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ORIGINAL ARTICLE

Normative data of the digit span test for the Turkish population aged between 50 and 83 years

Sayı menzili testi'nin 50-83 yaş aralığındaki Türkiye popülasyonu için norm değerleri

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ABSTRACT

Objectives: This study aimed to determine normative values stratified by age, education, and sex for the digit span test (DST), a commonly used tool for assessing attention, short-term memory, and working memory in Türkiye, in the Turkish population aged 50 and above.

Patients and methods: A total of 340 healthy individuals (139 males, 201 females; mean age 64.4±8.5; range, 50 to 83 years) were included in the study, stratified by age (three levels: 50-59 years, 60-69 years, 70-83 years), education (three levels: 0-5 years, 6-11 years, 12 years and above), and sex (female, male) variables. The participants' longest digit span forward (DSF), digit span backward (DSB) scores and total DST scores were included in the analyses. The relative contributions of age, education, and sex variables to DST scores were examined using multiple linear regression analysis, while their main effects and interaction effects were investigated using a 3×3×2 ANOVA design. Test-retest reliability of the DST was determined by tests administered in 12-month intervals.

Results: Demographic variables accounted for 25 to 38% of the variance in the longest DSF and DSB scores and total DST scores. Significant main effects of age, education, and sex were observed on the longest DSF scores and total DST scores, while only age and education had main effects on the longest DSB scores. The DST demonstrated strong test-retest reliability.

Conclusion: This study established normative values for the DST subscores for individuals aged 50-69 and 70-83 years with low, moderate, and high levels of education. Notably, years of education emerged as the strongest predictor of DST performance. Overall, advanced age, lower educational attainment, and female gender were associated with reduced DST performance.

Keywords: Digit span test, normative data, neuropsychological test, reference values.

ÖZ

Amaç: Bu çalışmada, Türkiye'de dikkat, kısa süreli bellek ve çalışma belleğinin değerlendirilmesinde sıklıkla kullanılan sayı menzili testi (SMT)'nin 50 yaş ve üzeri Türkiye popülasyonunda yaş, eğitim ve cinsiyete göre tabakalandırılmış norm değerlerinin belirlenmesi amaçlandı.

Hastalar ve yöntemler: Araştırmaya 50 yaş ve üzeri 340 sağlıklı birey (139 erkek, 201 kadın; ort. yaş: 64,4±8,5; dağılım 50-83 yıl), yaş (üç düzey: 50-59 yaş, 60-69 yaş, 70-83 yaş), eğitim (üç düzey: 0-5 yıl, 6-11 yıl, 12 yıl ve üzeri) ve cinsiyet (kadın, erkek) değişkenlerine göre dahil edildi. Katılımcıların en uzun ileri sayı menzili (İSM) ve geri sayı menzili (GSM) puanları ile toplam SMT puanları analizlere dahil edildi. Yaş, eğitim ve cinsiyet değişkenlerinin SMT puanları üzerindeki göreceli katkıları çoklu doğrusal regresyon analiziyle, ana etkileri ve birbirleri arasındaki etkileşim etkileri ise 3×3×2 ANOVA deseniyle incelendi. Sayı menzili testinin test tekrar-test güvenirliği 12 ay ara ile uygulanan testler ile belirlendi.

Bulgular: Demografik değişkenler, en uzun İSM ve GSM puanları ve toplam SMT puanlarındaki varyansın %25-38'ini açıkladı. En uzun İSM puanları ve toplam SMT puanları üzerinde, yaş, eğitim ve cinsiyet ana etkileri; en uzun GSM puanları üzerinde yaş ve eğitim ana etkileri saptandı. Sayı menzili testinin yüksek test-tekrar test güvenirliğine sahip olduğu gözlendi.

Sonuç: Çalışmada, SMT'nin alt puan türleri için norm değerleri 50-69 yaş ve 70-83 yaş aralığındaki düşük, orta ve yüksek eğitime sahip bireyler için oluşturuldu. Eğitim yılının SMT performansının en güçlü yordayıcısı olarak dikkat çekmiştir. Genel olarak, ileri yaş, düşük eğitim düzeyi ve kadın olmanın düşük SMT performansıyla ilişkili olduğu gözlendi.

