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ORIGINAL ARTICLE

Iranian Normative Data for the Trail-Making Test Stratified by Age, Gender, and Education

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Abstract

Purpose: Executive functions and attention are often impaired in neurological, medical, and psychiatric disorders. This study aimed to, in addition to collecting Iranian normative data, examine whether the demographic variables are associated with performance in one of the most widely used neuropsychological tools to measure cognitive status.

Materials and Methods: The present study as part of the Iranian Brain Imaging Database (IBID) was implemented on three hundred medically and cognitively healthy people aged 20 to 70. Each decade consisted of 60 participants and the gender proportion was equal in each decade. Five decades of age (20 to 70 years old) and scores obtained in the Trail Making Test (TMT; defined in terms of two scores of the completion time of its two parts A and B) were the independent and dependent variables, respectively.

Results: According to correlation coefficients, age and education had a significant negative and positive association with both parts A and B ($p=0.01$), respectively, with no significant association between gender and TMT scores ($p>0.05$). According to multivariate analysis of variance, the interaction of age, gender, and education did not lead to a significant difference in the TMT scores ($p=0.309$). Tukey's post hoc test showed that participants under 40 took significantly less time to complete TMT-A than those over 50, while in TMT-B, participants under 30 years completed in a shorter time than those over 30 years old ($p<0.01$).

Conclusion: Our findings indicate that age and education have a significant association with the performance of the Iranian healthy population in the well-known measure of executive function and attention, and it is necessary to interpret TMT scores using normative data gathered in regional settings.

Keywords: Trail Making Test; Attention; Executive Function; Neuropsychological Assessment; Normative Data.

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1. Introduction

Many societies today are struggling with problems that affect their cognitive health, in addition to other aspects of health. Based on research and clinical reports, phenomena such as aging and road traffic accidents have been so widespread in some societies that they challenged many health policies and systems [1, 2]. Iran is one of the countries facing such problems. It is estimated that the proportion of people over 60 in Iran in 2022 exceeded 10% of the total population [3]. Also, according to the estimates of the Iranian Forensic Medicine Organization, from 1997 to 2020, 5,760,835 people were injured in road accidents and 472,193 deaths occurred [4]. Such incidents can lead to various cognitive complications, which in many cases may be permanent [5]. Due to the growing trend of problems endangering cognitive health and the need to have neurocognitive abilities to maintain daily functioning and handle individual, family, and social duties and obligations, knowing and measuring cognitive abilities becomes increasingly important. The goal of neuropsychology as an interdisciplinary field since its inception has been to design valid and reliable tools to measure neurocognitive functions [6]. Neuropsychological assessment can influence various clinical decisions, from diagnosis and prediction of future functioning to determining educational and vocational status after neurosurgery [7].

Cognitive health relies on a broad set of cognitive capacities that include various domains such as attention and concentration, memory, motor skills and construction, visuospatial abilities, processing speed, verbal/language skills, and executive functions [8]. Various neuropsychological tools have been designed and implemented in the past century to measure cognitive functions [7]. The Trail Making Test (TMT) is a well-known and widely used neuropsychological test, which is very popular in clinical and research settings [6]. The TMT measures various capacities and functions, emphasizing attention and executive function [6]. Based on the recent survey, TMT was the most frequently used neuropsychological assessment measure in general, the fourth most frequently used measure of attention, concentration, and working memory, the second most frequently used measure of executive function, and the ninth most frequently used measure of sensory/motor functioning [7].

Although TMT is often used as a stand-alone neuropsychological measure, it is also included as one of the subtests in several test Batteries. Originally, it was one of the components of the Army Individual Test Battery and a few decades later was adapted by Ritan and Wolfson into the Halstead–Reitan Neuropsychological test Battery [9]. This test has recently been included in some test batteries specifically designed for specific disorders/diseases such as anorexia nervosa [10], dementia [11], and Huntington's [12]. TMT has been used for cognitive evaluation of a wide range of neurological and psychiatric disorders such as schizophrenia [13], obsessive-compulsive disorder [14], dementia [11], delirium [15], traumatic brain injury [13], migraine [16], cancer [17], and acute stroke [18]. TMT has also been used repeatedly to measure cognitive performance in the normal population [19, 20]. In addition, the age range of TMT implementation is wide and includes from childhood [21] to adulthood [15, 16, 19] to old age [20].

