fizjoterapia polska

POLISH JOURNAL OF PHYSIOTHERAPY

OFICJALNE PISMO POLSKIEGO TOWARZYSTWA FIZJOTERAPII

THE OFFICIAL JOURNAL OF THE POLISH SOCIETY OF PHYSIOTHERAPY

NR 2/2017 (17) KWARTALNIK ISSN 1642-0136

Wpływ terapii z wykorzystaniem nowoczesnych technologii na aktywność i wytrzymałość dzieci z mózgowym porażeniem dziecięcym

The impact of technology-based therapy on activity level and endurance of children with cerebral palsy

Wpływ przebytego udaru mózgu na moc i prędkość skracania się mięśni

The impact of stroke on the power and shortening velocity of the muscles

TROMED TRAINING
program szkoleniowy

REHABILITACJA KARDIOLOGICZNA W PRAKTYCE

Szkolenie skierowane do osób zajmujących się problematyką rehabilitacji kardiologicznej, podzielone na dwa moduły.
Moduł I obejmuje zasady rehabilitacji kardiologicznej, metody diagnostyczne i terapeutyczne oraz rolę fizjoterapeuty w procesie rehabilitacji.
Moduł II omawia zagadnienia Kompleksowej Rehabilitacji Kardiologicznej u chorych po ostrym zespole wieńcowym, po zabiegach kardiochirurgicznych, po wszczepieniach kardiostymulatora oraz u chorych z chorobami współistniejącymi.

SCHORZENIA STAWU BARKOWEGO - REHABILITACJA Z WYKORZYSTANIEM ELEMENTÓW TERAPII MANUALNEJ

Szkolenie skierowane do fizjoterapeutów oraz studentów fizjoterapii, obejmujące zagadnienia z anatomii i fizjologii obręczy barkowej, podstaw artro i osteokinematyki, charakterystyki wybranych urazów i uszkodzeń w obrębie obręczy barkowej, profilaktyki schorzeń barku, diagnostyki pourazowej barku oraz praktycznego zastosowania technik manualnych w rehabilitacji

DIAGNOSTYKA I LECZENIE MANUALNE W DYSFUNKCJACH STAWU KOLANOWEGO

Szkolenie skierowane do fizjoterapeutów oraz studentów fizjoterapii, obejmujące zagadnienia z anatomii stawu kolanowego, biomechaniki struktur wewnątrzstawowych, charakterystyki wybranych uszkodzeń w stawie kolanowym, diagnostyki pourazowej stawu kolanowegooraz praktycznego zastosowania technik manualnych w rehabilitacji.

PODSTAWY NEUROMOBILIZACJI NERWÓW OBWODOWYCH - DIAGNOSTYKA I PRAKTYCZNE ZASTOSOWANIE W FIZJOTERAPII

Szkolenie podzielone na dwie części. Zajęcia teoretyczne obejmują zagadnienia dotyczące budowy komórek nerwowych, anatomii i fizjologii obwodowego układu nerwowego i rdzenia kręgowego, pozycji napięciowych i pozycji początkowych testów napięciowych w kończynach oraz kręgosłupie. Zajęcia praktyczne obejmują wykonanie neuromobilizacji dla nerwów obwodowych i opony twardej oraz przykładowe wykorzystania neuromobilizacji w jednostkach chorobowych.

TERAPIA PACJENTÓW Z OBRZĘKIEM LIMFATYCZNYM

Szkolenie podzielone na zajęcia teoretyczne z zakresu anatomii i fizjologii gruczołu piersiowego oraz układu chłonnego, objawów raka piersi, leczenia chirurgicznego, rehabilitacji przed i pooperacyjnej oraz profilaktyki przeciwobrzękowej. Zajęcia praktyczne mają na celu zapoznanie z metodami stosowanymi w terapii przeciwobrzękowej, praktycznym wykorzystaniem materiałów do kompresjoterapii oraz omówieniem zaopatrzenia ortopedycznego stosowanego u pacjentek po mastektomii.

FIZJOTERAPIA W ONKOLOGII - ZASADY POSTĘPOWANIA W WYBRANYCH PRZYPADKACH KLINICZNYCH

Szkolenie obejmuje zagadnienia dotyczące epidemiologii nowotworów i czynników ryzyka, diagnostyki, leczenia oraz następstw leczenia nowotworów (leczenie układowe, chirurgiczne, chemioterapia, radioterapia), podstaw terapii pacjentów leczonych w chorobach nowotworowych piersi, płuc, przewodu pokarmowego, okolicy głowy i szyi, układu moczowo-płciowego, układu nerwowego. Część praktyczna to ćwiczenia oraz metody fizjoterapeutyczne w jednostkach chorobowych.

