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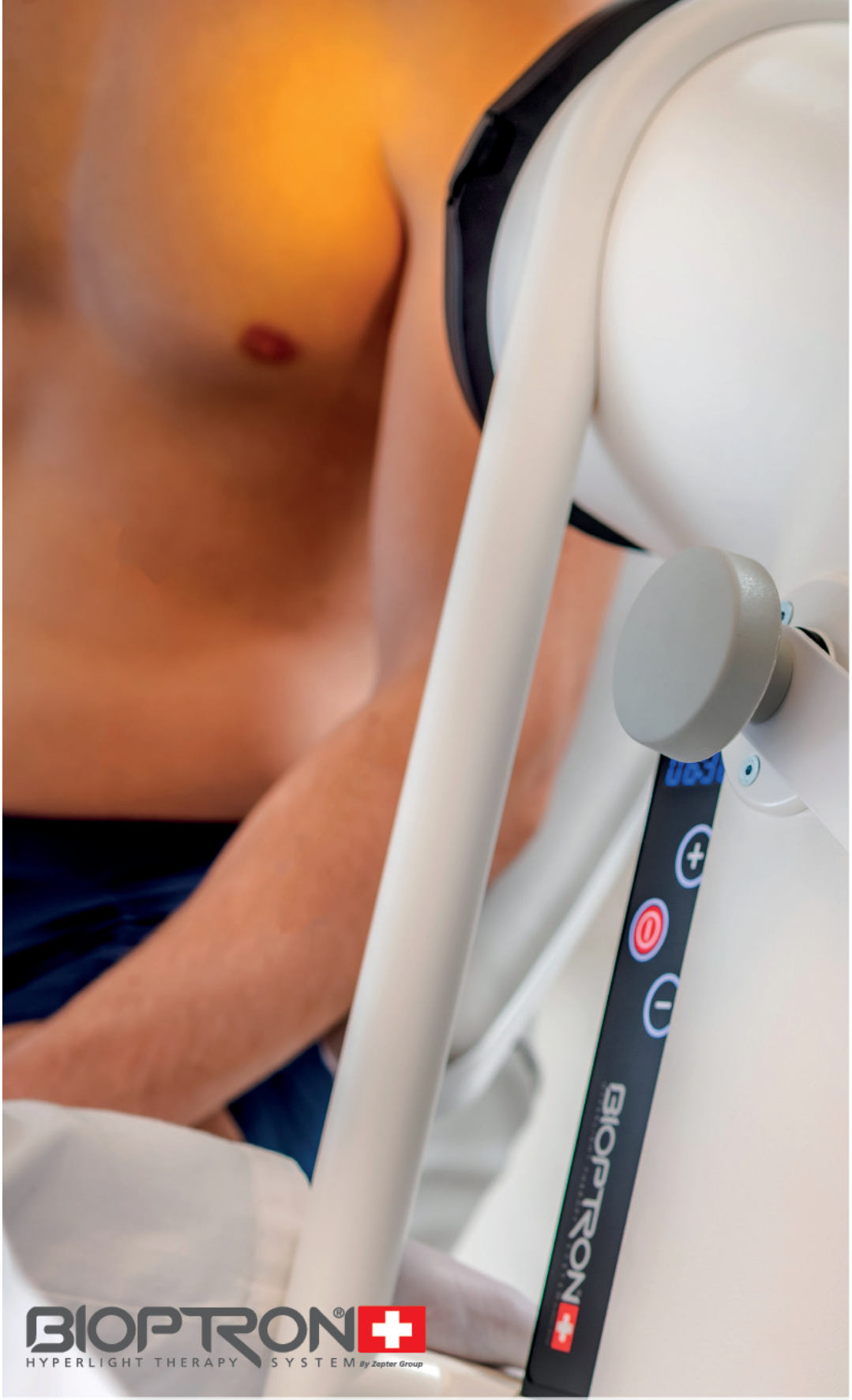

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Fizjoterapia jest nieodzownym składnikiem sukcesu we współczesnym sporcie, ponieważ przed sportowcami stawia się coraz wyższe wymagania. Muszą oni walczyć nie tylko z rywalami, ale także z wydajnością własnego organizmu. Z pomocą przychodzą nowoczesne urządzenia do fizjoterapii i rehabilitacji, które dają wytchnienie zmęczonym mięśniom, przyspieszając ich regenerację i likwidując bóle.

