Original article

Alternate hand wall toss test: normative reference value in young adults and its correlation with anthropometric measures — a cross-sectional study

Alternate hand wall toss test: valor de referência normativo em jovens adultos e sua correlação com medidas antropométricas — um estudo transversal

Mohammad Arhaan Naru[1]
Angel Gupta[2]
Nitesh Verma[3]
Geetanjali Kaul[4]
Pooja Mehra[5]

[1,2,4,5]Maharishi Markandeshwar Medical College and Hospital (Solan). Himachal Pradesh, India.
[3]Corresponding contact. Maharishi Markandeshwar Medical College and Hospital (Solan). Himachal Pradesh, India.
research.journal2105@gmail.com

ABSTRACT | INTRODUCTION: The alternate hand wall toss test (AHWTT) is a simple, cost-effective, and portable method to assess eye-hand coordination, kinesthetic awareness, and motor control. **OBJECTIVE:** To establish normative reference values for the AHWTT in young adults aged 18–26 years and evaluate its correlation with anthropometric measures. **METHODS:** A total of 457 participants (232 males, 225 females) aged 18–26 years were recruited through purposive sampling. Anthropometric data — height, weight, BMI, waist and hip circumference, and waist-hip ratio (WHR) — were recorded. Participants stood 2 meters from a wall and completed three 30-second AHWTT trials with one-minute rest intervals. The highest score among the trials was used for analysis. Normality was assessed using the Kolmogorov–Smirnov test. Independent t-tests compared sex-based performance, and Pearson's correlation coefficient assessed relationships between AHWTT scores and anthropometric variables. Intra-rater reliability was evaluated using the intra-class correlation coefficient (ICC). **RESULTS:** The mean AHWTT score was 25.33 ± 3.94, with males (28.40 ± 2.81) outperforming females (22.16 ± 1.89). The 21–23 years old group had the highest performance. AHWTT scores positively correlated moderately with height (r = 0.642) and weight (r = 0.418), weakly with WHR (r = 0.296), and negligibly with BMI (r = 0.087). The test showed excellent intra-class reliability (ICC = 0.957). **CONCLUSION:** This study provides normative AHWTT values for young adults and highlights the influence of sex, age, and height on performance. The AHWTT may serve as a reliable tool for assessing coordination and motor skills in clinical and sports settings.

KEYWORDS: AHWTT. Eye-Hand Coordination. Motor Skills. Normative Values. Visual Perception.

RESUMO | INTRODUÇÃO: O *alternate hand wall toss test* — AHWTT (teste de arremesso contra a parede com mãos alternadas) é um método simples, econômico e portátil para avaliar a coordenação olho-mão, a consciência cinestésica e o controle motor. **OBJETIVO:** Estabelecer valores de referência normativos para o AHWTT em jovens adultos de 18 a 26 anos e avaliar sua correlação com medidas antropométricas. **MÉTODOS:** Um total de 457 participantes (232 homens, 225 mulheres) com idades entre 18 e 26 anos foram recrutados por meio de amostragem intencional. Dados antropométricos — altura, peso, IMC, circunferência da cintura e do quadril e relação cintura-quadril (RCQ) — foram registrados. Os participantes permaneceram a dois metros de uma parede e completaram três testes de AHWTT de 30 segundos com intervalos de descanso de um minuto. A maior pontuação entre os testes foi utilizada para análise. A normalidade foi avaliada pelo teste de Kolmogorov-Smirnov. Testes t independentes compararam o desempenho baseado no sexo, e o coeficiente de correlação de Pearson avaliou as relações entre as pontuações do AHWTT e as variáveis antropométricas. A confiabilidade intra-avaliador foi avaliada pelo coeficiente de correlação intraclasse (CCI). **RESULTADOS:** A pontuação média do AHWTT foi de 25,33 ± 3,94, com os homens (28,40 ± 2,81) superando as mulheres (22,16 ± 1,89). A faixa etária de 21 a 23 anos apresentou o melhor desempenho. As pontuações do AHWTT correlacionaram-se positivamente de forma moderada com a altura (r = 0,642) e o peso (r = 0,418), fracamente com a RCQ (r = 0,296) e de forma insignificante com o IMC (r = 0,087). O teste apresentou excelente confiabilidade intraclasse (CCI = 0,957). **CONCLUSÃO:** Este estudo fornece valores normativos do AHWTT para jovens adultos e destaca a influência do sexo, idade e altura no desempenho. O AHWTT pode servir como uma ferramenta confiável para avaliar a coordenação e as habilidades motoras em ambientes clínicos e esportivos.

