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EFFECT OF VIRTUAL REALITY TRAINING ON BALANCE AND FUNCTIONALITY IN CHILDREN WITH CEREBRAL PALSY: A RANDOMIZED CONTROLLED TRIAL

ORIGINAL ARTICLE

ABSTRACT

Purpose: The aim of this study was to investigate the effectiveness of virtual reality training on balance and functionality in children with Cerebral Palsy.

Methods: Children with spastic Cerebral Palsy were randomly divided into the virtual reality training group (27 children, mean age: 9.2 years) and control group (25 children, mean age: 9.4 years). The virtual reality training group received virtual reality training using the XBox One Kinect gaming system and the control group received conventional physiotherapy training for eight weeks. The Pediatric Balance Scale, The Gross Motor Function Measurement-88, The Quality of Upper Extremity Skills Test, The Functional Reach Test, The Sit to Stand Test and The Pediatric Disability Evaluation Inventory were measured at baseline and after treatment sessions.

Results: Total motor function, upper extremity skills and balance in both groups improved after training ($p < 0.05$). A comparison between groups demonstrated that the improvements in upper extremity functions was greater in the control group than in the virtual reality training group ($p < 0.05$).

Conclusion: The results of our study showed that Kinect-based virtual reality training is beneficial in improving balance, motor function and upper extremity skills in children with Cerebral Palsy.

Key Words: Balance, Cerebral Palsy, Children, Virtual Reality

SEREBRAL PALSİLİ ÇOCUKLARDA SANAL GERÇEKLİK EĞİTİMİNİN DENGE VE FONKSİYONELLİK ÜZERİNE ETKİSİ: RANDOMİZE KONTROLLÜ ÇALIŞMA

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Bu çalışmanın amacı, Serebral Palsili çocuklarda sanal gerçeklik eğitiminin denge ve fonksiyonellik üzerine etkisini araştırmaktır.

Yöntem: Spastik Serebral Palsili çocuklar rastgele sanal gerçeklik eğitim grubuna (27 çocuk, ortalama yaş: 9,2 yıl) ve kontrol grubuna (25 çocuk, ortalama yaş: 9,4 yıl) ayrıldı. 8 hafta boyunca sanal gerçeklik eğitim grubuna XBox One Kinect oyun sisteminin kullanıldığı sanal gerçeklik eğitimi ve kontrol grubuna konvansiyonel fizyoterapi eğitimi verildi. Pediatrik Denge Ölçeği, Kaba Motor Fonksiyon Ölçeği-88, Üst Ekstremite Becerilerinin Kalitesi Testi, Fonksiyonel Uzanma Testi, Oturup Kalkma Testi ve Pediatrik Özürlülük Değerlendirme Envanteri başlangıçta ve tedavinin sonunda ölçüldü.

Sonuçlar: Her iki grupta da eğitim sonunda total motor fonksiyon, üst ekstremite becerileri ve dengede ilerleme görüldü ($p < 0,05$). Gruplar arası karşılaştırma üst ekstremite fonksiyonlarındaki ilerlemenin kontrol grubunda sanal gerçeklik eğitim grubuna göre daha fazla olduğunu gösterdi ($p < 0,05$).

Tartışma: Çalışmamızın sonuçları, Kinect tabanlı sanal gerçeklik eğitiminin Serebral Palsili çocuklarda denge, motor fonksiyon ve üst ekstremite becerilerini geliştirmede faydalı olduğunu göstermiştir.

Anahtar Kelimeler: Denge, Serebral Palsi, Çocuklar, Sanal Gerçeklik

INTRODUCTION

CP is a complex disorder characterized by posture and movement impairments. Such impairments limit children's independence in activities in daily life and social participation (1,2).

Balance skills are an integral part of gross motor skills and affect functional capacity and independence in activities of daily living such as getting dressed. Postural balance also plays an important role in the development of upper extremity functions. Upper limb function is a critical determinant of the ability to perform daily activities and to participate in the home environment. Impaired muscle tone, abnormal postural control and muscle coordination and deficits of sensory organization effect balance capacity in children with CP (3,4). Inadequate postural control and balance reactions prevent the voluntary skills and independence in activities of daily living. Thus, balance training to improve general motor skills and level of independence in activities of daily living is one of the main goals of rehabilitation (3-5). CP cannot be cured, but several interventions focus on reducing the impairments and increasing the independence in daily life (6). Physical therapy, aims to improve motor function, balance and independence in activities of daily living, plays an important role in the treatment of disorders (2). This therapy involves a long process and this process can become exhausting and boring for children. It may reduce motivation and have negative effects on participation in treatment (7). Virtual reality training (VRT) is more effective in motivating and can continue to hold children's interest during intervention. Therefore, the use of virtual reality (VR) in CP rehabilitation has increased in recent years (7,8).