LOGOPEDIA W FIZJOTERAPII

Szkolenie obejmuje następujące zagadnienia teoretyczne: założenia, zakres działań i uprawnienia terapii logopedycznej, narzędzia diagnozy logopedycznej, grupy pacjentów objętych terapią logopedyczną (dzieci z opóźnionym rozwojem mowy i dorośli, m.in. pacjenci z afazją, SM, chorobą Parkinsona), zaburzenia mowy a globalne zaburzenia rozwoju psychoruchowego, dysfunkcje układu ruchowego narządu żucia, wspólne obszary działania fizjoterapeuty i logopedy.
Część praktyczna obejmuje studium przypadku: ćwiczenia - kształtowanie umiejętności świadomego i prawidłowego operowania oddechem.

INFORMACJE I ZAPISY

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PODSTAWY NEUROREHABILITACJI - UDAR MÓZGU - MODUŁ 1

Szkolenie obejmuje zajęcia teoretyczne omawiające mechanizm udaru mózgu i jego następstwa kliniczne, diagnostyki dla potrzeb fizjoterapii, rokowań, mechanizmów zdrowienia, plastyczności układu nerwowego oraz aktualne zaleceniach dotyczące fizjoterapii pacjentów po udarze mózgu. Zajęcia praktyczne to przykłady terapii pacjentów w okresie wczesnej i wtórnej rehabilitacji, propozycje rozwiązywania problemów strukturalnych i funkcjonalnych oraz wykorzystanie metody Bobathów w rehabilitacji pacjentów po udarze mózgu.

PODSTAWY NEUROREHABILITACJI - UDAR MÓZGU - MODUŁ 2

Szkolenie obejmuje warsztaty praktyczne z zakresu diagnostyki funkcjonalnej pacjentów, podstawowych problemów strukturalnych i funkcjonalnych oraz propozycje terapii: reedukacji funkcji kończyny górnej i dolnej oraz wybranych strategii rehabilitacji. Omawiane jest również zagadnienie dysfagii, w tym objawy zaburzeń połykania, testy i ocena zaburzeń, zasady bezpiecznego karmienia, strategie terapeutyczne, ćwiczenia miofunkcyjne oraz specjalne techniki ułatwiające połykanie.

SCHORZENIA NARZĄDÓW RUCHU U DZIECI I MŁODZIEŻY - ZASADY I KRYTERIA LECZENIA ORTOPEDYCZNEGO

Szkolenie obejmuje zagadnienia wad postawy u dzieci i młodzieży, wad wrodzonych narządów ruchu, wczesnego wykrywania nabytych schorzeń narządów ruchu, naukę badania ortopedycznego oraz zbierania wywiadu oraz praktyczne wskazówki oraz koncepcje w stosowaniu ortez i aparatów ortopedycznych.

Szkolenie skierowane do lekarzy ortopedów, pediatrów, lekarzy rodzinnych, lekarzy rehabilitacji medycznej, fizjoterapeutów oraz średniego personelu medycznego.

WSPÓŁCZESNE METODY LECZENIA WYBRANYCH DYSFUNKCJI STAWU SKOKOWEGO I STOPY

Szkolenie obejmuje zagadnienia z anatomii, biomechaniki stawu skokowego i stopy, metodyki badania stopy, postępowania w leczeniu urazów stawu skokowego i stopy, nabytych zniekształceniach stopy (przyczyny, objawy, sposoby postępowania) oraz pozostałych dysfunkcjach w obrębie stawu skokowego i stopy (entezopatie, przeciążenia, zapalenia, zespoły uciskowe nerwów, gangliony, zmiany zwyrodnieniowe, stopa cukrzycowa, stopa reumatoidalna).

CHOROBA ZWYRODNIENIOWA STAWÓW - ALGORYTM POSTĘPOWANIA DIAGNOSTYCZNO-TERAPEUTYCZNEGO

Szkolenie obejmuje następujące zagadnienia: choroba zwyrodnieniowa stawów - podstawowe pojęcia, algorytm postępowania diagnostyczno-terapeutycznego , nowoczesne metody leczenia w chorobie zwyrodnieniowej stawów, nauka prawidłowej oceny zaawansowania choroby zwyrodnieniowej w oparciu o wywiad, badania ortopedyczne i badania dodatkowe, zastosowanie ortez i aparatów ortopedycznych w chorobach zwyrodnieniowych.

Szkolenie skierowane do lekarzy ortopedów, pediatrów, lekarzy rodzinnych, lekarzy rehabilitacji medycznej, fizjoterapeutów oraz średniego personelu medycznego.

MOBILNOŚĆ I STABILNOŚĆ W SPORCIE I FIZJOTERAPII

Szkolenie obejmuje następujące zagadnienia: znaczenie treningu mobilności i stabilności w sporcie i fizjoterapii, definicja mobilności, przyczyny ograniczeń, strategie postępowania oraz techniki pracy nad zwiększeniem mobilności z użyciem przyborów, definicja stabilności, przyczyny zaburzeń, strategie postępowania oraz trening stabilności w sporcie i fizjoterapii - zajęcia praktyczne.

MÓZGOWE PORAŻENIE DZIECIĘCE - ALGORYTM POSTĘPOWANIA DIAGNOSTYCZNO-TERAPEUTYCZNEGO

Szkolenie obejmuje następujące zagadnienia: MPD - zespół symptomów, etapy leczenia, cele i wskazówki terapeutyczne, kwalifikacje pacjenta do danego etapu leczenia, nauka badania ortopedycznego w Mózgowym Porażeniu Dziecięcym, zastosowanie ortez i aparatów ortopedycznych w MPD.

