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Integracja Sensoryczna układu przedsionkowego, jako jeden z elementów kompleksowej rehabilitacji dziecka z uszkodzonym słuchem

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Physiotherapeutic assessment in gynecology


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MEDICAL INNOVATION

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Movement analysis of fully immersive virtual reality therapeutic module for usage in physical therapy field

Analiza ruchu dla w pełni immersyjnego modułu terapeutycznego wirtualnej rzeczywistości do zastosowania w dziedzinie fizjoterapii

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Abstract

Objective. To analyze the users' movement during performing the tasks of Fully Immersive Virtual Reality Therapeutic module.
Methods. An observational study was conducted at the Faculty of Physical Therapy, Cairo University, Egypt. Healthy college-aged volunteers participated invited to participate in the study from 1st January 2023 to 25th April 2023. All participants were invited to use the fully immersive VRaputic® software module (Vibilo™). Movement analysis was performed via Kinovea 0.9.5x64 version video analyzing software on different views of photographs of each participant.
Results. The arc of motion performed during the module was in the following joints and directions in the upper limb: shoulder joint (flexion (133.58 ± 5.10)), elbow joint (flexion (99.42 ± 5.66), and extension (2.35 ± 1.41)).
Conclusions. It was concluded that the selected fully immersive VRaputic® software (Vibilo™), a therapeutic module, could be prescribed for the management of kinesiophobia, shoulder dysfunction, elbow stiffness, low back pain, hip and knee joint dysfunction, and neurological cases (post-stroke, cerebral palsy, Erb's palsy) based on different joints' arc of motion performed during the module.

Keywords

movement analysis, physical therapy, virtual reality

Streszczenie

Cel. Ocena i analiza ruchów użytkowników podczas modułu terapeutycznego w Pełnej Immersyjnej Wirtualnej Rzeczywistości.
Metody. Obserwacyjne badanie przeprowadzone na Wydziale Fizjoterapii Uniwersytetu Kairskiego w Egipcie. Zdrowi studenci w wieku akademickim zostali zaproszeni do udziału w badaniu od 1 stycznia 2023 r. do 25 kwietnia 2023 r. Wszyscy uczestnicy wypróbowali pełen immersyjny moduł oprogramowania VRaputic® (vibilo™). Analiza ruchu została przeprowadzona za pomocą oprogramowania do analizy wideo Kinovea wersja 0.9.5x64 na różnych widokach fotografii każdego uczestnika.
Wyniki. Łuk ruchu wykonywany podczas modułu dotyczył następujących stawów i kierunków w kończynie górnej: staw ramienny (zgięcie (133,58 ± 5,10)), staw łokciowy (zgięcie (99,42 ± 5,66) i rozciąganie (2,35 ± 1,41)).
Wnioski. Wniesiono, że wybrany pełen immersyjny moduł oprogramowania VRaputic® (vibilo™), moduł terapeutyczny, mógłby być sugerowany w zarządzaniu kinesiofobią, dysfunkcją barku, sztywnością łokcia, bólem dolnego odcinka kręgosłupa, dysfunkcją stawu biodrowego i kolanowego oraz przypadkami neurologicznymi (po udarze, mózgowe porażenie dziecięce, porażenie Erba) na podstawie różnych łuków ruchu stawów wykonywanych podczas modułu.

Słowa kluczowe

analiza ruchu, fizjoterapia, wirtualna rzeczywistość

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Introduction

Virtual reality (VR) technology has been used in various health care settings. It can provide a fully immersive environment that stimulates both the visual and proprioceptive senses of the users [1:3]. Carrougher and coworkers concluded that VR has a significant effect on decreasing pain, improving joint mobility, and motor function for individuals with musculoskeletal system disorders, burn injuries [4], and neurological conditions like post-stroke [5-7].

VR therapy appears to be more interactive and is better tolerated by patients [6]. It enhances patients' motivation and adherence to exercise programs, especially in the rehabilitation of chronic conditions which require a prolonged exercise program and high exercise repetitions [7]. Recently, virtual reality exercise training is considered an effective additional therapeutic modality to conventional rehabilitation programs [1, 7].

