Development of a Field Test for Evaluating Aerobic Fitness

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ABSTRACT

The purpose of this study was to investigate the reproducibility and utility of a standardised and externally paced field test (15-m Incremental Shuttle Walk and Run Test [15mISWRT]) to assess aerobic fitness in middle-aged adults. Fourteen middle-aged participants performed the 15-m ISWRT three times within one week (Test 1, Test 2, Test 3). Reproducibility of the 15-m ISWRT was tested by comparing 15-m ISWRT performance (distance completed), HR_{max}, and $\dot{V}O_{2max}$ for each test. The utility of the 15-m ISWRT for evaluating $\dot{V}O_{2max}$ over a wide range in middle-aged adults was tested by comparing the range of $\dot{V}O_{2max}$ obtained from the portable expired gas analyzer with the $\dot{V}O_{2max}$ reference values and ranges for health promotion published by Japan's Ministry of Health, Labour and Welfare. A multiple comparison of distance completed in the 15-m ISWRT Test 1, Test 2, and Test 3 found no significant difference between Test 2 and Test 3. The ICC was 0.99 for Test 2 vs. Test 3. $\dot{V}O_{2max}$ measured from the 15-m ISWRT in Test 3 had a minimum value of 22.8 ml/kg/min and a maximum value of 38.7 ml/kg/min. In conclusion, the 15-m ISWRT is reliable and useful for evaluating $\dot{V}O_{2max}$ in middle-aged adults.

Development of a Field Test for Evaluating Aerobic Fitness in the Middle-aged Adults

INTRODUCTION

Lifestyle diseases and metabolic syndrome due to overeating and insufficient exercise are currently a problem facing many middle-aged adults people in developed countries [8, 22], and there is growing concern over the aerobic fitness of this age group.

It is clear that aerobic fitness in middle-aged adults correlates negatively with risk factors for high blood pressure and coronary artery disease [12, 21, 25], and it contributes to prevention of lifestyle diseases and reduced mortality if maintained at a high level [2, 3, 23]. $\dot{V}O_{2max}$ and anaerobic threshold (AT) are recognized as objective and valid standards for aerobic fitness [5, 14, 24], and the proper evaluation of $\dot{V}O_{2max}$ and AT is, therefore, important in assessing the health and healthcare needs of middle-aged adults.

$\dot{V}O_{2max}$ can be evaluated using a cardiopulmonary exercise test (CPX) or field tests [13, 20]. The CPX provides an accurate measure of $\dot{V}O_{2max}$, but it is not widely used in clinical settings because it requires expensive, complicated equipment and trained staff, whereas field tests are a widely used alternative because they are simple, inexpensive, and do not require specialized equipment.

The 1500-m fast walk and 20-m shuttle run test (20-m SRT) are currently used as field tests for middle-aged adults [10, 13], and they are recommended in Japan by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

However, the 1500-m fast walk has certain drawbacks. The exercise workload is not quantified, since the participants walk at their own pace, producing test results influenced by the participants' own inclinations and comfort zones. The test is therefore not standardised, and its reliability and validity have not been sufficiently studied. This

test is also restricted by weather and location, since it requires a track and is usually performed outside.

The 20-m SRT has been well studied in young people, showing good reproducibility and a strong correlation between test performance and $\dot{V}O_{2max}$ [4, 15, 17], but it has not been tested in middle-aged adults. Because the 20-m SRT was originally developed to evaluate the aerobic fitness of athletes, the estimated $\dot{V}O_{2max}$ at the first stage was set at 27.8 ml/kg/min, a high level of exercise intensity. This field test cannot therefore be used to evaluate aerobic fitness below a $\dot{V}O_{2max}$ of 27.8 ml/kg/min, and it would impose an excessive, high-risk workload on middle-aged adults.