Szkolenie skierowane do lekarzy ortopedów, pediatrów, lekarzy rodzinnych, lekarzy rehabilitacji medycznej, fizjoterapeutów oraz średniego personelu medycznego.

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The impact of technology-based therapy on activity level and endurance of children with cerebral palsy

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Streszczenie
Cel pracy. Celem pracy jest ocena wpływu terapii z wykorzystaniem zewnętrznego kontrolera ruchu, jakim jest Kinect (tzw. terapii z wykorzystaniem wirtualnej rzeczywistości), na sprawność funkcjonalną dzieci z mózgowym porażeniem dziecięcym na przykładzie trzech wybranych modułów terapeutycznych Tratwa (Raft), Wioślarz (Oarsman), Siłownia (Gym).
Materiał i metodyka. Do niniejszego projektu zaproszono czternaścioro dzieci w przedziale wiekowym 8-12 lat z rozpoznaniem mózgowego porażenia dziecięcego (MPD). Dzieci były poddawane rehabilitacji z wykorzystaniem tradycyjnych metod. Jednocześnie jako forma terapii wspomagającej, na okres dwóch miesięcy (w tym czasie wykonano trzy badania), została włączona terapia z wykorzystaniem wirtualnej rzeczywistości. Dwa miesiące po zakończeniu terapii wykonano czwarty pomiar, kontrolny.
Wyniki i wnioski. Analiza wyników badań parametru aktywność, wykazała, że terapia dała pozytywne rezultaty, natomiast 2-miesięczna przerwa spowodowała spadek wyników w porównaniu z ostatnim pomiarem podczas terapii. W badaniu wytrzymałości nie uzyskano istotnej zmiany wartości w trakcie terapii. Być może należałoby wydłużyć czas trwania pracy dziecka z danymi modułami terapeutycznymi. W modułach Raft i Gym, w których pacjenci ćwiczą koncentrację, w czasie trwania terapii maleje wartość aktywności. Oznacza to, że pacjenci z biegiem czasu wykonują ćwiczenia uważniej i bardziej precyzyjnie. Wytrzymałość natomiast od drugiego pomiaru do czwartego wzrasta. W module Oarsman, w którym pacjenci ćwiczą szybkość, wartość aktywności od pierwszego do czwartego pomiaru rośnie. Pacjenci ćwiczą szybciej.

Słowa kluczowe:
rehabilitacja, wirtualna rzeczywistość, program SeeMe

Abstract
Objectives. This study aims to evaluate the impact of therapies using external motion controllers, such as Kinect (i.e. virtual reality therapies) on functional fitness of children with cerebral palsy on the example of three selected therapeutic modules: Raft, Oarsman, and Gym.
Methods and materials. Fourteen children aged 8-12 years and diagnosed with cerebral palsy (CP) were invited to participate in the study. The children have undergone traditional rehabilitation therapy. Additionally, they have also been treated with virtual reality therapy for two months, as a form of supporting treatment (three tests were conducted at that time). Two months after the therapy a fourth control test was conducted.
Results and conclusion. Analysis of activity level has demonstrated that the therapy period has yielded positive results, while the two-month break has caused a decrease in the therapeutic results in comparison to the last test. Endurance evaluation conducted in the therapy period has not produced a significant result, but this might be remedied by a prolonged exposure to the given therapeutic modules. In the Raft and Gym modules, which have been designed to improve attention, activity level decreases in the course of the therapy. This is an indication that, over time, patients pay increasingly more attention to the exercises, focusing on movement precision. In the Oarsman module, in which patients practice movement that prioritizes speed, activity level increases between the first and the fourth test, along with the patients' training intensity

Key words:
rehabilitation therapy, virtual reality, SeeMe program

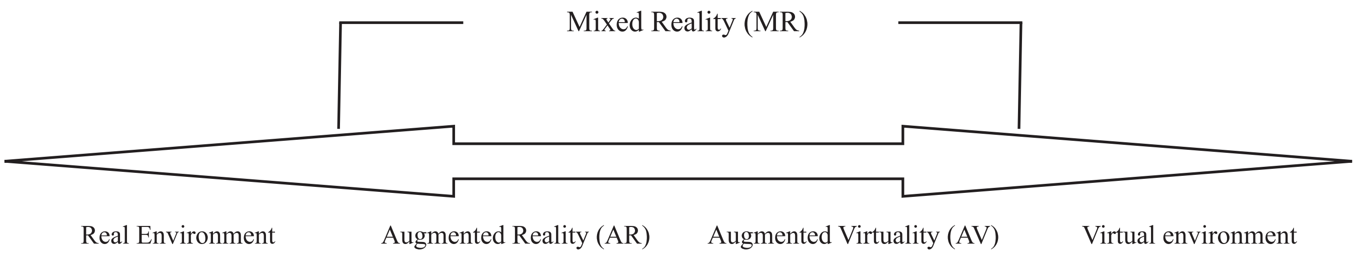
This study was funded by a grant from the Polish Ministry of Science and Higher Education, as part of the national grant program for young scientists and doctoral candidates.