Motion and posture analysis technology are developing quickly; they are deemed important effective diagnostic tools, particularly for musculoskeletal system disorders [8]. Recently, 2D biomechanical analysis such as Kinovea software provides a simple, rapid, effective, and low-cost method of kinematic evaluation compared to other sophisticated laboratory approaches [8, 9].

Aim

Analyzing the motion of virtual reality users' performance inside a virtual environment is essential to identify the goals achieved by each VR training module or to modify the virtual scenario to meet the needs of each patient. This provides valuable context and guidance for the therapist to clarify, select, and suggest the appropriate VR training scenarios for each diagnosis and matched to each patient problem list to achieve the desired outcomes. It will help to identify the expected therapeutic uses of the emerging VR technology in rehabilitation.

Methods

Participants

Healthy college-aged volunteers (both genders) were invited to participate in the current study. The VRapeutic® (Full immersive game-based therapy) is a new therapeutic Egyptian software. It has the potential to provide intensive, repetitive, and task-oriented training. A fully immersive VRapeutic® software module (Vibilo™ module) was selected. The study protocol followed the applicable regulations and guidelines and was approved by the local ethical committee of the Faculty of Physical Therapy, Cairo University (P.T.REC/012/004703). All participants signed an informed consent.

Vibilo™ module description: A book ordering activity, where the participant is instructed to put back books on the floor or on a side table into their shelves in the library. It simulates upper limb functional tasks related to arm-reaching to target (book), grasp, and then release (formed by holding one hand controller on the affected side) (Figure 1, 2). It consists of 3 levels; level 1: It is the easiest level; a very simple task to put back books requires less attention from the participant. In level 2: Audio-visual distractors (repeated sound of a parrot) are introduced, while the participant is required to order books according to their color (more attention). Level 3 features a distracting task during book ordering. The complexity and duration of the tasks, the number of books, and the nature of distractors are all customizable. The Vibilo™ module is appropriate for users from 6 years old, with IQ > 70, with no history of epilepsy or seizures. The expected duration to complete the task wholly, or in part, with a required VR dose is 20 minutes.