VRT increases the neuroplasticity and motor learning associated with active participation, motivation and active repetition (9,10). VR games promotes a systematic practice of functional movements and multi-sensory feedback. Practice of the goal-directed movements, audio-visual feedback and motivation are important components for motor gains. VR approach includes the main principles of the motor learning theories such as the repetition of functional tasks, the feedback mechanism and the patient's motivation. VRT has positive effects on postural control, balance, gross motor function and upper extremity functions in children with CP (9,10).

Although VRT is a relatively new rehabilitation method, currently its popularity on the rise. In the majority of studies, Nintendo Wii (79%) is preferred over XBox Kinect (13%) and Sony PlayStation (8%). This difference can be caused by the fact that the Nintendo Wii is the first gaming system that is easily accessible and can be easily integrated into rehabilitation programs (11). The Kinect has controller-free game play with the player using their body in a natural way. Kinect games enables users to interact with the virtual environment without any balance board or remote controller. It is easy to use and provides different environments to encourage repetitive tasks. However, there is a lack of studies addressing the effects of Kinect games in children with CP. Our aim was to evaluate the effect of Kinect games on balance, motor function and upper extremity skills in children with spastic CP.

METHODS

This randomized controlled trial was conducted between October and January 2017. This trial was approved by the Ethical Committee of the İzmir Dokuz Eylül University Faculty of Medicine (Approval Date: 14.09.2017 and Approval Number: 2017/22-27). A written informed consent was obtained from parents, and all procedures were carried out according to the Helsinki Declaration.

Participants

The study was carried out in a rehabilitation center for special children, in Kütahya. Inclusion criteria were as follows: (1) diagnosis of spastic cerebral palsy; (2) ability to walk with an assistive device or independently; (3) ability to understand and follow simple verbal instructions; (4) no excessive spasticity in any joint (score [illegible]3 on the Modified Ashworth Scale).

Children who had any orthopedic surgery or botulinum toxin injection in the past 6 months, any limitation of ranges of motions preventing upper extremity movements, any visual or auditory impairments affecting the viewing of screen were excluded.

The sample size was calculated with the G-Power (ver. 3.1) software. Based on a similar study, estimated sample size was calculated to be at least 46 participants (effect size: 75%, α level: 0.05, desired power: (β), 80%) (12). 68 children who met the inclusion criteria were divided into two groups with simple randomization technique using envelope technique and sequentially numbered: VRT group (n = 34), was indicated as “1” and the control group (n = 34) was indicated as “2”.

Measurements

Evaluations were performed before and after training. Demographic characteristics of the children were recorded.

Primary Outcomes

The Pediatric Balance Scale (PBS), a child-adapted version of The Berg Balance Scale, consists of 14 items that are scored from 0 points to 4 points with a maximum score of 56 points. The scale examines many of the functional activities such as sitting, standing, transfers and stepping (13). For Sit to Stand Test (STST) patients were asked to stand up straight from a chair and then sit down without support during 30 seconds. After three repetitions, the mean measurement was calculated and determined as the final score (14). The Functional Reach Test (FRT) measures the maximal distance that children can reach forward while maintaining a fixed base of support in the standing position. The normal values of FRT ranged from 23.0 to 36.5 cm for 6-12 years old Turkish children. A score between 6-10 inches indicates a moderate risk for falls (15,16).

Secondary Outcomes

The Gross Motor Function Measurement-88 (GMFM-88), was used to measure gross motor function quantitatively. GMFM consists of 88 items divided into five basic dimensions: lying & rolling, sitting, crawling & kneeling, standing and walking, running & jumping. Each item was given scores between 0 and 3; 0 means that the activity cannot be initiated, and three means the activity is completed (17).