Introduction

This study is concerned with using augmented reality, which will be referred to in this paper as virtual reality, for motor improvement in children with cerebral palsy. This particular choice of nomenclature is in line with the official description provided by the developer of the rehabilitation program used in this study (i.e. SeeMe Brontes Processing). However, recent months have brought new developments in this area. With state of the art technologies permeating virtually all aspects of life, the debate over what actually constitutes virtual reality (VR) and augmented reality (AR) and where the line between these two concepts should be drawn has become more relevant than ever. Although VR and AR are frequently conflated in the public consciousness, technological progress demands that these two terms be defined separately [1,2,3,4].

The release of Pokèmon Go, a free-to-play, location-based mobile game developed by Niantic, in July 2016 has spurred new analyses of the virtual reality concept. In contrast to the better known virtual reality games, Pokèmon Go uses augmented reality technology. Despite its novel approach to video game entertainment, it became the most frequently downloaded mobile app in the United States within three days of its release [5,6,7,8]. In separating VR and AR, the reality-virtuality continuum diagram (Fig. 1) created by Milgram and Kishin in 1994 proves to be a helpful tool. Figure 1 presents the relationship between the real world and the virtual one, in which the middle ground (i.e. the part of the axis between its opposite ends) is described as Mixed Reality (MR). MR is then subclassified into Augmented Reality and Augmented Virtuality (AV). In accordance with this model, the fewer real elements a system includes, the closer it is to virtual reality [4, 9].

Fig.1 Virtual Continuum (Milgram & Kishino 1994)



Current research, however, is mostly based on the augmented reality – virtual reality dichotomy. Azuma, who created the concept of augmented reality, describes it as an environment that combines elements of the real world and the virtual one, and allows for three-dimensional movement. In this vein, the virtual world serves as an extension of the real world [10]. For Lanier and Bryson, on the other hand, virtual reality is a way to use computer technology to create interactive and three-dimensional effects that give the impression of spatial presence [11].

Nevertheless, the discussion presented in the previous paragraphs merely scratches the surface of the terminological problem that exists within VR research, especially given the introduction of the term ‘phantomatics’ (fantomatyka). According to the PWN dictionary of Polish, ‘phantomatics’ is a term that denotes a “(…) method for creating the presence of artificial intelligence in the human mind” and was initially used by Stanisław Lem, a Polish science-fiction author, in his works. Another term that further complicates the issue is ‘hyperreality’, which refers to a reality type that is more real than reality itself. Technological progress has also brought other changes to the discourse on VR, but this goes beyond the scope of this paper [12].

Despite the terminological changes introduced in this paper, it is primarily concerned with virtual reality, which is described by the developers of the system used in the analysis as an artificial environment presented to the patients by means of specialized software. VR has already found use in motor rehabilitation therapies (diseases and injuries of the central nervous system and the musculoskeletal system) and cognitive therapies. The importance of introducing new technologies into medicine and physical therapy is also being recognized by more and more Polish researchers. The best proof of that is the fact that technology-based therapies have been devoted a separate session on the 2nd International Congress on Rehabilitation Medicine in Poland (II Międzynarodowy Kongres Naukowy Rehabilitacji Polskiej), organized in April 2016 in Warsaw. Papers presented during that session were focused on the role of robots in therapy, telerehabilitation, biomedical engineering, and the brain-computer interface in neurorehabilitation. Hence, this paper follows the latest trends in contemporary rehabilitation medicine and physical therapy.

Objectives

The aim of the study is to evaluate the impact of therapies using external motion controllers, such as Kinect (i.e. virtual reality therapies) on functional fitness of children with cerebral palsy on the example of three selected therapeutic modules: Raft, Oarsman, and Gym.

Materials and methods

The study was granted approval by the Senate Research Ethics Committee at the University of Physical Education in Wrocław (Akademia Wychowania Fizycznego we Wrocławiu) as of 8 July 2014. The therapy and the tests were conducted in day care centers for children with disabilities and in schools with integrated classrooms, including: John Paul the Second's Long Term Care and Nursing Home for Children in Jaszkotle 21, en route to Kąty Wrocławskie (Zakład Opiekuńczo-Leczniczy dla Dzieci im. Jana Pawła II); School Complex No. 21 in Wrocław, ul. Ignuta 28 (Zespół Szkół nr 21 we Wrocławiu); and Special Purpose

School Complex and Education Center in Głogów, ul. Sportowa 1 (Zespół Placówek Szkolno-Wychowawczych w Głogowie). Fourteen children aged 8-12 years and diagnosed with cerebral palsy (CP) were tested.

The treatment group comprised fourteen children diagnosed with cerebral palsy (CP) who were subjected to traditional therapies, such as joint mobilization of upper and lower extremities, muscle strengthening therapies, balance exercises, coordination exercises, gait rehabilitation, functional exercises, Neuro-Developmental Treatment (NDT-Bobath), or Prorioceptive Neuromuscular Facilitation (PNF) on a daily basis. The traditional rehabilitation therapy had been conducted before this study begun and continued throughout its entire duration. Additionally, patients were subjected to virtual reality therapy, as a form of supporting treatment, for a two-month period.

