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THE VALIDITY OF ALTERNATIVE HAND WALL TOSS TESTS IN KOREAN CHILDREN

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ABSTRACT

Background and objective

The purpose of this study was to identify how the difficulty level of the Alternative Hand Wall Toss (AHWT) test changed according to the distance between the wall and the subject (2.0 or 1.2 m) and to determine the proper distance for 11–12-year-old elementary school students.

Material and methods

Fitness measurement data from participants of "A Study on Development of Fitness Accreditation Standards for National Fitness Award 100 Elementary School Students (aged 11 to 12) in 2018" (total n=2753; 2.0 m, n=1428; 1.2 m, n=1325) were selected. The ratios of numbers, means, and standard deviations of subjects who were unable to measure according to distance were calculated. Difficulty levels of six fitness tests including the AHWT test were calculated by applying the Rasch model of the Item Response Theory (IRT), and AHWT test difficulty levels according to distance, 2.0 and 1.2 m, were compared. All statistical significance levels were set at $p<0.05$.

Results

Our findings were as follows: First, the ratios of subjects who performed 0 point (action) according to distance were 41 and 5.2% at 2.0 and 1.2 m, respectively. Second, there was no difference in the difficulty level among five test items except for the AHWT test; the difficulty level of the AHWT test was higher at 2.0 m than at 1.2 m. Third, there was test partiality based on gender when the distance was set to 2.0 m, but there was no test partiality when the distance was set to 1.2 m.

Conclusion
In conclusion, it is difficult to discriminate the ability of 11–12-year-old subjects if the distance to the wall is set to 2.0 m in the AHWT test because the difficulty level is too high. Therefore, we recommend setting the distance to 1.2 m for 11–12-year-old subjects.

Key Words: *alternative hand wall toss; elementary school students; item response theory; Rasch model*

INTRODUCTION

Coordination is the ability to control movements of muscles via the nervous system and locomotive organs. Eye–hand coordination refers to a sequence in which the brain understands visual information from the eyes and guides hand movements efficiently.[1] The Alternate Hand Wall Toss (AHWT) test is a representative test used in sports medicine to measure eye–hand coordination. In the AHWT, a ball is thrown from one hand in an underarm action against a wall at a distance of 2 m or 3 feet, and an attempt is made to catch the ball with the opposite hand.[2] AHWT has been used in studies involving university students,[3] children,[4] and youth.[5] The characteristics of the previous studies using AHWT were as follows: most were conducted using distances of 2 m, regardless of age, except for a few studies (3 feet in the study by Marcus,[5] and 1 m in the study by Weedon et al.[6]). Thus, the tests measured the same level of difficulty regardless of age.[3,4,7,8]

In general, as age increases, motor ability increases, and then starts decreasing from a certain point of age. Using the identical test tool, the difficulty of the test tool may vary depending on the age of the subject; therefore, age may be an important factor in discriminating the ability of the subject. A pull-up test is usually performed to measure arm muscle endurance.[9] The National Children and Youth Fitness Study I (NCYFS I) reported that 10–30% of boys aged 10–14 and 60% of girls aged 10–18 could not perform any pull-ups.[10] The President's Council on Physical Fitness and Sports National School Population Fitness Survey reported similar results. A total of 40% of boys aged 6–12 could not do more than one pull-up, and 25% could not do any, whereas 70% of girls aged 6–17 could not do more than one, and 55% could not do any.[11] To overcome this problem, a 90° push-up test is included as an alternative to the pull-up test in FitnessGrams for elementary school students and adolescents. This is a representative example of a test tool with difficulty suitable for the characteristics of the subject.[9] Therefore, in order to effectively determine the subject's ability, it is necessary to use tools with normal difficulty suitable for the characteristics of the subject.

Since 2010, the Ministry of Culture, Sports and Tourism has been conducting the "National Fitness Award 100" Project, evaluating levels of physical fitness in adults, seniors, and adolescents, in order to promote health. The "National Fitness Award 100" Project has been recognized as a successful national project because it provides personalized exercise prescriptions and free physical fitness care for each citizen by suggesting a fitness level tailored to various life stages based on gender and age throughout Korea, as well as systematic and objective evaluations. In 2018, the Ministry of Culture, Sports and Tourism conducted a research project to develop physical fitness evaluation standards and guidelines in order to expand the range of subjects from existing adolescents, adults and the elderly to elementary school students aged 11–12 years. The group was divided into distances of 1.2 and 2.0 m to identify the proper distance between the wall and the subject during the AHWT test in 11–12-year-old elementary school students.