The Quality of Upper Extremity Skills Test (QUEST) was used to assessment of quality of upper extremity movement and hand skills in four domains: dissociated movement, grasp, protective extension and weight bearing. For each domain, a percentage score was calculated and the scores of the four domains summed to a total percentage score. It has strong reliability for children aged 2-12 years (18).

The Pediatric Disability Evaluation Inventory (PEDI) was used to assess function, activity and participation of the children. The Functional skills section of PEDI consisting of 197 items was used. Summary scores of this items indicate the children’s capacity of daily life skills in three domains; self-care, mobility and social-function (19).

Intervention

After the baseline measurements, children in both groups were applies an exercise training schedule that consist of 45 minutes/day, 2 days/8weeks. In the VRT group performed training using only video games and control group received neurodevelopmental treatment (NDT).

In the VRT group, Xbox Kinect (Xbox One Kinect, Microsoft, United States) game console, Kinect sensor, Kinect adapter, XBox One control and 82 inch LG monitor used. Seven games were selected to improve balance, reaction time, coordination, postural control, weight transfer and upper extremity functions. Each games performed at least 2 times. Rest periods were given between games.

In fruits Ninja games, children were asked to smash the fruits that appear on the screen by moving his arms up-down and right-left. There were some goals such as not detonating bombs, cutting power-up fruits, and exceeding 250 points in the game. During the tennis game, children were asked to hit the ball at the specified time by moving his arm up-down and front-back. Failing to hit the ball in time or throwing it out of bounds means losing points. In soccer game, the children represented the player who aims to score a goal and the goalkeeper who aims not to concede, respectively. They were asked to try to score a goal by hitting the ball. When the ball passed to the opposing team, they were asked to hold the ball by raising their arms to the side, up and reaching forward. The aim of the climbing game was to climb the wall by making bilateral upper extremity movements and jumping. In the bowling game, children stretched his arms forward and picked ball up from the ground by flexing the fingers and wrists. Then, they were asked to throw the ball forward and try to break the clubs. In the targeting game, children were asked to try to hit the targets on the target board by moving their arms right-left, up-down. In the wake racing game, children were asked to pass through the green circles on the screen by using the watercraft by transferring weight to the right-left, forward-backward, and rotating left and right. The goal of the virtual reality games was to develop balance, weight transfer, weight shifting, active use of children's limbs and to increase attention and focus.

In the control group, appropriate to the functional level of each child, individualized NDT program was applied. This program included activities that improving tone-regulating activities, upper extremity activities, daily living activities such as getting dressed, grasping and reaching, balance and mobility training, sit to stand activities and walking exercises.

NDT session consisted of following exercises: balance exercises in sitting and standing position, balance training on different balance boards, reaching and ball throwing-keeping exercises on trampoline, weight bearing activities in different positions, walking exercises in different directions, stretching and strengthening exercises, exercises to increase upper extremity functions, activities of daily living which include dressing, writing, using kitchen equipment such as fork and spoon.

Statistical Analysis

For data analysis, SPSS version 17.0 (SPSS Inc., Chicago, USA) was used. The distribution of the variables was measured with visual (plots/histograms) and analytical (Kolmogorov–Smirnov test) methods. Categorical data were reported in terms of frequency while continuous data were reported in terms of mean ± standard deviation (X±SD). Demographic characteristics of the children were compared using the chi-squared and Mann–Whitney U test. A Wilcoxon signed-rank test was used to test the mean differences between the pre and post-training process. The Mann–Whitney U test was used to determine whether the differences and changes between the scores in the study and control groups were statistically significant. The level of significance was set at $p < 0.05$. Cohen's d was used to determine the effect size and magnitude of difference between the measurements. Cohen classified effect sizes as small (0.2), medium (0.5), and large (≥ 0.8) (20).

RESULTS

52 children completed the training: 27 in the VRT group and 25 in the control group. Figure 1 shows an overview of the study protocol. Both groups were statistically identical in terms of age, gender, height and weight ($p> 0.05$) (Table 1). There was a difference with regard to dominant hand and orthosis ($p< 0.05$). While most of the children in the VRT group were predominantly left-handed, in the control group the dominant hand was right. Orthosis use in VRT group was higher than control group.

