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VALIDITY AND RELIABILITY OF THE 6-MINUTE PEGBOARD RING TEST IN PATIENTS WITH PULMONARY HYPERTENSION

ORIGINAL ARTICLE

ABSTRACT

Purpose: Patients with pulmonary hypertension (PH) may have limitations in the upper extremity function. This study aimed to investigate the validity and reliability of the 6-minute pegboard ring test (6PBRT) in patients with pulmonary hypertension PH.

Methods: This study included 31 patients with PH. The upper extremity function was measured using the 6PBRT. Muscle strength was assessed for shoulder flexor, shoulder abductor, elbow extensor, and elbow flexors muscles using with a digital dynamometer, and handgrip strength using the hand dynamometer. Limitation of the activities of daily living was evaluated using the Milliken Activities of Daily Living Scale. The intra-class correlation coefficient (ICC) was used to determine test-retest reliability.

Results: The 6PBRT showed excellent test-retest reliability with the ICC=0.98 (95% CI 0.82–0.99). The standard error of measurement (SEM) and minimal detectable change (MDC) was calculated as 5.9 and 16.4, respectively. The patients with New York Heart Association (NYHA) Class III had significantly lower scores in the 6PBRT compared to the patients with Class II showing the known-groups validity of the 6PBRT (p=0.005). The 6PBRT was significantly and strongly correlated with age (r=-0.628, p<0.001), functional class (r=-0.502, p=0.004), activities of daily living (r=0.522, p=0.003), moderately correlated with dominant side shoulder flexor (r=0.360, p=0.047), shoulder abductor (r=0.388, p=0.031), elbow flexor (r=0.406, p=0.036) and handgrip muscles strength (r=0.375, p=0.041).

Conclusion: This study showed that 6PBRT has excellent test-retest reliability and good validity, including known-groups and convergent in PH. These results support the use of 6PBRT as a practical upper extremity performance assessment tool in patients with PH.

Key Words: Exercise Test; Patient Outcome Assessment; Pulmonary Hypertension; Upper Extremity.

PULMONER HİPERTANSİYONLU HASTALARDA 6-DAKİKA PEGBOARD RİNG TESTİNİN GEÇERLİĞİ VE GÜVENİRLİĞİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Pulmoner hipertansiyonu (PH) olan hastalarda üst ekstremite fonksiyon limitasyonları görülebilmektedir. Bu çalışmanın amacı pulmoner hipertansiyonlu (PH) hastalarda 6-dakika pegboard ring testinin (6PBRT) geçerlik ve güvenirliğinin araştırılmasıydı.

Yöntem: Bu çalışmaya 31 PH hastası dahil edildi. Üst ekstremite fonksiyonu 6PBRT ile ölçüldü. Kas kuvveti için dijital dinamometre ile omuz fleksor, omuz abduktor, dirsek ekstansor ve dirsek fleksor kasları ve el dinamometresi ile kavrama kuvveti ölçüldü. Günlük yaşam aktivitelerinin limitasyonu Milliken Günlük Yaşam Aktiviteleri Ölçeği ile değerlendirildi. Test-tekrar test güvenirliğini belirlemek için sınıf içi korelasyon katsayısı (ICC) kullanıldı.

Sonuçlar: 6PBRT için ICC değeri 0,98 (% 95 CI 0,82-0,99) bulundu. Ölçümün standart hatası (SEM) ve tespit edilebilir minimal değişim (MDC) değerleri sırasıyla 5,9 ve 16,4 olarak hesaplandı. Bilinen grupların geçerliği yönünden "New York Heart Association (NYHA)" Sınıf III olan hastalar 6PBRT'de Sınıf II hastalara göre anlamlı derecede düşük skorlara sahipti (p=0,005). 6PBRT, yaş (r=-0,628, p<0,001), fonksiyonel sınıf (r=-0,502, p=0,004), günlük yaşam aktiviteleri (r=0,522, p=0,003) ile güçlü düzeyde, dominant taraf omuz fleksor (r=0,360, p=0,047), omuz abduktor (r=0,388, p=0,031) ile dirsek fleksor (r=0,406, p=0,036) kaslarının kuvveti ve kavrama kuvveti (r=0,375, p=0,041) ile anlamlı ve orta düzeyde korelasyon gösterdi.

