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Research Article

9-Hole Peg Test in Brachial Plexus Birth Injury: What May It Mean from Total Palsy to Upper Trunk Injuries?

Doğumsal Brakiyal Pleksus Yaralanmasında 9-Delikli Peg Testi: Total Palsiden Üst Trunkus Yaralanmalarına Kadar Ne Anlama Gelebilir?

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ABSTRACT

Purpose: The aim of our study is to investigate the relationship of the 9-hole-peg test with self-care activities and motor function in brachial plexus birth injury with different injury types. **Material and Methods:** The study included 91 children aged 5-16 years, 18 had total brachial plexus injury and 73 had upper trunk injury. All children were assessed with the 9-hole-peg test, active movement scale (AMS) and Wee-FIM self-care section. The relationship between 9-hole-peg test, AMS and Wee-FIM scores were examined by calculating Spearman correlation coefficient. **Results:** In 73 children with upper trunk injury, there was a strong negative correlation between the 9-hole-peg test and self-care activities ($p<0.01$, $r=-0.73$), and a moderate negative correlation between the 9-hole-peg test and total upper limb function ($p<0.01$, $r=-0.68$). There was a moderate negative correlation between all 15 joint movements assessed AMS and the 9-hole peg test ($p<0.01$, $-0.59<r<-0.37$), moreover the highest correlation was with shoulder, finger and thumb movements. Many children with total brachial plexus injury were unable to complete the 9-hole-peg test**. Conclusion:** The performance of children with upper trunk injuries on the 9-hole peg test may reflect performance in self-care activities and overall function of the upper limb, but this test may not be appropriate for children with total brachial plexus injuries based on active finger and wrist movements.

Keywords: Brachial Plexus; Birth Injuries; Outcome Assessment; Self-Care.

ÖZ

Amaç: Çalışmamızın amacı, farklı yaralanma tiplerine sahip doğumsal brakiyal pleksus yaralanmalarında 9-delikli peg testinin öz bakım aktiviteleri ve motor fonksiyon ile ilişkisini araştırmaktır**. Gereç ve Yöntem:** Çalışmaya, yaşları 5-16 arasında değişen, 18'inde total brakiyal pleksus ve 73'ünde üst trunkus hasarı olan 91 çocuk dahil edilmiştir. Tüm çocuklar 9-delikli peg testi, aktif hareket ölçeği ve Wee-FIM öz bakım bölümü ile değerlendirilmiştir. 9-delikli peg testi, aktif hareket ölçeği ve Wee-FIM skorları arasındaki ilişki Spearman korelasyon katsayısı hesaplanarak incelenmiştir. **Sonuçlar:** Üst trunkus yaralanması olan 73 çocukta, 9-delikli peg testi ile öz bakım aktiviteleri skoru arasında güçlü bir negatif korelasyon ($p<0.01$, $r=-0.73$) ve toplam üst ekstremite fonksiyonu ile orta düzeyde negatif korelasyon ($p<0.01$, $r=-0.68$) vardı. Aktif hareket ölçeği ile değerlendirilen 15 eklem hareketi ile 9-delikli peg testi arasında orta derecede negatif korelasyon vardır ($p<0.01$,$-0.59<r<-0.37$), bununla birlikte en yüksek korelasyon omuz, parmak ve başparmak hareketlerinde mevcuttur. Total brakiyal pleksus hasarı olan birçok çocuk 9-delikli peg testini tamamlayamadı. **Tartışma:** Üst trunkus yaralanmalarında, 9-delikli peg testi sonucu öz bakım aktiviteleri ve üst ekstremitenin toplam fonksiyonunu yansıtabilir, ancak bu test total pleksus yaralanması olan çocuklarda aktif el bileği ve parmak hareketlerine bağlı olarak uygun olmayabilir.

Anahtar Kelimeler: Brakial Pleksus; Doğum Yaralanmaları; Sonuç Değerlendirmesi; Özbakım.