Singh and colleagues modified the 20-m SRT to produce the 10-m Incremental Shuttle Walking Test (10-m ISWT) [20] for evaluating the aerobic fitness of patients with chronic obstructive pulmonary disease (COPD). Because the 10-m ISWT uses an external sound to control walking speed, it can increase the exercise load to the limits of the participant's fitness in the same way as the CPX. The test also has high reproducibility over repeated measurements [20] and shows a good correlation between test performance and peak oxygen intake $\dot{V}O_{2peak}$ [19]. This test is now widely used throughout the world as a field test for evaluating the aerobic fitness of patients with respiratory and cardiovascular disease. However, because the 10-m ISWT was developed for COPD patients, the maximum estimated $\dot{V}O_{2max}$ calculated from 10-m ISWT test performance is 30.2 ml/kg/min, making it unsuitable for evaluating aerobic fitness when $\dot{V}O_{2max}$ is above 30.2 ml/kg/min.

Based on the $\dot{V}O_{2max}$ reference values and ranges for health promotion in people aged 50-59 years [11], published by Japan's Ministry of Health, Labour and Welfare

(MHLW), it is clear that the exercise intensities of the 20-m SRT and 10-m ISWT tests are unsuitable for middle-aged adults.

It is apparent from this brief survey of methods for evaluating aerobic fitness in the middle-aged adults that none of the existing field tests satisfy the expected conditions of standardisation, validity, safety, and simplicity. In view of this, we extended the 10-m course of the 10-m ISWT to create a 15-m incremental shuttle walk and run test (15-m ISWRT). A pilot study [16] of the 15-m ISWRT demonstrated that the $\dot{V}O_{2max}$ range measurable from this test was 7-52 ml/kg/min, and that 15-m ISWRT performance correlated very closely with $\dot{V}O_{2mean}$ (r = 0.95, p < 0.01) at each level. However, the test was not validated for older participants because the pilot study used healthy adults in their twenties.

The aim of the present research was to investigate the utility of the 15-m ISWRT based on whether it showed reproducibility over repeated measurements and could be used to evaluate $\dot{V}O_{2max}$ over a wide range in middle-aged adults.

METHODS

Participants

Initially, 25 potential participants responded to recruitment announcements distributed to participants at local health workshops, hospital employees, university staff, and members of private sports clubs. Of the 15 who were accepted as meeting the study selection criteria, 14 took part in the study. Fourteen participants who fulfilled the selection criteria for this research performed the 15-m ISWRT three times within one week (Test 1, Test 2, Test 3). The participants' physical characteristics were (mean ±

standard deviation): age, 49.4 ± 6.0 years; height, 162.1 ± 5.0 cm; and weight, 59.8 ± 9.4 kg. Participants' selection criteria were: 1) 40-59 years old; 2) male; 3) capable of running; 4) no history of bone and joint disease or cardiorespiratory disease that would impede the exercise; and 5) gave consent to take part in the research. This study met the ethical standards suggested by Harriss and Atkinson [9], and ethics approval was obtained from the Nagasaki University Graduate School Ethics Committee.

Study Design

HR and oxygen intake ($\dot{V}O_2$) for 3 minutes at rest before start of the 15-m ISWRT and during the 15-m ISWRT were measured continuously on a breath-by-breath basis using a portable expired gas analyzer (AT-1100 Ver.3.01, Anima Corp, Tokyo, Japan). The variables measured were 15-m ISWRT performance (distance completed), maximum heart rate (HR_{max}), and $\dot{V}O_{2max}$. $\dot{V}O_2$ at the completion of the 15-m ISWRT was taken as $\dot{V}O_{2max}$. Reproducibility of the 15-m ISWRT was tested by comparing 15-m ISWRT performance (distance completed), HR_{max}, and $\dot{V}O_{2max}$ for each test (Test 1, Test 2, Test 3). The utility of the 15-m ISWRT for evaluating $\dot{V}O_{2max}$ over a wide range in middle-aged adults was tested by comparing the range of $\dot{V}O_{2max}$ obtained from the portable expired gas analyzer with the $\dot{V}O_{2max}$ reference values and ranges for health promotion published by MHLW [11].

