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## Original Article

# Population based norms for the box and blocks test in healthy right-handed Taiwanese adults



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## ABSTRACT

**Background:** This study establishes norms for the Box and Block Test (BBT) in healthy Taiwanese adults between 15 and 75 years of age.

**Methods:** 621 right-handed healthy adults (296 males and 325 females) completed the study. All participants performed the BBT following the standard protocol. An age by gender by testing hand analysis of variance (ANOVA) was performed to determine differences for the variables of interest.

**Results:** On average, females performed better on the BBT than males by approximately 2 points ( $p < 0.001$ ). Across all participants, dominant hand performance was 2.8 points higher than non-dominant hand performance ( $p < 0.001$ ). Significant changes of BBT scores across life span were observed at the ages of 30, 45 and 60 years old. Average scores across all age groups are at least one standard deviation below the previously established American norms for each corresponding age group.

**Conclusion:** When using the BBT test with adult Taiwanese clients, clinical practitioners should strongly consider using right-handed normative data from Taiwanese individuals as the norms for this population differ from the previously established norms from American adult participants.

Manual dexterity is defined as the ability to use the hands and fingers to perform accurate and delicate movements [1]. It relies on the integration of sensory and motor function and

requires intact range of motion, muscle strength and sensation to allow for object manipulation [2]. Impaired manual dexterity is a common clinical problem for individuals with

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**At a glance of commentary****Scientific background on the subject**

Accurate assessment of manual dexterity is crucial for evidence-based practice and norm-referenced assessments. The purpose of this article is to establish norms for the Box and Block Test in healthy Taiwanese adults between 15–75 years of age.

**What this study adds to the field**

It is important to consider the ethnicity of the individual being assessed during use of the Box and Block Test. When clinical practitioners use the BBT with Taiwanese clients for assessing manual dexterity, the Taiwanese adult norms should be referenced instead of the American norms.

various diagnoses [3] and can affect the performance of activities of daily living (ADL) as well as instrumented activities of daily living (IADL). Williams et al. (1982) showed that manual dexterity is a significant predictor for ADLs in elderly females. In order to address these deficits with clients, clinicians must rely on assessment tools that can accurately address manual dexterity.

Norm-referenced assessment of manual dexterity are important for clinical evaluation before implementing treatments [3]. Of the many dexterity tests, the Box and Block Test (BBT) is one of the most widely used dexterity assessments to evaluate the function of unilateral gross manual dexterity in clinical practice [4]. The development of the assessment was originally proposed by Anna Jean Ayres and Patricia Holser Buehler for individuals with cerebral palsy [3]. In 1957, Buehler and Fuchs refined and copyrighted the test to the current form. The BBT measures an individual's ability to transit blocks from one compartment of a box to the other compartment. It is a timed test, lasting one minute per assessed arm and both limbs are typically tested. The strengths of the BBT include the durability of the tool, the ease in which the test can be administered to individuals with various diagnosis and strong psychometric values. Validity and reliability have been well established for the BBT, and high inter-rater reliability and great construct validity have been previously shown [3–5].

Recently, antidotal evidence was provided from Taiwanese occupational therapists (OTs) that suggested the BBT scores from healthy adults in Taiwan were constantly below the American norms by as much as 2 standard deviations. At the same time, entry-level OT students questioned the lack of normative data for Taiwanese individuals as the everyday occupations of Americans and Taiwanese differ. Students practiced administering the BBT and found that their performances were below the established American norms and the gap was not improved even after several practice attempts. As this phenomenon was being repeatedly observed by multiple Taiwanese OTs, it was clear that a systematic comparison of the population norms was needed [6].

The American norms were established in 1985 by Mathiowetz et al. on participants in the midwest region of the United

States with an age range of 20–80 years [3]. For the past 30 + years, these norms have been widely applied in both the research and clinical settings for assessing manual dexterity function. Currently, no Taiwanese or Asian norms for the BBT have been reported. If the previously defined norms are not appropriate for Taiwanese, it is critical to establish Taiwanese or Asian population norms as a reference for clinical evaluation. Accurate assessment of manual dexterity is crucial for evidence-based practice and norm-referenced assessments, such as the BBT, are necessary for reducing measurement error and improving clinical decision making. The purpose of this study was to establish right-handed Taiwanese population norms for the BBT. We hypothesized that the performance from right-handed Taiwanese population was below the American norms.