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Pełna oferta:

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Application of virtual reality and video games in pediatric physiotherapy. Systematic review

Wykorzystanie rzeczywistości wirtualnej i gier video w fizjoterapii dzieci. Artykuł przeglądowy

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Abstract

In recent years, intensive research has been carried out on virtual reality (VR) and its application in the treatment of pediatric patients. The basic objective of this review is to present the advantages, effectiveness and role of VR physical therapy in selected disease entities by comparing the results of VR research from the last 5 years. 17 articles were obtained from online databases: Pubmed, Researchgate, NCBI, Sage Journals, Oxford Academic. The analyzed studies concerned the use of VR in the treatment of pediatric patients with cerebral palsy, Down syndrome, developmental dyspraxia, risk of developmental dyspraxia, patients with burn injuries, juvenile idiopathic arthritis and ADHD. This review contains research on VR selected on the basis of their reliability, number and age of participants, and the year of publication. We excluded review articles in the selection of studies. The analysis of selected original research papers showed that VR physical therapy offers a number of advantages not found in standard physiotherapy and achieves comparable effects.

Key words:

VR, physiotherapy, rehabilitation, children, video, games

Streszczenie

W ostatnich latach intensywnie prowadzone są badania na temat wirtualnej rzeczywistości (VR) i jej zastosowania w terapii pacjentów pediatrycznych. Podstawowym założeniem tej pracy przeglądowej było przedstawienie zalet, efektywności i roli terapii wykorzystującej technologię VR w wybranych jednostkach chorobowych poprzez zestawienie wyników badań nad VR z ostatnich 5 lat. Pozyskanych zostało 17 artykułów z internetowych baz danych: PubMed, ResearchGate, NCBI, SageJournals, Oxford Academic. Opracowane badania dotyczyły zastosowania VR w terapii pacjentów pediatrycznych z dziecięcym porażeniem mózgowym, zespołem Downa, dyspraksją rozwojową, ryzykiem dyspraksji rozwojowej, pacjentów po oparzeniach, młodzieńczym idiopatycznym zapaleniem stawów oraz ADHD. W pracy zawarte zostały badania dotyczące VR wybrane na podstawie ich wiarygodności, liczby i wieku uczestników, roku publikacji. W doborze badań wykluczyliśmy prace przeglądowe. Analiza wybranych oryginalnych prac badawczych wykazała, że terapia z wykorzystaniem VR oferuje szereg zalet nieobecnych w standardowej fizjoterapii oraz osiąga porównywalne efekty.

Słowa kluczowe:

VR, physiotherapy, rehabilitation, children, video, games

Introduction

About 100,000 children annually benefit from pediatric rehabilitation financed by the National Health Fund in Poland [1]. In chronically ill patients (congenital defects, neurodevelopmental diseases, diseases leading to permanent disability) requiring long-term therapy, a single therapeutic session usually lasts about 1 hour – a child in preschool or early school age will have a huge problem with maintaining attention, which is crucial for the effectiveness of the therapeutic procedure. The problem will be even greater when the patient suffers from diseases of the central nervous system (CNS) with impaired concentration. The key factor in the treatment of pediatric patients is their degree of commitment and motivation to actively participate in therapeutic activities. Research on the effectiveness of therapy with the use of virtual reality VR indicates that the child is more willing to participate if the excercises are conducted with the use of this technology [2, 3, 4, 5]. The methods using VR and video games allow to provide the child with feedback in the form of displaying achieved result, verbal encouragement by an interactive robot connected to the game or attractive audiovisual effects in response to a specific child's movement encouraging further progress [5, 6, 7, 8]. Another advantage of using VR-based methods and games is the ability to adjust the level of difficulty of therapeutic tasks by changing the game settings, making therapy more appropriately adjusted to the patient, which is crucial due to the wide spectrum of disease advancement [7, 9, 10]. VR technologies and video games are becoming widely available and their cost is decreasing. As a result, more and more patients can benefit from this type of therapy. Classes can be conducted at the patient's home, which makes the therapy more comfortable, safer in the current epidemiological situation and eliminates the problem of traveling to a therapeutic center [4, 10, 11, 12, 13, 14].

Scientific research from recent years presents the possibilities of using VR devices and video games to improve adults. Few studies have been published to date to evaluate the use of this technology in pediatric physiotherapy. Including it in a standard children's rehabilitation program requires scientific evidence of the effectiveness of the proposed solutions.

Objective

The objective of this work is to compile research using VR technology and video games to answer the question of what is the scientific evidence for the effectiveness of the use of the above solutions in pediatric rehabilitation.

Methods

The PRISMA 2009 protocol was used to prepare this systematic review [15].