The purpose of this study was to investigate how the difficulty of the AHWT test changes depending on the distance (2.0 or 1.2 m) between the wall and the subject, based on the physical strength measurement data of the National Fitness Award 100 Project for elementary school students aged 11–12 years in Korea. This study assessed the validity of AHWT according to distance by using a large sample of measurement data based on a national fitness test, and showed that the AHWT can be used as a test of eye–hand coordination in the field for 11–12-year-old elementary school students.

METHODS

Participants

This study applied physical strength measurement data from 2604 elementary school students aged 11–12 who underwent AHWT testing as part of "A Study on Development of Fitness Accreditation Standards for National Fitness Award 100 Elementary School Students (aged 11 to 12) in 2018." The physical fitness measurements were conducted at 11 elementary schools in seven cities and provinces in the Republic of Korea. After explanation of the project's purpose and goal and obtaining consent, measurements were performed. Descriptive statistics showing the characteristics of the subjects are displayed in Table 1. The study protocol was approved by the ethics committee of the Korea Institute of Sport Science, Seoul, Republic of Korea and the study conformed to the standards set by the latest revision of the Declaration of Helsinki.

Alternate Hand Wall Toss

AHWT is a test that measures coordination, in which a ball is thrown from one hand in an underarm action against the wall at a certain distance from the wall and is attempted to be caught with the opposite hand. The total number of repetitive actions for 30 s is recorded.[2] In this study, distances were set to 2.0 and 1.2 m and which was the basis for division into two groups. First, the ball was thrown with the right hand and caught with the left hand, and then thrown with the left hand and caught with the right hand; this was recorded as a single action.

Data Analyses

We measured the ratios, averages, and standard deviations of the number of subjects who could not be measured based on the distance (2.0 or 1.2 m) from the wall (the number of subjects who performed 0 time). The Rasch model

FIG. 1 Alternate Hand Wall Toss Test Method.

TABLE 1 Descriptive Statistics Showing the Characteristics of the Subjects Selected as Research Data

Gender		Aged	Height (cm)	Weight (kg)	Body mass index (kg/m²)	Waist hip ratio (%)
2.0 m	Male	11 (n=414)	147.62±6.68	45.64±10.04	20.80±3.59	0.87±0.06
		12 (n=338)	155.57±7.74	51.49±10.90	21.16±3.58	0.86±0.06
	Female	11 (n=358)	149.95±6.62	43.72±8.49	19.59±2.91	0.80±0.06
		12 (n=318)	154.66±5.85	48.64±9.02	20.27±3.21	0.78±0.06
1.2 m	Male	11 (n=372)	147.38±7.40	45.62±13.27	20.56±4.62	0.86±0.06
		12 (n=304)	155.61±7.98	52.08±14.36	21.35±4.77	0.86±0.06
	Female	11 (n=326)	148.30±6.26	43.03±10.52	19.26±3.78	0.80±0.06
		12 (n=323)	153.85±6.33	47.98±11.19	20.08±3.92	0.78±0.06

Note: Results are expressed as mean±standard deviation.

of Item Response Theory (IRT) was used to measure the difficulty of the test at distances of 2.0 and 1.2 m. When applying the Rasch model of IRT, it was not possible to estimate the ability of the subject when the number of items (test tools) was one. Therefore, this study calculated the difficulty of six test tools including grip strength, progressive aerobic cardiovascular endurance run, sit-and-reach, standing long jump, side step, and AHWT. Because the values measured using the six test tools are all different from each other, the test tools were equalized. Specifically, six variables were equalized on the same scale through visual binning based on percentiles for each variable by considering five categories determined by the Rasch model's graded response model.[12]

The Rasch model measured the difficulty of each variation with the logit value that is interval-scaled from ordinal scales (very good=5, good=4, average=3, poor=2, very poor=1) that is unable to perform the four fundamental arithmetic operations. It was designed such that a higher logit value was considered indicative of greater difficulty.[13,14] The fit of the test tool was verified using the infit and outfit indexes. These indicate the consistency of the difficulty according to the particular variable and follow the distribution with an expected value of 1.0. When the fit index is closer to the expected value, the analysis data is more appropriate for the model, and a value less than 0.5 or greater than 1.5 suggests that the data are inappropriate.[15]

Unidimensional verification, the basic assumption of the Rasch model, reviewed the Point-Measure Correlation (PMC), and this was assumed by correlations between the five-category index and the total category index (index sum) for each variable. Variables above 0.30 can imply unidimensionality.[16] The verification of the difference in the difficulty calculated by distance was conducted,[17] and the formulas are shown as formulas 1, 2, and 3.