**Methods****Participants**

621 participants were recruited for the study (age range: 15–75 years; 296 males and 325 females). The sample included Taiwanese individuals with diverse occupations who were recruited in various communities from geographically dispersed across Taiwan by convenience sampling. Only three left handed individuals volunteered for the study. Because the majority of Taiwanese are right-handed and the performance of gross manual dexterity may exhibit different patterns between right- and left-handed participants, data from the three left-handed

**Table 1** Box and Block Test scores for healthy Taiwanese adults across age groups. Scores are mean (SD).

Age group	Gender	N	Right hand	Left hand
15–19	Male	20	77.40 (4.95)	73.65 (6.59)
	Female	21	76.86 (3.76)	75.43 (4.63)
20–24	Male	35	76.20 (7.76)	72.06 (6.90)
	Female	34	77.03 (8.28)	73.62 (6.55)
25–29	Male	29	75.41 (6.24)	73.34 (5.01)
	Female	20	78.00 (6.84)	73.60 (9.32)
30–34	Male	24	73.17 (7.04)	71.92 (7.23)
	Female	23	77.30 (6.12)	74.13 (7.75)
35–39	Male	20	72.35 (5.70)	69.60 (5.48)
	Female	23	75.26 (8.18)	71.83 (6.34)
40–44	Male	22	72.41 (6.37)	70.32 (6.94)
	Female	21	70.52 (7.65)	70.19 (5.81)
45–49	Male	20	70.70 (7.96)	68.65 (8.25)
	Female	22	71.27 (9.33)	68.55 (8.85)
50–54	Male	20	70.10 (9.73)	66.35 (8.85)
	Female	20	72.35 (7.64)	70.00 (7.38)
55–59	Male	24	70.5 (7.72)	67.29 (6.27)
	Female	35	72.03 (6.93)	70.11 (6.40)
60–64	Male	33	67.42 (6.50)	64.42 (6.95)
	Female	35	71.20 (6.05)	67.34 (4.77)
65–69	Male	23	64.91 (8.83)	62.35 (8.74)
	Female	36	69.72 (4.84)	67.58 (4.64)
70–74	Male	26	63.27 (6.60)	60.69 (5.63)
	Female	35	69.00 (6.10)	65.40 (6.30)

participants were excluded and only data from right-handed individuals was further analyzed. All participants were right-handed as defined by the Edinburgh Handedness Inventory [7], and able to follow the verbal instructions to complete the test. Exclusion criteria included any known neurological disease (ex: stroke), acute pain in the testing arm or past severe arm injuries, which might interfere with gross manual dexterity in the testing arm. All participants provided informed and written consent as approved by the Institutional Review Board of Chang Gung Memorial Hospital. Detailed demographics data are provided in [Table 1](#).

### Test administration procedure

Before testing, all participants underwent a brief interview to ensure they met the inclusion criteria. Test procedures followed those established by Mathiowetz et al. (1985). Participants were seated in a standard stationary chair facing the testing table. The BBT testing box (L: 25.4 cm x W: 53.7 cm x H: 8.5 cm) was placed lengthwise and close the edge of the table (table size: at least L: 90 cm x W: 150 cm x H: 100 cm) in front of the participant. The testing box is partitioned at the center into two compartments by 18.7 cm high divider. Participants were instructed to sit comfortably, with their hands on the sides of the box. 150 cubes measuring 2.5 cm on each side were placed in the box into the compartment that corresponded to the hand that would be tested. To administer the test, the experimenter sat facing the participant on the other side of the testing table. Before beginning the first test, the experimenter read the standardized verbal instructions to the participant and asked if they had any questions. The instructions provided to the participant stated that they were required to grasp one cube at a time with the identified testing hand, and transport it over the partition to the other side of the box as fast as possible. They were instructed to contact the individual blocks using only their fingertips and the fingertips should cross the partition during the transportation of each block. If two or more cubes were picked up at a time, the experimenter only counted one. As long as the fingertips crossed the partition, the cube was counted even if it came to rest on the floor or on the table. The experimenter then demonstrated the standard procedures and transported three cubes over partition to the other compartment in the same direction as the participant was expected to perform the task. A 15 s practice session was provided to ensure that the task was fully understood. If participants made mistakes during the practice session, the experimenter would give the correct instructions again before the actual test. Once the task was clearly understood, individuals were given the verbal cues of ready and begin to start each trial. Each trial lasted for 60 s and timing was done by the experimenter using a stopwatch. All participants were tested once with the dominant hand first and repeated the same procedure with the non-dominant arm. At the conclusion of each trial, the experimenter counted the total number of cubes successfully transported in one minute and the count was recorded as the score.