Anahtar sözcükler: Sayı menzili testi, norm verileri, nöropsikolojik test, referans değerler.

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With neuropsychological assessment becoming a routine practice in hospitals and various health centers across our country, the need for tests standardized for Türkiye has increased. The digit span test (DST), one of the subtests among memory and intelligence scales developed by Wechsler,[1,2] is widely used to evaluate attention, concentration, short-term memory, and working memory. The DST is an easily and quickly administered test, suitable for bedside examination, and does not require the individual to be literate. Additionally, the DST is a good measure of general intelligence, with 50% of the variance attributable to the g factor.[3-5] In Türkiye, the DST is also referred to as the number series test, number sequence test, number span test, or digit range test.

The test consists of two parts: the digit span forward (DSF) and the digit span backward (DSB). In the DSF section, a number is spoken each second in various sequences, and the individual is expected to repeat the numbers in the same order. In the DSB section, the individual is asked to repeat the sequences of numbers in reverse order. In both sections, the length of the number sequences gradually increases; there are two trials for each digit span (e.g., 528 and 371; 2946 and 5238), and the test is terminated after two consecutive incorrect responses within the same digit span.

The DSF and DSB sections must be independently evaluated since they are based on different cognitive functions.[5-7] The DSF is associated with attention, auditory short-term memory, and rote learning, whereas the DSB, in addition to attention and short-term memory, also involves the manipulation of information, thereby requiring working memory, one of the executive functions. High scores in the DSB indicate cognitive flexibility, the use of repetition and other memory strategies, tolerance to stress, and high concentration.[3]

There are two different scoring methods for DSF and DSB performance. The total DSF/DSB score reflects the number of trials in which the individual is successful. The longest DSF/DSB score indicates the longest sequence of numbers the individual successfully repeats. The longest DSF/DSB is also referred to as the maximum DSF/DSB. For example, in the DSF section, an individual who repeats a sequence of seven digits will have a longest (maximum) DSF of seven. The total DSF score can vary between 5 to 10 points depending on the number of successful trials. In cases where only the total DSF/DSB score is reported, the individual's longest digit span cannot be determined, which complicates clinical assessment.[8] It is stated that using the longest (maximum) digit span as a scoring procedure is better than the number of successful attempts (total span score) in evaluating DST performance.[7,9] Since the longest digit span scores are accepted and used by clinicians as pure measures of attention (DSF) and working memory (DSB), they have been added as routine scores in the latest version of the Wechsler Adult Intelligence Scale.[10]

Normative values for total DSF and DSB scores in Türkiye were examined in an unpublished postgraduate thesis.[11] The study included 180 healthy individuals and established normative values for six age groups (17-27, 28-38, 39-49, 50-60, 61-71, and 72-82 years) and three levels of education (primary, secondary, and high school, associate degree, and above). However, in Özdeniz's[11] study, the effects of variables on DST performance were assessed using one-way analysis of variance (ANOVA); therefore, the potential interaction effect between age and education variables could not be examined. Similarly, the interaction of sex with other variables was not examined.

The validity, reliability, and normative study of the Turkish population for the Wechsler Memory Scale-Revised[2] was conducted by Karakaş[12] with 353 participants within the scope of the BILNOT battery (neuropsychological test battery for cognitive potentials). The study included five age groups (20-24, 25-34, 35-44, 45-54, and 55 and over) and three education groups (5-8 years, 9-11 years, and 12 years and over). The effects of age and education on total DSF and DSB scores were identified.[12] Findings related to the validity and reliability of the total DST scores were reported within the BILNOT battery; however, the normative values of the test were not shared. The change in DST performance with advancing age necessitates conducting normative studies with narrow age ranges. Due to the assessment of individuals aged 55 and over in a single group within the BILNOT battery[12] and the unavailability of normative values, there is still a need for DST normative studies for individuals over 50 in Türkiye.

