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VIRTUAL REALITY IN CARDIAC REHABILITATION AFTER OPEN HEART SURGERY IN CHILDREN: A REVIEW ARTICLE

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ABSTRACT

Congenital heart disease (CHD) is the most common birth defect, affecting 0.8–0.95% of live births worldwide. It causes a range of symptoms from excessive sweating and fatigue to more severe complications like heart failure and pulmonary hypertension. Although surgery improves survival rates, many children have neurological, motor, and developmental impairments after surgical correction. Even after successful heart surgeries, children with CHD often suffer from different symptoms like pain, breathing difficulties, decrease functional capacity, delayed physical development and in some cases complex defects may require heart transplants.. Cardiac rehabilitation (CR) significantly improve physical, psychological, and social recovery in children post-surgery. Within 24-48 hours of surgery early rehabilitation is crucial. The early Phase of CR focuses on mobilization and pain management, while later phases aim to improve strength and endurance.

Virtual Reality (VR) in pediatric rehabilitation is game-like environments that improve motivation and focus. It can help manage pain and anxiety, offering both distraction and therapeutic benefits during rehabilitation. VR provides a corrective psychological and physiological environment.

Key Words: Cardiac rehabilitation, Open heart surgery, Virtual reality.

Congenital heart disease

Congenital heart disease (CHD) is the most common birth defect, and it is often stated that the incidence of CHD globally is 0.8% (8 per 1,000 live births) with more recent studies finding increases to as high as 0.95% (9.5 per 1,000) **(Hasan *et al.*, 2023)**

Previous studies reported that CHD are one of the most common birth defects, affecting approximately 1.35 million newborns worldwide every year but 1 million children of all ages in the USA. **(Akamagwuna and Badaly, 2019).**

Children with CHD commonly have ongoing neurologic, motor, and developmental deficits after surgical correction. The cause is multifactorial and includes brain injury before, during, and after heart surgery. some of these impairments are incisional (sternotomy and donor graft leg) pain and drainage, continuous pain from the shoulders and

neck, thoracic pain, respiratory problems, feelings of weakness, sleeping difficulties including chest wall pain with side lying, waking frequently and early, more nightmares than usual, problems with wound healing, problems with eating, ineffective coping and depression **(Bowler *et al.*, 1998 and Thomas, 2003).**

The general signs of CHD include: excessive sweating, fatigue, poor feeding, rapid heartbeat, shortness of breath, chest pain, cyanosis, and clubbed fingernails. The CHD develops shortly after birth and the symptoms do not develop until early childhood or teenage years. However, some complications may develop during adulthood such as problem with growth and development of heart and body, the infections of respiratory tract, throat, lungs and sinuses, heart infection, endocarditis, pulmonary hypertension, high blood pressure, and the heart being unable to pump enough blood which can cause a heart failure **(Sun *et al.*, 2015).**

Open heart surgery

Development of recent cardiac surgical techniques resulted in an increasing number of successful CHD correction. These patients are a growing group that desires and strives to live a complete life, with full accomplishment of aspirations and professional plans **(Gierat-Haponiuk *et al.*, 2015).**

Surgical correction of CHD has contributed to increase the survival rates of these patients, resulting in a quality of life close to normal. However, clinical signs of decompensation such as cyanosis, dyspnoea and nutritional changes , as well as reduced exercise capacity, may occur in patients, even after surgical correction of the disease **(Feltez *et al.*, 2015).**

An open-heart surgery is performed in patients if heart defect is serious and cannot be repaired by catheter method. Usually one or more heart surgeries are required depending upon the severity of the congenital heart disease. The heart surgeons may use open-heart surgery to close holes in the heart with stitches or a patch, repair or replace heart valves, widen arteries or openings to heart valves, repair complex defects, such as problems with the location of blood vessels near the heart or how they are formed. Rarely, babies are born with multiple defects that are too complex to repair and these babies need another new heart after their birth. **(Sun *et al.*, 2015).**

At pediatric intensive care unit children have functional impairment regardless of their underlying diagnosis due to the presence of drains, catheters and tubes, excessive use of sedatives, and the children's fragile condition limit patients' exploration of the environment and of their physical potential **(Butler *et al.*, 2017).**

Cardiac rehabilitation in children

Cardiac rehabilitation (CR) is a comprehensive measure aimed to restore the physical, psychological and social condition of people with

CHD, Conducting a CR in children after open-heart surgery improves their quality of life, social status. Exercises performed during CR are easy and effective **(Baibolova *et al.*, 2024).**

The beginning of CR is within 24-48 hours post surgery but it is individually depending on medical condition **(Spencer *et al.*, 2001).**

The patient's medical condition depend on the type of heart disease, malformations associated with the cardiac presentation and surgical procedure itself. **(Da Silva *et al.*, 2011).**

Phases of cardiac rehabilitation: phase I (inpatient), phase II (home phase), phase III (hospital-based outpatient departments), phase IV(maintainace phase). (**DeTurk and Cahalin, 2018)**

Physical therapy exercises like breathing exercises, thoracic expansion, chest percussions, vibration. Thoracic compressions show positive results in improving the patient's functional capacity, improve lung function, remove secretions from the airway, and restoring normal cardiorespiratory function. **(Bangde *et al.*, 2023)**