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Brachial plexus birth injury (BPBI) is a multiple peripheral nervous injury resulting from injury to the brachial plexus during delivery. The incidence of BBPI is 0.42-5.1 per 1000 live births (Andersen, Watt, Olson et al., 2006). The extent of the damage can vary from single nerve root to total BP lesions, and this has an impact on the functional capacity of the affected upper extremity. Depending on the severity of the injury, a broad spectrum of disorders may occur, ranging from temporary functional restrictions to lifelong disabilities (Leblebicioğlu and Pondaag, 2024; van Dijk, Pondaag and Malessy, 2001).

BPBI is frequently classified anatomically according to the injured nerve roots or based on the active movements of the affected arm. Depending on the injured nerve roots, BPBI is mainly categorized into two main groups which are upper trunk injuries (C5, C6 with or without C7) (accounting for approximately 80% of all BPBI) and total plexus injuries (Al-Qattan, 2003; Hale, Bae and Waters, 2010).

The nerve damage leads to disorders in body structures and functions such weakness in the muscles, instability or contractures in the joints, structural changes in the musculoskeletal system and sensory deficiencies (Brown, Wernimont, Phillips et al., 2016; Delioğlu, Uzumcugil and Gunel, 2022; Hale et al., 2010). At the same time, various degrees of activity and participation limitations also occur (Delioglu, Üzümcügil, Öztürk et al., 2021). With increasing age, difficulties in self-care activities that are used in daily life become more evident (Partridge and Edwards, 2004).

Activities of daily living assessments and various hand function tests are commonly used as functional outcome measures to assess performance in BPBI (Chang, Justice, Chung et al., 2013). The 9-hole peg test has been reported as one of the most frequently used functional outcome measures to assess performance in BPBI in treatment management (Chang et al., 2013). Despite its frequent use in clinical practice and research (Chang et al., 2013), the 9-hole peg test was not recommended for use in the international Delphi study that is related assessment of the BPBI (Pondaag and Malessy, 2018). Even if such an international recommendation exists, it is not explained why this test should not be used (Pondaag and Malessy, 2018). Additionally, what this test may mean in BPBI and for what purpose it can be used have not been investigated in detail.

The aim of our study is to investigate and detail the relationship of the 9-hole peg test with self-care activities and motor function in BPBI with different injury types.

MATERIAL AND METHODS

This cross-sectional study was conducted in Hacettepe University between June 2023 and November 2023 and was approved by Hacettepe University Non-Interventional Clinical Research Ethics Board (GO 23/132). The families were informed about the study and those willing to participate signed written consent forms.

The medical records of all patients undergoing routine follow-up at our hospital were examined by their therapist, who is the first author of the study. Inclusion criteria were determined as children with BPBI between the ages of 5 and 16, since the 9-hole peg test is applied in children older than 4 years. Exclusion criteria from the study were having any orthopedic, neurological or systemic disease other than BPBI and having undergone surgery and/or botulinum toxin injection in the last 6 months.

Participants

During the study period, 103 children and their families applied for routine physiotherapy and rehabilitation follow-ups. Twelve children were not included in the study because they had undergone surgical treatment in the last 6 months. Of the 91 children included in the study, 18 (19.8%) had total brachial plexus injury and 73 (80.2%) had upper trunk brachial plexus injuries.

All children enrolled in the study have received regular physiotherapy and home programs since birth. All children receive regular physiotherapy 2 days per week and home programs that are specifically designed for each child and are updated every 2 months during routine evaluations; it is also recommended that each child receive at least one home program per day. The physiotherapy and home programs are organized by the authors of the study.

The children who participated in the study had no history of surgery within the last 6 months. Of the 18 children with total plexus injury, 10 (55%) had a history of reconstructive neurosurgery within one year of birth, while 17 (23.2%) of the 73 patients with upper trunk injury had a history of reconstructive neurosurgery within one year of birth. Forty-two percent (46.1%) of all children had a history of secondary musculoskeletal surgery for various purposes.