The articles included in this review were selected on the basis of the following criteria: 1) children, adolescents and young adults under the age of 21, 2) a study conducted on at least 10 people, 3) published from 2015-2020 (except Yee Pay Wuang 2011 [20]), 4) research using VR technology, 5) systematic reviews excluded. In the search for articles on VR technology and games, we used the following keywords: vr, physiothera-

py, rehabilitation, children, video, games.
Articles were searched from the following online databases: Pubmed, Researchgate, NCBI, Sage Journals, Oxford Academic.
The criterion for selecting the publication was the use of video games and VR games to improve balance, control and motor skills, reaction time, motor and functional development, postural control, coordination, range of motion, pain perception, and motivation of patients with various disease entities affecting these functions. Studies performed before 2015 and those involving less than 10 patients were excluded.
Two authors (KdT and JB) independently verified the titles and abstracts of 145 articles obtained after research with the previously described selection criteria. Articles that seemed appropriate to
be included in the work have been fully analyzed. Two authors independently extracted data from the articles contained in this review. The extracted data included: number of patients, age range, patient's disease entity, duration of the study, device used, study purpose and treatment effect. The procedure for

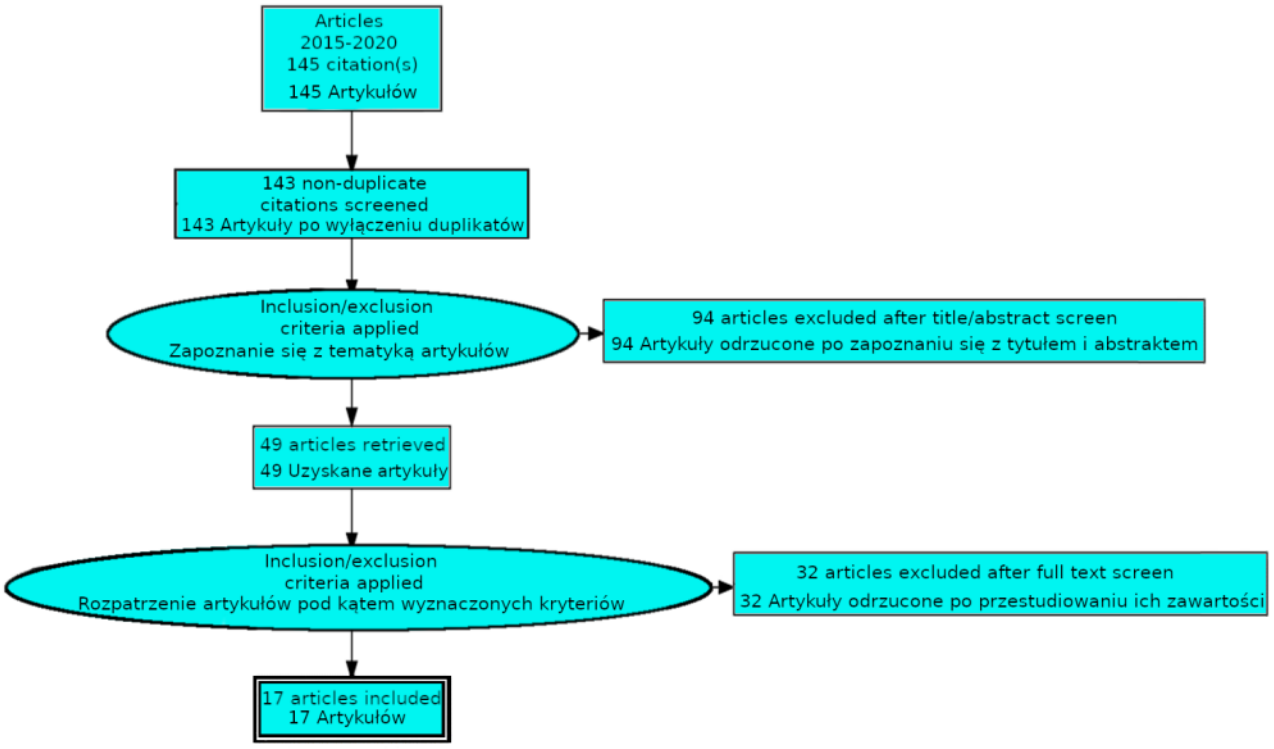

Figure 1. Procedure for selecting articles for analysis

selecting articles for analysis is presented in Figure 1.