### Data analysis

IBM SPSS Statistics for Windows, version 22.0 was used to perform the statistical analysis. An age (12 age groups) by gender (male vs. female) by testing hand (dominant vs non-dominant hand) analysis of variance was performed to determine differences for the variables of interest. We divided participants into 12 age groups by a 5-year interval as established American norms. Given the age range was between 15 and 74 years; therefore, the 12 age groups were 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69 and 70–74 years. Post hoc analyses using Bonferroni correction were performed when justified. The alpha level was set at  $p < 0.05$ .

### Results

Descriptive statistics for each gender, testing hand and age group are presented in [Table 1](#). Significant main effects were present for gender, testing hand and age (all  $p < 0.001$ ). Post hoc analysis showed females had significantly higher BBT scores than males by an average of 2 points. Dominant (right) hand BBT scores were significantly greater than non-dominant (left) hand scores by 2.8 points (R:72.16 vs. L:69.37).

For the main effect of age, the post-hoc, Bonferroni corrected analysis revealed significant changes in BBT scores across the predefined age groups. Individuals in age groups under 30 years of age (3 groups) performed significantly better than participants in age groups above 45 years of age (6 groups) (all  $p < 0.001$ ). For participants in the 30–40 year old age groups (2 groups), BBT scores were significantly higher than that of participants in age groups greater than 60 years old (3 groups) (all  $p < 0.05$ ). Results are presented in [Fig. 1](#) and [Fig. 2](#).

A comparison of the current findings to the American norms established by Mathiowetz in 1985 shows that the average BBT scores for Taiwanese right-handed adults were lower than the American right-handed norms by 5 points in both hands for right-handed participants regardless of age groups.

### Discussion

Given the clinical focus on hand related interventions by OTs, the development of standardized norm referenced assessment tools for manual dexterity is crucial. Accurate and timely initial assessment is a necessity for the screening and identification of possible manual dexterity deficits in the clinical populations we treat. The Box and Block test is a well-established tool that meets the needs of clinical OTs, but the referenced normative values must accurately address the demographics of the populations using the assessment. Our results provide the Taiwanese adult norms for the BBT in healthy adults between 15 and 75 years of age. Similar to previous studies, we found that female participants had significantly greater manual dexterity scores than males and participants scored significantly higher average scores with their dominant hand as compared to their non-dominant