Tartışma: Bu çalışma PH'da 6PBRT'nin mükemmel bir test-tekrar test güvenirliğine ve iyi düzeyde bilinen gruplar ve yakınsak geçerliğine sahip olduğunu göstermiştir. Bu sonuçlar üst ekstremite performansının değerlendirilmesinde 6PBRT'nin pratik bir değerlendirme aracı olduğunu desteklemektedir.

Anahtar Kelimeler: Egzersiz Testi; Hasta Sonuç Değerlendirmesi; Pulmoner Hipertansiyon; Üst Ekstremite.

INTRODUCTION

Pulmonary hypertension (PH) is defined as the pulmonary artery pressure measured by right heart catheterization equal to or greater than 25 mmHg (1). The PH is a pathophysiological, life-shortening disease that involves multiple conditions such as pulmonary arterial hypertension and chronic thromboembolic pulmonary hypertension (2).

Many symptoms, such as skeletal muscle weakness, dyspnoea, and fatigue, cause exercise intolerance and reduced exercise capacity in patients with PH (3,4). Therefore, the assessment of exercise intolerance has a vital role in the management of PH. Traditionally, the lower extremity-related tests (i.e., six-minute walk test [6MWT] and cardiopulmonary exercise test [CPET] using a treadmill or bicycle) have been commonly used in patients with PH (5). However, in recent years, some studies have suggested that patients with PH also have limitations in the upper extremity function (6,7). Many activities of daily living, such as eating, dressing, hygiene, and vocational tasks, are impaired (8,9). This activity limitation is related to many activities of daily living involving unsupported upper extremity movements, which lead to dyspnoea and fatigue in patients with the cardiopulmonary disease (10). Therefore, determination of strength, endurance, and exercise capacity of the upper extremities emerge as an essential issue in the management of PH. One of the tests serving this purpose is the six-minute pegboard and ring test (6PBRT), which has been found as valid and reliable in patients with chronic obstructive pulmonary disease (COPD) (11-13). As the 6PBRT has been frequently used in the clinical and research practice of the patients with PH, it is essential to know its validity and reliability (7,14). This study aimed to investigate the validity and reliability of the 6PBRT in patients with PH.

METHODS

Participants

Thirty-one patients with PH diagnosed according to the current guidelines (15) from the PH Outpatient Clinic, the Department of Cardiology, Dokuz Eylül Hospital were recruited to this study from November 2017 to July 2019. The inclusion criteria included the New York Heart Association (NYHA) functional class II and III, aged older than 18 years, undergoing a right heart catheterization and being diagnosed with PH, and receiving drug therapy for the last three months. Patients with restrictive or obstructive pulmonary disease or orthopedic disease, which would affect exercise tests, were not included in the study. Non-Interventional Research Ethics Committee of Dokuz Eylül University approved the study (Approval Date: 12.10.2017 and Approval Number: 2017/24-29). Informed consent was obtained from all the participants before entering the study.

A study showed significant correlations between the 6PBRT and age, handgrip strength, and shoulder flexor muscle strength in the patient with COPD (16). Another study showed that the 6PBRT had a very high test-retest reliability in patients with COPD (11). The sample size calculations ranged from 4 to 7 participants for a study power of 0.80 and alpha error probability of 0.05 using the G*Power (Ver. 3.1.9.4, Dusseldorf University, Germany) considering high correlation coefficients (17). As the pre-computed sample size tables for reliability studies suggested that 27 participants were enough and the validity and reliability study of the 6PBRT in the patients with COPD included 27 participants, we decided to recruit at least 27 participants (11,18). Post-hoc power analysis was conducted using the test-retest reliability results (ICC=0.98, $p<0.001$, n=31) with using the G*Power (Ver. 3.1.9.4, Dusseldorf University, Germany) and posthoc study power was calculated as >0.99 which indicated that the sample size was adequate (17).

Measures

Demographic and clinical characteristics of the patients with PH were collected using interviews and from last month's medical records except for pulmonary arterial pressure which was taken from last catheterization results. Because as an invasive assessment, catheterization did not repeat for the study.