An individual's performance on a neuropsychological assessment is interpreted by comparing his/her scores with previously collected scores from a reference group [22]. Therefore, to interpret the scores obtained from neuropsychological assessment and reduce the possibility of false diagnoses, it is necessary to collect appropriate normative data. Considering the effect of some demographic variables on people's performance in neuropsychological tools, raw scores are transformed into relative measures corrected for the effect of such variables [23]. The simplest method to generate normative data for neuropsychological tests is to determine the distribution of scores based on central and dispersion indicators (means and standard deviations), whether for the entire sample or classifying the sample based on demographic variables. Eventually, Central and dispersion indicators obtained for the entire sample or sub-samples can be used to transform raw scores into measures such as T and Z scores that can be easily interpreted [22, 23].

So far, normative data for TMT have been prepared in different languages such as Chinese [24], French [25], Spanish [26], Scandinavian [27], and Arabic [28]. Most of these studies on TMT have provided normative data classified by demographic variables [29]. In general, the literature shows that age has a significant relationship with performance in TMT and as age increases, performance declines [29]. On the other hand, a little correlation has been reported between gender and TMT scores [30]. Finally, according to the literature, the association between education and TMT performance is less than age and a weak-to-moderate association has been documented [29]. The relationship between education and the two parts of TMT is also different [29]. The influence of education on TMT-A is 3 to 10% and TMT-B is reported to be 7 to 16% [29].

Lack of access to regional normative data is one of the common problems faced by neuropsychologists in evaluating people's cognitive status [31]. This also applies to neuropsychological assessment in Iran. To the best of our knowledge, despite the high importance and widespread use of TMT, its normative data has not yet been collected in Iran. This test has the advantage of being short and easy to use. Considering the increasing use of neuropsychological evaluations and the need to access regional normative data, the present study aimed to gather the normative data appropriate to the Iranian healthy population, with a longer age range (ages 20 to 70) and an equal proportion of two genders in the study sample. In addition to the above objectives, we sought to answer the question of whether, like some normative data in the populations of other countries [29, 30], demographic variables of age, gender, and education affect the neurocognitive functions of attention and executive function assessed by TMT in the Iranian population.

2. Materials and Methods

2.1. Data

The present study was implemented in 2017-2018 as part of the Iranian Brain Imaging Database (IBID) project to collect normative measures of the brains of Iranian healthy people for future investigation and interventional purposes [32-35]. To complete these normative data, a series of well-known and widely used tests were implemented in the Iranian healthy population. The tests were performed in the same order and one day. As a result, a considerable neural, cognitive, and psychological database was collected for further analysis. The TMT was one of the neuropsychological measures implemented to examine executive function and attention. The research sample consisted of three hundred medically and cognitively healthy people aged 20 to 70. Each decade consisted of 60 participants and the gender proportion was equal in each decade. Five decades of age (20 to 70 years old) and scores obtained in the Trail Making Test (TMT; defined in terms of two scores of the completion time of its two parts A and B) were the independent and dependent variables, respectively.

2.2. Procedure

The recruitment of participants in the research was based on advertisements in local media and social networks (For complementary information, see Batouli *et al.* [32, 33] and Sisakhti *et al.* [34, 35]). To exclude individuals with cognitive, medical, and mental health problems from the study, all participants were interviewed twice by a general practitioner and a trained cognitive psychologist [33]. Due to the impact of diseases and their treatments on cognitive function, the interview by the general practitioner was especially focused on present and past medical and psychiatric history such as medication, hospitalization, and major physical and mental trauma. In addition, after entering participants in the study and gathering the data from them, if the obtained scores in cognitive and mental health tests were extreme outliers (>±3.3 standard deviation), they would be excluded from the sample [33]. After cognitive, medical, and mental health screening, eligible individuals were invited to participate in functional and structural imaging in the National Brain Mapping Laboratory (NBML) and comprehensive cognitive and psychological assessment [33]. The inclusion criteria included speaking fluently in Farsi, ability to read and write, and age from 20 to 70 years. The exclusion criteria consisted of having a history of illicit drugs, systemic, psychiatric, and neurological illness; the current use of any medication affecting neurocognitive performance, and visual and auditory defects affecting performance in tests. Due to the length of the various phases of this project and the necessity of a long presence of the participants, a small gift was given to them. Participants entered the study voluntarily and signed a written consent before implementing the study measures. The present study was approved by the ethics committee of the National Institute for Medical Research Development (code: IR NIMAD REC 1396 319; for complementary information see Batouli *et al.* [33]).

