted for by relative $VO_{2peak}$. There was no relationship between TE and absolute $VO_{2peak}$, ($R^2 = 0.28$, $p > 0.05$). Table 2 presents the observed absolute $VO_{2peak}$, relative $VO_{2peak}$, $VE_{peak}$, HRM, and TE for test 1 and test 2 and the difference in these measures between tests. Absolute $VO_{2peak}$, relative $VO_{2peak}$, and TE increased (mean ± SD) 0.04 ± 0.1 $L{\cdot}min^{-1}$, 1 ± 1.1 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ and 28 ± 8.1 s respectively. HRM and $VE_{peak}$ decreased by 3 ± 0.3 $beats{\cdot}min^{-1}$ and 2.8 ± 1.6 $L{\cdot}min^{-1}$ respectively.

Subjective feedback from participants suggested that the test accurately simulated the actions used in competitive sparring situations. In addition, participants reported that they "felt more motivated" performing the new test than previous aerobic assessment tests.

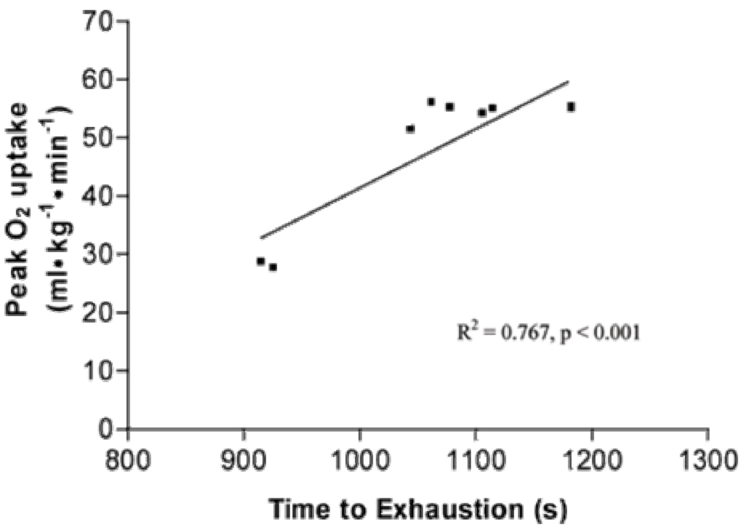


**Figure 2.** Relationship between TE and $VO_{2peak}$.

**Table 2.** Observed $VO_{2peak}$, $VE_{peak}$, HRM, and TE for test 1 and test 2.

| Subject | $VO_{2peak}$ ($ml•kg^{-1}•min^{-1}$) | | $VE_{peak}$ ($L•min^{-1}$) | | HRM ($beats·min^{-1}$) | | TE (s) | |
|---|---|---|---|---|---|---|---|---|
| | Test 1 | Test 2 | Test 1 | Test 2 | Test 1 | Test 2 | Test 1 | Test 2 |
| 1 | 55.0 | 55.4 | 114.6 | 114.3 | 192 | 186 | 1182 | 1182 |
| 2 | 55.2 | 55.1 | 138.8 | 131.2 | 195 | 189 | 1078 | 1114 |
| 3 | 51.4 | 56.1 | 150.3 | 146.7 | 201 | 200 | 1044 | 1062 |
| 4 | 28.8 | 27.6 | 135.7 | 134.3 | 184 | 180 | 915 | 926 |
| 5 | 54.3 | 55.2 | 113.5 | 112.4 | 185 | 186 | 1106 | 1182 |
| *Mean* | *48.9* | *49.9* | *130.6* | *127.8* | | | | *1093* |
| *( SD)* | *(11.4)* | *(12.5)* | *(16.0)* | *(14.4)* | *191 (7)* | *188 (7)* | *1065 (98)* | *(106)* |
| *Difference* | *1.0 ± 1.1* | | *- 2.8 ± 1.6* | | *- 3 ± 0* | | *28 ± 8* | |

## DISCUSSION

At present, this is the first sports specific test to assess the aerobic fitness of competition Karate practitioners. The first thing to detail is the fact that the new test simulates the actions used in competition Karate. All participants are familiar with other means of aerobic fitness testing, the most common being the multistage fitness test or 'bleep' test (Léger et al., 1988). Participants reported that the new test accurately simulated the actions they used in competition sparring, and this in turn "increased motivation" to perform well on the new test compared to previous aerobic capacity testing.

The difference between test 1 and test 2 absolute $VO_{2peak}$, relative $VO_{2peak}$, HRM, and TE was 0.04 $L·min^{-1}$, 1 $ml·kg^{-1}·min^{-1}$, -3 $beats·min^{-1}$, and 28 s, respectively. These relatively small, non-significant differences indicate that the newly developed test demonstrates potential test re-test reliability in these variables. $VE_{peak}$ displayed a significant difference between the two tests, decreasing 2.8 $L·min^{-1}$ in the second test. This finding indicates the new test is potentially less reliable at assessing $VE_{peak}$.

