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A Preliminary Study on the Effects of 4-Week Training Program with Interactive Floor Support on Plantar Pressure Distribution in Sedentary Individuals

Onur Aydoğdu, Rafet Umut Erdoğan, Zübeyir Sarı, Mine Gülden Polat

Marmara University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, İstanbul, Türkiye.

Correspondence Author: Onur Aydoğdu
E-mail: fztonuraydogdu@hotmail.com
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ABSTRACT

Objective: Our purpose was to investigate on the effects of foot exercises by using interactive floor support as a modality of rehabilitation technology on plantar pressure distribution in sedentary individuals.

Methods: Participants who were aged between 18-35, who agreed to participate voluntarily and had no pathology developed in the lower extremities in the past 6 months were included in this study. In order to determine the plantar pressure distribution change of all participants, the first and last evaluation was measured with Emed® Pedobarography. Balance and proprioception exercises on both lower extremities for 12 sessions (for four weeks, three sessions per week, lasts 15 minutes each) were performed with an interactive floor device.

Results: A total of 15 healthy and sedentary subjects (12 female, 3 male, with a mean of 20,27±0,961 years and 21,31 ± 3,027 kg/m^2 BMI) completed the four-week training protocol. Maximum force of total and hindfoot in both feet significantly decreased after 4-week training (p<.05). In addition, changes of total peak pressure and total contact area values after 4-week training program in both feet were not significant (p>.05).

Conclusion: Based on our results, the present study revealed that the 4-week training programme with interactive floor support for ankle joint could decrease maximum force of total and hindfoot on the bottom of the dominant and non-dominant side feet in healthy and sedentary individuals. Future investigation should be conducted to clarify the effects of long-term training programs with interactive floor support on plantar pressure distribution in patients with foot deformities.

Keywords: Sedentary lifestyle, technology, exercise, lower extremity

1. INTRODUCTION

Physical inactivity may be characterized by a lifestyle with reduced physical activity, which may lead to a poor posture, posture disorders and decreased energy expenditure. Physical inactivity may also lead to many anatomical and physiological disorders related to impaired health outcomes, such as development of anxiety and depression, obesity, gaining weight, some cardiovascular diseases, and other problems as well (1). In addition of them, because of sedentary lifestyle, many musculoskeletal disorders may occur in all parts of the body. One of the most common musculoskeletal problems is foot posture abnormalities (2).

Feet are the organs that carry body weight and allow walking. One of the main components of the feet is the arch that provides body weight support and plantar pressure distribution (3). Measurement of plantar pressure distribution is clinically useful and important because it can identify anatomical foot deformities, guide the diagnosis and treatment of gait disorders (4). Many researches have investigated that plantar pressure on the bottom of the foot has an important biomechanical meaning (5-8). In addition, plantar pressure distribution can also help physiotherapists interpret the foot deformities and evaluate gait (3).

Research on foot pressure distribution have focused on specific pathologies and deformities (4). In one of the study investigating importance of foot pressure distribution, it has been reported that excessive plantar pressures may be correlated with development of ulcers in neuropathic feet (9). In addition, it has been shown that sedentary lifestyle is correlated with higher plantar pressures under 2–5 toes of the foot (10). It has also been reported that there is a correlation between high plantar pressures and low level of physical activity in a study investigating relationship between plantar pressures, physical activity and sedentariness among preschool children by Mickle et

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al (11). Based on the foregoing assessments, examination of the foot health of sedentary people may be very important (2).

Therapeutic exercises such as foot-muscle training may reduce over pronation and help re-structuring the foot (3). However, there are limited studies investigating the effects of foot-muscle training on plantar pressure distribution, especially in sedentary people. In a study by Kyung Lee, closed kinetic chain exercises significantly changed the contact area and peak contact force of hindfoot in patients with stroke (12). However, it would be better to reveal the effects of foot-muscle training on plantar pressure distribution to understand the underlying mechanism.

In addition to enhancing patient monitoring and adherence, the use of technology by healthcare professionals also help to ease pressure on healthcare services (13). As treatment request is anticipated to extend in future, rehabilitation technology that enables patients to complete training with less therapist involvement will play a crucial role in this (14).