2.3. Measure

Since its invention in the 1930s, the Trail Making Test has been a well-known tool for stand-alone screening of cognitive impairment or as one component of a test battery [29, 36]. This test has two parts: A and B. In TMT-A, the participant is required to connect numbers in order from 1 to 25 with a pencil. Also, the participant must pass over each circle only once and the trail must pass through all the circles. TMT-B consists of a series of numbers and letters. It requires that the participant connect in order the numbers from 1 to 12 and the letters from A to L, first a number and then a letter [37]. Scoring is done based on the time taken to complete two parts of TMT in seconds [37]. These two parts do not examine the same cognitive abilities. TMT-B is more complex than TMT-A and requires more cognitive resources, particularly perceptual and executive capacities. In addition to both parts being a measure of attention, some researchers consider TMT-A as an index of visual search and motor speed, and TMT-B as an index of executive function. TMT-B is assumed to represent cognitive flexibility among executive abilities [36]. Neuroimaging studies also indicate the role of frontal and somewhat temporal brain regions in TMT performance in both healthy and patient populations [29].

2.4. Statistical Analysis

To analyze the research data, descriptive statistics including central (mean) and dispersion (standard deviation and range of changes) indicators were used to describe participants' features, and Pearson's and Spearman's correlation coefficients were used to examine the association of age with TMT scores and the association of education and gender with TMT scores, respectively. Multivariate Analysis of Variance (MANOVA) was used to evaluate the differences between the participants in terms of age, gender, education, and the interaction of these variables in TMT scores. After confirming the assumption of homogeneity of error of variances by Levine's test, Tukey's post hoc test was used to investigate the difference between each age group and other groups in each score. Statistical significance was determined based on a p-value below 0.05.

A total of 300 healthy people participated in our study. The age range of the sample was 20–70 years, with 60 participants in each decade of age and an equal proportion of genders in each group. Most of the participants had a diploma and bachelor's or master's degree, and the frequency of participants with under-diploma or doctorate education was less (For complementary information, see [32-35]). Therefore, according to Tombaugh [38], two levels of diploma/sub-diploma and higher diploma were used to investigate the effect of education level on TMT scores.

3. Results

The mean and standard deviation of the completion time of the participants in TMT-A were 35.87 and 21.09, and in TMT-B 87.66 and 58.44, respectively. Table 1 shows the mean, standard deviation, and minimum and maximum scores of the participants classified by age, gender, and education. As can be seen, in both TMT-A and TMT-B, along with increasing age, the completion time has increased. However, these differences have not been seen between women and men. Also, participants with academic education spent relatively less time on both subtests.

As seen in Table 2, Pearson's correlation coefficient showed that age has a significant positive correlation with the completion time in both TMT-A and TMT-B (p=0.01). This means that with increasing age, participants

Table 1. Central and dispersion indicators of TMT performance classified by age, gender, & education

	TMT-A		TMT-B	
	M (SD)	Range	M (SD)	Range
Total	35.87 (21.09)	12-218	87.66 (58.44)	27-614
Age Category				
20-30 [n=68]	27.63 (9.10)	12-54	59.80 (21.62)	27-159
31-40 [n=71]	29.63 (10.81)	13-75	65.40 (27.30)	31-175
41-50 [n=67]	35.09 (14.01)	12-83	85.90 (39.58)	37-211
51-60 [n=57]	41.76 (16.63)	21-117	117.31 (60.65)	31-356
61-70 [n=37]	55.60 (43.41)	27-218	140.15 (104.55)	54-614
Gender				
Male [n=150]	35.84 (21.67)	12-175	89.49 (52.66)	31-356
Female [n=150]	35.89 (20.65)	12-218	86.07 (63.17)	27-614
Education Category				
<=12 [n=76]	39.55 (19.33)	12-117	110.56 (84.69)	34-614
>12 [n=224]	34.91 (21.97)	12-218	81.19 (45.81)	27-291