PALAVRAS-CHAVE: AHWTT. Coordenação Olho-Mão. Habilidades Motoras. Valores Normativos. Percepção Visual.

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1. Introduction

The alternate hand wall toss test (AHWTT) is a widely recognized field-based assessment used to evaluate kinesthetic awareness and coordination of complex body movements[1]. Due to its simplicity, low cost, portability, and ease of administration, it is a practical and safe option for assessing motor skills across various age groups and settings[2]. The test primarily measures eye-hand coordination (EHC), along with related attributes such as visual concentration, flexibility, agility, and reaction time[3].

EHC is a crucial skill-based component of fitness that enables individuals to perform everyday activities and athletic tasks with precision. It involves the integration of visual input and motor output, requiring both hands and eyes to function in synchrony[4-6]. The act of catching, a central element of AHWTT, demands special and temporal judgement of an object's trajectory, speed and weight[7]. This process is mediated by several sensorimotor systems including vision, vestibular function, proprioception, and cognitive domains like memory and attention[8-10]. It facilitates the execution of complex movements with enhanced precision and fluidity, primarily due to the continuous refinement of neural pathways that foster efficient communication between the brain and muscles, which is crucial for the development of both fine and gross motor skills, essential for the performing variety of daily activities[5,11].

Previous literature has established AHWTT as a valid and reliable tool for the assessment of EHC[12]. Certain studies indicate that males often outperform females in EHC[13,14], and that athletes tend to display higher accuracy compared to non-athletic population[14]. AHWTT performance has also been correlated with EHC, body fat percentage, waist-hip ratio (WHR) and reaction time[12,15,16]. Additionally, a study found lack of correlation of AHWTT between EHC and WHR in football players[16]. Furthermore, there is emerging evidence linking core muscle strength to EHC performance[17,18].

The significance of this test has been well established in previous studies among children and sports such as volleyball[1], archery, shooting, fencing[3], football[12,18], rugby[19], tennis[20], basketball[15] and badminton[21].

Despite its widespread use, limited research exists on establishing normative data for AHWTT performance and its relationship with anthropometric parameters in healthy adults, additionally, existing studies have not sufficiently examined whether these associations vary by sex. Young adults represent a critical period of neuromuscular maturity and peal physical performance. Therefore, the primary aim was to establish reference norms for AHWTT and its correlation with anthropometric measures in adults aged between 18 to 26 years. The secondary aim was to assess the intra-rater reliability of tests within a single session.

2. Method

2.1 Study design and participants

This cross-sectional observational study was conducted in the gymnasium of the Department of Physiotherapy at the Maharishi Markandeshwar Medical College and Hospital from July 2024 to December 2024. A total of 457 participants (232 males and 225 females), aged 18-26 years, were recruited using purposive sampling. Participants enrolment took place on 28th October 2024. The study received approval from Institutional Ethical Committee under number MMMCH/IEC/24/923. The study has been registered under Clinical Trial Registry of India with CTRI No. CTRI/2024/10/075039.

Inclusion criteria comprised healthy young adults aged 18-26 years, with full range of motion of shoulder, elbow, wrist joint, and fingers. Exclusion criteria included history of acute or subacute injuries/trauma/pathologies to the wrist, hand, elbow and shoulder[1,2,13], musculoskeletal conditions affecting upper extremity (ganglion cysts, carpal tunnel syndrome, lateral and medial epicondylitis, rotator cuff injuries), neurological conditions affecting balance and coordination[17], cognitive disorder, visual impairments, cardiorespiratory disorders[18] and individuals with abnormal gait patterns and assistive devices.