Study inclusion criteria:

- cerebral palsy (tetraparesis) diagnosis;
- age between 8 and 12 years;
- motor function impairment at GMFCS level I, II or III (Gross Motor Function Classification System) [13];
- undergoing traditional rehabilitation therapies, such as general rehabilitation exercises, PNF or NDT-Bobath;
- permission to participate in the study granted by parents or legal guardians.

Study exclusion criteria:

- severe or profound mental retardation, classified in accordance with the International Classification of Diseases 10 (ICD 10);
- forceful involuntary movements, such as ataxia or myoclonic seizures;
- visual impairments that do not allow for 2m range of vision;
- having underwent orthopedic procedures in 12 months before the study;
- terminating therapy and withdrawing from the study.

The therapy used SeeMe, a motion rehabilitation system that utilizes virtual reality, developed by Brontes Processing Sp. z o.o. It uses biofeedback to provide supporting treatment in rehabilitation therapy by employing extended reality and a Kinect motion controller. Each patient in the treatment group participated in individual rehabilitation sessions with the SeeMe program two times a week for a total of eight weeks. The sessions lasted for about 40 minutes. Patients were subjected to supporting treatment with SeeMe that included eleven exercise modules: Warm Up, Cleaner, Ball, React, Raft, Maze, Space, Gym, Sorter, Oarsman, and Slide. Each therapy session begun with the patients warming up, which was conducted in the Warm Up module specifically designed for that purpose. The analysis presented in this study focused on three selected modules: Raft, Gym, and Oarsman.

Raft

In the Raft module, the patient's task is to steer a virtual raft in such a way that she collects as many fish as possible while avoiding the oncoming virtual floating barrels. To achieve that, the patient has to move her body to the sides when the fish approach the raft. Thanks to the three-dimensional graphics and biofeedback the module creates a realistic impression of actually steering a raft. The exercise can also be conducted in the "balance mode", in which the patient moves her torso to the sides in a sitting position. This allows for motion training primarily in the coronal plane, and for balance and proprioception training. Furthermore, the Raft module helps in improving attention, multitasking skills, and decision making time.

Gym

The Gym module is essentially a virtual recreation of a gym. What makes it stand out among other modules is the fact that the patient controls a three-dimensional avatar, the position of which corresponds to her own body position (the patient sees the model from behind). Hence, she can interact with the virtual environment by making realistic, corresponding body movements that are not mirror images of what she sees on the screen. The physical therapist instructs the patient to hit or box cubes that appear in the virtual space. The cubes come in three different colors and the patient is awarded points for hitting each green cube and subtracted points for hitting red cubes (positive and negative stimulus). When the patient hits a gray cube she is neither awarded nor subtracted points. If the patient manages to successfully fulfill the therapist's instructions several times in a row, the system increases the score multiplier. Hitting a red cube brings the multiplier back to one.

Oarsman

In the Oarsman module, the patient's task is to cover a distance on a virtual kayak, which is controlled by making symmetrical upper limb rowing movements that are mirror images of those of the avatar shown on screen. The intensity and range of the patient's movements determines the speed at which the kayak moves. The direction of the kayak, however, remains fixed (it moves only forward). The patient is instructed to repeat this exercise several times and her times on each run are compared, which can serve as a motivational factor (record breaking).

In total, four tests were conducted. The first three took place during the therapy period (at the beginning of the study, after four weeks, and after eight weeks) and the last one was conducted eight weeks after the therapy had terminated. A treatment progress report was drafted for each training session. Progress was evaluated with regard to the following parameters:

1. Endurance – calculated as time between the start of the game and the moment when efficiency drops below average efficiency for a given session and does not rise again above that value; unit – [sec]. Endurance is calculated in ten second intervals on the basis of the ratio between the highest possible score for that time interval and patient's actual game score.
2. Activity level – calculated as sum of activity levels from all intervals; unit – [unit]. This parameter represents the intensity of the patient's movements and serves as

a comparative indicator. It has no unit. Activity level is calculated on the basis of the ratio of total distance between the body points tracked by Kinect (joints, head, torso) and time.

Results

Statistical analysis was conducted in STATISTICA for a significance level of $\alpha = 0.05$. Treatment group consisted of four girls and ten boys aged between 8 and 12 years. The results of the basic descriptive statistics are presented in Table 1.