Note: TMT: Trail Making Test

Table 2. Pearson and Spearman Correlation Coefficients

	TMT-A		TMT-B	
	Coefficient	Sig.	Coefficient	Sig.
Age [a]	0.413**	0.000	0.498**	0.000
Gender [b]	0.052	0.377	-0.053	0.371
Education [b]	-0.179**	0.003	-0.223**	0.000

Note: TMT: Trail Making Test; **: Correlation is significant at the 0.01 level (2-tailed); [a]: Pearson Correlation Coefficient; [b]: Spearman Correlation Coefficient.

Table 3. Test of homogeneity of variances

	TMT-A	TMT-B
Levene Statistic	1.054	1.113
Sig.	0.413*	0.383*

Note: TMT: Trail Making Test; *: Confirming the assumption of homogeneity of variances at 0.05 level

spent more time on both subtests. Also, Spearman's correlation coefficient showed that the education level has a significant negative correlation with the time spent to complete both subtests ($p<0.01$), which means that the time required to complete two subtests decreases along with the increase in the level of education. However, according to the Spearman correlation coefficient, there was no difference in the completion time of any of the two subtests between the genders ($p>0.05$).

Levene's test was used to examine the homogeneity of variances. Based on this test, the assumption of homogeneity of variances in the case of the time spent for completion of TMT-A (p=0.413) and TMT-B (p=0.383) was confirmed (Table 3).

As shown in Table 4, MANOVA displays that there is a significant difference between age (F=13.906, p=0.000) and education (F=31.891, p=0.000) in the time spent to complete the subtests, while this difference was not seen in gender (F=0.794, p=0.453). Also, there was a significant difference between participants with academic education and those with sub-academic education in different age groups (F=7.403, p=0.000). In addition, the interaction of gender and education (F=1.21, p=0.3) and age, gender, and education (F=0.561, p=0.81) did not lead to a significant difference in scores.

Table 5 shows the difference of participants in different groups in terms of the time spent to complete the subtests. Participants' age made a significant difference in their speed to complete both subtests (TMT-A: F=5.605, p=0.000; TMT-B: F=30.758, p=0.000). There was no difference between men and women in terms of completion time of TMT-A (F=0.925, p=0.337) and TMT-B (F=1.242, p=0.266). The speed of people with academic education was not significantly different from people with sub-academic education in TMT-A (F=3.099, p=0.080). Still, in TMT-B, a significant difference was seen between the two groups (F=62.506, p=0.000), according to Table 1, the first group (M=81.19, SD=45.81) completed TMT-B faster than the next group subjects (M=110.56, SD=84.69). Men and women in different age groups did not have a significant difference in the completion time of TMT-A (F=0.488, p=0.785) and TMT-B (F=0.902, p=0.480). Also, there was a significant difference in the speed of people with academic education from people with sub-academic education in different age groups in completing TMT-A (F=2.479, p=0.032) and TMT-B (F=13.274, p=0.000). However, the interaction of age and gender (TMT-A: F=1.38, p=0.241; TMT-B: F=1.918, p=0.167) and age, gender, and education (TMT-A: F=0.388, p=0.817; TMT-B: F=0.644, p=0.632) did not lead to a significant difference in the completion time of any of the subtests.

Tukey's post hoc test was used to examine the differences between different age groups of participants in scores of the subtests. As seen in Table 6, participants under 40 took significantly less time to complete the TMT-A than those over 50. Participants aged 61-70 spent more time than those aged 41-60 ($p<0.05$). In TMT-B, participants under 30 years old compared to those over 30 years old, and participants between 30 and 50 years old compared to those over 50 years old completed in a shorter time ($p<0.01$), but between participants 51-60 and 61-70 were not seen significant difference ($p>0.05$).