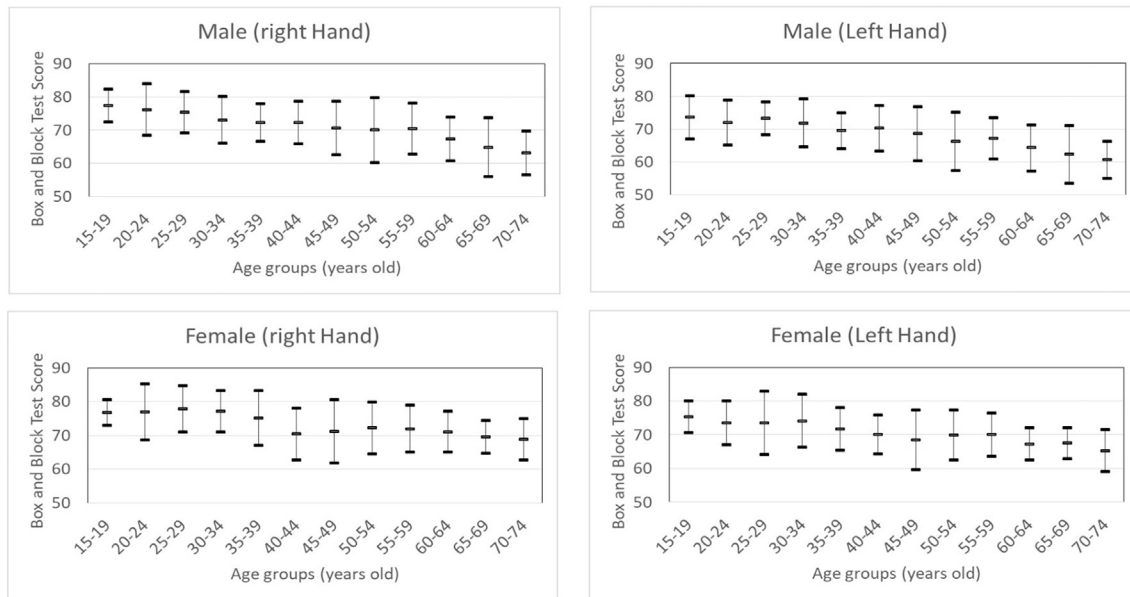


Fig. 1 Box and Block Test scores of healthy right-handed Taiwanese adults for each age group.

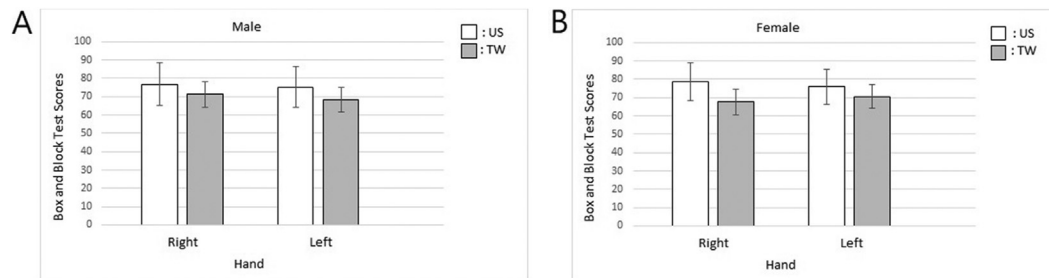


Fig. 2 A comparison of the average BBT scores for Taiwanese right-handed adults to the American right-handed norms regardless of age groups. (Note: TW, Taiwanese; US, American).

hand. Additionally, manual dexterity degenerated as age of the participant increased especially after the age of 40 years. In contrast to the original report, the average performance of Taiwanese participants across all age groups was at significantly lower than the corresponding normative data for American participants. The current findings indicated that there is a discrepancy between the previously established American norms and the Taiwanese norms presented here.

Our sample included only right-handed Taiwanese individuals. In Taiwan, the cultural preference is for children to be raised as dominant right-handed individuals. This means that from a time early in life parents are promoting right-handed performance of activities of daily living and instrumental activities of daily living by placing tools in the right hand including writing/coloring/drawing implements, toys and games. This has likely resulted in individuals who are incompletely right-handed, but who have completed tasks with their right hand for their entire life. Confounding physiological considerations such as eye dominance may play a role in the performance of motor tasks. Only three of the 624 totally individuals who volunteered for the study identified as

left-handed, which supports the assertion of a very low number of Taiwanese identifying as left-handed. This is vastly different from the 7% of individuals who identified as left-handed in the original BBT norms citation [3]. This difference between cultures also illustrates the need for normative data to be established for the Taiwanese population.