Table 1. Demographic Characteristics of the Children

	VRT group (n=27) X±SD	Control group (n=25) X±SD	x2	p
Age (year), (X±SD)	9.20±2.08	9.40±2.25	-481	0.630
BMI (kg/m²), (X±SD)	16.53±3.87	16.45±4.30	-303	0.762
Sex, n (%)				
Female	10(37)	11(44)	0.261	0.609
Male	17(63)	14(56)		
Dominant hand, n (%)				
Right	10(37)	17(68)	4.985	*0.026
Left	17(63)	8(32)		
Orthosis, n (%)				
User	20(74)	11(44)	4.877	*0.027
Not user	7(26)	14(56)		

*p <0.05; P: Mann–Whitney U test; x2: chi-square test; BMI: Body mass index

Table 2. Preintervention Group Similarities of Groups in Outcome Measures

	VRT group (n=27) X±SD	Control group (n=25) X±SD	p
PBS (0-56)	44.88±10.93	48.96±4.92	0.419
FRT (cm)	18.62±9.01	21.46±6.80	0.260
STST (repetition)	10.44±4.34	10.40±3.81	0.861
GMFM -88(%)	87.41±9.82	90.95±6.23	0.227
QUEST (%)			
Total	88.81±13.98	89.44±8.91	0.533
Dissociated movement	88.04±13.89	86.40±13.10	0.379
Grasp	82.16±20.85	85.73±11.47	0.941
Protective extension	95.57±11.43	92.99±11.73	0.638
Weight bearing	92.22±14.59	92.64±9.65	0.273
PEDI (%)			
Total	165.48±24.52	164.28±27.81	0.833
Self-care	59.92±10.41	56.32±13.02	0.359
Mobility	45.62±11.38	47.40±8.58	0.734
Social function	59.88±9.17	59.32±8.25	0.985

PBS: Pediatric Balance Scale; FRT: Functional Reach Test; STST: Sit to Stand Test; GMFM-88: Gross Motor Function Measurement-88; QUEST: Quality of Upper Extremity Skills Test; PEDI: Pediatric Disability Evaluation Inventory

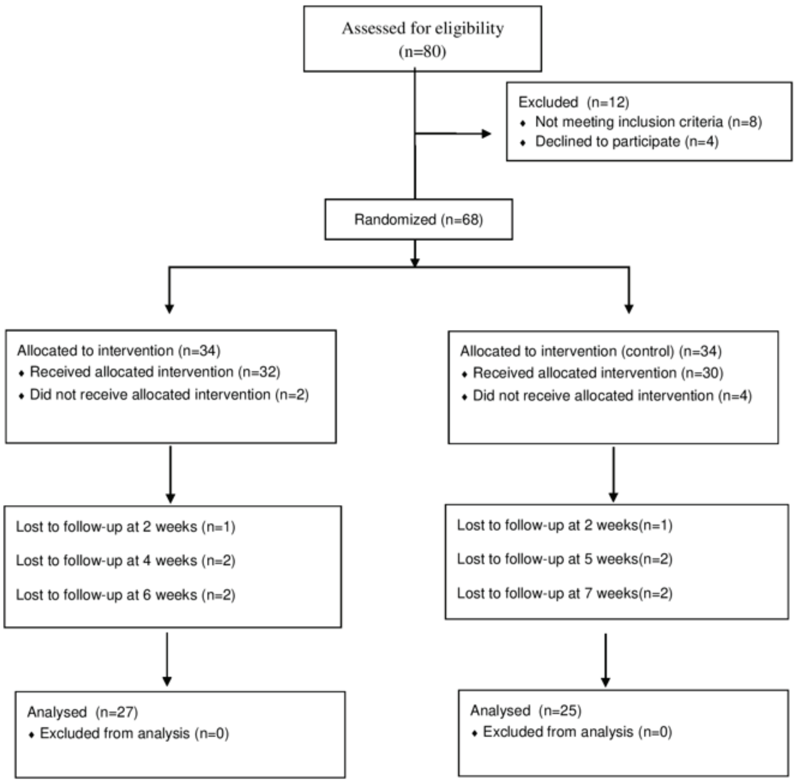

Figure 1. Flow Diagram of the Progress Through the Phases of a Randomized Trial of Two Groups

Table 3: Comparison of Outcome Measures at Baseline and After 8 Weeks in the Groups