Up to our knowledge, no previous study has investigated on the effects of foot-ankle exercise alone by using rehabilitation technology on plantar pressure distribution in sedentary individuals. Therefore, we investigated whether training programme for ankle joint led to changes in plantar pressure distribution after four-week training program with interactive floor support in sedentary individuals. We hypothesized that foot-ankle exercises using with interactive floor support as rehabilitation technology would change plantar pressure distribution by helping re-shaping the foot after four weeks in sedentary individuals.

2. METHODS

2.1. Ethics

This study was approved by the Non-Interventional Ethics Committee of Marmara University Faculty of Health Sciences (Protocol Number: 52, Date: 28.03.2019). All subjects were informed about the study prior to their participation and written informed consent was obtained from each subject.

2.2. Participants

This study was performed in the Faculty of Health Sciences, Marmara University, İstanbul, Türkiye. Students in the Department of Physiotherapy and Rehabilitation who were aged between 19-23, who were physically sedentary individuals according to their own statements, and who agreed to participate voluntarily were included in this study. Sociodemographic attributes [age, gender, height, body weight and body mass index (BMI)] were collected from participants at the beginning of the study (Table 1).

Participants who were aged between 18-25, who agreed to participate voluntarily and had no pathology developed in the lower extremities in the past 6 months were included in this study. Participants who had a congenital or chronic lower limb pathology and/or participants with acute/chronic problems affecting their visual perception or balance were excluded. The subjects were excluded if they had any orthopaedic problems, such as musculoskeletal pain, limited range of motion, foot or fracture history, any type of injury or surgery in the lower extremity, foot or ankle deformities including hallux valgus, pes planus or cavus, etc. The subjects who participated in sportive and physical activities regularly were also excluded from the study.

2.3. Study Design

In order to determine the plantar pressure distribution change of all participants, the first and last evaluation was measured with Emed® pedobarography device at the beginning and end of the 4-week training program. The balance and proprioception exercises determined by the research team were performed with using an interactive floor device applied as rehabilitation technology.

2.4. Plantar Pressure Assessment

In our study, in order to determine to change of plantar pressure distribution, Novel Emed® pedobarography device was used (Figure 1). This device has been shown to be a reliable and valid method to measure plantar pressure (15). The patients whose plantar pressure were to be assessed walked on the platform where the device was located, and measurements were made five times for each foot. The average of the measurements were determined as the plantar pressure distribution. Most Emed® systems are used in 4 sensor / cm2 high sensor resolution mode and at a frame rate of 50 or 100 Hz (16). With the user-defined narrowed sensor area, this platform area can be scanned at frequencies greater than 800 Hz. Emed® motion analysis provides frame-by-frame input and output signals for digital video and EMG synchronization. All Emed® platforms carry the CE mark for the calibrated Class 1 medical device with a temperature range 10-40°C and a calibrated pressure range from 10 kPa to 1.27 MPa (www.novel.de/products/emed/ Accession Date: 25.08.2021).

Figure 1. *Assessment of plantar pressure distribution using Novel Emed® pedobarography device*

2.5. Training Program

In our study, participants' training program were performed on interactive floor projection device (TTL Technology, Elsa Med. Company, TR). The device which is used in this study contains 3000 Ansilumen LED projection. Its resolution is 1024x768 pixels and has IR/3D sensor system, Windows 7 pro 64 bit OS, Intel I5 Processor, 4 GB DDR3 1333 RAM and 300 Mbps Wireless 802.11b/g/n. The device is placed on the ceiling three meters above the ground. The size of the projection area's is approx. 3 square meters (the length is 2 and the width is 1.5 meters). The participants did balance and proprioception exercises on both dominant and non-dominant lower extremities for 12 sessions (for four weeks, three sessions per week, lasts 15 minutes for each lower extremity) by using games such as Balloon Popping, Ball Collecting, and Shape Crushing on the device (Table 1).