Özdeniz[11] and Karakaş's[12] studies examined total forward and backward DST scores. However, in both international[5,13-17] and national literature,[18,19] as well as in clinical neuropsychology practice in Türkiye, the longest (maximum) DSF and DSB scores are commonly used in DST scoring, and these scores are reported in neuropsychological evaluation reports. Despite its widespread use, there is no normative study conducted on the Turkish population for this scoring method in the literature.

The international literature demonstrates that DST performance is affected by demographic variables, such as age, education, and sex.[13,14,20,21] Generally, advancing age and lower education levels negatively affect DST performance. The impact of sex on test performance is unclear; while some studies report no significant effect of sex,[14,15,22] there are also studies that report a minimal effect.[14,20,21]

The performance in DST is known to be affected in neurological disorders such as traumatic brain injury, multiple sclerosis, and Alzheimer's disease (AD).[7] Kurt et al.[18] demonstrated that low DST scores could predict the transition to mild cognitive impairment, which was considered a prodromal stage of AD, in individuals with subjective memory complaints. Individuals over the age of 50 are at risk for many neurological diseases that affect attention functions. For individuals in this age group, there is a need for normative values stratified according to demographic variables.

The current study aimed to examine the effect of age, education, and sex on the longest DST scores in the Turkish population over 50 years of age, establish stratified normative values for DST for variables with detected effects, and determine the test-retest reliability. The participants included in the unpublished postgraduate thesis[11] and the BILNOT Battery[12] are observed to be at least primary school graduates. Few tests within neuropsychological test batteries can be administered to illiterate individuals, and the DST is one of these tests. Therefore, the current study sought to establish normative values for DST within a broad sample that included illiterate individuals. Hence, the DST normative values, widely used in cognitive assessments of individuals aged 50 and over both in Türkiye and worldwide, will be made available to clinicians and researchers. The findings of the study are expected to contribute to DST practices in our country and to the interpretation of test results.

PATIENTS AND METHODS

In this study, DST scores of 340 individuals (139 males, 201 females; mean age 64.4±8.5; range, 50 to 83 years) who were determined to be cognitively healthy based on neurological examinations, detailed neuropsychological assessments, laboratory tests, and brain imaging findings conducted at the Dokuz Eylul University, Graduate School of Health Sciences, Department of Neurosciences, between January 2011 and December 2018 were retrospectively examined within the scope of past research. The DST was administered to participants as part of the routine neuropsychological assessment. Detailed information about the neuropsychological test battery utilized has been shared in past studies.[23,24]

Individuals with Mini-Mental State Examination scores <27 were not included in the study.[25] The exclusion criteria were the presence of clinical depression and a score of 14 or above on the Yesavage et al.'s[26] Geriatric Depression Scale. Additionally, individuals with drug or substance use that could affect cognitive processes, as well as those with a history of traumatic brain injury, stroke, or epilepsy, were excluded from the study.

The study included 340 healthy individuals over 50 whose neuropsychological test scores were compatible with age and education norms stratified according to age (three levels: 50-59 years, 60-69 years, and 70-83 years), education (three levels: 0-5 years, 6-11 years, and 12 years and over), and sex (female, male). At least 10 participants were included for each condition in the 3×3×2 ANOVA design created. The demographic characteristics of the participants are presented in Table 1.

Digit span test

The DST consists of two parts: the DSF and the DSB. In the DSF, digits from 1 to 9 are spoken in a mixed order at a rate of one digit per second, and the individual is asked to repeat these digits in the same order. Starting with a three-digit sequence (e.g., 528), one digit is added to the sequence as the individual successfully repeats the sequence. In the DSB, however, participants are asked to repeat the presented digits not in the same order but backward, starting from the end. The test is terminated after two consecutive incorrect responses within the same digit span.

The individual's longest (maximum) DSF and DSB scores are recorded in the test. The highest possible score for DSF is 8, while it is 7 for DSB. In this study, the total DST scores obtained by summing the DSF and DSB scores have also been calculated and included in the analyses.