Prior to participation, comprehensive information regarding the study procedures, and written informed consent was obtained. The study was conducted in compliance with the principles outlined in the Declaration of Helsinki (2023) and the National Ethical Guidelines for Biomedical Research involving human participation (2017)[22,23]. All methods were performed in accordance with relevant institutional guidelines, regulations, and ethical standards.

2.2 Sample size estimation

Based on an unpublished pilot study involving 50 participants (25 males, 25 females), a sample size calculation was performed using the formula $(Z\alpha\sigma/d)2$, with $Z\alpha = 1.96$, $\sigma = 3.94$, and $d = 0.36$ which indicated a sample size of 457. Data from the pilot study were excluded and did not contribute to the final study sample.

2.3 Instrumentation and procedure

Upon inclusion, demographic and anthropometric measures of participants were taken by the primary researcher at baseline. Body weight was measured on a digital weighing machine and height was recorded using a stadiometer. Body mass index (BMI) was subsequently calculated. Waist circumference (WC) was measured at the narrowest point between the 10th rib and tip of the iliac crest, with arms abducted at 70°-80°. Hip circumference (HC) was measured at the widest part of the buttocks with arms crossed over chest. The waist-hip ratio was calculated by dividing the WC by the HC[16]. Participants were asked to wear comfortable clothing and footwear during the assessment. The test was conducted between 9:00 am to 11:00 am to eliminate variability due to time-of day effects and performance related bias.

2.4 Alternate hand wall toss test (AHWTT)

Prior to the testing participants were briefed about the procedure, and the examiner demonstrated the test. A 5-minute standardized warm-up was administered comprising of jogging (2-minutes), dynamic stretches for upper and lower limbs, lateral spinal flexion and clockwise and anticlockwise arm circles.

To commence the test, a 5cm wide line was marked on the floor at a 2-meter distance from the wall. Participants were instructed to face the wall and position themselves behind the marked line and toss a 60-gm tennis ball on the wall in an underarm action with either dominant or non-dominant hand and catch it with opposite hand for duration of 30 seconds. A total of 3 test trials were conducted with 1-minute of active rest in between. All three trials were documented to evaluate intra-rater reliability and best of three trials were selected for final analysis. Prior to testing each participant was allowed two practice trials. The highest number of successful catches within this time period were recorded using a digital stopwatch. In the event of a missed catch, the test was restarted. Scores were categorized as poor (<15 catches), fair (15-19 catches), average (20-28), good (30-35 catches), excellent (>35 catches)[4,6,16,21]. Throughout the study, confidentiality and privacy of all participants was ensured.

2.5 Statistical analysis

Analysis was carried out using IBM SPSS software (version 20, SPSS Inc., Chicago, IL). The distribution of outcome variables was assessed for normality using Kolmogorov-Smirnov test as well as visual inspection through P-P plots, Q-Q plots and histograms. Data were found to be normally distributed ($p \geq 0.05$). Descriptive statistics were reported as mean ± standard deviation (SD). Group comparison based on sex and age, were evaluated using independent sample t-test, with significance set at $p \leq 0.05$. To verify correlation between the variables, Pearson correlation coefficient (r) was used, where 0.00-0.10; 0.10-0.39; 0.40-0.69; 0.70-0.89 and 0.90-1 represent negligible, weak, moderate, strong and very strong correlation between the variables respectively[24]. Intra-rater reliability of AHWTT was assessed using Shrout and Fleiss' criteria, which are interpreted as follows: < 0.5; 0.5-0.75; 0.75-0.9 and > 0.9 indicates poor, moderate, good and excellent reliability respectively[25]. No missing data was observed during the study.

3. Results

3.1 Demographic

The demographic characteristics of the participants are summarized as follows: the age was 21.30±2.51(18-26 years), height was 166.87± 9.74 (152-186 cm), weight was 64.35±14.88 (49.83-106.64 kg), BMI was 23.06±4.73 (16.65-34.04 kg/m2) and WHR was 0.78±0.10 (0.72-0.92). Based on sex, descriptives of the study were shown in table 1 in form of mean ± SD, 95% confidence interval (CI) and range.