Table 1 Statistical analysis of results showing mean data values and standard deviations (SD)

	Measurement 1		Measurement 2		Measurement 3		Measurement 4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Endurance								
Raft	82.14	10.51	81.43	12.31	84.29	11.58	85.71	5.14
Gym	74.29	21.38	82.14	8.93	77.86	16.26	83.57	8.42
Oarsman	86.43	8.42	76.43	15.5	80	11.77	84.29	7.56
Activity level								
Raft	17220.57	16852.39	15319.36	17275.4	13136.57	11565.35	10004.93	8564.31
Gym	50034.07	43840.98	71991.21	64305.01	74752.21	43036.5	79822.46	52273.59
Oarsman	35467.43	16491.8	33120.21	24615.56	21481.29	14757.08	34921.11	21841.91

To test the normality of data distribution a Shapiro-Wilk test was conducted. As p-value for all variables was less than the chosen significance level ($p < 0.05$), the null hypothesis assuming normal distribution of analyzed variables was rejected.
Further testing was conducted with the use of the Kruskal-Wallis test, a non-parametric equivalent of ANOVA. Results of the tests (presented in Table 2) show that p-value for all modules and analyzed parameters (activity level and endurance) was greater than the chosen significance level ($p > 0.05$). Thus, the test demonstrated no significant difference between the results.

Table 2 Kruskal-Wallis test results

Parameter	Module	Chi-square	df (degrees of freedom)	p value
Activity	Raft	1.2766	3	0.7347
	Oarsman	4.0639	3	0.2546
	Gym	5.4044	3	0.1445
Endurance	Raft	1.2701	3	0.7363
	Oarsman	1.5286	3	0.6757
	Gym	4.9636	3	0.1745

The Kruskal-Wallis test is used to assess whether results of an analysis come from the same population i.e. whether they have similar distributions. The results for this analysis were not significant ($p > 0.05$) for both parameters in all modules, failing to reject the null hypothesis stating that they come from the same population. This is an indication that they have a similar distribution or have similar values in subsequent measurements.

The next step in the analysis was to conduct a multivariate analysis of variance (MANOVA) and a Wilks test, comparing the differences between subsequent measurements. Results of the analysis of activity level are as follows:

Wilks' Lambda = 0.31036,
Chi^2 = 43.875,
df = 8.000,
p = 0.00000006006

Tab. 3. Tabela przedstawia estymowanie wartości dla aktywności
Table 3 Estimated values of activity level

	Pomiar 1 Measurement 1	Pomiar 2 Measurement 2	Pomiar 3 Measurement 3	Pomiar 4 Measurement 4
Tratwa/Raft	35467.43	33120.21	21481.29	34921.11
Wioślarz/Oarsman	50034.07	71991.21	74752.21	79822.46
Siłownia/Gym	17220.57	15319.36	13136.57	10004.93

The p-value in this test is less than the chosen significance level ($p < 0.05$) [Table 3]. Hence, the null hypothesis assuming equal means in the subgroups was rejected in favor of the alternative hypothesis. This is an indication that the difference in activity level of children in subsequent measurements was statistically significant.

Results of the analysis of endurance are as follows:
Wilks' Lambda = 0.80901,
Chi2 = 7.9481,
df = 8.0000,
p = 0.4386

Table 4. Estimated values of endurance

	Measurement 1	Measurement 2	Measurement 3	Measurement 4
Raft	86.42857	76.42857	80.00000	84.28571
Oarsman	74.28571	82.14286	77.85714	83.57143
Gym	82.14286	81.42857	84.28571	85.71429

The test has shown that p-value for this parameter is greater than the chosen significance level ($p > 0.05$) [Table 4]. Hence, it fails to reject the null hypothesis assuming equal means in the subgroups, which leads to the conclusion that the group means have not significantly changed between subsequent measurements.
The Wilks' Lambda test is used to assess whether group means are equal. For activity level, the test yielded a p-value of p = 0.00000006006, which means that the null hypothesis assuming equal group means can be rejected for this parameter. Hence, it is concluded that not all means of subsequent measurements are equal, indicating a significant change in activity level.
For the endurance parameter, the test yielded a p-value of p = 0.4386, which means that it failed to reject the null hypothesis assuming equal means in subsequent measurements. Thus, it can be concluded that group means are equal, indicating no significant changes between the subsequent tests.
The statistical tests have shown no difference between groups. The Kruskal-Wallis test yielded no significant differences for all modules with regard to both parameters. The Wilks' Lambda test yielded a significant difference between activity levels and no significant difference for endurance. Figure 2 shows a graphical representation of the results of the four tests.
Box-plots for endurance and activity level in the Raft module.
Figure 2 shows changes between measurements of activity level. The median in the first measurement is significantly below the middle value between the upper and lower quartile. Moreover, the variance in the second measurement is significantly greater for all modules, which is an indication of greater diversity in the data. The third measurement usually has a smaller variance. Median in the Raft module is similar to previous values. In the Oarsman module it increases, being greater than in the first and second measurement, while in the Gym module it decreases, being smaller than in the first and second measurement.