Statistical analysis

The relative contributions of age, education, and sex on DST scores were examined using multiple linear regression analysis. Separate

TABLE 1
Demographic data of the participants according to age, education, and sex

Education level	Sex		50-59 years n	50-59 years Mean±SD	60-69 years n	60-69 years Mean±SD	70-83 years n	70-83 years Mean±SD
Low (0-5 years)	Males	n	10		10		10	
		Age		56.10±3.00		64.30±2.31		73.80±4.54
		Education		4.50±1.58		4.50±1.58		5.00±0.00
	Females	n	10		20		19	
		Age		55.30±3.34		65.20±2.75		72.84±2.50
		Education		4.80±0.63		4.05±1.85		3.68±2.11
Moderate (6-11 years)	Males	n	15		12		12	
		Age		53.87±2.92		64.92±2.75		75.67±4.81
		Education		10.00±1.46		9.50±1.68		11.00±0.00
	Females	n	22		27		23	
		Age		54.68±2.80		64.41±3.45		74.91±3.38
		Education		10.18±1.37		9.56±1.83		9.87±1.63
High (>12 years)	Males	n	15		30		25	
		Age		54.27±3.24		64.57±3.28		75.40±4.06
		Education		14.87±0.92		15.17±2.00		15.52±1.98
	Females	n	39		25		16	
		Age		54.54±2.95		64.68±2.98		73.19±3.31
		Education		15.13±1.91		15.76±2.51		15.06±1.53

SD: Standard deviation.

analyses were conducted for DSF, DSB, and total DST scores. The contributions of variables to the regression model were first examined using the forced entry method; subsequently, analyses were repeated with the stepwise selection method to determine the most significant model. Age and education were included in the model as continuous variables. The sex variable was coded as 0 for males and 1 for females.

A 3×3×2 ANOVA design was utilized to examine the main effects of age, education, and sex on DST subscores and the interactions between these variables. The ANOVA design included age (three levels: 50-59, 60-69, and 70-83 years), education [three levels: 0-5 years (low), 6-11 years (moderate), and 12 years and over (high)], and sex (two levels: female and male). In post hoc comparisons, the Bonferroni correction was used. For determining DST norms, based on the findings of factorial ANOVA, groups that did not differ from each other were combined, and norm values for the newly formed groups were reported.

Furthermore, the test-retest reliability of the longest DSF, DSB, and total DST scores was examined using Pearson correlation analysis, utilizing DST scores applied to 60 participants with a 12-month interval in previous years. Lastly, the correlation between the longest DSF and DSB scores was evaluated with Pearson correlation analysis. All statistical analyses were conducted using IBM SPSS version 29.0 software (IBM Corp., Armonk, NY, USA). A p-value <0.05 was considered statistically significant.

RESULTS

Preliminary analyses

Initially, the suitability of the data for multiple linear regression and ANOVA assumptions was tested. For this purpose, raw DSF and DSB scores were converted to Z scores for the examination of extreme values. Since there was no data outside the range of ±3.26 in the Z score, all participants were included in the analyses for determining normative data. In multiple linear regression analysis, at least 40 participants are required for each independent variable.[27] The sample size of 340 individuals included in the normative data analyses for age, education, and sex variables met this requirement. Before factorial ANOVA, the normal distribution of DSF, DSB, and total DST scores for the conditions created according to age, education, and sex was examined. The normal distribution of data was determined using histogram plots and skewness values.

Multiple linear regression analysis findings

When the relative contributions of age, education, and sex variables on DSF scores were examined, all variables were found to have a significant contribution to the regression model. All the variables included together accounted for 34% of the variance. Years of education alone explained 29% of the variance. Years of education and age together were responsible for 32% of the variance. Age and years of education had significant contributions to the regression model of DSB scores, while sex did not make a meaningful contribution to the model. When age and years of education were included together in the model, they accounted for 27% of the variance. Years of education alone explained 25% of the variance.

Examining the relative contributions of age, education, and sex variables on total DST scores, all variables were determined to significantly contribute to the regression model. All the variables included together accounted for 38% of the variance. Years of education alone explained 34% of the variance. Years of education and age together were responsible for 37% of the variance. The findings of the multiple linear regression analysis are presented in Table 2.