Six-Minute Pegboard and Ring Test

The 6PBRT was performed using a pegboard with two upper and lower pegs set at participants'

shoulder level and above the shoulder level (20 cm) (11). During the test, the participants moved 10 lightweight wooden rings each of the lower pegs to the upper pegs using both hands simultaneously. Then, they moved the rings back from the upper pegs to the lower pegs. This activity continued for six minutes. The aim was to move as many rings as possible during the six minutes. The score was reported as the number of rings that were simultaneously moved. In every minute, the standardized verbal encouragement was given to the participants. Heart rate, blood pressure, scores for the sensation of dyspnoea and upper extremity fatigue (modified Borg scale 0-10) were measured before and immediately after each test. The photograph of the equipment used in the 6PBRT is available in another study (7).

Muscle Strength

Muscle strength was measured for shoulder flexor, shoulder abductor, elbow extensor, and elbow flexors muscles using a digital dynamometer (Manual Muscle Tester™, Lafayette Instrument Company, Lafayette, Indiana, USA), and handgrip strength using Jamar® hand dynamometer (Patterson Medical, Warrenville, USA) (19,20). Muscle tests were repeated three times for both sides, and the highest value was recorded as kg. Muscle strength were expressed as percentages of the expected values.

Milliken Activities of Daily Living Scale

The limitations in the activities of daily living were evaluated using the Milliken Activities of Daily Living Scale (MAS), a patient-reported outcome measure (21). The MAS scale includes 47 items related to different activities of daily living, including preparing meals, eating, self-care, dressing oneself, manual manipulation of objects, house cleaning, and washing clothes, and other activities. An integrated scoring procedure is available that uses the product of each ability score multiplied by each necessity score, giving in a possible score of 15 for each item and a possible total integrated score of 705. A total score was used in this study. Lower scores indicate a higher level of limitation in the ability to perform daily tasks with upper extremities. The validity and reliability of the MAS for the Turkish population have been found suitable (21). The required permission for the MAS was provided.

Protocol

Firstly, the demographic and clinical data were collected, and the MAS was administered. Then, muscle strength assessments were performed. After an adequate resting period, the first trial of the 6PBRT was conducted. Dyspnoea and fatigue were evaluated using the Borg scale, and heart rate and blood pressure were recorded before and after the 6PBRT. After a 1-hour resting period, the second trial of the 6PBRT was performed. The first values of the level of dyspnoea and fatigue and heart rate were checked before the second trial to ensure that the patients were stable. The same physiotherapist administered all assessments.

Statistical Analysis

The Shapiro-Wilk test and histogram graphics were used to check the normality of the data. The demographic and clinical characteristics of the participants were reported using descriptive statistics. The intraclass correlation coefficient (ICC) with two-way random effects and absolute agreement methods was used to assess the test-retest reliability (22). The strength of reliability was interpreted as excellent for ICC value >0.90. Ninety-five per cent Confidence Interval (95% CI) was calculated to investigate the measurement variability. The Standard Error of Measurement (SEM) was calculated using the formula, "standard deviation of the mean difference/√2" and the Minimal Detectable Change (MDC) was calculated as "SEMx1.96x√2." To assess the know-groups validity, we investigated the difference between the patients with NYHA Class II vs Class III using the Mann-Whitney U test. Since the Class III patients expected to have impaired functional performance, they would have significantly lower scores in the 6PBRT compared to the patients with Class II. To assess the convergent validity of the 6PBRT, we hypothesized that there would be moderate to strong correlations between the 6PBRT and age, NHYA classes, shoulder flexor, shoulder abductor, elbow extensor, elbow flexor and handgrip muscles strength, and performance of the activities of daily living. Correlations between the variables were examined using Pearson's correlation coefficients.

Table 1: Characteristics of Participants with Pulmonary Hypertension.