Table 1. Demographic characteristics of participants

	Male (*n* = 232)			Female (*n* = 225)		
Outcome variables	**Mean ± SD**	**95% CI**	**Range**	**Mean ± SD**	**95% CI**	**Range**
Age (years)	21.7 ± 2.6	21.1, 22.4	18-26	20.8 ± 2.3	20.2, 21.4	18-26
Height (cm)	174.3 ± 6.2	172.7, 175.9	152-186	159.1 ± 5.8	157.5, 160.6	152-176
Weight (Kg)	71.1 ± 14.5	67.3, 74.7	49.8-106.6	57.4± 11.7	54.3, 60.4	35.5-82
BMI (Kg/cm2)	23.3 ± 4.3	22.2, 24.4	16.6-34.1	22.7 ± 5.1	21.4, 24.1	14.2-34.2
WC (cm)	80.4 ± 10.2	77.8, 83.0	63-105	71.9 ± 13.5	68.4, 75.5	35.5-99
HC (cm)	97.1 ± 10.5	94.3, 99.7	78-125	97.1 ± 9.1	94.7, 99.4	77-120
WHR (cm)	0.8 ± 0.1	0.8, 0.8	0.7-0.9	0.7 ± 0.1	0.7, 0.7	0.3-0.8

Source: the authors (2024).
Abbreviations: CI - confidence interval, SD - standard deviation, cm - centimeters, Kg - kilograms, BMI - body mass index, WC - waist circumference, HC - hip circumference, WHR - waist-hip ratio.

3.2 Normative value of AHWTT

The overall mean, SD, 95% CI and range of participants are 25.33±3.94; 24.62,26.05 (19-34). For male and female, the values were 28.40±2.81; 27.68,29.12 (21-34) and 22.16±1.89; 21.67,22.65 (19-27) respectively. Age and sex-specific reference norms were presented in table 2.

Table 2. Analysis between groups based on age and sex

Age range	No. of participants	Mean ± SD	95% CI	Range	*t*-value	*p*-value
18-20	Overall (n=140)	24.4± 3.3	23.5, 25.2	19-31	12.5	<0.001
	Male (n=65)	27.3 ± 2.6	26.2, 28.4	23-31		
	Female (n=75)	22.2 ± 1.7	21.6, 22.8	19-27		
21-23	Overall (n=167)	26.8 ± 3.8	25.4, 28.2	19-34	10.9	0.36
	Male (n=87)	29.8 ± 1.9	28.8, 30.7	27-34		
	Female (n=80)	23.2 ± 2.1	21.9, 24.4	19-26		
24-26	Overall (n=150)	25.6 ± 4.6	23.8, 27.5	20-32	9.4	0.09
	Male (n=80)	28.5 ± 3.1	26.9, 30.1	21-32		
	Female (n=70)	20.5 ± 0.8	19.9, 21.1	20-22		

Source: the authors (2024).
Abbreviations: CI - confidence interval, SD - standard deviation.

3.3 Correlation of AHWTT with anthropometric measures

Correlation analysis revealed that AHWTT had a moderate correlation with height and weight, weak correlation with WC and WHR and negligible correlation with BMI as shown in table 3.

Gender-based analysis, as shown in table 4, reflects that male exhibited a weak correlation with weight, BMI, HC and WC, while it had a negligible relation with height and WHR. On the other hand, females demonstrated a positive but negligible relation with HC and negative correlation with all other anthropometric measures.

Age group analysis showed that participants aged 18–20, displayed a moderate correlation with height and weak correlation with other anthropometrics. On the contrary, in participants aged 21–23, it showed strong relation with height and weak with weight and WHR. Additionally, in participants aged 23–26, it showed strong correlation with height, moderate with weight, WC and WHR and weak with BMI and HC as shown in table 5.