Data Collection Tools

9-Hole Peg Test: The nine-hole peg test (NHP), a hand performance test commonly used in pediatric patients, was used as a functional outcome measure (Chang et al., 2013). This test consists of nine pegs 9 mm wide and 32 mm long. There is a platform with standard 9-10 mm holes spaced 32 mm apart. The time taken for the subject to insert and remove all the pegs from the holes in the platform is recorded (Poole, Burtner, Torres et al., 2005). Both tests are repeated three times and the mean values are used (Aktaş, Eren, Keniş-Coşkun et al., 2018). In our

study, the 9-hole peg test was applied to the affected side only and the total time to insert and remove the pegs was used for statistical analysis.

Wee-FIM: Self-care activities within activities of daily living in children with BPBI were assessed using the Turkish version of the Wee-Functional Independence Measure (Wee-FIM) scale (Aybay, Erkin, Elhan et al., 2007). The Wee-FIM scale consists of 18 items that assess the level of independence under the subheadings of self-care, sphincter control, mobility, movement, communication and social integration. Each item of the Wee-FIM has a score ranging from 1 to 7 points, with a total score ranging from 18 to 126 points (18-36: completely dependent, 37-90: needs supervision and assistance to perform activities, 90-126: completely independent). For this study, self-care activities such as eating, grooming, bathing, dressing upper extremities, dressing lower extremities and toileting were assessed. 6 Self-care activities were scored between 6-42 points, with 42 points indicating that all self-care activities could be performed completely without assistance (or independently) (Aybay et al., 2007; Ottenbacher, Msall, Lyon et al., 2000; Öksüz, Alemdaroglu, Kilinç et al., 2017).

The Active Movement Scale (AMS): The AMS developed specifically for BPBI and is a standardized evaluation of AROM of 15 movements in the affected side using an eight-point scale. It has established psychometric properties in this population (Curtis, Stephens, Clarke et al., 2002). The 15 AMS movements include: shoulder (abduction, adduction, flexion, external rotation, and internal rotation), elbow (flexion and extension), forearm (pronation and supination), wrist (flexion and extension), finger (flexion and extension), and thumb (flexion and extension). For each movement, the range of 0-4 points is evaluated in gravity eliminated position, while the range of 5-7 represents movement against gravity. A score of 0 indicates no contraction, while a score of 7 indicates full motion against gravity. AMS-Total score is the sum of the scores of 15 movements and represents the total function of the affected upper extremity. AMS-Total score has been used as the gold standard in similar studies and has been recommended for use (Duff and DeMatteo, 2015; Ho, Curtis and Clarke, 2012; Zuo, Ho, Hopyan et al., 2023).

Procedure

An experienced pediatric and hand physiotherapist (KD, 1st researcher) informed the children's parents about the Wee-FIM survey and accompanied them in answering the survey. At the same time, KD explained the 9-hole peg test to the children and recorded the results of this test. The AMS were performed by experienced pediatric and hand physiotherapists (KD, 1st researcher; TF, 2nd researcher). Sociodemographic data of the children and parents were obtained from hospital records and during the interviews.

Data Analysis

Statistical analyses were performed using IBM SPSS version 23.0 (IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp). The assumption of the normal distribution of variables was examined using the Shapiro-Wilk test and histograms, boxplots, and Q-Q plot. At the same time, the descriptive statistics of the continuous data were given as mean and standard deviation for normally distributed variables, median Quartile 1-Quartile 3 for non-normally distributed variables, and frequencies and percentages for categorical data. The relationship between 9-hole peg test, AMS total score, AMS score of the 15 different joint movements and Wee-FIM self-care activities score was examined by calculating Spearman correlation coefficient (Hayran and Hayran, 2011). The strength of the correlation coefficient was interpreted as follows: 0.00-0.10 negligible correlation, 0.10-0.39 weak correlation, 0.40-0.69 moderate correlation, 0.70-0.89 strong correlation, 0.90-1.00 very strong correlation. Statistical significance was set as $p<.05$ (Mukaka, 2012; Schober, Boer and Schwarte, 2018).