Results

The number of found articles was 145, and after a thorough analysis and excluding works that did not meet the criteria, 17 articles were selected.
The publications concerned the following diseases: 9 related to cerebral palsy, 2
related to Down's syndrome, 1 related to developmental dyspraxia, 1 to the risk of developmental dyspraxia, 2 related to patients with burn injuries, 1 related to juvenile idiopathic ar-

thritis, 1 related to ADHD. The number of participants ranged from 10 to 111 people aged 4 to 20. A total of 737 people participated in the research. Table 1 details the 17 selected artic-

Table 1. Characteristics of the studied groups

Author	Number of study participants	Age range	Disease entity
Chunhee Cho 2016 [16]	N = 18	4–16	Cerebral Palsy
Morteza Pourazar 2018 [17]	N = 30	7–12	Cerebral Palsy
Yuping Chen 2018 [6]	N = 17	9,86 ± 1,3	Cerebral Palsy
Burcu Metin Ökmen 2019 [18]	N = 41	5–15	Cerebral Palsy
Hsieh-Chun Hsieh 2018 [19]	N = 40	7 ± 1,5	Cerebral Palsy
Devrim Tarakci 2016 [13]	N = 30	5–18	Cerebral Palsy
Jane Elizabeth Sajan 2017 [7]	N = 20	5–20	Cerebral Palsy
Valeska Gatica-Rojas 2017 [20]	N = 32	7–14	Cerebral Palsy
Bruno Bonnechère 2015 [5]	N = 10	7–13	Cerebral Palsy
Nicolás Gómez Álvarez 2019 [21]	N = 16	6–12	Down syndrome
Yee-Pay Wuang 2011 [22]	N = 105	7–12	Down syndrome
Emmanuel Bonney 2017 [23]	N = 111	6–10	Developmental dyspraxia
L. Straker 2015 [11]	N = 21	9–12	The risk of developmental dyspraxia
Ingrid Parry 2015 [24]	N = 17	5–18	Burn injuries
Eleonora I. Lozano 2018 [25]	N = 66	5–12	Burn injuries
Nilay Arman 2019 [26]	N = 62	6–18	Juvenile idiopathic arthritis
Valentin Benzing 2019 [27]	N = 51	8–12	ADHD

les.

Eight studies used the Nintendo Wii console, five used Xbox 360 Kinect studies, one used Super Pop VRTM System study, one Microsoft Kinect Camera study, one Darwin-OP study, two Sony Playstation 2 Eye Toy studies, one PC study using a dedicated gaming platform, one Sony Playstation 3 study. The therapy lasted from 3 weeks to 14 months. Table 2 provides information on the therapeutic interventions undertaken by the investigators.

In order to verify the effects of the therapy, the researchers used the assessment of various movement parameters, including: gait, balance, muscle strength, range of motion and coordination. Detailed information on the size of the study and control groups, the tests performed, the parameters tested and

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Table 2. Summary of information on the physiotherapy performed, its purpose and achievments

Author	Duration of the study	Device used	Purpose of therapy	The effect of the therapy
Chunhee Cho 2016 [16]	8 weeks, 3 sessions a week	Nintendo Wii	Treadmill training comparison with VR treadmill training	Significantly greater improvement in parameters in the group using the VR device
Morteza Pourazar 2018 [17]	4 weeks, 3 sessions a week for 25 minutes	Xbox 360 Kinect	Study of the impact of VR physical therapy on reaction time	Children from the experimental group significantly improved their reaction time, the effectiveness of this method is indicated due to the component of motivation and safety, difficult to achieve in conditions other than VR
Yuping Chen 2018 [6]	5 weeks, 2 sessions a week for 20 minutes	Super Pop VRTM system, Microsoft Kinect Camera & Robot Darwin-OP	A study checking the impact of feedback from an interactive robot on the effects of VR physical therapy and upper limb movement	Children performed more successful reaches, movement time, average speed, path and number of movement units while getting verbal feedback from Robot Darwin-OP
Burcu Metin Ökmen 2019 [18]	4 weeks, 3 sessions a week, 1 hour each	PC using a special gaming platform	Study of the influence of VR on motor and functional development	The BFMF, GMFCS test and the FMS scale showed an improvement in the parameters in the experimental group, with a statistically significant advantage over the control group
Hsieh-Chun Hsieh 2018 [19]	12 weeks, 5 sessions a week for 40 minutes	Nintendo Wii	Research on the influence of a gaming platform on posture control	Significantly better results were obtained in the balance tests and less fluctuations in posture were obtained in experimental group