Table 1*. Training program on interactive floor projection device*

Training Game	Training Sessions					
	Week 1					
	First Session		Second Session		Third Session	
	Left Foot	Right Foot	Left Foot	Right Foot	Left Foot	Right Foot
Balloon Popping	3 min.	3 min.	4 min.	4 min.	5 min.	5 min.
Ball Collecting	3 min.	3 min.	4 min.	4 min.	5 min.	5 min.
Shape Crushing	3 min.	3 min.	4 min.	4 min.	5 min.	5 min.
	Week 2, 3 & 4					
	First Session		Second Session		Third Session	
	Left Foot	Right Foot	Left Foot	Right Foot	Left Foot	Right Foot
Balloon Popping	5 min.	5 min.	5 min.	5 min.	5 min.	5 min.
Ball Collecting	5 min.	5 min.	5 min.	5 min.	5 min.	5 min.
Shape Crushing	5 min.	5 min.	5 min.	5 min.	5 min.	5 min.

Balloon Popping

The aim of the balloon popping game is for the participant to explode the virtual balloons which are moving from one way to the opposite by quickly moving both feet in the dorsi and plantar flexion directions. The participant who moves his or her ankle during the popping process also have to move quickly within the interactive floor area, and try to pop as many balloons as possible (Figure 2).

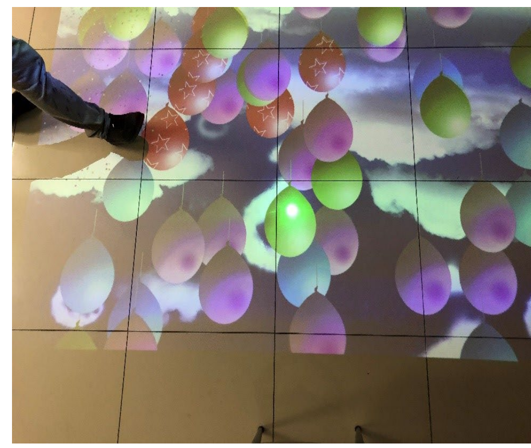

Figure 2. *Training games (balloon popping) on interactive floor projection device*

Ball Collecting

The ball collecting game is played with a maximum of 4 participants. Participants choose a dragon for themselves before the game starts. With the starting signal, they try to collect as many balls as possible by quickly moving their feet in the dorsi and plantar flexion direction. The game ends with a total of 200 balls being shared among the participants (Figure 3).

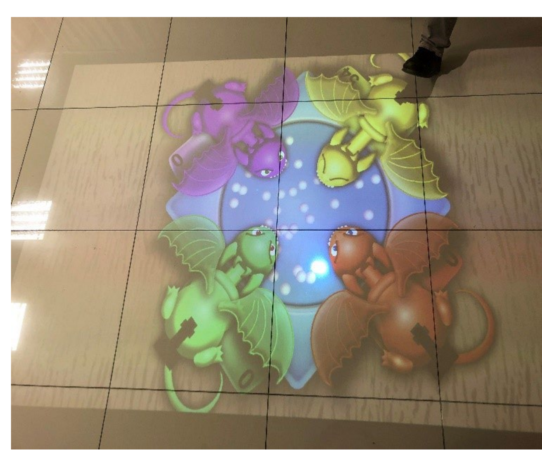

Figure 3. *Training games (ball collecting) on interactive floor projection device*

Shape Crushing

The shape crushing game can be played with a single participant at one time. The participant stands in the middle of the interactive floor area and tries to crush the virus-shaped objects coming from the environment. The participant, whose one lower extremity is in a stable position, reaches out with the other lower extremity in the direction of the viruses, tries to crush the viruses by moving his foot in the dorsi and plantar flexion direction (Figure 4).

Figure 4. *Training games (shape crushing) on interactive floor projection device*

2.6. Statistical Analysis

In the classification of the data obtained in the study, qualitative and quantitative statistical methods were evaluated with the SPSS 11.5 statistical program in the 95% confidence interval, and the significance were evaluated at the level of p<.05.

Demographic characteristics are presented as frequencies, means and standard deviations (SD). As the distribution of data did not meet the parametric test criteria (data distribution histograms, examining the mean and standard deviation values and Kolmogorov-Smirnov test), the statistical analysis was performed by using non-parametric tests. The comparison of the values of the plantar foot distribution was analysed by using the Wilcoxon Signed Rank Test.

There was no calculated power analysis in the study. The sample size was determined by convenience sampling method in order to availability of participants who intends to participate this study voluntarily (17).