Table 3. AHWTT correlation with anthropometric measures

Outcome variables	Pearson correlation (*r*)	*p*-value
AHWTT & Height	0.642	<0.001
AHWTT & Weight	0.418	<0.001
AHWTT & BMI	0.087	0.345
AHWTT & HC	0.063	0.497
AHWTT & WC	0.277	0.002
AHWTT & WHR	0.296	0.001

Source: the authors (2024).
Abbreviations: AHWTT - alternate hand wall toss test, BMI - body mass index, WC - waist circumference, HC - hip circumference, WHR - waist-hip ratio.

Table 4. AHWTT correlation based on sex

Outcome variables	Male		Female	
	Pearson coefficient (*r*)	*p*-value	Pearson coefficient (*r*)	*p*-value
AHWTT & Height	0.093	0.477	-0.025	0.848
AHWTT & Weight	0.151	0.247	-0.004	0.976
AHWTT & BMI	0.124	0.339	-0.010	0.993
AHWTT & HC	0.122	0.35	0.083	0.530
AHWTT & WC	0.11	0.398	-0.085	0.521
AHWTT & WHR	0.007	0.959	-0.135	0.307

Source: the authors (2024).
Abbreviations: AHWTT - alternate hand wall toss test, BMI - body mass index, WC - waist circumference, HC - hip circumference, WHR - waist-hip ratio.

Table 5. AHWTT correlation based on age group

Outcome variables	Age group	Pearson coefficient (*r*)	*p*-value
AHWTT & Height	18-20	0.578	<0.001
	21-23	0.764	<0.001
	24-26	0.762	<0.001
AHWTT & Weight	18-20	0.368	0.004
	21-23	0.186	0.316
	24-26	0.642	<0.001
AHWTT & BMI	18-20	0.107	0.410
	21-23	-0.334	0.66
	24-26	0.226	0.247
AHWTT & HC	18-20	0.108	0.407
	21-23	-0.275	0.135
	24-26	0.117	0.554
AHWTT & WC	18-20	0.218	0.92
	21-23	-0.022	0.906
	24-26	0.509	0.006
AHWTT & WHR	18-20	0.186	0.151
	21-23	0.168	0.367
	24-26	0.505	0.006

Source: the authors (2024).
Abbreviations: AHWTT - alternate hand wall toss test, BMI - body mass index, WC - waist circumference, HC - hip circumference, WHR - waist-hip ratio.

3.4 Intra-rater reliability

Reliability was examined between tests to determine its consistency of all three trials in single session. A 2-way random effect intraclass correlation coefficient (ICC) model with absolute agreement was used and test values were determined as α =0.957 and 95% CI (0.81,0.95) suggesting that the test is highly reliable and consistent as per Shrout and Fleiss criteria[25].

4. Discussion

In this one-time study, all 457 participants completed the study without withdrawal. Our study is first to establish reference norms for AHWTT in young adults aged between 18 to 26 and explore its correlation with anthropometric measures, thereby contributing to both clinical practice and research endeavors. Normative value helps to identify the performance of the participants and compare the individual's performance to a peer population group of similar age and gender, identifying the clinical significance and developmental needs according to same. The results demonstrated that there was statistical and clinically significant difference in male and female individuals. Males consistently demonstrated superior catching efficiency compared to females across all age groups with the 21-23 year demonstrating the highest efficiency, followed by the 24-26 year and 18-20 year groups. Among males, catching efficiency was highest in the 21 to 23 and least in 24 to 26 years. In contrast, females demonstrated the highest and least catching efficiency in the 18-20 and 24-26 age groups respectively.

This disparity is probably explained by the fact that males are more likely than women to be exposed to and encouraged to participate in sports throughout their formative years, which offers numerous chances to improve coordination, response time, and visuomotor integration. Because of the demands of systematic training and practice, sports groups are known to exhibit higher levels of catching efficiency as compared to non-athletic cohorts[19].