$$< \Delta \hat{b} = \hat{b}_F - \hat{b}_F \quad (1)$$

$$S_{\Delta\hat{b}} = \sqrt{S_{\mathrm{F}}^2 + S_{\mathrm{R}}^2} \quad (2)$$

$$d = \frac{\left(b_{\mathrm{f}}' - b_{\mathrm{r}}\right)}{\mathrm{SE}_{\left(b_{\mathrm{f}}' - b_{\mathrm{r}}\right)}} = \frac{\Delta\hat{b}}{S_{\Delta\hat{b}}} \quad (3)$$

The *d* value calculated using Formula 3 represents significance level under the condition that assumes the *z* distribution. In this study, *d* values over ±1.96 in the 95% confidence interval of the *z* distribution were considered to represent a statistically significant difference.[18] Visual binning for descriptive statistics and equalization were performed using SPSS software (version 25.0, IBM Corp., Armonk, NY, USA). Winsteps software (version 3.65.0, Winsteps, Chicago, IL, USA) was used to calculate the difficulty of the Rasch model. Data are presented as means±standard deviations. All statistical significance levels were set at $p<0.05$.

RESULTS

Table 2 displays the descriptive statistics of the measured values in the AHWT test for 2604 elementary school students aged 11–12 years when the distance between the wall and the subjects was set to 2.0 or 1.2 m. The subjects performed an average of 4.7 repetitions at a distance of 2.0 m, and an average of 13.2 repetitions at a distance of 1.2 m. Skewness indicates how much symmetry in the normal distribution is satisfied. It appeared that the skewness values were asymmetric because they departed from 0 and did not satisfy normal distribution when they were more than ±1.0. The skewness value of Table 2 shows that the normal distribution was not satisfied with more than 1.0 at 2.0 m but was satisfied with less than 1.0 at 1.2 m.

Table 3 shows the ratio of the subjects who performed 0 repetitions when the distance between the wall and subject was set to 2.0 or 1.2 m

TABLE 2 Descriptive Statistics of Alternate Hand Wall Toss Test at a Distance (2.0 or 1.2 m) between the Wall and Subjects

Gender	Age	2.0 m					1.2 m				
		Mean	Standard deviation	Min	Max	Skewness	Mean	Standard deviation	Min	Max	Skewness
Male	11	4.92	6.66	0.00	31.00	1.43	12.97	8.42	0.00	33.00	0.18
	12	3.92	5.74	0.00	29.00	1.73	13.09	8.38	0.00	32.00	0.10
Female	11	4.66	6.35	0.00	25.00	1.41	13.73	8.53	0.00	35.00	0.21
	12	5.09	6.54	0.00	26.00	1.30	13.01	8.86	0.00	36.00	0.22
Total	4.66	6.35	0.00	31.00	1.46	13.19	8.54	0.00	36.00	0.18	

TABLE 3 Ratio of the Subjects Who Performed 0 Time in the Alternate Hand Wall Toss Test at a Distance (2.0 or 1.2 m) between the Wall and Subjects

Gender	Age	2.0 m			1.2 m		
		N	F	Ratio	N	F	Ratio
Male	11	414	165	39.9%	372	22	5.9%
	12	338	148	43.8%	304	15	4.9%
Female	11	358	148	41.3%	326	13	4.0%
	12	318	124	39.0%	323	19	5.9%
Total	1428	585	41.0%	1325	69	5.2%	

N: F = number of subjects who performed 0; N = Number of subjects.

during the AHWT test. We found that 41.0% (585 of 1428) at 2.0 m had 0 repetitions, and 5.0% (69 of 1325) performed 0 repetitions at 1.2 m.

Table 4 shows the results of calculating the difficulty of the test by applying the Rasch model. First, unidimensional verification, the basic assumption of the Rasch model, showed that all PMC values were over 0.3, except for grip strength at 1.2 m, satisfying the unidimensional assumption. Infit and outfit indexes were between 0.5 and 1.5; therefore, the difficulty by variable was consistent. There were no statistically significant differences in logit values of variables, except for the AHWT test groups performed at distances of 2.0 and 1.2 m between the wall and the subject. However, the AHWT test showed a statistically significant difference (d=7.42, p<0.001).

Table 5 shows the results of differences in the difficulty of AHWT test according to distance by gender and age. The results were as follows: males aged 11 years (d=3.01, p=0.003), males aged 12 years (d=7.64, p<0.001), females aged 11 years (d=6.65, p<0.001), and females aged 12 years (d=2.47, p=0.013) showed all statistically significant differences. In all categories, the test difficulty was found to be higher at 2.0 m than at 1.2 m.