15-m ISWRT procedure

The 15-m ISWRT was performed on a straight, 15-m course on level ground. The participant moved back and forth over the 15-m course, which had a guide pole placed

0.5 m from each end to prevent sharp changes of direction. Participants had to walk or run at the prompting of a sound played at regular intervals from the 10-m ISWT CD, reaching the guide pole at the opposite side before the next sound was heard. Travel speed ranged from level 1 to level 12, increasing by increments of 15 m/min. Level 1 speed was set at 2.7 km/h, so that three lengths of the 15 m course were covered in 1 minute (1.5 return trips). With each increase in level, the number of lengths travelled was increased by one, so that level 2 was four lengths (2 return trips) per minute, and so on until the final level 12 required 14 lengths per minute (7 return trips). Table 1 shows the protocols for the 15-m ISWRT. Stopping criteria conformed to the American College of Sports Medicine's Guidelines for Exercise Testing and Prescription [1]. Inability to cover the 15-m course within the set time was an additional stopping criterion.

Statistical Analyses

Reproducibility of the 15-m ISWRT was investigated using repeated measures ANOVA for each variable (15-m ISWRT performance, HR_{max}, $\dot{V}O_{2max}$) in the three 15-m ISWRT tests (Test 1, Test 2, Test 3). In addition, the reproducibility of each variable among the three tests was evaluated by the intraclass correlation coefficient (ICC). The relationship between $\dot{V}O_{2max}$ and 15-m ISWRT performance was evaluated using Pearson product-moment correlation analysis and simple linear regression. SPSS (18.0J for Windows) was the statistical software used, with the significance level set at $< 5\%$.

RESULTS

Reproducibility of the 15-m ISWRT based on repeated measurements

Measurements from the three 15-m ISWRT tests performed in one week (Test 1, Test 2, Test 3) are presented in Table 2. Of the measured variables (distance completed, HR_{max}, $\dot{V}O_{2max}$), distance completed showed significant differences in Test 1 vs. Test 2 and Test 1 vs. Test 3 ($p<0.05$), but no significant differences were found in HR_{max} and $\dot{V}O_{2max}$ in the three tests. Table 3 shows the mean difference (d) ± standard error (SE), 95% confidence intervals (CI), and ICC for each variable (distance completed, HR_{max}, $\dot{V}O_{2max}$).

Range of $\dot{V}O_{2max}$ measured from the 15-m ISWRT

$\dot{V}O_{2max}$ measured from the 15-m ISWRT in Test 3 had a minimum value of 22.8 ml/kg/min and a maximum value of 38.7 ml/kg/min (Figure 1). The correlation between distance completed and $\dot{V}O_{2max}$ was high (r = 0.79; $p<0.01$), and it was represented by the regression equation: $\dot{V}O_{2max}$ = 13.5 + 0.02 distance where $\dot{V}O_{2max}$ is in ml/min/kg and distance is in meters (Figure 1).

DISCUSSION

This study is the first trial of an incremental and progressive field test for evaluating aerobic fitness in middle-aged adults. The reproducibility and utility of the 15-m ISWRT for evaluating $\dot{V}O_{2max}$ in this group were demonstrated. The correlation between 15-m ISWRT performance and $\dot{V}O_{2max}$ could be expressed by the regression equation: $\dot{V}O_{2max}$ (ml/min/kg) = 13.5 + 0.02 distance (m).

Reproducibility of the 15-m ISWRT

$\dot{V}O_{2max}$ and HR_{max} for the 15-m ISWRT during Test 1, Test 2, and Test 3 showed no significant differences on repeated measures ANOVA, indicating that the exercise intensity was similar in each test. In addition, very good intraclass correlation was shown for both $\dot{V}O_{2max}$ (ICC = 0.98) and HR_{max} (ICC = 0.92).