4.1 Normative ranges for AHWTT

The mean values of test for participants aged 18-26 year in the present study is 25.33±3.94. In comparison, Millard et al., reported values of 29.70±3.50 for athletic and 19.55±4.48 for non-athletic population aged 19-35 years[19]. Also, the current study showed that values for male and female participants were 28.40±2.81 and 22.16±1.89, respectively. Conversely, Rajani et al. reported mean score 20.92±3.06 for males and 19.88±3.35 for female badminton players aged between 18-30[18]. Another study evaluating EHC on students ranged from 20-44 years and their results reflects the mean values of 30.42±6.39 in males and 21.04±8.37 in females[2].

4.2 Correlation of AHWTT with anthropometric measures

Correlation analysis revealed a strong correlation with height (r=0.642), medium with weight (r=0.418), weak with WHR (r=0.296) and very weak with BMI (r=0.087) in young adults. Our findings are consistent with those of Mong et al., who reported no significant correlation between eye-hand coordination and BMI, waist-hip circumference, or body fat percentage among professional football players, suggesting that adiposity indices are poor predictors of coordination. In contrast, some reports have suggested that body dimensions, particularly waist–hip ratio and body fat percentage, may contribute to variations in coordination performance[12,15]. However, our results demonstrated only weak associations with these measures, indicating that such relationships may be context-dependent, varying by sport, population, or level of physical activity. In contrast, studies on football players reported no significant correlation was reported between EHC and BMI, waist-hip circumference (WHC) and body fat percentage[12,16].

Hence, the findings of the current study imply that catching efficiency of all participants varied from average to good in every age group. The absence of excellent catching efficiency among participants is likely attributable to their non-professional status. Males exhibited superior catching efficiency which is aligned to a study conducted on children reporting that EHC improves with age, from childhood to adolescence[26]. Interestingly, out of all anthropometric measures, height and weight shows strong correlation in 21-26 years age group.

The present study demonstrated excellent intra-rater reliability of AHWTT, with an ICC of 0.957, indicating high consistency across repeated trials within a single session. According to Shrout and Fleiss criteria[25], values above 0.90 reflect excellent reliability, suggesting that the AHWTT can be administered with minimal measurement error when repeated by the same examiner. These findings are in agreement with previous reports that have validated AHWTT as a stable and reproducible tool for assessing eye–hand coordination and related motor skills[4,25]. The excellent reliability observed strengthens the clinical and research utility of AHWTT, making it a dependable tool for longitudinal assessments, monitoring changes following interventions, and establishing normative data in diverse populations.

4.3 Clinical implications

This test can serve as an evaluative tool in clinical settings for both the sexes to identify coordination deficit, assess visual perception and enhance motor skills. It can help in tailoring rehabilitation protocol for upper limb injuries and standardize the assessment across different populations and settings. Furthermore, it can be incorporated into therapeutic interventions designed to restore and improve EHC, fine motor control and enhance reaction time which can substantially impact their academic performance, overall well-being, and participation in physical activities.

4.4 Strengths and limitations

The strength of the study is the standardized test distance across sex, minimizing any potential

variable bias that could affect the outcomes based on gender differences. Reference norms have been established for each age group in this study. While this study offers valuable insights, certain limitations should be acknowledged. First, geographical area of the participants is homogenous which may limit generalizability. Second, reaction time and agility were not assessed, which could potentially have an impact on the overall performance, as they play a crucial role in physical performance and functionality. Other potential confounders include base of support, hand size, and lateral reach of the participants which may influence the test.

5. Conclusion

In this study we established the normative values of AHWTT in young males and females. Participants with age range of 21-23 have a greater catching efficiency than other age groups. The findings showed that height was strongly correlated and BMI was least correlated with AHWTT.

Authors' contributions

The authors declared that they have made substantial contributions to the work in terms of the conception or design of the research; the acquisition, analysis or interpretation of data for the work; and the writing or critical review for relevant intellectual content. All authors approved the final version to be published and agreed to take public responsibility for all aspects of the study.

Competing interests

No financial, legal, or political conflicts involving third parties (government, private companies, and foundations, etc.) were declared for any aspect of the submitted work (including but not limited to grants and funding, advisory board participation, study design, manuscript preparation, statistical analysis, etc.).

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