One possible explanation for the discrepancy between the American and Taiwanese norms could be hand grip strength. A previous study demonstrated that hand grip strength was a significant predictor for hand dexterity [8] while a different study found that Taiwanese mean grip strength values were significantly lower than the norms for Caucasians [9]. Additionally, Wu et al., (2009) proposed that palm length was one of the significant predictor for grip strength, other than age and gender, and anthropometric based inference indicates that Taiwanese individuals have shorter palm lengths based on their shorter average standing height, as compared to Americans. Based on these two factors, it stands to reason that BBT performance differs between Taiwanese and American healthy adults. However, the difference between Taiwanese and American healthy adults decreased as age

increased. We postulate that the slowing of the motor system associated with aging is a possible explanation for this finding.

While the overall norms were different between the original work and the findings presented herein, the trends within our data match those of previous studies. Females showed greater performance in dexterity task than males which is consistent with previous findings [10–12]. One potential causative mechanism for this finding may be related to body scale which is the ratio between the size of the finger and the size of testing tools. A previous study reported that women performed significantly better than men on the Purdue Pegboard test [13]. However, the gender difference did not persist after the authors used the thickness of the index finger and thumb as a covariate. Similar results were also found by Peters and Campagnaro (1996). When they accounted for the finger size of participants, the gender difference in manual dexterity were no longer present [14]. Furthermore, they indicated that males and females were skilled in different types of dexterity tasks. Given these findings, it is not valid to claim that females are more dexterous than males, only that females score higher on the BBT test than their male counterparts.

In agreement with previous research, participants scored better on the BBT with their dominant hand than their non-dominant hand. This finding is likely due to the increased speed at which the dominant hand is controlled [10,11,15]. Interesting, right-handed individuals have been noted to have more prominent functional asymmetry than left-handers [16,17]. Future studies should investigate the relationship between hand dominance and BBT scores as this could affect the accuracy of clinical assessment. Considering our participants were all right-handed, the current findings supported the hypothesis that right-handers were asymmetrical in performing the dexterity task but we cannot address the potential asymmetry difference between right and left hand dominant individuals.

Also similar with many previous studies, the age group analysis indicates that dexterity declines with age [10–12]. We found that across our grouped age brackets, declines in BBT scores were seen starting at age 30 and continuing across the age continuum. While this study does not address the causes of this decline, previous studies have indicated that age related changes to manual dexterity performance may be related to loss of muscle strength [18–20], decreased proprioception and tactile sensitivity and slower motor performance [21–23]. Recently the Automated Box and Blocks Test (ABBT) has been developed and validated to be a reliable objective tool for clinical rehabilitation [24]. Combining the Kinect sensor and analysis algorithm, the system can provide the automatic outcomes including the total score, the cubes' displacement, average velocity and the time [25]. More in-depth analysis of the BBT performance which is possible using the automated testing methodology, may elucidate the impact of aging on coordination and dexterity.

### Limitations

There were several limitations to our study. First, the sample size and the distribution of gender was uneven for each age

group. However, the total sample size and the distribution of gender were similar with the American norms established by Mathiowetz in 1985. Second, we only recruited right-handed healthy individuals and the potential application on individuals with left-handed should be further explored. Third, we did not collect any anthropometric data, such as grip strength or palm length to normalize the results. Therefore, we were unable to fully explore the potential impact of anthropometrics (the size of the finger and the size of testing tools) on the BBT performance. Finally, the current study only recruited healthy Taiwanese adults as participants whether the results represent all Asians remains unknown. Future research should examine the BBT scores from other Asian countries to better understand the extent to which the current findings are representative of the larger population.

### Conclusion

This study collected the BBT scores from healthy right-handed individuals between the ages of 15 and 75 years. These data established the adult Taiwanese BBT norms. The current findings indicated lower performance than American BBT scores across all age groups, thus indicated that the previously established BBT norms may not be a good fit for the Taiwanese population. Comparatively higher BBT scores were generated by female participants, individuals performing the test with their dominant hand and younger adults. When clinical practitioners use the BBT with Taiwanese adults, comparison to the Taiwanese norms will provide a more accurate assessment of gross manual dexterity than comparison to the American norms.

### Conflicts of Interest

The authors report no conflicts of interest.

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