3. RESULTS

3.1. Participants

25 subjects were assessed for suitability and 5 subjects were excluded. Four subjects who were sportive and physically active individuals and one subject stated that he had a fracture in the foot and ankle complex in childhood. The included 20 subjects started for training. During the training period; five subjects were lost to follow-up since they did not join the sessions regularly (Figure 5). A total of 15 healthy and sedentary subjects (12 female, 3 male) completed the four-week training protocol in Marmara University, between October 2019 – January 2020. The dominant extremities of all the subjects in the study were right. The age of participants ranged between 19 and 23 years with a mean of 20,27±0,961 years. Demographic data and general characteristics for the subjects are displayed in Table 2.

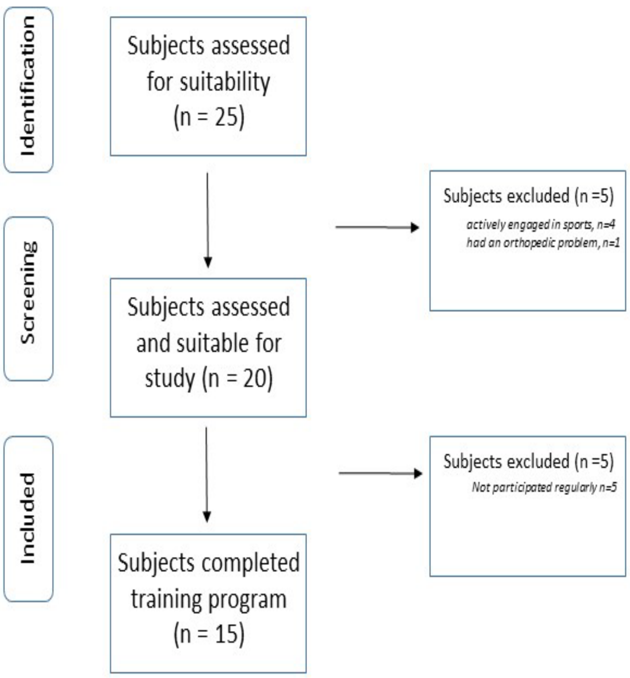

Table 2. *Demographic characteristics of participants*

	n	Mean ± SD	Minimum – Maximum
Gender Male Female	 3 (20%) 12 (80%)	-	
Age (years)	15	20.27 ± 0.961	19 – 23
Height (cm)	15	171.93 ± 9.004	156 – 188
Body Weight (kg)	15	63.27 ± 11.26	44 – 86
BMI (kg/m²)	15	21.31 ± 3.027	17.26 – 30.11

Values are presented as mean ± SD

n: number, SD: Standard Deviation, BMI: Body Mass Index

3.2. Plantar Pressure Distributions

Table 3, 4 and 5 indicate the pre – and post-training plantar pressure distributions for each foot. The mean values of maximum force for pre – and post-training were shown in Table 3. Maximum force of total and hindfoot in both feet significantly decreased after 4-week training (p<.05). In addition, changes of maximum force of forefoot in the non-dominant leg and changes of maximum force of toes in the dominant leg were significant (p<.05).

***Table 3**. Comparison of maximum force variables at pre – and post-training*

Foot Region			DL		NDL	
Maximum Force	Total	Pre-Training	1570.31±394.86	-%31.7	1612.91±446.56	-%33.1
		Post-Training	1072.57±361.88		1079.43±369.97	
		z	-2.442		-2.101	
		p	**.015***		**.036***	
	Hindfoot	Pre-Training	495.05±108.98	-%8.5	517.66±151.52	-%12.0
		Post-Training	452.75±82.85		455.35±96.56	
		z	-1.988		-2.329	
		p	**.047***		**.020***	
	Midfoot	Pre-Training	202.83±157.16	-%14.9	192.24±120.75	-%10.4
		Post-Training	172.59±71.11		172.19±91.76	
		z	-0.398		-1.250	
		p	0.691		0.211	
	Forefoot	Pre-Training	648.63±148.22	-%4.6	709.66±220.60	-%9.9
		Post-Training	618.90±120.95		639.17±120.33	
		z	-1.306		-1.988	
		p	.191		**.047***	
	Toes	Pre-Training	222.71±100.19	-%19.3	191.37±91.47	-%10,7
		Post-Training	179.68±84.86		170.93±97.59	
		z	-2.442		-1.477	
		p	**.015***		.140	

DL: Dominant Leg, NDL: Non-Dominant Leg
*Wilcoxon-signed rank test, *p<.05*
Values are presented as mean ± SD
The percentage values (%) presents amount of change in the parameters.