Factorial ANOVA findings

For the longest DSF scores, significant main effects of age [$F_{(2,322)}$=6.071; p=0.003], education [$F_{(2,322)}$=37.607; p<0.001], and sex [$F_{(1,322)}$=7.522; p=0.006] were detected. Further analyses found that individuals in the 70-83 age group had lower DSF scores compared to the 50-59 (p=0.001) and 60-69 (p=0.049) age groups. There was no significant difference between the 50-59 and 60-69 age groups (p=0.107). Significant differences were found among all education levels; individuals with higher education had higher DSF scores compared to those with low (p<0.001) and moderate (p<0.001) levels of education, and individuals with moderate education had higher DSF scores compared to those with low education (p=0.001). Additionally, it was found that males had higher DSF scores than females (p=0.006). For the longest DSF scores, the interaction effects of age × education [$F_{(4,322)}$=0.569; p=0.685],

TABLE 2
The explanation of DST subscores with the age (years), education (years), and sex model in the multiple linear regression analysis

	b	SE	β	t	*p*	R^2	ANOVA
DSF							
(Constant)	5.951	0.420		14.182	<0.001	0.34	$F_{(3.339)}$= 57.231; p<0.001
Age	-0.026	0.006	-0.200	-4.465	<0.001		
Education	0.121	0.011	0.507	11.328	<0.001		
Sex	-0.313	0.102	-0.137	-3.067	0.002		
DSB							
(Constant)	3.831	0.390		9.832	<0.001	0.27	$F_{(2.339)}$= 61.333; p<0.001
Age	-0.016	0.006	-0.131	-2.801	0.005		
Education	0.107	0.010	0.491	10.493	<0.001		
Sex							
Total DST							
(Constant)	9.866	0.683		14.449	<0.001	0.38	$F_{(3.339)}$= 69.092; p<0.001
Age	-0.043	0.010	-0.190	-4.396	<0.001		
Education	0.227	0.018	0.558	12.895	<0.001		
Sex	-0.421	0.168	-0.108	-2.503	0.013		

Total DST: Total score of the digit span test; SE: Standard error; DSF: Digit span forward; DSB: Digit span backward.

age × sex [$F_{(2,322)}$=0.391; p=0.677], education × sex [$F_{(2,322)}$=0.879; p=0.416], and age × education × sex [$F_{(4,322)}$=0.549; p=0.700] were not significant.

Significant main effects were found for age [$F_{(2,322)}$=4.009; p=0.019] and education [$F_{(2,322)}$=38.078; p<0.001] regarding the longest DSB scores. No main effect was found for the sex of individuals [$F_{(1,322)}$=1.105; p=0.294]. Further analyses revealed that individuals in the 70-83 age group had lower DSB scores compared to those in the 50-59 (p=0.014) and 60-69 (p=0.015) age groups. No significant difference was found between the 50-59 and 60-69 age groups (p=0.892). Significant differences were found among all education levels; individuals with higher education had higher DSB scores compared to those with low (p<0.001) and moderate (p<0.001) levels of education, and individuals with moderate education had higher DSB scores compared to those with low education (p<0.001). For the longest DSB scores, the interaction effects of age × education [$F_{(4,322)}$=0.080; p=0.988], age × sex [$F_{(2,322)}$=0.336; p=0.715], education × sex [$F_{(2,322)}$=0.248; p=0.780], and age x education × sex [$F_{(4,322)}$=0.127; p=0.972] were not significant.