RESULTS

The mean age of the all children participating in the study was 7.9±2.2 years, 48.4% (n=44) were female and 51.6% (n=47) male, 33.0% (n=30) had left and 67% (n=61) had right limb involvement. There was no difference between the ages of the two main groups of the study (p=0.85), children with total plexus injury and children with upper plexus injury. The demographic data of the children are given in Table 1.

Of the 18 patients with total brachial plexus injury, 14 were unable to complete peg insertion and 11 were unable to complete peg removal. Therefore, the median, minimum and maximum values of the overall outcome of peg insertion and removal in children with total brachial plexus injury were not calculated. The results of the AMS assessment of 15 joint movements, total AMS scores, and Wee-FIM self-care section scores for children with both upper trunk and total brachial plexus injuries are shown in Table 2.

Table 1. Demographic data of the children.

Characteristics		
Age (Years)	**Mean ± SD**	**Range**
Age of all children (n=91)	7.9±2.2	6-15
Age of children with total plexus injury (n=18)	8.0±2.3	6-13
Age of children with upper trunk injury (n=73)	7.9±2.1	6-15

Type of Injury	**Frequency**	**Percent**
Children with total plexus injury	18	19.7
Children with upper trunk injury	73	80.3

Gender of children	**Frequency**	**Percent**
All children – Girl (n=91)	44	48.4
All children – Boy (n=91)	47	51.6
Children with total plexus injury – Girl (n=18)	8	44.4
Children with total plexus injury – Boy (n=18)	10	55.6
Children with upper trunk injury – Girl (n=73)	36	49.3
Children with upper trunk injury – Boy (n=73)	37	50.7

Affected Side	**Frequency**	**Percent**
All children – Right (n=91)	61	67.0
All children – Left (n=91)	30	33.0
Children with total plexus injury – Right (n=18)	13	72.2
Children with total plexus injury – Left (n=18)	5	27.8
Children with upper trunk injury – Right (n=73)	48	65.8
Children with upper trunk injury – Left (n=73)	25	34.2

Table 2. Functional outcomes according to injury types.

	Upper Trunk Injuries n=73			**Total Plexus Injuries n=18**		
	M[25-75]	Min	Max	M[25-75]	Min	Max
Shoulder Abduction-AMS	5[3-6]	2	7	2[2-3]	2	3
Shoulder Flexion-AMS	6[3-6]	3	7	2.5[2-3]	2	3
Shoulder Adduction-AMS	6[5-6]	3	7	3[2-3]	2	5
Shoulder Ext. Rot.-AMS	5[3-6]	1	7	2[1-2]	1	2
Shoulder Int. Rot.-AMS	5[3-6]	1	7	3[2-3]	1	5
Elbow Flexion-AMS	6[6-7]	3	7	3[3-5]	2	5
Elbow Extension-AMS	6[6-7]	3	7	3[2-5]	1	6
Supination-AMS	5[3-6]	2	6	2[2-3.5]	1	6
Pronation-AMS	6[6-6]	2	7	2.5[2-6]	1	6
Wrist Flexion-AMS	6[6-7]	2	7	3[1-5]	1	6

Continue (Table 2).