***Table 4.** Comparison of peak pressure variables at pre – and post-training*

Foot Region			DL		NDL	
Peak Pressure	Total	Pre-Training	476.33±99.32	+%1.3	508.00±162.33	-%7.3
		Post-Training	482.67±151.80		471.00±96.82	
		z	-0.114		-0.910	
		p	.910		.363	
	Hindfoot	Pre-Training	298.33±82.99	-%7.0	291.33±71.05	+%1.0
		Post-Training	277.33±53.21		294.33±76.45	
		z	-0.228		-0.346	
		p	.819		.729	
	Midfoot	Pre-Training	152.67±123.99	-%12.4	138.00±66.73	+%9.4
		Post-Training	133.67±39.93		151.00±80.36	
		z	-1.323		-1.894	
		p	.186		.058	
	Forefoot	Pre-Training	380.00±122.37	+%5.3	428.33±173.03	-%5.0
		Post-Training	400.00±146.61		407.00±128.22	
		z	-0.767		-0.440	
		p	.443		.660	
	Toes	Pre-Training	376.67±152.14	-%7.3	335.33±177.98	-%13.9
		Post-Training	349.00±183.77		288.67±145.69	
		z	-0.824		-2.345	
		p	.410		**.019***	

DL: Dominant Leg, NDL: Non-Dominant Leg
*Wilcoxon-signed rank test, *p<.05*
Values are presented as mean ± SD
The percentage values (%) presents amount of change in the parameters.

The mean values of peak pressure for pre – and post-training were shown in Table 4. Changes of peak pressure of toes in the non-dominant leg were significant (p<.05).

The mean values of contact area for pre – and post-training were shown in Table 5. Contact area of hindfoot in both feet significantly decreased after 4-week training (p<.05). Changes of contact area of toes in the dominant leg were significant (p<.05).

***Table 5.** Comparison of contact area variables at pre – and post-training*

Foot Region			DL		NDL	
Contact Area	Total	Pre-Training	155.76±37.21	-%5.1	154.79±42.88	-%4.9
		Post-Training	147.73±19.77		147.18±19.25	
		z	-1.477		-0.256	
		p	.140		.798	
	Hindfoot	Pre-Training	38.57±8.71	-%6.5	39.60±14.20	-%10.3
		Post-Training	36.05±5.29		35.52±5.67	
		z	-2.385		-1.988	
		p	**.017***		**.047***	
	Midfoot	Pre-Training	33.16±12.65	-%5.4	32.10±13.60	-%5.6
		Post-Training	31.36±6.14		30.31±6.59	
		z	-0.511		-0.284	
		p	.609		.776	
	Forefoot	Pre-Training	54.84±8.01	+%0.1	55.73±9.75	-%1.7
		Post-Training	54.87±7.37		54.80±7.47	
		z	-0.398		-0.454	
		p	.691		.650	
	Toes	Pre-Training	28.58±11.70	-%12.6	26.57±8.43	-%3.0
		Post-Training	24.97±5.98		25.77±6.02	
		z	-2.385		-0.398	
		p	**.017***		.691	

DL: Dominant Leg, NDL: Non-Dominant Leg
*Wilcoxon-signed rank test, *p<.05*
Values are presented as mean ± SD
The percentage values (%) presents amount of change in the parameters.

4. DISCUSSION

This study conducted to investigate the effects of 4-week training programme for ankle joint via interactive floor projection device applied as rehabilitation technology on plantar pressure distributions in sedentary and healthy individuals. One of the main findings of our study is that maximum force of total and hindfoot in both feet significantly decreased after foot exercises training. According to the results, changes about maximum force between pre and post assessment of dominant leg's toe and non-dominant leg's forefoot area were significant. We think that the 4-week training program for ankle joint decreased the foot pressure distribution by restructuring the foot. In contrast to the present study, Unver et al. reported that maximum plantar force was significantly increased in midfoot after 6-week short foot exercises while maximum force in fore and hindfoot remained similar. We believe that this difference was basically caused because of the subjects who participated in studies. It is known that pes planus leads to higher plantar pressure in medial midfoot (18). In addition, there are some else significant differences including measuring of plantar pressure region, training protocol, etc between the present study and other one. From this point, we may report from our results that foot exercises via interactive floor projection support in sedentary individuals may help re-shaping the foot and re-distributing the plantar pressure on dominant foot as well as non-dominant foot. Thus, this study setting has shown that the training program which includes balance and proprioception exercises by using technology may lead a better plantar pressure distribution especially on maximum plantar force and even in a population with young and sedentary adults, whose have no deformities on lower limbs.