Author	Duration of the study	Device used	Purpose of therapy	The effect of the therapy
Devrim Tarakci 2016 [13]	12 weeks, 24 training sessions	Nintendo Wii	Comparison of balance training using the Nintendo Wii and conventional kinesiotherapy methods	The experimental group obtained a greater improvement in balance compared to the control group
Jane Elizabeth Sajan 2017 [7]	3 weeks, 6 sessions a week for 45 minutes	Nintendo Wii	Comparison of the control of the progress of balance exercises in children with cerebral palsy using Nintendo Wii games with the group subjected to standard physical therapy	The experimental group improved the control over the upper limb compared to the control group. The obtained equilibrium control in both groups was the same
Valeska Gatica-Rojas 2017 [20]	6 weeks, 3 sessions a week	Nintendo Wii	Effect of exercises on the Nintendo Wii console on standing balance compared to the group subjected to standard physiotherapy	The experimental group improved their standing balance compared to the control group, and the progress continued for 2-4 weeks after the end of therapy
Bruno Bonnechère 2015 [5]	4 weeks, 30 minutes a week	Nintendo Wii	Balance testing after training using a game designed for children with cerebral palsy	There was an improvement in balance in a static sitting position, no improvement in a dynamic sitting position
Nicolás Gómez Álvarez 2019 [21]	5 weeks, 2 sessions a week	Nintendo Wii	Study of the effect of using VR on motor skills and postural control	Improvement in general motor skills has been shown, especially in the field of manipulative skills

Author	Duration of the study	Device used	Purpose of therapy	The effect of the therapy
Yee-Pay Wuang 2011 [22]	24 weeks, 2 sessions a week, 1 hour each	Nintendo Wii	Comparison of the effects of therapy in the group with the use of Nintendo Wii, the group subjected to standard physiotherapy and the control group on sensorimotor functions	The group subjected to standard physiotherapy and the group using the Nintendo Wii significantly improved their parameters compared to the control group. The group using the Nintendo Wii achieved significantly better results compared to the group undergoing standard physiotherapy in terms of hand-eye coordination
Emmanuel Bonney 2017 [23]	5 weeks, 2 sessions of 20 minutes a week	Sony PlayStation 3 & Xbox	Study of the impact of training with the use of VR on learning motor skills in the case of diversified movement training and repetitive movement training	Progress was steady, with all of them having comparable improvement in both the test and control groups
L. Straker 2015 [11]	16 weeks	360 Kinect	Coordination study in the group using VR movement games and in the group performing standard physical activities. The secondary goal was to determine the child's and parent's perception of the child's physical condition in both groups	No differences in improving coordination between the experimental group and the control group. Children in the experimental group perceived their motor skills as higher, which may be motivating to engage in physical activities in the future

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Author	Duration of the study	Device used	Purpose of therapy	The effect of the therapy
Ingrid Parry 2015 [24]	3 weeks, 2 sessions a day and a 6-month follow-up examination	PlayStation II Eye Toy	/ Comparison of improvement in range of motion and perceived pain in the group treated with VR and standard physiotherapy	Both groups ultimately achieved the same return to range of motion, however, the experimental group made much greater progress by week 3 of the study compared to the control group. In addition, the group using standard therapy reported increasing pain during therapy, while the group using VR did not report greater pain
Eleonora I. Lozano 2018 [25]	14 months	Xbox 360 Kinect	Comparison of ranges of motion, activity and satisfaction levels between the test and control group. Both groups received standard physiotherapy, of which the experimental group additionally received VR physical therapy	The experimental group showed a greater improvement in ranges of motion and statistically greater satisfaction. The activity of the patients depended on the percentage of body burn injuries
Nilay Arman 2019 [26]	8 weeks, 3 sessions a week	Xbox 360 Kinect	Comparison of the effects of performing daily activities with household utensils and a group exercising everyday activities using the Xbox 360 kinect	The group using virtual reality achieved a slightly higher improvement in results compared to the control group in terms of strength of most upper limb muscles, grip strength and satisfaction with the therapy
Valentin Benzing 2019 [27]	8 weeks, 3 sessions a week, 30 minutes each	Xbox 360 Kinect	Study of the impact of VR physical therapy on motor skills, executive skills and ADHD symptoms in children with ADHD	Cognitive improvement was shown, but no effect on ADHD symptoms was noted

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Table 3. Detailed information on the conduct of the studies