Preintervention X±SD	VRT group (n=27)				Control group (n=25) X±SD			
	Postintervention X±SD	p	Effect size	Preintervention X±SD	Postintervention X±SD	p	Effect size	
PBS (0-56)	44.88±10.93	46.85±8.54	*0.001	0.2	48.96±4.92	49.96±4.82	*0.001	0.2
FRT (cm)	18.62±9.01	22.62±8.90	*0.000	0.44	21.46±6.80	26.30±5.62	*0.000	0.77
STST (repetition)	10.44±4.34	11.37±3.70	*0.007	0.23	10.40±3.81	12.16±4.15	*0.000	0.44
GMFM -88(%)	87.41±9.82	89.09±9.00	*0.000	0.18	90.95±6.23	92.13±5.57	*0.000	0.2
QUEST (%)								
Total	88.81±13.98	89.17±13.17	*0.027	0.02	89.44±8.91	90.97±8.69	*0.001	0.17
Dissociated movement	88.04±13.89	88.80±13.81	0.109	0.05	86.40±13.10	87.71±12.78	*0.005	0.1
Grasp	82.16±20.85	82.84±20.31	0.102	0.03	85.73±11.47	86.33±11.53	0.180	0.05
Protective extension	95.57±11.43	95.57±11.43	1000	0	92.99±11.73	95.49±9.36	0.066	0.23
Weight bearing	92.22±14.59	92.22±14.59	1000	0	92.64±9.65	94.48±8.94	*0.042	0.2
PEDI (%)								
Total	165.48±24.52	167.70±23.83	*0.001	0.09	164.28±27.81	166.16±27.46	*0.001	0.07
Self-care	59.92±10.41	60.29±10.34	0.059	0.03	56.32±13.02	56.92±12.87	*0.038	0.04
Mobility	45.62±11.38	47.40±9.98	*0.001	0.17	47.40±8.58	48.64± 7.78	*0.005	0.15
Social function	59.88±9.17	59.88±9.17	1.000	0	59.32±8.25	59.32±8.25	1.000	0

* p< 0.05.

There was no statistically significant difference in outcome measures between the two groups at initial assessments (p> 0.05, Table 2).

Comparisons of the outcome measures within the groups after 8 weeks are shown in Table 3. The PBS, FRT, STST and GMFM-88 scores changed statistically after treatment in both groups (p< 0.05). Only QUEST total score increased in the VRT group, whereas QUEST total scores and dissociated movement and weight bearing subscale scores increased significantly in the control group (p< 0.05). Total and mobility subscale scores of PEDI increased significantly in VRT group (p< 0.05). In control group self-care and mobility subparameters of PEDI and total PEDI scores increased significantly (p< 0.05).

Comparing the two groups, in VRT group, the degree of impact on FRT was moderate (Cohen's d: 0.30–0.80), while the impact on PBS, STST, GMFM, QUEST and PEDI were smaller (Cohen's d< 0.30) (Table 3). In control group, the degree of impact on PBS, STST, GMFM, QUEST and PEDI were smaller, while the degree of impact on FRT and STST was moderate (0.30–0.80).

Comparisons between the groups revealed significantly greater improvements in OUEST total scores and all of the subscale scores except for the grasp in the control group than in the VRT group (p< 0.05, Table 4).

DISCUSSION

Our aim was to examine the effect of VRT on balance, motor functions and upper extremity functions of children with CP. It was found that VRT and NDT approaches which are applied in similar durations have a positive effect on balance, gross motor function, functional skills and upper extremity functions. The NDT group showed greater improvement in the upper extremity skills than the VRT group.

As inadequate postural control and balance reactions prevent the voluntary skills and independence in daily life, balance training is quite important in CP rehabilitation. Besides daily life activities such as self-care activities require a good upper extremity function (3,21).

Motivation is very important in the CP rehabilitation process because interventions take a long time to achieve targeted functional gains. Conventional training may become boring for children (7).

Because of the game features VR is a good motivator to use as a form of intervention for children with CP. VR games can provide children with disabilities the chance to participate in games otherwise inaccessible (9). In light of this knowledge, we chose VRT in our study.