Another main finding of our study is that changes of total peak pressure and total contact area values after 4-week training program in both feet were not significant. Even more importantly, although maximum plantar force of total in both feet significantly decreased after 4 week, total peak pressure and total contact area were not significantly changed. We could deduce that the 4-week training program by using interactive floor projection support solved the lack of optimal foot pressure distribution which is one of the negative effects caused by physical inactivity by re-shaping the feet. Up to our knowledge, there is no study investigating the effects of interactive floor projection on plantar pressure distribution. Therefore, it is not possible to compare our results with a similar clinical trial. However, there is a study conducted by Braun et al to determine how nursing home residents would respond to the interactive floor projection and it is reported that interactive floor projection may be a promising modality in individuals with nursing home residents to increase their physical activity level (19).

When we examine the general characteristics of the participants in this study, only one participant is obese (Type I) and rest of them are normal or underweight (BMI ≤ 25 kg/m^2). Yıldırım-Şahan et al. reported that increased BMI causes increased plantar pressures (20). Therefore, there was no abnormal score in plantar pressure of participants before the training.

Interactive floor projection is not a brand-new technology but there are very limited studies which ran as a medical treatment plan and based on interactive floor projection device. The study by Takahashi et al. (21) indicates that, this device could use in a unique population such as children with special needs due to its high visual and auditory effects. By using this device, participants may have a higher concentration and cooperation while doing exercises or physical activities that planned to be done. Another study by Hsieh et al demonstrated that interactive floor projection support helped improve the scoring for the scales of behavior and mental health in paediatric patients hospitalized for cancer treatment in Taiwan (22). Consequently, although limited numbers of it, these findings confirm that current technologies such as interactive floor projection support may be beneficial as a therapeutic modality for clinicians. In addition, no side and adverse effects were encountered during the study.

In the present study, there are some limitations which should be addressed. The subjects performed only 4 week – training program. However, it should be 8 or 12 weeks to investigate the effects of exercise program. Another limitations were the lack of follow – up and control group. Moreover, relatively small sample size and gender distribution were the important limitations of this study. We could also add lack of objective measurements for physical activity as a limitation in the study. Therefore, further studies are recommended to investigate the long-term effects of interactive floor projection with a larger sample size and with control group.

5. CONCLUSION

Based on our results, the present study revealed that 4-week foot exercises program with interactive floor projection applied as rehabilitation technology could decrease maximum force of total and hindfoot on the bottom of the dominant and non-dominant side feet in healthy and sedentary individuals. Interactive floor projection support including balance and proprioception games has the potential to provide a better plantar pressure distribution in physically inactive individuals. Future investigation should be conducted to clarify the effects of long-term interactive floor projection training program on plantar pressure distribution in patients with foot deformities such as diabetic foot, ulceration, etc.

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Conflicts of interest: *There is no conflict of interest in the study.*

Ethics Committee Approval: *This study was approved by Ethics Committee of Non-Interventional Ethics Committee of Marmara University Faculty of Health Sciences, (approval date 28.03.2019 and number 52)*

Peer-review: *Externally peer-reviewed.*

Author Contributions:

Research idea: OA, RUE, ZS, MGP
Design of the study: OA, RUE, ZS, MGP
Acquisition of data for the study: OA, RUE, ZS, MGP
Analysis of data for the study: OA, RUE, ZS, MGP
Interpretation of data for the study: OA, RUE, ZS, MGP
Drafting the manuscript: OA, RUE, ZS, MGP
Revising it critically for important intellectual content: OA, RUE, ZS, MGP
Final approval of the version to be published: OA, RUE, ZS, MGP

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