Author	Disease entity	Number of participants	Parameters measured	Tests used	Result
Chunhee Cho 2016 [16]	Cerebral Palsy	Study group: 9	Gait	10 meter walk test, 2 minute walk test	Significant improvement of balance and endurance in walking in the experimental group
			Balance	PBS - Pediatric Balance Scale	Significant improvement in the balance in the experimental group
		Control group: 9	Muscle strength	Digital measurement of muscle strength	Significant improvement in muscle strength in the experimental group compared to the control group
			Motor skills	Gross motor function scale	Significant improvement of motor skills on the functional scale of large motor skills compared to the control group
Morteza Pourazar 2018 [17]	Cerebral Palsy	Study group:15 Control group: 15	Simple reaction time (SRT) and Discriminative Reaction Time (DRT)	RT - 888 Automatic Response Time Measurement Device	Significant improvement in parameters of simple reaction time and discriminative reaction time in the experimental group
Yuping Chen 2018 [6]	Cerebral Palsy	Study group: 7 children with cerebral palsy, 10 healthy children Control group: -	Influence of interactive elements of therapy on its results	Super Pop VRTM, a Microsoft Kinect Camera	Children performed more successful arm reaches , faster movements and shorter delays between each reach when receiving feedback from the interactive robot
Burcu Metin Ökmen 2019 [18]	Cerebral Palsy	Study group:21 Control group: 20	The impact of VR physical therapy on the motor and functional development of a child with cerebral palsy	Bimanual Fine Motor Function (BFMF) test, gross motor functional scale, Functional Mobility Scale (FMS)	Significant improvement in motor skills and mobility in the experimental group

Autor Author	Jednostka chorobowa Disease entity	Liczba osób Number of participants	Badane parametry Parameters measured	Wykorzystane testy Tests used	Wynik Result
Hsieh-Chun Hsieh 2018 [19]	Cerebral Palsy	Study group: 20 Control group: 20	Postural balance control	Center–of-pressure sway, the Berg Balance Scale (BBS), Fullerton Advanced Balance Scale (FAB), and Timed Up and Go (TUG) test scores	Significant improvement in the measurements of Center–of-pressure sway, the Berg Balance Scale (BBS), Fullerton Advanced Balance Scale (FAB), and Timed Up and Go (TUG) test in the experimental group
Devrim Tarakci 2016 [13]	Cerebral Palsy	Study group: 15 Control group: 15	Balance	Center–of-pressure sway, the Berg Balance Scale (BBS), Fullerton Advanced Balance Scale (FAB), and Timed Up and Go (TUG) test scores, Functional Stretch Test, Test Up and Go (TUG), Nintendo Wii Fit gaming results, 10-meter walk test, 10-step climb test and children's functional independence scale (Wee FIM)	Significant improvement of all parameters tested in the experimental group
Jane Elizabeth Sajan 2017 [7]	Cerebral Palsy	Study group: 10	Postural balance and control Upper limb functionality, abilities	Static posturography, modified Berg scale Box and block test, QUEST scale (Quality of Upper Extremity Skills Test)	Significant improvement in the functionality of the upper limbs in the experimental group, other parameters without significant improvement compared to the control group
		Control group: 10	Visually- perceptual Functional mobility	T Test for Visual-Perceptual Skills (TVPS) - third edition Measurements of your walking speed and distance traveled	

Autor Author	Jednostka chorobowa Disease entity	Liczba osób Number of participants	Badane parametry Parameters measured	Wykorzystane testy Tests used	Wynik Result
Valeska Gatica-Rojas 2017 [20]	Cerebral Palsy	Study group: 16 Control group: 16	Functional mobility center-of-pressure (CoP) sway (CoPSway) Standard deviation in the medial-lateral (SDML) and the anterior-posterior (SDAP) directions, and velocity in both directions (VML and VAP)	Force platform	Improvement of all parameters lasting up to 2-4 weeks
Bruno Bonnechère 2015 [5]	Cerebral Palsy	Study group:10 Control group: -	Balance	Trunk Control Measurement Scale (TCMS)	Significant improvement in trunk stabilization in the experimental group
Nicolás Gómez Álvarez 2019 [21]	Down syndrome	Study group: 9 Control group: 7	Impact of VR physical therapy on the motor development of patients with Down syndrome	Center of pressure displacement, TGMD-2- Test of Gross Motor Development	Significant improvement in gross motor test results and a slight improvement in other parameters in the experimental group
Yee-Pay Wuang 2011 [22]	Down syndrome	Study group: 53 patients undergoing standard physiotherapy, 52 patients undergoing VR physical therapy Control group: 50	Comparison of standard therapy with VR physical therapy	BOT-2 - Bruininks– Oseretsky Test of Motor Proficiency, VMI - Visual Motor Integration, TSIF - Test of Sensory Integration Function	Significant improvement in parameters in the group treated with VR
Emmanuel Bonney 2017 [23]	Developmental dyspraxia	Study group: 56 Control group: 55	Comparison of the impact of varied and repetitive movement games on learning motor skills	Game scores	No difference