Our study showed a significant improvement in balance after VRT. These results were consistent with the findings by some studies (22-25). Consistent with previous studies, the virtual environment may have improved the balance by stimulation of the learning mechanism through multi-sensory feedback, continuous repetition of movements, and active participation. VR games include unexpected body movements that threat postural stability. Users should maintain postural stability in space during training (26). Practice and feedback that are the essential components for motor gestures may have increased the balance scores by construction and coordination of new muscle synergies (23,24). In the present study there was no significant difference in balance scores between groups. We suggest that both modalities can be used for improving balance in CP.

In literature, the effects of VRT on gross motor function are conflicting (24-26). Brien and Sveistrup showed that there was no significant improvement in GMFM scores after VR-based balance training on 5 consecutive days. In this previous study, the training probably was not long enough to gain functional improvements. Arnoni et al found positive effects of VR-based therapy on GMFM in children with CP after eight weeks intervention using XBox Kinect games. Şahin et al showed that improvement in motor function in the VR group which combined with traditional occupational therapy was greater than control group. In our study, both groups showed improvement in GMFM total scores. Our results suggest that the VRT might have been able to provide motor gains through multi-sensory stimuli and active repetition. Also, there was no difference between groups. That's why we think that VRT can be an alternative method to conventional treatment.

Ko et al studied the effect of VR intervention for children with hemiplegic CP and reported improved hand function (27). VR intervention and strengthening exercises had similar effect. Zoccocilo et al trained 22 children with CP with Kinect and concluded that although VRT improved upper limb motor skills, conventional therapy stil was superior for improving performances in manual activities of daily living (28). Similar to this study, in our study, both treatment approach was effective for improving upper extremity functions, but NDT was superior to VRT. The result of this study showed that NDT was more effective to improve the quality of upper extremity skills, in particular dissociated movement and weight bearing, evaluated by QUEST. Kinect can very well detect the movements of proximal joints such as shoulder and arm, but not designed to detect distal joint movements such as wrist and fingers. In Kinect games, grasping and upper extremity movements on each joint can be performed separately but it is not designed to improve hand skills that are used in daily life activities. NDT is an effective therapeutic approach for improving hand functions and quality of upper limb movements. This approach includes exercises that improve hand functions and hand use in daily activities. Kinect games were all controlled by gross limb and hand movements, but NDT includes fine hand and finger movements that related to activities of daily living (28,29). We think that all of these reasons are reflected in the results.

Urgen et al. reported that the improvement of PEDI scores in the study using Nintendo Wii for 33 children with hemiplegic CP (30). Similar to the literature, in the present study there was a significant increase in PEDI total scores in both groups. In the VRT group, improvement was observed in the PEDI total and the mobility subscale scores. We think that significant improvements of balance scores are reflected in the PEDI results. Unlike the VRT group, in the control group the self-care subscale score was also increased. Self-scale subscale strictly related to activities of daily living seemed to benefit more by NDT.

First limitation of our study was about the heterogeneity of group related to the CP classification as in other studies in the literature. The VR games we used didn't contain daily life activities and Kinect device wasn't sensitive enough to detect fine hand movements. Our study is not evaluating the long-term effects of treatment programs. Another limitation is that the difference in dominant hand type between the groups. Hand dominance is an important factor in the performance of motor skills. Gross manual dexterity and grip strength which are the best predicted the manual ability of children with CP differ in the dominant and non-dominant hand. Another limitation of our study is about the heterogeneity of groups about orthosis. The use of orthoses, which was closely related to functional limitation, differed between the groups.

As a conclusion, our study demonstrated that Kinect gaming system play a positive role in the improvement of the balance, motor function, upper limb skills and functional performance of children with CP. Although the VRT was not superior to NDT alone, VRT may also be a good alternative choice as it provided a positive effect. Therefore, we recommend that the addition of VRT as a supportive treatment to routine treatment of children with CP may be benefit for motor gains.

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Conflict of Interest: The authors declare that they have no conflicts of interest.

Author Contributions: Concept – AG, ÖF; Design - AG, ÖF; Supervision – AG; Resources and Financial Support - ÖF; Materials –ÖF; Data Collection and/ or Processing – ÖF; Analysis and/ or Interpretation - ÖF; Literature Research - ÖF; Writing Manuscript – AG, ÖF; Critical Review – AG, ÖF.

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