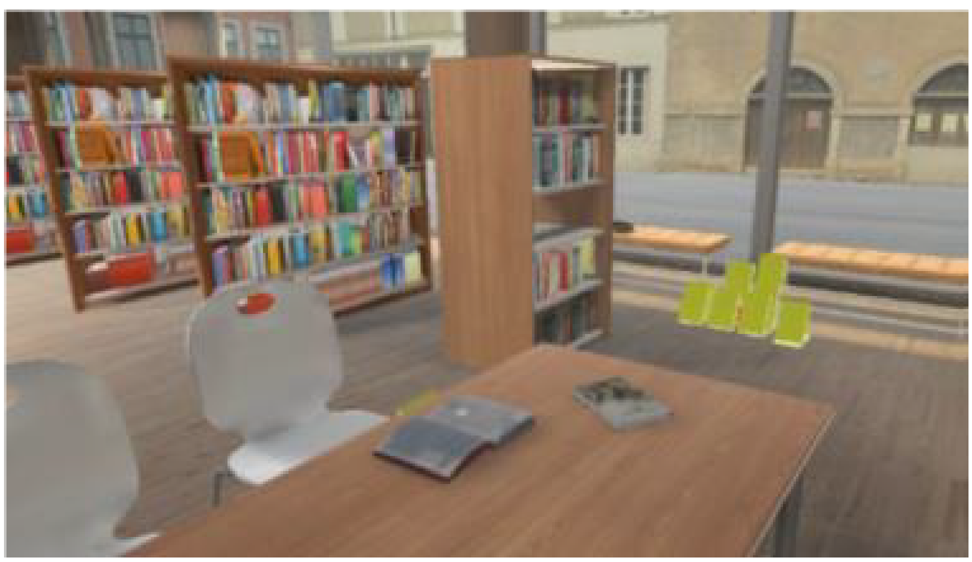

Figure 1 and 2. The Viblio™ module of VRaputic® opening page

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Instruments and procedures

• A digital camera (Samsung; model: ST66), videos and photographs of each participant were taken from different views within the virtual environment.
• Kinovea 0.9.5x64 version: A video analyzing software. All photographs were imported into the video analyzing software.
• Markers were placed on the following anatomical landmarks: spinous process of the 7th cervical vertebra, acromion, lateral humeral epicondyle, olecranon, anterior & posterior superior iliac spine, 5th lumbar spinous process, greater trochanter, lateral femoral epicondyle, and head of fibula. The kinematics of each joint and angles were drawn and analyzed using the cross marker tool, line tool, and angle tool of the software [9] (Figure 3, 4). Each event was paused, and the maximum measurements of each angle for all the joints were taken for each participant and recorded in the data sheet to be analyzed.
• VRapeutic® virtual reality gaming software (version 2019.4.40f1 LTS, Vibilo™ Module).
• Oculus Quest 2 headset Head-Mounted Display (HMD) with a resolution of 1440 x 1600 pixels and a field of view of 96×94 degrees.
• Two Oculus Touch Controllers. The participant wears the Oculus Quest headset and holds the wireless hand controller, allowing him/her to enter and connect with the virtual library system, interact, walk in, and manipulate books. The virtual environment engages the participants to perform the required repetitive motions needed for motor learning.