Table 4. Multivariate analysis of variances (MANOVA) of demographic categories and TMT scores

Effect	F	Hypothesis df	Error df	Sig.	Partial η^2
Age	13.906	10	504	0.000	0.216
Gender	0.794	2	252	0.453	0.006
Education	31.891	2	252	0.000	0.202
Age * Gender	0.569	10	504	0.840	0.011
Age * Education	7.403	10	504	0.000	0.128
Gender * Education	1.210	2	252	0.300	0.010
Age * Gender * Education	0.561	8	504	0.810	0.009

Table 5. Tests of Between-Subjects Effects

Source	**Dependent Variable**	**df**	**Mean Square**	**F**	**Sig.**	**Partial η^2**
Age	TMT-A	5	2112.869	5.605	0.000	0.100
	TMT-B	5	57231.641	30.758	0.000	0.378
Gender	TMT-A	1	348.795	0.925	0.337	0.004
	TMT-B	1	2311.211	1.242	0.266	0.005
Education	TMT-A	1	1168.291	3.099	0.080	0.012
	TMT-B	1	116304.270	62.506	0.000	0.198
Age * Gender	TMT-A	5	183.843	0.488	0.785	0.010
	TMT-B	5	1677.937	0.902	0.480	0.018
Age * Education	TMT-A	5	934.650	2.479	0.032	0.047
	TMT-B	5	24698.093	13.274	0.000	0.208
Gender * Education	TMT-A	1	520.302	1.380	0.241	0.005
	TMT-B	1	3567.953	1.918	0.167	0.008
Age * Gender * Education	TMT-A	4	146.110	0.388	0.817	0.006
	TMT-B	4	1197.682	0.644	0.632	0.010

Table 6. Significance of mean differences in the age groups (Tukey Post Hoc)

Age Category		**TMT-A**			**TMT-B**		
I	J	M_I-M_J	SE	Sig.	M_I-M_J	SE	Sig.
20-30	31-40	-2.135	3.476	0.990	-6.689	7.723	0.954
	41-50	-7.37	3.433	0.267	-26.221*	7.626	0.009
	51-60	-14.291*	3.593	0.001	-57.835*	7.983	0.000
	61-70	-28.069*	4.286	0.000	-68.622*	9.521	0.000
31-40	41-50	-5.233	3.502	0.668	-19.532	7.781	0.125
	51-60	-12.155*	3.660	0.013	-51.146*	8.131	0.000
	61-70	-25.933*	4.342	0.000	-61.933*	9.645	0.000
41-50	51-60	-6.922	3.619	0.397	-31.614*	8.040	0.002
	61-70	-20.700*	4.307	0.000	-42.401*	9.569	0.000
51-60	61-70	-13.778*	4.436	0.025	-10.787	9.855	0.883

4. Discussion

In this study, we aimed to generate normative data for the well-known and widely used neuropsychological test of attention and executive functioning and examine the possible effect of age, education, and gender on the performance of the Iranian healthy population in two subtests of TMT. Our findings demonstrated that age has a significant negative correlation with both TMT-A and TMT-B, which means that TMT performance declined with age. Unlike age, education had a significant positive correlation with both subtests, which means that TMT performance increases along with increasing education level. However, no significant association was observed between TMT and participants' gender. In addition, MANOVA showed a significant difference in TMT scores between different age groups and education levels, with no difference between the two genders.

Our study demonstrated that TMT performance as a measure of attention and executive functioning declines with age. This finding is consistent with the results of many literature studies [38-43]. In Tombaugh's study on 911 community-dwelling individuals aged 18-89, there was a significant decline in TMT performance with increasing age [38]. However, the effect of age and education on TMT-A and TMT-B was not the same; in TMT-A, performance declines markedly with age and not with education [38]. In one study on 1966 Japanese participants, the relationship between age and speed of responding in TMT was reported [40]. In a study of French-speaking Quebec participants, while age was positively correlated with performance on the TMT-B, it was only a significant predictor of performance on the TMT-A [25]. The results related to the relationship between age and TMT performance have also been repeated in the older age groups. In a study of 1923 healthy individuals aged 55 and older, age accounted for the most variance in TMT-A, while education accounted for the most variance in TMT-B [43].