Autor Author	Jednostka chorobowa Disease entity	Liczba osób Number of participants	Badane parametry Parameters measured	Wykorzystane testy Tests used	Wynik Result
L. Straker 2015 [11]	The risk of developmental dyspraxia	Study group: 10 Control group: 11	Comparison of the development of coordination and the perception of own motor skills in the group subjected to VR physical therapy with the control group not using VR physical therapy	Movement Assessment Battery for Children (MABC-2), three-dimensional analysis of one-leg balance, finger-to-nose test and perception of physical abilities by the child and parent	No improvement of parameters in the experimental group. Nevertheless, patients after VR physical therapy assessed their abilities better than patients in the control group
Ingrid Parry 2015 [24]	Burn injuries	Study group: 9 Control group: 8	Comparison of ranges of motion, level of perceived pain, degree of effort and satisfaction with therapy	Study of ranges of motion using a goniometer	Improving the range of motion in both groups, reducing the pain sensation in the experimental group, increasing satisfaction in the experimental group
Eleonora I. Lozano 2018 [25]	Burn injuries	Study group: 31 Control group: 35	Effect of Xbox Kinect™ Therapy on ROM and Therapy Satisfaction	Study of the ranges of motion, Activity Scale for Children (ASK © p - Activities Scale for Kids) modified Wong-Baker FACES® scale checking satisfaction with therapy	Significant improvement in the range of motion and satisfaction with therapy in the experimental group
Nilay Arman 2019 [26]	Juvenile idiopathic arthritis	Study group: 31 Control group: 31	Comparison of the effects of everyday activity training on the group using materials from home and the group using xbox 360 kinect, on muscle strength, grip strength, pain level, ability to perform and participate in everyday activities	Dynamometer Muscle Strength Measurements, Numeric Raing Scale (NRS), Childhood Health Assessment Questionnaire (CHAQ), Canadian Occupational Performance Measure (COPM), Duroza Hand Index (DHI - Duruoz Hand Index)	Significant improvement in all parameters in both groups, however, the group using VR phical therapy achieved significantly higher results in the strength of most muscles of the upper limb, grip strength, COPM and Duruoz Hand Index tests
Valentin Benzing 2019 [27]	ADHD	Study group: 28 Control group: 23	Effect of VR exercises on motor skills, executive skills and ADHD symptoms in children with ADHD.	Simon Task	The experimental group achieved a faster overall reaction time relative to the control group
				Flanker Task	The experimental group performed the changing tasks faster than the control group
				Color span backward task	No differences between the experimental group and the control group

their results are presented in Table 3.
Fifteen of the eighteen studies were randomized. A follow-up study was conducted in two publications [20, 25]. In one of them, the deterioration of the measured parameters was noted compared to the measurement before the intervention [20], in the second, patients from the experimental group obtained a better result than patients from the control group [25]. Two articles did not include the control group in the study [5, 6].

Discussion

Research included in this systematic review showed improvements in gait, balance, muscle strength, motor skills and mobility in patients with cerebral palsy and improved motor skills in patients with Down syndrome. Virtual reality intervention showed a comparable improvement of motor skills in children with dyspraxia when compared with conventional therapy. There was no improvement in coordination in patients at risk of dyspraxia, however, the subjects reported an improvement in the perception of their own motor skills, which may translate into an increase in their motivation to undertake further activities, improvement in the range of motion, reduction of perceived pain and
increased satisfaction with treatment. A significant improvement in the muscle strength of the upper limb has been observed as a result of the use of VR technology in the therapy of children with juvenile idiopathic arthritis. There was improvement in reaction time and reaction time under changing conditions in children with ADHD.
The use of VR in physiotherapy of children brings a number of benefits, including the possibility of precise adjustment of therapy parameters to the patient's abilities and needs. The patient can constantly receive feedback on the effectiveness of the actions performed by converting the performed movements into virtual points. The games engage the patient's attention and therefore sessions can last longer, be more frequent and more intense. Games provide the patient with new, unprecedented stimuli. This stimulates the formation of new neural connections by increasing cortical activity and activating mirror neurons. Tasks given to patients can be based on complex and global movements specifically adapted to the parameter being improved, which translates into activation of more muscle groups and improvement of balance. The use of this technological solution can have a positive effect on the efficiency of functional movements used in everyday activities. Many studies indicate an important aspect of motivation, which is provided by the feedback, patient’s control over the game, competition with another player or computer, various challenges or the ability to monitor progress. Many researchers indicated that the child's motivation may be the main factor determining the effectiveness of therapy [3, 9].
The attractiveness of VR is an argument for using it in therapy. Getting patients interested in therapeutic activities can be a challenge, while the role of patient involvement and motivation is indicated as one of the key factors in achieving high results in therapy [28, 29]. The use of VR pgysical therapy also reduces the patient's pain perception, which, combined with the attractiveness of VR games, may increase the willingness to actively participate in exercises. The continuous development of VR technology makes the devices that can be used become cheaper, easier to use, more accessible and enables the

physiotherapist to monitor, even remotely, the therapeutic tasks performed by the patient. Thanks to these technological advances, the possibilities of conducting and continuing therapy at the patient's home increase [24, 30].