Significant main effects of age [$F_{(2,322)}$=6.528; p=0.002], education [$F_{(2,322)}$=51.431; p<0.001], and sex [$F_{(1,322)}$=5.033; p=0.026] were found on the total DST scores obtained by summing the longest DSF and DSB scores. Further analyses revealed that the total DST scores of individuals in the 70-83 age group were significantly lower than those in the 50-59 (p=0.001) and 60-69 (p=0.011) age groups. No significant difference was found between the 50-59 and 60-69 age groups (p=0.295). Significant differences were found across all education levels; individuals with higher education had higher total DST scores than those with low (p<0.001) and moderate (p<0.001) education, and individuals with moderate education had higher total DST scores than those with low education (p<0.001). Additionally, it was found that males had significantly higher total DST scores than females (p=0.026). For total DST scores, the interaction effects of age × education [$F_{(4,322)}$=0.140; p=0.967], age × sex [$F_{(2,322)}$=0.015; p=0.985], education × sex [$F_{(2,322)}$=0.492; p=0.612], and age × sex × sex [$F_{(4,322)}$=0.257; p=0.905] were not significant.

Normative data

In the factorial ANOVA, significant main effects of age and education were found on the longest DSF and DSB scores and total DST scores. The normative values were stratified by education since further analyses revealed significant differences across all levels of education. Since no difference was found between the 50-59 and 60-69 age groups for any DST subscores, normative values were established by combining these two age groups into a single group for ages 50-69 and a separate group for ages 70-83. Furthermore, significant main effects of sex were found on the longest DSF and total DST scores, and accordingly, normative values for DSF, DSB, and total DST scores were stratified by sex.

Normative values for the longest DSF and DSB scores and total DST scores were reported as mean ± standard deviation; additionally, scores corresponding to the fifth and 95^{th} percentiles were shared to determine the lower and upper limits for each group (Tables 3-5).

Correlation between DST subscores and test-retest reliability

The correlation between DSF and DSB scores was 0.59 (p<0.001). The test-retest reliability coefficients were 0.83 (p<0.001) for DSF scores, 0.72 (p<0.001) for DSB scores, and 0.84 (p<0.001) for total DST scores.

DISCUSSION

It is known that the performance on neuropsychological tests can be influenced by demographic variables, and the level of this influence may vary among studied populations. This situation complicates the detection of cognitive disorders and necessitates the standardization of neuropsychological tests for different languages and cultures, particularly when assessing older individuals with different languages, cultures, and educational levels.

In this study, the effects of age, education, and sex on the longest (maximum) DSF and DSB scores of the DST, a test frequently used in neuropsychology practice in Türkiye, were determined, and normative values for the subscores of the test were established for males and females aged 50 to 83 years with low, moderate, and high levels of education. Digit span forward scores and total DST scores, obtained from the sum of DSF and DSB scores, were found to be influenced by age, education, and sex, while DSB scores were only affected by age and education. No interaction effects were observed between age, education, and sex variables for any subscores. In general, advanced age, lower levels of education, and being female were associated with lower DST performance.

TABLE 3
Normative values of the longest DSF scores

		Education level														
		Low (0-5 years)					Moderate (6-11 years)					High (>12 years)				
Age groups	Sex	n	Mean±SD	Median	5%	95%	n	Mean±SD	Median	5%	95%	n	Mean±SD	Median	5%	95%
50-69 years	Males	20	4.95±0.69	5.00	4.00	6.00	27	5.78±0.85	6.00	5.00	7.60	45	6.09±1.16	6.00	4.00	8.00
	Females	30	4.67±0.96	5.00	3.00	6.45	49	5.08±0.70	5.00	4.00	6.50	64	6.00±1.10	6.00	4.25	8.00
70-83 years	Males	10	4.80±0.79	5.00	4.00	6.00*	12	4.92±1.51	4.00	4.00	8.00*	25	5.88±1.13	6.00	4.00	8.00
	Females	19	4.32±0.75	4.00	3.00	5.80†	23	4.78±0.67	5.00	3.20	6.00	16	5.63±0.96	6.00	4.00	7.00†

DSF: Digit span forward; SD: Standard deviation; * Represents the score corresponding to the 90% of the group; † Represents the score corresponding to the 94% of the group.