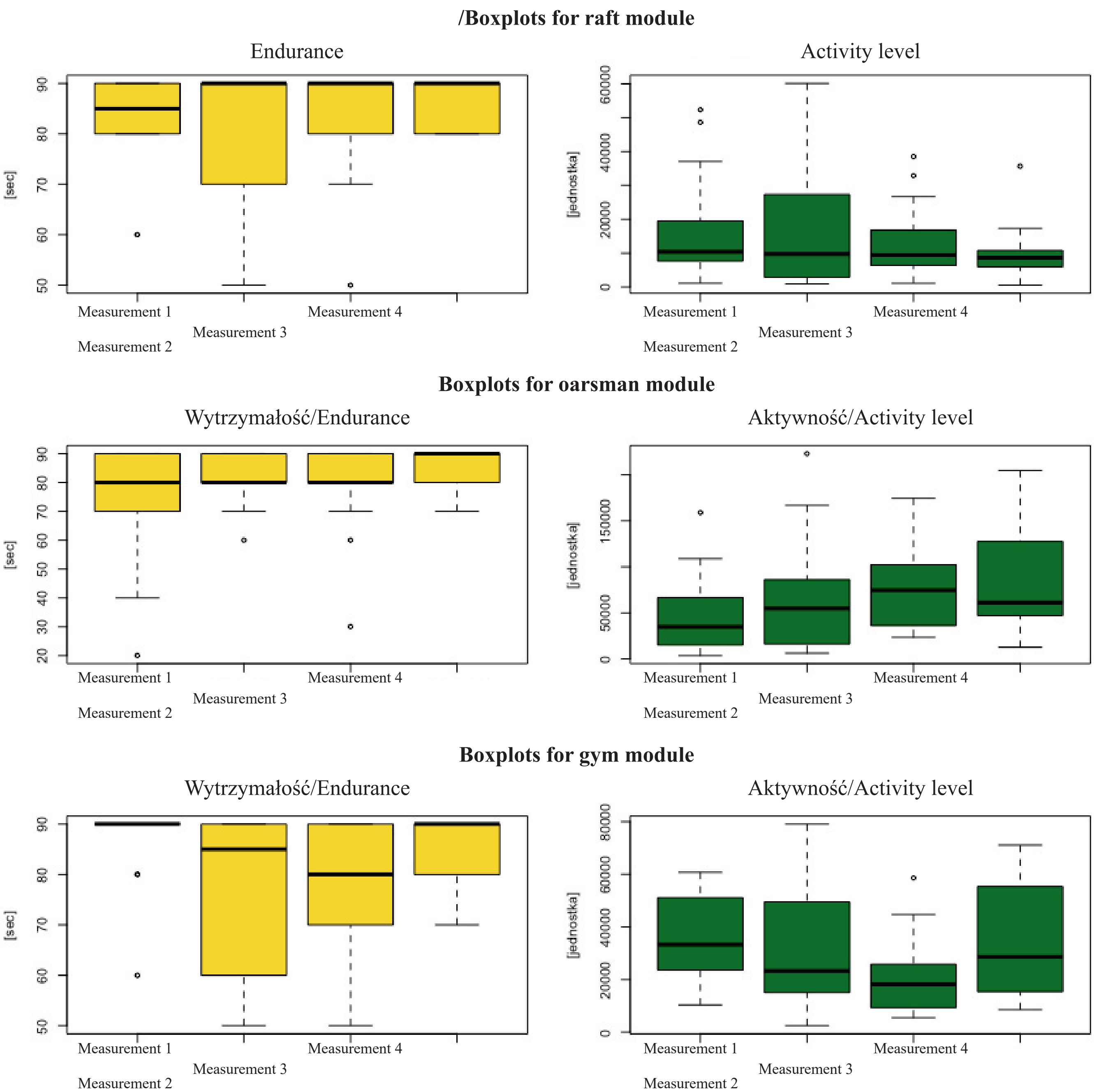


Fig. 2. Graphical representation of endurance and activity level for the Raft, Oarsman, and Gym modules across four measurements

Discussion

Modern technology provides many different ways to visualize movement. Virtual reality has become a quite popular one among them, with extensive research being done on VR-based therapies; however, there are considerable differences between studies conducted in this vein, as researchers use different software and motion controllers, and focus on different parameters, often custom-tailored with mathematical algorithms created by programmers. Hence, comparing them is a challenging endeavor, despite the overarching VR concept. Furthermore, it is difficult to average the results for all of the therapeutic modules in this study due to the fact that patients were training different skills in each of them.