VR technology in physiotherapy offers great opportunities for monitoring certain parameters of the patient. In some studies, a three-dimensional limb motion tracking system is used with a camera and appropriate software, but it is not a standard measurement procedure. By obtaining information about the patient's ability to perform specific motor tasks, it is possible to provide appropriate feedback, motivating for further exercises or leading to the correction of possible errors, adjust the level of difficulty of the task to the patient's abilities, or obtain data on the progress and improvement of the exercising parameters [6, 7, 9, 10]. In the future, thanks to increased awareness and further technological advances, exercises using VR can be an important element of a healthy, active lifestyle [31].

Virtual reality includes many forms that can be adapted to the patient's needs. These include two-dimensional forms, in which the image is displayed on the monitor screen, and three-dimensional forms, which provide depth to the image and increase immersion - the feeling of identifying with the game and plunging into virtual reality. VR technology is a rapidly growing field in the video game industry. One of the novelties is the immersion cave, which aims to enrich the virtual reality experience with the possibility of walking and running in the designated zone.

There is still no research on the basis of which it is possible to unequivocally determine whether physiotherapy with the use of VR should be the main component of therapeutic treatment or only its complement.

Attention should also be paid to the correct implementation of exercises with the use of virtual reality, especially if they are performed at home, without the direct supervision of a physiotherapist. In order to improve the course of therapy with the use of virtual reality, it is necessary to consider how to effectively introduce the element of patient supervision [32].

Another issue that requires research is the phenomenon known as virtual disease "cybersickness". It is a disease with symptoms similar to motion sickness and is caused by conflicting information perceived by the various senses. The list of side effects includes headache, seizures, nausea, fatigue, drowsiness, confusion, apathy, and dizziness [9, 33]. It was assumed that this disease may occur mainly in people with postural instability, but research has shown that any user of virtual reality may be at risk of its occurrence [34]. Ways to prevent cybersickness include proper calibration of the VR system, use of a more natural user interface (UI), use of touch interfaces, and appropriate dosing of the duration of VR physical therapy. An important factor supporting the course of therapy with the use of VR is increasing the sense of immersion in relation to the virtual world, which, according to research, is inversely proportional to the chance of cybersickness [9, 35, 36]. In the longer term, it is necessary to conduct reliable studies on the occurrence of undesirable ailments as a result of the use of VR in children.

It is worth emphasizing the importance of using VR technology in the case of telerehabilitation. The patient can remotely execute the therapist's instructions, adjusting the program to individual needs. Telerehabilitation relieves the patient financially and

eliminates the problem of transport to medical facility. It allows for a smooth transition between institutionalized care and full independence in a amiliar environment, as well as greater involvement of the patient and his family in the rehabilitation process. This form of treatment also allows patients to work in a group and compete with other patients with similar disabilities [37].
Follow-up studies to document the durability of the therapeutic effects and possible side effects may be a suggestion for further research. Currently, there are major shortcomings in long-term studies in the field of VR physical therapy. In addition, there are no clear guidelines as to whether this method is to be the leading form of physiotherapy in a given condition, or a complementary tool in the rehabilitation program. In the analyzed studies, the length of the sessions and the length of the therapeutic cycles differed significantly. On this basis, it is impossible to determine how long a therapeutic session should last and how many sessions should be included in the cycle to obtain the desired effect.
An issue worth considering is also the influence of the selection of a specific VR device on the effectiveness of therapy. Research shows differences in therapeutic progress resulting from the use of devices from different companies and the importance of the appropriate selection of the device in relation to the specificity of a given movement [38, 39].

Conclusions

In summary, the results of the analyzed studies indicate that the use of VR technology can have a number of advantages such as: feedback on the movement performed by the patient, adjusting the device to the individual needs of the patient, attractive audiovisual setting, providing new stimuli, increasing the general interest and involvement of the patient in the therapy. The results obtained in the research included in this paper suggest that VR technologies may constitute the basis or element of effective physiotherapy in pediatric patients with cerebral palsy, Down syndrome, developmental dyspraxia, risk of developmental dyspraxia, patients after burns, juvenile idiopathic arthritis and ADHD. The promising results of the above studies indicate the need to develop guidelines regarding the form, methods and frequency of using VR technology in children's physiotherapy.

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