There was a strong relationship between TE and relative $VO_{2peak}$ (Figure 2) and potentially a large percentage (59.3%) of the variance in TE is attributed to relative $VO_{2peak}$. Performance on the new test involves weight-bearing exercise utilising both upper and lower limbs. It is well established that relative $VO_{2peak}$ relates strongly to performance for weight-bearing whole body exercise as witnessed in the present study (Haug et al. 1999). The present finding indicates that the new test potentially assesses the appropriate capacity of the aerobic system.

In developing the new test, a format similar to that of Léger et al. (1988) was used. The 20m shuttle run test was designed to increase to such intensity that it was almost impossible, if not impossible, to complete. It was our aim that the new test should also be of an intensity that prevented completion. However, it is noticeable that one participant completed the new test on both occasions, indicated by a TE of 1182 seconds. Another participant completed the test on the second testing occasion, increasing time to exhaustion by 76 s. Both participants had a $VO_{2peak}$ equal to or greater than 55 $ml·kg^{-1}·min^{-1}$. Moreover, these participants reported that they could have continued exercising longer had the test not ended.

Current guidelines for maximal aerobic capacity testing indicate $VO_{2peak}$ should be achieved within 8 – 15 mins (BASES, 1997). In the present test, only one participant achieved $VO_{2peak}$ within this time (Participant 4, Table 2). For those participants that did not complete the test ($n$ = 3), average time to achieve $VO_{2peak}$ was 16.9 mins and 17.2 mins for tests 1 and 2 respectively. This, coupled with the fact that time to completion of the test is already 19 mins and 42 s (1182 s/60), indicates that the new test is perhaps already too long. Further time additions (e.g. an increase in number of exercises/stages) would be impractical. It would be more practical to consider the new test to be of insufficient intensity to achieve $VO_{2peak}$ within guideline duration. Likewise, the new test appears of insufficient intensity for individuals with a $VO_{2peak}$ 55 $ml·kg^{-1}·min^{-1}$ or greater.

### *Implications for test development*

Due to the small $n$, consideration to the possible presence of both type I and type II error needs to be given. A larger $n$ would reduce the possibility of these errors occurring and provide sufficiently statistical significant results. This should be addressed accordingly in continuation study of the new test. Additional further developments to the test include a need to increase intensity at an earlier stage in an effort to prevent completion of the test. This could be achieved by eliminating early stages used as a warm up period, and increasing the number of stages within each exercise. However, when performing a maximal oxygen uptake test on a treadmill or cycle ergometer, work rate or intensity progressively increases by either increasing speed (treadmill) or workload (cycle) until volitional exhaustion. One of the restrictions of the new Karate test is the fact that work rate cannot be assessed nor altered in the same manner as treadmill or cycle ergometry workload. In the new test participants are asked to perform each technique with as much force as possible. Towards the end of the test, it was noticeable that participants were not able to maintain the same level of force as that of earlier stages. The problem lies in distinguishing if participants are giving a maximal effort each time they perform the activity bout. Test developments will look to address this issue via methods of assessing power output during the test. The use of force transducers within a boxing punch bag (Karpitowski et al., 1994) and boxing manikin (Smith et al., 2000) to monitor strike forces has been shown to provide accurate and reliable force and power outputs in boxers. The adoption of such methods for assessment of force/power output in the new test warrants further investigation.

Finally, subjective feedback provided information regarding the effectiveness of the new test in simulating actions specific to competitive karate. As a result, participants reported feeling "more motivated" performing the new test compared to previous non-specific aerobic assessment tests. The use of appropriate psychological inventories (Reeve and Deci, 1996) may have allowed for quantification of this improved motivation. Further developments will look to employ such methods, providing additional ecological validity to the work.

In summary, the new test accurately simulates the actions used in competition Karate and anecdotal reports are that the test is more motivating than other familiar methods of assessing aerobic capacity in Karate practitioners. Time to exhaustion during the test was strongly related to relative $VO_{2peak}$. At present, the new test does not allow us to quantitatively measure performance effort, making it difficult to distinguish a 'true' $VO_{2peak}$. The use of force transducers could be assessed to address this issue.

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**KEY POINTS**

- This is the first attempt at an aerobic fitness test specific to competitive Karate practitioners
- Anecdotal reports are that the new test accurately simulates the actions used in competition Karate
- Relative $\mathbf{V}O_{2peak}$ was significantly related to time to exhaustion, with 63.5% of the variance in time to exhaustion attributed to relative $\mathbf{V}O_{2peak}$.
- Test developments include the use of force plates and transducers to assess force/power output during the test

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