A regression equation to predict true maximal oxygen consumption of taekwondo athletes using a field test

Cem Cetin, *MD, PhD,* ***Hilmi Karatosun,*** *MD, PhD,* ***Metin L. Baydar,*** *MD, PhD,* ***Kaan Cosarcan,*** *MD.*

ABSTRACT

Objective: The purpose of the present study was to examine the validity of using a 20 meter multistage shuttle run test to estimate maximal oxygen uptake.

Methods: Twenty-two elite taekwondo athletes (11 male, 11 female, members of the Turkish young national team), participated in the study. The respiratory gas exchange parameters were measured using portable gas analysis system while shuttle run test was carried out. All tests were performed last August 2004, in the gymnasium of Suleyman Demirel University, Isparta, Turkey.

Results: Analysis of the test scores showed a mean score on gas analysis of 51.79 ml/kg/min and a mean score of 43.59 ml/kg/min on the shuttle run test. On average, the scores predicted by the shuttle run test were 16% lower than those for the gas analysis score. The correlation between the tests was significant at a level of r = 0.810.

Conclusion: Maximal oxygen consumption (VO_2 max) can be predicted from shuttle run test scores, but not as indicated with the test package. In order to obtain the true score one must apply a regression equation.

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When testing the athletes for maximal oxygen consumption (VO_2 max) it is important that the testing method is accurate and valid.[1] The measurement of oxygen consumption (VO_2) and carbon dioxide production (VCO_2) are standard tools of exercise in physiology that are used to assess aerobic capacity, exercise intensity and energy expenditure. In addition, measurement of VO_2 and VCO_2 allows indirect measures of substrate utilization. For many years the technique for the collection and analysis of these gases has been the Douglas bag method. Although this technique is still considered the gold standard, it has several disadvantages and its own sources of error. Firstly, no breath-by-breath data can be obtained, and therefore rapid changes in ventilation or VO_2 cannot be studied. Secondly, the method is time consuming due to the requirement of sampling and analysis after collection. In addition, the bags are made of Polyvinyl chloride material, which is slightly permeable to the external air. Increasing technology, though, has seen the emergence of portable and automated on-line, breath-by-breath gas analysis systems. These systems allow the continuous measurement of gas volumes and concentrations and the immediate display of this information on-line, and therefore markedly increase the efficiency of the gas analysis procedure.

The greatest downfall of this test is its cost, and consequently there has been a search for a cheaper, yet still accurate test of VO_2 max. Some of the tests used include the 1.5 mile run, the 12 minute run,

From the Department of Sports Medicine, Faculty of Medicine, Suleyman Demirel University, Isparta, *Turkey*.

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Address correspondence and reprint request to: Dr. Cem Cetin, Department of Sports Medicine, Suleyman Demirel University, Faculty of Medicine, Isparta 32260, *Turkey*. Tel. +90 (246) 2112374. Fax. +90 (246) 2370240. E-mail: cem@med.sdu.edu.tr

Table 1 - Mean score (ml/kg/min) on gas analysis and on the shuttle run test of each athletes (n=22).

Subject	Shuttle run test VO_2 max	Gas analysis VO_2 max
1	41.86	50.30
2	37.79	44.60
3	42.85	44.70
4	36.76	35.90
5	39.87	44.10
6	35.12	48.30
7	41.86	47.20
8	36.42	37.10
9	42.52	42.70
10	38.83	33.20
11	40.54	51.90
12	50.84	59.20
13	49.24	61.80
14	46.80	66.30
15	44.61	50.70
16	47.71	55.80
17	47.71	59.20
18	49.85	56.40
19	48.63	68.20
20	43.65	62.00
21	50.55	62.80
22	44.92	57.10
Mean	43.59	51.79

VO_2 max - maximal oxygen consumption

step tests, the Astrand Rhyming Cycle test, and the 20 meter shuttle run test. The use of a maximal multistage 20 meter shuttle run test to predict VO_2 max was first proposed by Lager and Lambert.[2] A maximal multistage 20 meter shuttle run test was designed to determine the maximal aerobic power of school children, healthy adults attending fitness class and athletes.[3] This test is now accepted as a valid method of indirectly estimating the maximal oxygen uptake.[4,5]

The VO_2 at maximal exercise is considered the best index of aerobic capacity and cardiorespiratory function. Maximal VO_2 is defined as the point at which no further increase in measured VO_2 occurs despite an increase in work rate (a plateau is reached) during graded exercise testing. Direct measures of VO_2 are reliable and reproducible and provide the most accurate assessment of functional capacity. This investigation will focus on comparing the 20 meter shuttle run test as described by the Leger and Mercier,[2] to a gas analysis test using a portable ergospirometry system together.

Each of the aforementioned tests have different degrees of accuracy, and can yield a different result for a given subject's VO_2 max . The purpose if this investigation was to determine the correlation, if any, that exists between the 2 tests, and if significant, to develop a regression equation to allow prediction of the value one would get from a gas analysis, from a given VO_2 outcome on the shuttle run test.