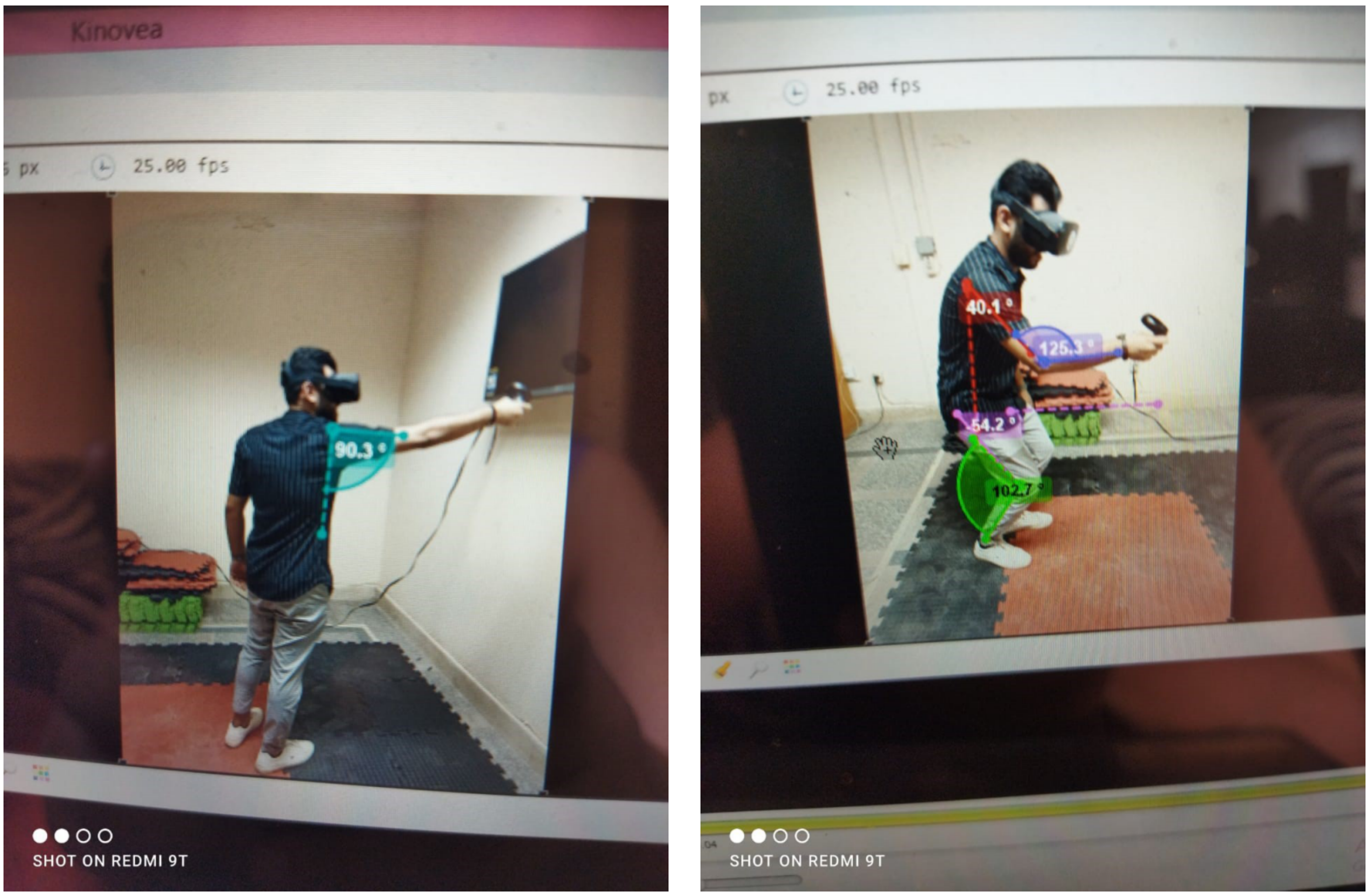

Figure 3 and 4. The participant during performing the tasks of the Viblio™ module of VRaputic®

Statistical analysis

Statistical analysis was performed using SPSS software for Windows, version 25.0 (Armonk, NY, USA). Results were expressed as mean ± standard deviation.

Results

Twenty females and four males participated in the study. Their demographic characteristics are presented in Table 1. Table 2 clarifies the arc of motion of different joints and directions that were achieved during the Vibilo™ module.

Table 1. Demographic characteristics of participants

	n = 24, Mean ± SD
Age [years]	22.38 ± 1.77
BMI [kg/m^2]	23.40 ± 0.63

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Table 2. Joint angles characteristics of participants

	Minimum	Maximum	n = 24, Mean ± SD
Shoulder flexion	125.0	145.5	133.58 ± 5.10
Elbow flexion	90.00	110.00	99.42 ± 5.66
Elbow extension	0.2	4.5	2.35 ± 1.41
Trunk flexion	44.5	69.7	58.79 ± 7.54
Hip flexion	85.3	119.9	105.86 ± 9.91
Knee flexion	122.0	143.0	133.05 ± 6.63

Discussion

The aim of the study was to analyze the user's movement during performing the tasks of fully immersive VR module.. Assessment of participant performance during a selected fully immersive VRaputic® software module seems to be a beneficial context for the therapist to recommend acceptable techniques suitable for each individual situation or setting and to accomplish the intended results.

The results of the study revealed that the selected Virtual Reality Therapeutic module seems to have a beneficial effect on improving joint kinematics and range of motion of the shoulder joint flexion, elbow joint (flexion and extension), entire upper limb functional performance i.e. reach to target, grasping targets, then release (arm-hand coordination activities) and object manipulation. Moreover, it includes trunk, hip, and knee flexion movements that further improve walking pattern and balance. Improvement in patient performance contributes to the achievement of one of the Sustainable Developmental Goals (Good health and well-Being, SDG 3).

These results were supported by Lin et al. [1] who concluded that virtual reality therapy improved pain, function, range of movement, and joint kinematics in patients with musculoskeletal system disorders or neurological disorders. Moreover, VR therapy minimized kinesiophobia and enhanced the quality of life. A systematic review concluded that adding VR exercises to a conventional exercise program had significant effects in the treatment of rheumatoid arthritis, knee osteoarthritis, chronic ankle instability, and following anterior cruciate ligament reconstructive surgery. However, there are still limited studies that investigate the efficacy of VR in rehabilitation following knee arthroplasty, fibromyalgia, and chronic low back pain [10].

A pilot study was performed to examine the effect of VR on shoulder joint motor functions in patients with frozen shoulders. The results showed significant improvement in shoulder joint mobility, motor performance, and muscle strength [11]. In addition, combined VR Exergaming (using bobo motion sensors submarine game & car game) and conventional exercise resulted in improvement in shoulder pain, range of motion, kinesiophobia, and quality of sleep in stage II frozen shoulder [12].

Another randomized study compared the effect of adding VR (oculus guided physical therapy by use of Hand Physics Lab on Oculus Quest game) and Maitland's mobilization versus conventional exercise and Maitland's mobilization in the treatment of frozen shoulder; they revealed significant improvement in pain, shoulder range of motion, and shoulder functional activities of daily living [13]. In addition, a previous study concluded that immersive VR using an interactive kitchen environment provided better improvement in upper limb functional activities and pain in patients with upper limb complex regional pain syndrome [14].