TABLE 4
Normative values of the longest DSB scores

		Education level														
		Low (0-5 years)					Moderate (6-11 years)					High (>12 years)				
Age groups	Sex	n	Mean±SD	Median	5%	95%	n	Mean±SD	Median	5%	95%	n	Mean±SD	Median	5%	95%
50-69 years	Males	20	3.40±0.68	3.00	2.05	4.95	27	4.07±1.11	4.00	2.40	6.60	45	4.60±1.14	4.00	3.00	7.00
	Females	30	3.43±0.73	3.00	2.00	5.00	49	3.90±0.82	4.00	3.00	5.00	64	4.50±0.93	5.00	3.00	6.00
70-83 years	Males	10	3.10±0.74	3.00	2.00	4.00*	12	3.83±0.84	4.00	3.00	5.00*	25	4.32±0.85	4.00	3.00	6.00
	Females	19	3.00±0.82	3.00	2.00	4.80†	23	3.61±0.84	4.00	2.20	5.80	16	4.13±1.03	4.00	2.00	5.98†

DSB: Digit span backward; SD: Standard deviation; * Represents the score corresponding to the 90% of the group; † Represents the score corresponding to the 94% of the group.

TABLE 5
Normative values of the longest total DST scores

		Education level														
		Low (0-5 years)					Moderate (6-11 years)					High (>12 years)				
Age groups	Sex	n	Mean±SD	Median	5%	95%	n	Mean±SD	Median	5%	95%	n	Mean±SD	Median	5%	95%
50-69 years	Males	20	8.35±0.99	8.00	7.00	10.00	27	9.85±1.79	10.00	7.40	13.80	45	10.69±2.07	10.00	8.00	15.00
	Females	30	8.10±1.40	8.00	6.00	10.45	49	8.98±1.25	9.00	7.00	11.50	64	10.50±1.74	11.00	8.00	14.00
70-83 years	Males	10	7.90±1.10	8.00	6.00	9.90*	12	8.75±2.18	8.00	7.00	13.00*	25	10.20±1.76	10.00	7.30	14.00
	Females	19	7.32±1.20	7.00	6.00	9.80†	23	8.39±1.31	8.00	6.20	11.60	16	9.75±1.53	9.50	7.00	12.00†

Total DST: Total score of the digit span test; SD: Standard deviation; * Represents the score corresponding to the 90% of the group; † Represents the score corresponding to the 94% of the group.

In the current study, individuals aged 70 and over had significantly lower DST scores compared to those in the 50-69 age range. The decline in DST performance with advancing age has been demonstrated in many studies.[8,13-15,20-22] A previous study that included both young and old individuals in the sample demonstrated larger age effects;[15] however, in studies examining only older individuals, as in the present study, smaller age effects were found,[21] or no age effect was observed.[16,17,28,29] Baddeley[30] suggested that success in a span test such as the DST did not initially require a high degree of manipulation and was instead determined more by memory capacity. However, as the task becomes more complex, in other words, as the number of digits repeated increases, the workload on working memory increases, making it more difficult to complete the task successfully.[30] With advancing age, it has been shown that working memory capacity decreases and that focused attention is required more during encoding.[31] The negative impact of advancing age on DST performance has been demonstrated to become apparent after the age of 55 in one study[22] and after the age of 65 in another study.[20] For the Turkish population, the deterioration in DST performance becomes evident after the age of 70. In the current study, similar age effects were found for both DSF and DSB scores.

This study detected that DSF and DSB scores and total DST scores were significantly affected by the level of education. When examining regression findings, education emerged as the strongest predictor of DST performance, with years of education alone explaining 25 to 34% of the variance in DST subscores. Furthermore, DST scores differed among individuals with low, moderate, and high levels of education, and DST performance improved as the level of education increased. These findings are consistent with previous studies in the literature.[13-17,20-22,28,29] The positive effect of education on cognitive functions is explained by the cognitive reserve theory,[32] which suggests that higher education makes cognitive functions more resilient against advanced age and pathologies. A previous study also demonstrated that higher education improved executive functions.[33]