A multiple comparison of distance completed in the 15-m ISWRT Test 1, Test 2, and Test 3 found no significant difference between Test 2 and Test 3, but significant differences were found between Tests 1 and 2 and between Tests 1 and 3. Since the distance completed was also better in Test 2 and Test 3 compared to Test 1, the practice effect may have been responsible. Previous field test research has also found that reproducibility of test performance (distance completed) improves in the second and subsequent runs [18, 20], and we similarly found that reliability of 15-m ISWRT test performance (distance completed) improved in the second and subsequent runs. However, the ICC was 0.98 for Test 1 vs. Test 2, 0.98 for Test 1 vs. Test 3, and 0.99 for Test 2 vs. Test 3. Since an ICC of 0.81-1.00 indicates an extremely strong correlation, distance completed was considered to have an extremely strong correlation between

tests.

Therefore, it appears that highly reliable measurements ($\dot{V}O_{2max}$, HR_{max}, distance completed) can be obtained in the 15-m ISWRT with preferably a single practice run and measurement on the second run.

Utility of the 15-m ISWRT

$\dot{V}O_{2max}$ measured from the 15-m ISWRT in Test 3 had a range of 22.8-38.7 ml/kg/min. The participants in that test achieved a minimum of level 6 and a distance of 495 m, and a maximum of level 10 and a distance of 1080 m. The minimum $\dot{V}O_{2max}$ value of 22.8 ml/kg/min falls below the lower limit of $\dot{V}O_{2max}$ for health promotion in people aged 40 to 59 years [11], while the minimum $\dot{V}O_{2max}$ value of 38.7 ml/kg/min falls above the reference value of $\dot{V}O_{2max}$ for health promotion in people aged 40 to 59 years [11]. Because of the strong positive correlation between exercise intensity and $\dot{V}O_2$, participants who completed the test at level 10 or above (none in this study) would have a $\dot{V}O_{2max}$ of at least 38.7 ml/kg/min as measured from the 15-m ISWRT, whereas those who finished the test below level 6 (none in this study) would have a $\dot{V}O_{2max}$ below 22.8 ml/kg/min. Furthermore, based on the expression $\dot{V}O_{2max}$ (ml/min/kg) = 13.5 + 0.02 distance (m), derived from this study for the relationship between distance completed and $\dot{V}O_{2max}$, the predicted $\dot{V}O_{2max}$ (= upper limit of $\dot{V}O_{2max}$ measured from the 15-m ISWRT) for completion of the 15-m ISWRT can be calculated as 44.1 ml/kg/min. This means that although the range of $\dot{V}O_{2max}$ measured from the 15-m ISWRT was 22.8-38.7 ml/kg/min in this study, the 15-m ISWRT can be considered adequate for measuring $\dot{V}O_{2max}$ outside this range. The group of people falling below

the minimum $\dot{V}O_{2max}$ for health promotion in people aged 40 to 59 years (= $\dot{V}O_{2max}$ < 26ml/kg/min) [11] has a high incidence of visceral fat accumulation, abnormal blood lipids, hypertension, and hyperglycaemia, and is at high risk of metabolic syndrome [6, 7]. The $\dot{V}O_{2max}$ range measured from the 15-m ISWRT adequately encompasses the $\dot{V}O_{2max}$ values of this group.

In summary, it is apparent that the 15-m ISWRT can be used to evaluate $\dot{V}O_{2max}$ over a wide range in middle-aged adults, including at its lower limit $\dot{V}O_{2max}$ values ($\dot{V}O_{2max}$ < 26 ml/kg/min), which are associated with a high risk for metabolic syndrome.

A limiting factor in this study was that the participant group comprised volunteers rather than being randomly selected. Thus, the possibility of selection bias cannot be ruled out. Furthermore, only middle-aged men, no women, were included. A future study using a large group of randomly selected participants is needed to address the limitations of this study.

CONCLUSION

The reliability and utility of the 15-m ISWRT designed for middle-aged adults and based on the 10-m ISWT developed by Singh and colleagues [20] were evaluated. Based on the results of this study, the 15-m ISWRT appears to be reliable and useful for evaluating $\dot{V}O_{2max}$ in middle-aged adults. The 15-m ISWRT is therefore highly recommended as a field test for evaluating aerobic fitness in middle-aged adults.