TABLE 4 Results of Test Difficulty by Variables and Differences in Difficulty

Test tool	2.0 m					1.2 m					d	p
	Logit	SE	Infit	Outfit	PMC	Logit	SE	Infit	Outfit	PMC		
Grip strength	−0.06	0.02	1.26	1.30	0.30	−0.02	0.02	1.28	1.31	0.29	−1.41	0.157
PACER	−0.04	0.02	1.13	1.14	0.40	−0.02	0.02	1.24	1.27	0.33	−0.71	0.480
Sit-and-reach	−0.05	0.02	1.26	1.31	0.30	0.00	0.02	1.25	1.26	0.34	−1.77	0.077
Standing long jump	−0.05	0.02	0.68	0.67	0.68	−0.01	0.02	0.71	0.69	0.69	−1.41	0.157
Side step	0.01	0.02	0.79	0.79	0.61	0.03	0.02	0.79	0.78	0.63	−0.71	0.480
Sit-ups	−0.03	0.02	0.87	0.85	0.58	−0.01	0.02	0.94	0.92	0.55	−0.71	0.480
AHWT	0.23	0.02	1.02	0.97	0.61	0.02	0.02	0.80	0.79	0.61	7.42	<0.001***

AHWT = Alternate Hand Wall Toss; PACER = Progressive Aerobic Cardiovascular Endurance Run; PMC = point-measure correlation; SE = standard error.
****p<0.001; tested by difference in the difficulty of the Rasch model.*

TABLE 5 Results of the Different in the Difficulty of Alternate Hand Wall Toss Test According to Distance by Gender and Grade

Gender	Age	2.0 m					1.2 m					d	p
		Logit	SE	Infit	Outfit	PMC	Logit	SE	Infit	Outfit	PMC		
Male	11	0.16	0.04	1.04	0.98	0.64	−0.01	0.04	0.88	0.85	0.59	3.01	0.003**
	12	0.52	0.05	0.78	0.78	0.57	−0.02	0.05	0.89	0.89	0.61	7.64	<0.001***
Female	11	0.50	0.05	0.76	0.74	0.55	0.03	0.05	0.77	0.78	0.67	6.65	<0.001***
	12	0.14	0.04	0.99	0.96	0.64	0.00	0.04	0.79	0.77	0.64	2.47	0.013*
Total	0.23	0.02	1.02	0.97	0.61	0.02	0.02	0.80	0.79	0.61	7.42	<0.001***	

PMC = point-measure correlation; SE = standard error.
**p<0.05, **p<0.01, ***p<0.001; tested by difference in the difficulty of the Rasch model.*

TABLE 6 Results of the Different in the Difficulty of Alternate Hand Wall Toss Test According to Gender by Distance and Grade

Distance	Age	Male					Female					d	p
		Logit	SE	Infit	Outfit	PMC	Logit	SE	Infit	Outfit	PMC		
2.0 m	11	0.16	0.04	1.04	0.98	0.64	0.50	0.05	0.76	0.74	0.55	5.31	<0.001***
	12	0.52	0.05	0.78	0.78	0.57	0.14	0.04	0.99	0.96	0.64	5.93	<0.001***
1.2 m	11	−0.01	0.04	0.88	0.85	0.59	0.03	0.05	0.77	0.78	0.67	0.62	0.535
	12	−0.02	0.05	0.89	0.89	0.61	0.00	0.04	0.79	0.77	0.64	0.31	0.757

PMC = point-measure correlation; SE = standard error.
****p<0.001; tested by difference in the difficulty of the Rasch model.*

Table 6 shows the results of assessment of the level of difficulty stratified by distance and age, according to gender. There was a significant difference in the level of difficulty between male and female students who were 11 years old (d=5.31, $p<0.001$) and 12 years old (d=5.93, $p<0.001$) when the distance was set to 2.0 m. However, there was no significant difference in the level of difficulty between male and female students who were 11 years old (d=0.62, p=0.535) and 12 years old (d=0.31, p=0.757) when the distance was set to 1.2 m.