Variables	Pulmonary Hypertension (n=31)	
	Mean±SD	**Min-max**
Age (years)	49.20±18.54	19.00-75.00
Body Mass Index (kg/m²)	25.60±5.63	16.53-39.04
Gender	**n**	**%**
Female/Male	26/4	83.9/12.9
NYHA Classification	**n**	**%**
Class II	20	64.5
Class III	11	35.5
Clinical Classification of Pulmonary Hypertension	**n**	**%**
Pulmonary Arterial Hypertension	29	93.5
Chronic Thromboembolic Pulmonary Hypertension	2	6.5
	Mean±SD	**Min-max**
mPAP (mmHg)	66.10±24.40	32.00-121.00
Cardiac Index (L/min/m²)	2.60±0.90	1.30-4.10
BNP Level (pg/ml)	492.20±975.60	8.00-3393.00
Muscle Strength	**Mean±SD**	**Min-max**
Dominant Shoulder Flexor (kg)	13.40±6.03	6.57-32.00
%Dominant Shoulder Flexor	71.11±20.27	33.48-115.41
Nondominant Shoulder Flexor (kg)	12.74±4.92	7.02-29.80
%Nondominant Shoulder Flexor	72.62±16.76	42.72-111.48
Dominant Shoulder Abductor (kg)	12.21±5.91	4.50-31.30
%Dominant Shoulder Abductor	81.49±23.74	36.07-130.17
Nondominant Shoulder Abductor (kg)	11.93±5.58	5.30-28.60
%Nondominant Shoulder Abductor	82.86±23.60	43.00-128.89
Dominant Elbow Extensor (kg)	9.70±2.81	5.80-17.00
%Dominant Elbow Extensor	84.66±24.70	52.07-140.23
Nondominant Elbow Extensor (kg)	9.38±3.17	5.90-17.20
%Nondominant Elbow Extensor	80.62±22.90	50.31-139.95
Dominant Elbow Flexor (kg)	13.34±5.00	7.25-27.10
%Dominant Elbow Flexor	79.61±19.95	43.11-122.23
Nondominant Elbow Flexor (kg)	13.09±5.14	6.80-28.20
%Nondominant Elbow Flexor	78.20±21.92	42.43-121.72
Dominant Handgrip (kg)	23.80±8.84	14.00-48.00
%Dominant Handgrip	84.65±17.16	53.36-116.21
Nondominant Handgrip (kg)	23.06±8.77	13.00-45.00
%Nondominant Handgrip	85.23±17.18	51.58-122.74
Milliken Activities of Daily Living Scale (47-705)	595.20±74.22	417.00-689.00

NYHA: New York Heart Association, mPAP: Mean Pulmonary Arterial Pressure, BNP: Brain Natriuretic Peptide.

Correlation coefficients were interpreted as strong (>0.50), moderate (0.30 to 0.50), and weak (0.20 to 0.30) (23). The paired t-test was used to evaluate the differences between pre- and post-test values, and pre-test values between trial 1 and trial 2. Statistical significance was set at $p<0.05$. The statistical analyses were conducted using the IBM SPSS software (Version 24.0, IBM Corp., Armonk, USA).

RESULTS

In total, 31 patients with PH participated in the study, and all patients completed the protocol. The patients' characteristics are summarized in Table 1.

Heart rate, systolic and diastolic blood pressure, dyspnoea, and arm fatigue increased significantly from pre- to post-test on both tests ($p<0.05$). There was no difference in baseline heart rate, systolic

Table 2: Results of the Six-Minute Pegboard Ring Test in Patients with Pulmonary Hypertension.

Variables	Trial 1			Trial 2			p[b]
	Pre-test	Post-test	p[a]	Pre-test	Post-test	p[a]	
Heart Rate (bpm)	85.90±11.50	91.80±10.40	**<0.001***	85.80±9.92	99.90±10.90	**<0.001***	0.922
Systolic Blood Pressure (mmHg)	118.83±14.13	123.20±15.10	**<0.001***	117.00±13.32	119.70±14.80	**0.020***	0.399
Diastolic Blood Pressure (mmHg)	74.90±9.52	77.60±10.61	**0.044***	74.03±10.33	76.00±8.90	**0.039***	0.811
Dyspnea (Modified Borg Scale)	0.60±1.11	1.12±1.91	**0.015***	0.40±0.70	1.20±1.90	**0.004***	0.214
Upper Extremity Fatigue (Modified Borg Scale)	0.41±0.92	4.40±3.13	**<0.001***	0.64±1.00	3.51±2.83	**<0.001***	0.165

*p<0.05. [a] Difference between pre-test and post-test (Paired sample t-test). [b] Difference between pre-test values in Trial 1 and Trial 2 (Paired sample t-test) 6PBRT: Six-Minute Pegboard Ring Test.

and diastolic blood pressure, dyspnoea, and arm fatigue between the trials (p>0.05). The detailed results are presented in Table 2.