The reasons for studying the 15-m ISWRT were as follows. 1) As with the 10-m ISWT, the exercise load in the 15-m ISWRT protocol was controlled externally and had been standardised. Furthermore, because it was an incremental test, a near-maximal

exercise load up to the symptomatic limit could be applied. 2) The procedure of the 15-m ISWRT is simple, and it does not use expensive equipment. Therefore, it can be administered indoors to many people in one session with just a straight 15-meter course and without the need for testers with specialist knowledge. 3) A pilot study [16] with young, healthy participants demonstrated the utility and validity of the 15-m ISWRT.

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FIGURE LEGEND

Figure 1. $\dot{V}O_{2max}$ measured with a portable expired gas analyzer versus distance on the

15m ISWRT.

The bold-type line shows the range of $\dot{V}O_{2max}$ for health promotion published by Japan's

Ministry of Health Labour and Welfare for men aged 40 to 59 years [11].

15mISWRT = 15m Incremental Shuttle Walk and Run Test, $\dot{V}O_{2max}$ = Maximal oxygen

uptake.

Development of a Field Test for Evaluating Aerobic Fitness in the Middle-Aged adults
- Validity of a 15-m Incremental Shuttle Walk and Run Test -

Table 1. The protocols of 15m Incremental Shuttle Walk and Run Test (15m ISWRT)

Level	15m Incremental Shuttle Walk and Run Test			
	Speed (km/h)	No of shuttles per level	Distance per level(m)	Sum (m)
1	2.7	3	45	45
2	3.6	4	60	105
3	4.5	5	75	180
4	5.4	6	90	270
5	6.3	7	105	375
6	7.2	8	120	495
7	8.1	9	135	630
8	9.0	10	150	780
9	9.9	11	165	945
10	10.8	12	180	1125
11	11.7	13	195	1320
12	12.6	14	210	1530

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Table 2. A mean value of Distance, HR_{max} and $\dot{V}O_{2max}$ in 15mISWRT for Test1, Test2 and Test3

	Test1	Test2	Test3
Distance（m）	755.4±166.4	783.2±156.2	790.7±157.5
		＊＊	
		＊＊	
HR_{max}（bpm）	172.0±9.3	173.1±9.8	174.3±8.5
$\dot{V}O_{2max}$（ml/kg/min）	30.4±4.8	30.1±4.9	30.5±4.5

Mean±Standard Deviation　　＊＊ p＜0.05

HR_{max} = Maximal heart rate, 15mISWRT = 15m Incremental Shuttle Walk and Run Test, $\dot{V}O_{2max}$ = Maximal oxygen uptake

Development of a Field Test for Evaluating Aerobic Fitness in the Middle-Aged adults
- Validity of a 15-m Incremental Shuttle Walk and Run Test -

Table 3. Reproducibility studies on the 15m Incremental Shuttle Walk and Run Test

	Distance			$\dot{V}O_{2max}$			HR_{max}		
	Mean d ± SE	95%CI	ICC	Mean d ± SE	95%CI	ICC	Mean d ± SE	95%CI	ICC
Test1 vs Test2	27.8 ± 9.0	8.6 - 47.2	0.98	-0.4±0.5	-1.4 - 0.6	0.97	-1.1±0.9	-3.0 - 0.8	0.97
Test1 vs Test3	35.3 ± 7.3	19.5 - 51.3	0.98	0.1±0.5	-1.0 - 1.2	0.96	1.5±0.9	-0.3 - 3.3	0.96
Test2 vs Test3	7.5 ± 9.1	-12.1 - 27.1	0.99	0.5±0.3	-0.3 - 1.3	0.98	2.6±1.2	0.0 - 5.2	0.92