Most normative studies have shown moderate correlations between age and TMT performance, which was in the range of r=0.40 for both subtests [29]. Regression-based studies also attribute 16 to 31% of TMT-A variance and 25 to 35% of TMT-B variance to age [29]. Altogether, the literature demonstrates a decline in some cognitive functions along with increasing age in the healthy adult population [43]. In particular, this pattern is observed in tests, such as TMT, in which responding requires motor speed [36]. Spending more time to complete both TMT subtests even in the absence of motor and sensory deficits indicates that TMT performance is sensitive to normal age-related decline in concentration, vigilance, and visuospatial ability [44]. Aging-related decline in executive abilities has also been proposed to explain the decrease in performance in many neuropsychological tests, including the TMT [6]. Some researchers have proposed the most noticeable change in TMT performance after 50-55 years of age [45, 46].

Another finding of our study showed that education has a significant correlation with TMT performance and participants' performance in this measure of attention and executive functioning improves with increasing levels of education. This is consistent with the findings of many studies [28, 42, 47]. This finding has been repeated in some studies of older people. In a sample of 1,966 older Japanese adults, education was significantly associated with TMT performance [40]. In a sample of 1923 adults over 55 years of age, education also showed a significant correlation, although it only accounted for most of the variance of TMT-B [43]. However, a study on centenarians showed that in this age group, the effect of age on the performance of both TMT subtests disappears [48].

Altogether, compared to age, research indicates a weaker correlation of education with TMT performance [29]. Some studies have reported this correlation as moderate [49] and others as weak [45]. According to the literature, 3 to 10% of the variance of TMT-A scores and 7 to 16% of the variance of TMT-B scores are accounted for by education [29]. This correlation or effect is not observed equally in all ages. In the study of an older Japanese sample, the effects of education were more noticeable in the first 6 years of education [50]. In the study of Bezdicek *et al.* (2012), the most noticeable effect was observed in participants with less than and more than 13 years of education [45].

Our other finding indicated that gender has no significant relationship with the performance of the participants in this neuropsychological test related to attention and executive functioning. This finding has been reported in many other studies [28, 42, 47]. In one of the most comprehensive studies conducted in 11 Latin American countries on a sample of 3977 people, the effect size was greater than 0.3 only in Honduras. Therefore, the gender-adjusted norm was generated only for that country, and that too only for TMT-A [42]. Overall, the literature has generally reported little effect of gender on TMT performance [29].

4.1. Limitations and Future Research

There are several limitations in our study. First, the education level of most of the participants in the study was higher than the diploma, and there were very few participants with an education lower than a diploma. The presence of equal or relatively equal proportions of participants with different levels of education in future studies can help to the generalizability of the obtained results. Second, the sample used in our study was relatively small. This sample size may not be enough to generalize the results to the healthy Iranian population. It is recommended to use a larger sample in future studies to collect normative data on the Iranian population. Third, the research sample was analyzed based on age, sex, and education, without differentiating them based on job, ethnicity, race, socioeconomic status, and cultural factors. Some pieces of evidence show that these variables may affect people's cognitive performance. Considering such variables may be important to collect normative data. Classifying the research sample based on the above variables in future studies can increase our understanding of the effect of different demographic variables on cognitive performance. It can provide more accurate normative data for use in clinical and research settings.

5. Conclusion

In sum, our study, in addition to generating normative data for the well-known and widely used measure of attention and executive functioning (Trail Making Test), showed that the correlation of age and education with TMT-A and TMT-B subtests is statistically significant, while gender did not show such a relationship. Considering the rapid aging of the population in Iran and the need for neuropsychological tools for diagnosis, treatment, prevention, and rehabilitation, findings like this help clinicians interpret the results of neuropsychological tests more accurately and reduce the possibility of false diagnoses of cognitive impairment. The findings of our study emphasize the importance of access of clinicians to appropriate normative data for the Iranian population.

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