The score of the 6PBRT in trial 1 and trial 2 was 157.00±41.06 and 165.30±41.81, respectively. The score of trial 2 was significantly greater than the trial 1 with a mean difference of 8.38±1.48 (p<0.001). Despite the statistical significance, no clinically relevant difference was observed as the difference (8.38±1.48) was lower than the MDC value which was found as 16.35. The 6PBRT showed excellent test-retest reliability with the ICC=0.98 (95% CI 0.82-0.99). The SEM and MDC were calculated as 5.90 and 16.35, respectively (Table 3).

As we expected, the patients with NYHA Class III had significantly lower scores in the 6PBRT compared to the patients with Class II (p=0.005), showing the known-groups validity of the 6PBRT. The 6PBRT score was 167 (150.3-196.8) for NYHA Class II and 132 (110-158) for NYHA Class III. The 6PBRT was significantly and strongly correlated with age (r=-0.628, p<0.001), functional class (r=-0.502, p=0.004), and activities of daily living (r=0.522, p=0.003). It was moderately correlated with shoulder flexor (r=0.360, p=0.047 for the dominant and r=0.391, p=0.030 for the nondominant sides), shoulder abductor (r=0.388, p=0.031 for the dominant and r=0.382, p=0.034 for the nondominant sides), elbow flexor (r=0.406, p=0.036 for the dominant and r=0.382, p=0.049 for the nondominant sides) and handgrip muscles strength (r=0.375, p=0.041 for the dominant and

Table 3: The Test Results and Test-Retest Reliability of the Six-Minute Pegboard Ring Test in Patients with Pulmonary Hypertension.

Variable	Trial 1 Mean±SD	Trial 2 Mean±SD	Difference Mean±SE	p[a]	ICC	95% CI	p[b]	SEM	MDC
6PBRT (repetition)	157.00±41.06	165.30±41.81	8.38±1.48	**<0.001***	0.98	0.82-0.99	<0.001*	5.90	16.35

*p<0.05. [a] Difference between Trial 1 and Trial 2 (Paired sample t-test). [b] ICC ICC: Intraclass Correlation Coefficient, SD: Standard Deviation, SE: Standard Error, CI: Confidence Interval, SEM: Standard Error of Measurement, SDC: Minimal Detectable Change. 6PBRT: Six-Minute Pegboard Ring Test.

Table 4: Correlations of the Six-Minute Pegboard Ring Test with Age, Functional Class, Muscle Strength, and Activities of Daily Living.

Variable		Age	NYHA	Shoulder Flexor Strength		Shoulder Abductor Strength		Elbow Extensor Strength		Elbow Flexor Strength		Handgrip Strength		MAS
				D	ND	D	ND	D	ND	D	ND	D	ND	
6PBRT	**r**	-0.628	-0.502	0.360	0.391	0.388	0.382	-0.039	0.038	0.406	0.382	0.375	0.428	0.522
	p	**<0.001***	**0.004***	**0.047***	**0.030***	**0.031***	**0.034***	0.847	0.850	**0.036***	**0.049***	**0.041***	**0.018***	**0.003***

*p<0.05. 6PBRT: Six-Minute Pegboard Ring Test, NYHA: New York Heart Association, MAS: Milliken Activities of Daily Living Scale, D: Dominant Side, ND: Non-dominant Side.

r=0.428, p=0.018 and for the nondominant sides). Table 4 shows the correlations coefficients.

DISCUSSION

To the best of our knowledge, this is the first study evaluating test-retest reliability, known-groups and convergent validity of the 6PBRT in the patients with PH. This study showed that 6PBRT has excellent test-retest reliability and good validity. The higher 6PBRT scores were significantly correlated with younger age, better functional class and performance in activities of daily living, and greater upper extremity muscle strength. Heart rate, systolic and diastolic blood pressure, dyspnoea, and arm fatigue significantly increased after the 6PBRT, indicating that the test creates the required load as an exercise stress test.