Wrist Extension-AMS	6[6-6]	2	7	1.5[1-2]	0	3
Finger Flexion-AMS	6[6-7]	3	7	2[2-3]	1	5
Finger Extension-AMS	6[6-6.5]	3	7	2[1-2]	0	3
Thumb Flexion-AMS	6[6-7]	3	7	2[1-3]	1	5
Thumb Extension-AMS	6[5-6]	2	7	1.5[1-2]	0	3
AMS Total Score	85[74-93.5]	54	101	37.5[30-46]	25	51
Wee-FIM	37[34-41]	28	42	27[24-29]	16	33
9-hole-Peg Insertion Time (sec)	21[15-29]	8	193	-	-	-
9-hole-Peg Removal Time (sec)	9[8-13]	5	28	-	-	-
9-hole-Peg Total Time (sec)	32[23-41]	15	211	-	-	-

Since 14 children with total brachial plexus injury were unable to complete the 9-hole peg test, relationship analyses were performed only on the data from children with upper trunk injury (n=73). There was a strong negative correlation between 9-hole Peg Test total time and AMS total score (p<0.01, r=-0.68). In addition, there was a moderate negative correlation between AMS scores and total 9-hole peg test time (p<0.01, -0.59<r<-0.42), whereas a weak negative correlation was found with elbow extension movement (p<0.01, r=-0.37). Table 3 shows the correlation analyses in detail.

Table 3. Relationships between all movement scores that evaluated with the AMS and 9-hole peg test results.

		9-hole Peg Test Total Time	
		p	**r**
Active Movement Scale	Shoulder Abduction	<0.01	- 0.53
	Shoulder Flexion	<0.01	- 0.59
	Shoulder Adduction	<0.01	- 0.57
	Shoulder Ext. Rotation	<0.01	- 0.51
	Shoulder Int. Rotation	<0.01	- 0.44
	Elbow Flexion	<0.01	- 0.44
	Elbow Extension	<0.01	- 0.37
	Supination	<0.01	- 0.47
	Pronation	<0.01	- 0.45
	Wrist Flexion	<0.01	- 0.43
	Wrist Extension	<0.01	- 0.42
	Finger Flexion	<0.01	- 0.51
	Finger Extension	<0.01	- 0.47
	Thumb Flexion	<0.01	- 0.52
	Thumb Extension	<0.01	- 0.57
	Total Score	<0.01	- 0.68

Ext.: External, Int.: Internal, r: Spearman correlation coefficient. p: Statistical significance was set as p<.05.

The relationship between 9-hole peg test total time, AMS total score and Wee-FIM self-care activities total score was also examined. While there was a strong positive correlation between AMS Total Score and Wee-FIM self-care activities (p<0.01, r=0.83), there was a moderate negative correlation between AMS Total Score and 9-hole peg test (p<0.01, r=-0.68). Also, there was a strong negative correlation between -hole peg test and Wee-FIM self-care activities (p<0.01, r=-0.73) Table 4 shows the correlation analyses in detail.

Table 4. Relationships between Active Movement Scale, Wee-FIM and 9-hole peg test results.

	AMS Total Score		Wee-FIM		9-hole Peg Test Total Time	
	p	**r**	**p**	**r**	**p**	**r**
AMS Total Score	-	1.00	<0.01	0.83	<0.01	- 0.68
Wee-FIM Self-Care Activities	<0.01	0.83	-	1	<0.01	- 0.73
9-hole-Peg Total Time (sec)	<0.01	- 0.68	<0.01	- 0.73	-	1.00

AMS: Active Movement Scale, sec: second, r: Spearman correlation coefficient, p: Statistical significance was set as p<.05.

DISCUSSION

The relationships between the 9-hole peg test scores of children with upper trunk injuries and the AMS scores of 15 active joint movements showed that this test is more related to shoulder movements, finger flexion, thumb flexion and extension. These results showed that the 9-hole peg is dependent on the function of shoulder and finger movements in terms of active joint movements or muscle strength. In upper trunk injuries, the moderate to strong correlation between AMS-Total Score, Wee-FIM self-care activities scores and 9-hole peg test results revealed that the 9-hole peg test can easily provide information about overall upper extremity function and independence in self-care activities. However, as many children with total plexus injuries were unable to perform the insertion, removal or both stages of the 9-hole peg test, detailed research could only be carried out using results from children with upper trunk injuries. Although this may appear to be a limitation of the study, it is actually a limitation of the 9-hole peg test, and these results show that this test is not suitable for children with total brachial plexus injury.