DISCUSSION

The difficulty of test tools is an important factor that effectively determines subject ability. Because difficult or easy test tools are not able to effectively determine subject ability, a number of tests have been modified to fit the characteristics of the subjects.[9] AHWT is a test tool used to measure eye–hand coordination.[2] For most previous studies, AHWT has been conducted at a distance of 2.0 m between the wall and the subject regardless of age, including children, adolescents, and the elderly. However, children, adolescents and the elderly may have difficulty in effectively distinguishing subject ability because of the high difficulty of the test. Therefore, we aimed to determine how the difficulty of the test changes according to the distance between the wall and subject using the physical fitness measurement data of 11–12-year-old elementary school students, and to propose a suitable distance for assessment of these students.

In the AHWT test, when the distances between the wall and the subject were set to 2.0 and 1.2 m, the average performance of the students at a distance of 1.2 m was higher than that of 2.0 m. At a distance of 1.2 m, skewness values were less than 1 in all categories and were close to the normal distribution; however, at a distance of 2.0 m, it was more than 1 and there was an asymmetric distribution shifted to the left. This can be explained by the ratio of the students who performed repetitions at these distances. Nearly half of the students (41.0%) performed 0 repetitions. If the distribution does not satisfy normality, the mean may be overestimated or underestimated, possibly creating an obstacle for norm-referenced evaluation using the mean and standard deviation.

We conducted this study by dividing groups according to distance; therefore, these results can also be interpreted as a result of the characteristics and the fitness levels of the groups. However, in terms of the differences of the difficulty values calculated by applying the Rasch model, there were no statistically significant differences in the difficulty values of the remaining variables, except for the AHWT test. We found neither test bias according to groups, nor differential item function (DIF) mentioned in the measurement evaluation area. Thus, there were no differences in physical fitness between the groups. In contrast, the AHWT test showed a statistically significant difference in difficulty based on distance, suggesting more difficulty among the group who performed the test at 2.0 m than the group performing it at 1.2 m. We also equalized different units of tests to solve the problem of the different test units. The distribution with difficulty near 0 is considered to be the suitable distribution, whereas the distribution of difficulty of the test performed at 2.0 m was regarded as unsuitable, with a large difference from 0 in all categories (gender·age).

Faber et al. [19] confirmed the validity and reliability of four different versions of AHWT test for 6–12-year-old table tennis players using a tennis ball and a table tennis ball, using 1.0 and 2.0-m distances between the wall and the subjects. The 1.0-m group showed better discrimination than did the 2.0-m group, and the table tennis ball test showed the highest reliability when tested at 1.0 m; therefore, the table tennis ball test was set at a distance of 1.0 m. Closer distance to the wall led to more rapid return of the ball, possibly requiring the subject to respond faster. However, based on the results of Faber et al.[19] and the results of this study, closer distance may lead to reduced difficulty in the test; thus, it may be a test used to distinguish younger students.

In the assessment of the level of difficulty stratified by distance and age according to gender, there was a significant difference in the level of test difficulty between male and female students who were 11 and 12 years old when the distance was set to 2.0 m. This indicates that the level of test difficulty based on gender was affected differently when the AHWT test was conducted at a distance of 2.0 m, indicating test partiality in measurement and evaluation portions. However, there was no difference in the level of test difficulty between male and female students who were 11 and 12 years old when the distance was set to 1.2 m, indicating no test partiality.

The limitations of this study were as follows. First, it is difficult to generalize the results of this study to all elementary school students, as the subjects in this study were limited to those who were 11–12-years old. Second, it is difficult to generalize the results to all nations (i.e., all ethnicities), as the subjects in this study were limited to Korean students. Third, there is a risk of over-interpretation that the 1.2-m distance between the wall and the subject is sufficient for all AHWT tests in 11–12-year-old subjects, because only 2.0 and 1.2 m distances between the wall and the subject were used for the AHWT test; thus, future studies should assess additional distances. However, we believe that the large number of subjects (n=2753) represents a considerable strength of this study. In addition, the elementary school students were from all areas of Korea; thus, the findings are highly representative of the Korean elementary school student population.

CONCLUSION

Overall, when performing the AHWT test for elementary school students aged 11–12 years, performing at a distance of 1.2 m from the wall rather than 2.0 m is effective and valid to distinguish subject ability. Importantly, the question of setting a distance to 1.2 m could be a constant subject of argument. It is obviously set in terms of the content validity of physical fitness examiners and field inspectors. Nevertheless, the research data of this study include meta-data from more than 2000 subjects. Validity and reliability are provided simply with the mean and standard deviation of the data; these can be useful as a basis for evaluation of the eye–hand coordination test. It is hoped that future studies will examine the reliability of the AHWT test, set at 1.2 m, through repeated measurement and cross-sectional research.

CONFLICTS OF INTEREST

The authors declare that no conflicts of interest exist.

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