Methods. ***Subjects.*** Twenty-two voluntary elite taekwondo athletes (11 male, 11 female, members of the Turkish young national team), participated in the study. They were aged 14 - 17 (16 ± 1.11) years, had a training history of 4 - 8 (6.77 ± 2.53) years, and trained 9 - 10 hours per week. Before testing, they were informed of the test procedures, and were required to provide written consent. In addition, immediately before the test, all subjects were examined by a physician to determine their health status.

Twenty meter shuttle run test. Each athlete was tested using "shuttle run test" according to Leger and Mercier.[2] In this test subjects had to run back and forth on a 20 meter course in the gymnasium and touch the 20 meter line; at the same time a sound signal was emitted from a prerecorded tape. Frequency of the sound signals were increased 0.5 km/h each minute from a starting speed of 8.5 km/h. Subjects were given verbal encouragement throughout the test and they continued until they could not reach the cones 3 times consecutively after the bleep sounds.

Portable gas analysis system. The respiratory gas exchange parameters were measured using a portable gas analysis system (Oxycon Mobile, Jaeger, Hoechberg, Germany). The expired gas was sampled continuously breath-by-breath for the measurement of VO_2. The volume and gas calibration of the gas analysis system was checked immediately before and after each test with standard calibration gases (16% O_2 and 4% CO_2). Volume calibration was checked via 2 L air pomp, which was in a receiver unit. A heart rate monitor (Polar Electro Sportester, Finland) was secured around the subject's chest and a portable gas analyzer was attached to a chest belt. The gas analyzer was interfaced with a personal portable computer to calculate and store breath-by-breath ventilatory gas exchange variables [VO_2, VCO_2, minute ventilation (VE), tidal volume (VT), respiratory exchange ratio (RER)]. Heart rate (HR) recording was interfaced with the gas analyzer using a short-range radio telemetry system.

The VO_2 values were considered maximal, when 2 of the following 3 criteria were met: 1) VO_2 plateau defined as a failure of oxygen uptake to increase by greater than 2 ml/kg/min with running speed increase. 2) HR >95% from the predicted individual of maximum (maximum HR was calculated by subtracting subject's age from 200**)**. 3) Respiratory exchange ratio >1.05.[6]

Results. Maximal oxygen uptake of 51.79 ± 2.12 ml/kg/min, VE of 106.32 ± 5.75 L/ min, VT of 1.91 ± 0.06 L, RER of 1.11 ± 0) and HR of 198 ± 1.41 beat/min were determined while maximal exercise was performed.

Analysis of the test scores showed a mean score on gas analysis of 51,79 ml/kg/min and a mean score of 43.59 ml/kg/min on the shuttle run test **(Table 1)**. On average, the scores predicted by the bleep test were 16% lower than those for the gas analysis score. The correlation between the tests was significant at a level of $r = 0.810$ with $n = 22$. There was a confidence level of $p<0.05$. Since a significant correlation exists, a regression equation was developed to predict VO_2 max score on the gas analysis the VO_2 max score in the shuttle run test. The regression equation is as follows:

VO_2 max gas analysis = 1.647·VO_2 max shuttle run test – 19.999

Discussion. The functional and energy demands of the event and physiological responses of taekwondo athletes are not well documented in the exercise physiology and sports medicine literature.[7] Thompson and Vinueza[8] reported only a minimal effect of taekwondo training on cardiorespiratory fitness, in contrast to Drobnic et al,[9] who reported high aerobic and anaerobic capacities of competitors. Heller et al[7] reported maximum oxygen uptake in males (54 ml/kg/min) higher than that reported by Thompson and Vinueza[8] (namely, 44 ml/kg/min), but lower than that observed by Drobnic et al[9] (namely, 57 - 63 ml/kg/min). The other physiological characteristics of elite female and male taekwondo athletes reported by Heller at al[7]; maximum HR (HRmax) (188 ± 8 beats min for female and 183 ± 6 beats min for male), maximum VE (VE max) (90.4 ± 8.9 L/min for female and 118 ± 17.4 L/min^{-1} for male), VO_2 max (41.6 ± 4.2 ml/kg/min for female and 53.9 ± 4.4 ml/kg/min for male). Thus, our results were; HRmax (197 ± 67 beats per minute for female and 199 ± 7 beats per min for male), VEmax (87.3 ± 17.5 L per minute for female and 125.4 ± 20.6 L per minute for male), VO_2 max (43.6 ± 6.1 and 60 ± 5 ml per min^{-1} per kg). The higher values are probably from the study design; and the athletes in our study is younger than athletic groups of Heller at al.[7] Nevertheless, one of the general recommendations for the assessment of VO_2 max is that subjects should perform rhythmic exercise, which requires large muscle mass. From the results, one can conclude that true VO_2 max can be predicted from shuttle run test scores, but not as indicated with the test package. In order to obtain the true score, one must apply a regression equation suggested above.

In conclusion, shuttle run test has the time and cost efficiency. Multiple subjects can be tested at once and the only equipment necessary are cones, a cassette player, and the 'bleep tape' (a one time cost). Furthermore, it is less intimidating to the subjects, as there is no restrictive headgear to wear. Thus, subjects are less apprehensive on the test.

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