In the current study, males had significantly higher DSF and total DST scores than females. The impact of sex on DSF and DSB scores is controversial in the literature. Many studies did not examine the effect of sex.[13,16,17,28] In some studies, no effect of sex on DST performance was detected,[15,22,29] while other studies found minimal but significant sex effects either on both DSF and DSB scores or only on DSB scores.[14,20,21] Peña-Casanova et al.[14] reported a minimal (2-3%) effect of sex on DST performance and did not include sex in further analyses. In the study by Gregoire and Van der Linden,[20] males performed better on the DSB than females, while in the study by Choi et al.,[21] males showed higher performance than females in both DSF and DSB. Moreover, Choi et al.'s[21] study found an interaction effect between education and sex on DSB scores, indicating that DSB scores of females decreased more compared to males as the level of education decreased. The inconsistencies in findings on sex in the literature are explained by differences in sample size and population characteristics among studies.[21] In the current study, no interaction effect between sex and age or education level was detected. Therefore, the superior performance of males in the DSF compared to females cannot be explained by higher education.

In this study, a strong relationship was found between DSF and DSB scores. Similarly, in normative samples including healthy individuals, moderate- to high-level correlations between the two subtests have been reported.[10,22,34,35] A latent variable modeling study reported a moderate correlation between short-term memory capacity and working memory capacity.[4] Consequently, it is expected that variables affecting DSF performance in individuals with preserved cognitive functions would also affect DSB scores to some extent. However, as the two subtests measure different cognitive skills, evaluating and reporting DST performance solely based on total DST scores is problematic.[7] When considering total DST scores alone, it is not possible to discern whether attention or working memory skills are preserved or impaired. For example, a person with a total DST score of 10 could have a DSF of 5, 6, or 7, while their DSB score could be 5, 4, or 3. Furthermore, DSF and DSB scores are reported to be affected differently by brain damage.[6] Therefore, reporting only the total DST scores can lead to loss of information compared to separately evaluating the DSF and DSB scores.[7]

The normal range for the DSF is considered to be 6±1.[36] Kaplan et al.[6] reported that 89% of their participants had a DSF range of 5 to 8. The normal range for the DSB is considered to be 4-5, with a score of 3 potentially considered borderline impairment depending on the individual's educational background, and a score of 2 indicating impaired performance for everyone.[7] In addition, it was reported that these scores typically decrease by 1 point after the age of 70.[7] In general, a difference of approximately 1 point (0.59-2 points) in favor of the DSF between an individual's longest DSF and DSB scores is considered normal.[6,14] In the present study, the mean DSF score was 5.41±1.12, with a range of 3 to 8, while the mean DSB was 3.99±1.03, with a range of 2 to 7. Of the participants, 80.9 had a longest DSF between 5 and 8, whereas 65.3% had a longest DSB between 4 and 7.

This study determined that DSF and DSB scores and total DST scores had high test-retest reliability. This finding is consistent with the high test-retest reliability reported for the DST within the WAIS-IV (r=0.83).[10] Despite the test-retest interval being two to 12 weeks in the WAIS-IV study and 12 months in the current study, similar reliability coefficients were obtained.

One of the strengths of the current study was that the sample for which the DST normative values were determined was verified to be cognitively healthy.[23,24] Individuals over the age of 65 are at risk for neuropsychiatric disorders, such as dementia, vascular disorders, and depression. The individuals included in the study were those without factors that could affect cognitive functions.

In conclusion, the DST is a commonly used, brief, and easily administered test for evaluating attention, verbal short-term memory, and working memory. Being one of the few neuropsychological tests that can also be administered to illiterate individuals enhances the utility of the DST. In this study, stratified normative values for the longest (maximum) DSF and DSB scores, commonly used and reported in the application of DST in Türkiye, were established for individuals aged 50 to 83 years and made available to clinicians and researchers. Consistent with international normative studies, years of education were found to be the strongest predictor of DST performance. The negative impact of advancing age on DST scores was observed to become pronounced after the age of 70. Furthermore, males performed better than females in the DSF. The findings of the study are expected to improve the clinical evaluation and interpretation of DST performance in individuals over 50 who are at risk for cognitive decline and neuropsychiatric disorders in our country.

Ethics Committee Approval: The study protocol was approved by the Dokuz Eylül University Ethics Committee (date: 20.02.2019, no: 2019/04-24). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each participant.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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