The 9-hole peg test has been used in BPBI to investigate sensorimotor function (Brown et al., 2016), to assess hand function on the unaffected side (Aktaş et al., 2018), to evaluate isolated hand function in upper trunk injuries (Immerman, Alfonso, Ramos et al., 2012), to investigate daily function and disability in young adults (de Heer, Beckerman and Groot, 2015), and in scientific studies to investigate the effectiveness of various treatments (Buesch, Schlaepfer, de Bruin et al., 2010; Chang et al., 2013). Despite this widespread use, the 9-hole peg test was not recommended for use in the international Delphi study that is related assessment of the BPBI (Pondaag and Malessy, 2018). The results of our study showed that it is not appropriate to use the 9-hole peg test in children with total plexus injury, similar to the international consensus. The reason for this is that the test could not be performed due to deficiencies in active grasping, releasing, pronation and thumb movements, as revealed in previous studies (Delioğlu et al, 2022). However, since the 9-hole peg test is easy to use in children with upper trunk injury, it can provide information about factors that are more difficult to measure, such as self-care activities.

In previous research, the 9-hole peg test has often been used to assess children with upper trunk injuries (Immerman et al., 2012). Similarly, our study found that 9-hole peg test scores had a moderate to strong relationship with overall upper extremity function and independence in self-care activities. These results show that the 9-hole peg test, which is easy to use in the clinic, may be useful in the clinical assessment of children with upper limb impairments.

Another important finding of our research is that the 9-hole peg test results in children with upper trunk injury have different levels of relationship with shoulder, elbow, hand and finger movements. It shows that the results of the 9-hole peg test can be affected by shoulder movements, finger flexion and thumb movements, or that the test result provides information about the performance of these movements. There are studies showing that not only shoulder or elbow functions but also hand function may be affected in upper trunk injury (Delioğlu et al., 2022; Immerman et al., 2012). The results of our study showed that thumb and finger functions also affect manual dexterity in children with upper trunk injury.

A limitation of the study is that the 9-hole-peg test was only investigated in its relationship with AMS and Wee-FIM. Hand performance may be affected by various factors, such as reaction time, muscle strength, proprioception in the hand or fingers, so the relationship between hand performance tests and proprioception or reaction time should be investigated in future studies. Although the small sample of patients with total palsy seems to be a limitation of the study, the number of participants is not inadequate, as only 4–19% of all BPBI patients have total injury (Strömbeck, Krumlinde-Sundholm, Remahl et al., 2007). The results of our study showed that the 9-hole peg test cannot be used in all cases depending on finger and wrist

movements in children with total plexus injury, so it would be useful to develop new hand or upper extremity performance tests for this area in future research.

In light of the results of our study, the 9-hole peg test is not an appropriate outcome measure or hand performance test that can be used in all cases in children with total brachial plexus injuries, depending on the isolated finger and wrist. In children with upper plexus injuries, the fact that the relationship between the 9-hole peg test and some joint movements that are shoulder, finger and thumb have the highest correlation coefficient indicates that this test may be most affected by the performance of these joint movements. The fact that the 9-hole-peg test was found to be strongly related to self-care activities showed that this test, which can be easily applied in the clinic, can also provide information about self-care activities. In conclusion, we think that the 9-hole-peg test can be used to obtain an idea about self-care activities and total function of the upper extremity in children with upper trunk injuries.

Ethical Approval

This study was approved by Hacettepe University Non-Interventional Clinical Research Ethics Board (GO 23/132).

Authors' Contribution

KD took part in data collection, data analysis and writing of the article. TF took part in the data collection and final editing of the article.

Conflicts of Interest Statement

The authors declare that they have no potential conflicts of interest.

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