The mean 6PBRT ring number was 157 in this study, which was lower than the mean ring number of healthy individuals reported in the previous studies. The norm values were 382.7 in Brazilian adults and 404.7 in Canadian adults for the similar age groups as our study (10,24). Another study was conducted in healthy adults who reported the mean 6PBRT score as 365.2 (25). However, we should note that these studies used a different reporting system as they multiplied the scores by "2". We preferred to use the same scoring system as described by the first study of the 6PBRT in the patients with COPD (11). Therefore, the norm values could be transformed as 192, 202, and 183, respectively (10,24,25). Due to the reduced functional capacity in the patients with PH, decreased upper extremity function is expected compared to healthy individuals. Heart rate, systolic and diastolic blood pressure, dyspnoea, and arm fatigue increased significantly from pre- to post-test on 6PBRT and returned to baseline values after the resting period. Lima et al. showed an increase in heart rate, blood pressure, dyspnoea, and arm fatigue on 6PBRT and recovery after the rest period in healthy individuals (25). These findings suggest that the 6PBRT could create the required loading as an exercise test.

We found an excellent test-retest reliability of the 6PBRT in PH patients, which is similar to other studies in healthy adults and patients with COPD (11,25). Lima et al. reported the ICC value as 0.91 (25). Zhan et al. found highly significant test-retest correlation coefficients (r=0.910) of the 6PBRT (11). Our study supported the previous findings that the 6PBRT has high test-retest reliability in different populations. In this study, 6PBRT completed safely and harmoniously. We found that the MDC was 16.35 in the patient with PH. The clinicians and researchers could accept that the scores above 16.35 is a valid change and not due to chance (26).

Our study demonstrated that the 6PBRT has good known-groups validity, which means that it could differentiate the patients with worse functional performance. As we expected, the patients with NHYA Class II had significantly higher scores in the 6PBRT compared to the patients with NHYA Class III. Ozcan Kahraman et al. also showed a similar result as the NYHA Class II patients with pulmonary arterial hypertension have significantly higher 6PBRT scores than those of the Class III patients (7). We found moderate-to-strong correlations between the 6PBRT scores and age, functional class, muscle strength, and daily living activities to previous studies' findings of convergent validity (10,27-29). In healthy adults, it was reported that there was a correlation between 6PBRT results and age (10). Janaudis-Ferreira et al. stated that there was a moderate correlation between 6PBRT performance and elbow and shoulder flexors muscle strength measured by a manual isometric dynamometer (29). In another study, Nyberg et al. reported a moderate correlation with shoulder flexors measured by isokinetic muscle function in moderate-to-severe stable patients with COPD (28). Ozsoy et al. showed significant correlations between the 6PBRT and age, handgrip strength, and shoulder flexor muscle strength in older patients with COPD (16). Felisberto et al. demonstrated the convergent validity of 6PBRT by comparing the performance in the test assessing peripheral muscle function, upper-extremity activities of daily living, and clinical impact of the disease (13). Calik-Kutukcu et al. also reported a significant correlation between 6PBRT score and with the number of cycles in activities of daily living simulation test in Global Initiative for Obstructive Lung Disease (GOLD) stage II-III COPD patients (27). All these results suggest that the 6PBRT has good validity, including known-groups and convergent. It could reflect the limitations in the upper extremity function.

There are some limitations to this study. First, we included only the patients with PH with NYHA Class II and III. In addition, the patients were recruited from only one center. These limitations decrease the generalizability of the results. Secondly, the minimal clinically important difference has not been investigated in our study. Further longitudinal study is needed to determine the minimal clinically important difference for the 6PBRT. Finally, we investigated the test-retest reliability of the 6PBRT on the same day. Therefore, performance results for the on different days were not known for the patients with PH. However, it was reported that same day performance gives better reliability results than different days (30).

In conclusion, this study showed that 6PBRT has excellent test-retest reliability and good validity, including known-groups and convergent. The higher 6PBRT scores were significantly correlated with younger age, better functional class, and performance in activities of daily living and greater upper extremity muscle strength. Heart rate, systolic and diastolic blood pressure, dyspnoea, and arm fatigue significantly increased after the 6PBRT, indicating that it creates the required load as an exercise stress test. The 6PBRT can reflect the functional limitations in the upper extremity in the patients with PH.

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Conflict of Interest: There is no conflict of interest.

Ethical Approval: Non-Interventional Research Ethics Committee of Dokuz Eylul University approved the study (Approval Date: 12.10.2017, and Approval Number: 2017/21-20).

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