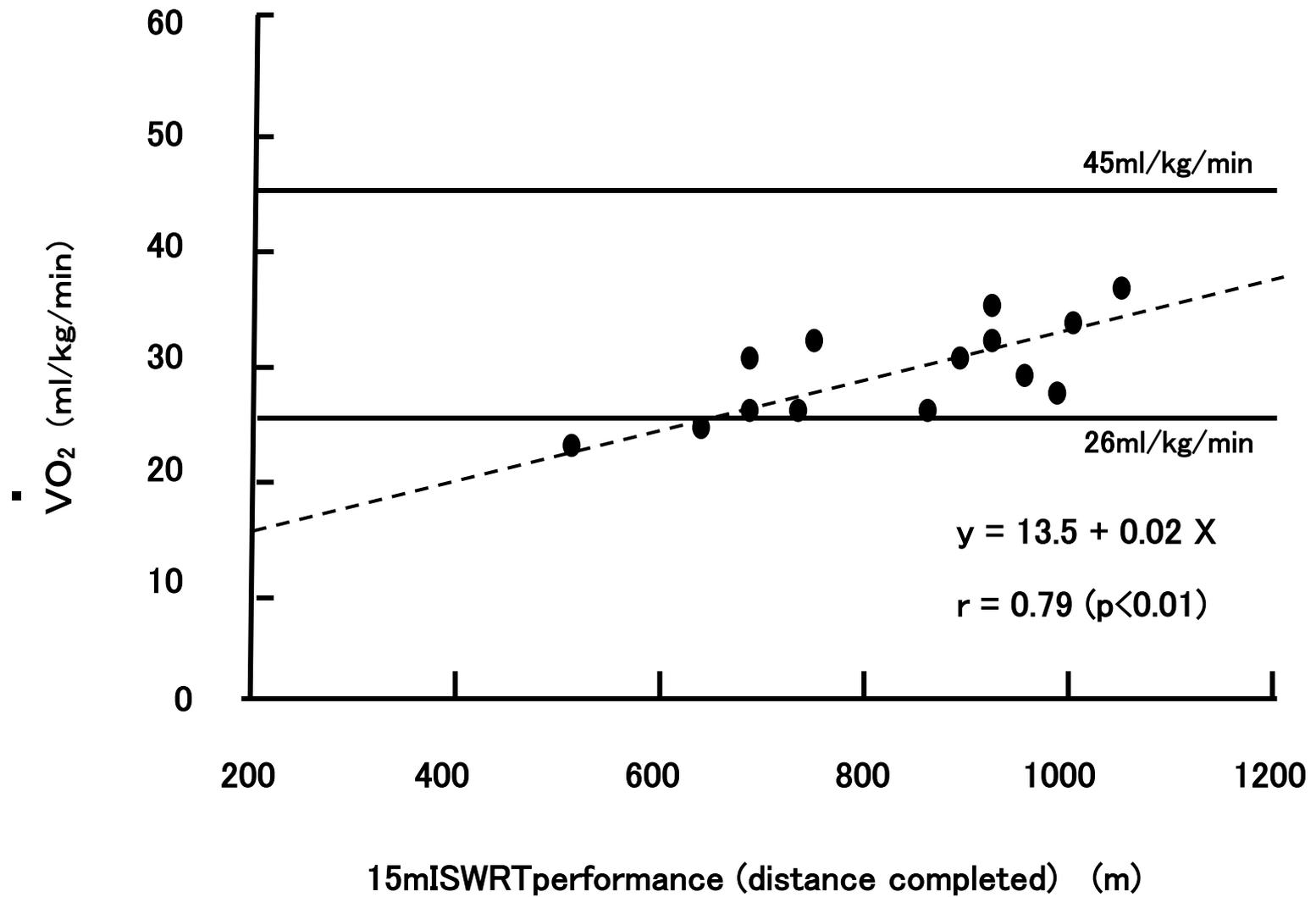CI = confidence interval; d = difference, ICC = intraclass correlation coefficient; SE = standard error.

Figure 1.