Another study revealed that Meta Quest 2 VR based rehabilitation using three different tasks (1st memory game matching button pairs, 2nd drawing a three-dimensional trajectory between highlighted planets to connect them, and 3rd touching pairs of hands (left and right) from their respective sides) significantly improved upper limb function and shoulder and elbow joint mobility in their study for upper limb injuries [15].

Similar results were obtained for both upper limb functional performance and pain in patients with subacromial impingement syndrome [16]. However, in a randomized controlled study on shoulder impingement syndrome, the authors didn't find any significant difference between VR exercise using Nintendo Wii (Nintendo, Kyoto, Japan) (boxing match, bowling game, and tennis game) and conventional exercise on pain, shoulder joint mobility, function, and acromiohumeral distance [17].

The combined effect of virtual reality (Armeo® Spring equipment) and a conventional exercise program was investigated on upper limb functional abilities and range of movement in chronic stroke. It was concluded that there was a significant improvement in upper limb functional performance (reaching, grasping & manipulating objects) and entire range of motion when compared to an isolated conventional exercise program [18]. These were also proven in similar previous studies [5, 6, 7, 19, 20] Systematic reviews also showed that VR exercise therapy is more effective than a conventional program in rehabilitation of upper extremity post-stroke [21-24].

The VR training (Nintendo Wii games) had a positive effect on shoulder, radioulnar, wrist joint range of motion, and upper limb function in children with obstetric brachial plexus injury (Erb's palsy type (C5, C6)) [25]. In addition, a VR exercise program (Armeo ® spring) was more effective than a conventional exercise program in improving upper extremity function, shoulder range of motion, and muscle strength in Erb's palsy [26]. It was proven that VR games effectively motivated children with brain lesions such as cerebral palsy, which could significantly improve range of motion function and muscle strength [27].

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Previous systematic reviews concluded that virtual reality training in children with cerebral palsy is considered an effective additional intervention to improve motor function abilities, strength, gait, and balance [28, 29]. Treadmill training with Virtual Reality could improve walking pattern, balance, function, and muscle strength in cerebral palsy [30].
Although it has been proven that VR provides effective pain relief, early mobility, increased range of motion, and early recovery of function in burn rehabilitation [4, 31-34], others found no statistically significant difference between VR therapy and conventional rehabilitation programs on either upper extremity function or pain during burn rehabilitation [33, 35]. In addition, virtual reality exercises are effective in improving pain and functional ability in patients with chronic low-back pain [36], total hip arthroplasty [37], knee osteoarthritis [38], and total knee replacement [39].
Maier and his co-workers in their systematic review suggested that specific VR systems are more beneficial than conventional therapy for upper-limb recovery, whereas nonspecific VR systems are not. Nonspecific VR (NSVR) systems including Nintendo Wii, Microsoft Xbox Kinect, and Sony PlayStation EyeToy are not adaptive and accessible for modification. Specific VR systems have the advantage that every principle could be customized to the patient's individual ability and necessity automatically [40]. All those features are present in the Vibilo™ module of VRaputic®.
Many protocols relied on therapists to individualize the practice to the patient's needs by selecting the training task or movement requirements or adjusting the difficulty parameters. Therefore, it was necessary to analyze the novel therapeutic modules introduced to the market, assess their potential effects, and determine which one would be of interest according to patient needs in their rehabilitation program.

Conclusion

It was concluded that the selected virtual reality therapeutic module (Vibilo™ module) introduced by VRaputic® could be suggested for management of kinesiophobia, shoulder dysfunction, elbow stiffness, low back pain, hip and knee joint dysfunction, and neurological cases (post-stroke, cerebral palsy, Erb's palsy). The module could optimize the movement of different joints based on the arc of motion during the module. The following joints and directions are presented: shoulder joint (flexion), elbow joint (flexion & extension), trunk, hip, and knee joint (flexion). Furthermore, the Vibilo™ module might improve cognition and attention in brain lesions.

Clinical message

Further research is needed to assess the efficacy of the Vibilo™ module in the treatment of shoulder dysfunction, elbow stiffness, low back pain, hip and knee joint dysfunction, stroke patient rehabilitation, cerebral palsy, and Erb's palsy.

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Competing interests
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