The Wilks' Lambda test has shown differences between the measurements of activity level, which is an indication that the results changed between the subsequent tests.
Analysis of activity level in the Raft module has shown that the interquartile range decreases, despite the fairly constant median. This means that all children achieved similar results by the end of the study. Analysis of activity level in the Oarsman module has shown improvement during the therapy period (i.e. by the third measurement). As this module was designed primarily for speed training, it can be assumed that children improved their movement speed during the therapy period. The fourth measurement has yielded better results than the first one, which leads to the conclusion that the therapy was successful. For the Gym module, activity level has decreased during the therapy period. The third measurement has smaller variance than the first one. This decrease in activity level can be explained by the presence of a competitive factor. The module measures activity yet demands a high level of concentration, as the patient needs to find the best way to maximize her score. In the course of the study, this has led the patients to carry out the exercise instructions more carefully and focus on precision. The analysis has shown that the fourth measurement of activity level has usually yielded better results than the first one but worse than the measurements made during the therapy period. This is a clear indication that the therapy has been successful, while the two-month delay of measurement after the therapy has caused a decrease in the analyzed parameters.
Although the endurance measurements show no significant change during the study period, the boxplots reveal that children actually improved their results in comparison to the initial test. Analysis of endurance for the Raft module has shown that the median reached 90, i.e. its peak value in the second measurement, which means that at least 50% of children achieved a maximum score. Furthermore, the fourth endurance test conducted after a two-month break in therapy yielded very good results. This leads to a conclusion that the therapy had an overall positive impact on the children, as its benefits were maintained after the study had ended. For some patients, the results even continued to improve further. The results of the fourth measurement, showing long-term therapy benefits can be explained with the fact that the children acquired new skills that were helpful outside of the study setting. Another factor that might have influenced the results of the last measurement was the mindset with which the children approached the test, as many of them were excited to resume therapy. The positive impact of the therapy can be inferred from the fact that the results in the fourth measurement are clearly better than in the first one. The difference between the highest and the lowest value of the endurance parameter decreased in the course of the study for all analyzed modules. This means that the patients that initially were classified as the weakest in the group caught up with the best ones by the end of the study. Despite the baseline differences, all patients eventually reached comparable results in the endurance test.
Similar data patterns were found in the results of the endurance test for the Gym module i.e. the median decrease with each subsequent measurement during therapy and the variance increased significantly in the second test. This effect might be explained by the same factor that influenced activity level i.e. the competitive nature of the task.
In the endurance test, the performance of some children was maintained at a maximum score since the first measurement;

however, in the second measurement the results of all children become comparable, coming close to maximum values.

Ferreira Dos Santos et al. have analyzed 43 studies on virtual reality. In this systematic review, the authors recognized how common different types of visualization have become in therapy. They also point out that drawing valid, far-reaching conclusions about a particular therapeutic tool would require a systematic approach to visualizing movement [14]. This, however, seems to be an impossible task given the rapid speed at which new technologies are developed and implemented. In 2014, when this study was being designed, Kinect was deemed state of the art technology and the most sophisticated virtual motion control device on the market. Recent years, however, witnessed the introduction of new, more accessible VR technologies, such as VR goggles that are compatible with smartphone apps and allow for fully immersive exploration of a virtual world.

Ravi et al. have also analyzed 31 studies on using virtual reality in rehabilitation for children with CP. This systematic review analyzed 369 participants in total with regard to their motor skills and balance, demonstrating that virtual reality rehabilitation is a promising intervention for this patient group [15]. Blume et al. analyzed the application of VR, combined with brain activity visualization created through near-infrared spectroscopy (NIRS), in therapies for children with attention deficits and motor hyperactivity. The study compared the efficacy of traditional 2D training with 3D one and yielded positive results [16]. Although, Blume et al. focused on children diagnosed with ADHD and not CP, many of the patients who participated in this study show similar symptoms. This proves that such a form of therapy can be successfully applied to patients with both motor and emotional problems.

In his work, Dobkin describes a tool that allows for similar analyses as the SeeMe program used in this study. This system can be used to remotely conduct rehabilitation sessions over the Internet. After each completed session, it provides such parameters as the number of repeats done by the patient, their speed, precision, and strength. Dobkin emphasizes the fact that such swift analyses can be conducted only with the use of specialized operating systems [17].

The possibility that the improvement of the analyzed physical parameters is due to a learning curve (i.e. the patients learning to respond better to some of the repetitive elements of the tasks) cannot be fully ruled out. Ericson et al. notes that this is a normal phenomenon, as physical activity influences hippocampus growth and can have a beneficial impact on memory. The MRI study conducted by Ericson et al. has shown that hippocampus can grow by up to 2% thanks to physical activity [18].

Despite the overall positive impact of technology on therapy, it is imperative to also take note of the fat that the American Psychiatric Association has introduced IAD (Internet Addition Disorder) into their classification of mental disorders. According to Lam, the symptoms of technology addiction include impatience, impulsiveness, worse sleep and memory. Moreover, the Internet might also be changing our brains and technology might be responsible for making young people feel isolated and for interfering with our own sense of identity [19, 29].

Rapidly changing technology has become a permanent element of everyday life. International companies are constantly competing with each other to create “the next big thing” that will revolutionize technology, while the world of medicine and physical therapy tries to keep up their pace. This study confirms that and shows relatively good impact of technology-based therapies on the treatment group.

Conclusion

The analysis of activity level has shown that the therapy is beneficial for children diagnosed with CP, while the two-month break caused a decrease in the results in comparison to the last measurement made during therapy.

No significant change in performance was observed in the endurance test. The children might have required longer training periods with the chosen modules to register any therapeutic benefits.

In the Raft and Gym modules, which were designed as attention training programs, the level of activity decreases in the course of the therapy. This is a clear indication that patients' attention span and precision increase, as the training progresses. Endurance, on the other hand, increased between the second and the fourth measurement.

In the Oarsman module, in which the patients are training movement speed, the level of activity increases between the first and fourth measurement, indicating a corresponding increase in speed.

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