Phase I rehabilitation focuses on somatic care targeting to achieve early mobilization. The important goals are pain reduction, thrombosis prophylaxis, circulatory system stabilization, and management of existing neurological deficits**. (Dimiati *et al.*, 2020)**

Cardiac rehabilitation is routinely used in patients who have undergone cardiac surgery. The application of deep breathing exercises, cough stimulation and chest vibration maneuvers may avoid deterioration of lung function and reduce the incidence of pulmonary complications. Breathing exercises increase coordination and efficiency of respiratory muscles and mobilize the chest. Deep breathing exercises improving vital capacity and lung compliance. **(Arcêncio *et al.*, 2008)**

The effect of physical exercise training programs in children and young adults with CHD have a significant improvement of physical parameters, the direct effects of physical exercise training on the heart or vasculature. The exercise training does not increase

the risk of arrhythmia in patients with CHD, by using an imaging technique MRI to assess cardiac effects and noted an improvement in ejection fraction and stroke volume. This is in line with findings in healthy individuals showing enhanced stroke volume after a period of exercise training **(Duppen *et al.*, 2013).**

Physical therapy exercises for children can be conducted in real-world or using technology such as virtual reality. **(Aronoff *et al.*, 2023)**

Virtual reality (VR)

Virtual reality technology simulates real-world experiences through multiple perceptual channels, including visual, auditory, and haptic feedback, creating immersive 3d multimedia environments. These environments can be controlled and displayed via computers, mobile

devices, or head-mounted displays (HMD), allowing users to interact with virtual environments that closely mimic real-world scenarios **(Bond *et al.*, 2019).**

Virtual reality is a promising and engaging intervention that may help to decrease pain and anxiety for children undergoing painful procedures and suffering from acute pain, children have always enjoyed games of pretend. While immersed in a game, they often become deeply absorbed and able to ignore aversive stimuli. Because VR makes it possible to transform how patients perceive their bodies. Providing distraction and enjoyment, virtual reality may provide a corrective psychological and physiological environment, and can facilitate rehabilitation for pediatric patients suffering from chronic pain **(Cummings and Bailenson, 2015).**

According to **Saeed *et al.*, (2017)** VR systems are classified according to the level of immersion they provide, ranging from non-Immersive system to semi-immersive VR and fully immersive VR.

A- Fully-Immersive VR, the immersion type of VR systems requires the user to wear a data glove and HMD that tracks the user's head movements that changes the view, The user using full immersion of VR technology has the ability of feeling of being part of the virtual environment. This type of VR system encases the audio and visual perception of the user in the virtual world and cuts out all outside information so that the experience is fully immersive. This type is expensive and has some disadvantages, including less determining images, burden and environmental problems concerning simulators.

B- Non-Immersive system, The non-immersive system is often called desktop virtual reality (without any input devices) and based on the displayed screens as it is a window to the virtual world without additional devices such as HMD, and it is sometimes called Window on World (WoW) systems. The most widely used VR system is the desktop system that consists of a standard computer monitor to display the virtual world. Although these systems provide a lower level of presence and perhaps interaction, they can achieve satisfactory levels of graphic quality, user comfort and convenience and lower costs. The desktop VR system is the least types of immersion and lowest cost of the VR systems. Non-immersive type of VR is mostly used in education. Examples of desktop VR systems are video games. It shows the non immersion system based on the screen that contains only 3D display without any interaction. It combines VR with real world attributes by integrating computer graphic objects into a real-world scene, but without interacting with objects that in screen.

C- Semi-Immersive system, This type of VR systems also called hybrid systems. The semi-immersive is a development desktop VR and

include additional devices such as Data Gloves. It keeps the simplicity of the desktop VR system, but with a high level of immersion and using physical models**.** In semi-immersive, the displayed virtual environment is set up onto the recognized real environment**.** For building semi-immersive system, the requirement is displaying, tracking sensors, and user interfaces**.** It allows the user to interact by using the hands and sometimes wear glasses or Data Gloves. The displayed information such as text, graphs, and images are jutting onto the transparent screen to allow the user to interact with the real environment.

Feelings of presence can be evoked by even a simple VR system, such as a 360◦ video viewed through a smartphone in a cardboard housing. However, a recent meta-analysis indicates that features such as improved tracking, stereoscopy, and wide field of view can make VR experiences feel more real, VR is particularly promising as a distractor for procedural and acute pain because of the deep sense of presence created by virtual worlds. The immersive features of virtual reality technology immerse the patient with rich sensory stimuli, creating a realistic experience and effectively directing attention away from adverse stimuli **(Dahlquist *et al.*, 2008 and Law *et al.*, 2010).**

Virtual reality requires a display in which the user sees the virtual environment. In the most common consumer systems, this is done through HMD. An HMD is a type of VR headset that displays digital images on two screens in front of the user's eyes. In phone-based VR systems such as Gear VR, Google Cardboard or Google Daydream, the HMD consists of a smartphone wrapped in an inexpensive case with lenses, such that the phone provides both the computing power and display **(Won *et al.*, 2017).**

The insertion of VR as a support for the physiotherapeutic treatment brings several benefits, including less pain after painful procedures and greater motivation during treatment , VR may use advanced interface technologies where the user is not in front of a monitor, but immersed in a tridimensional world generated by the software . The main reason for the use of treatment strategies with VR is based on the necessity of adding a motivation factor, which helps patients use movements expected by physiotherapeutic treatment like : relaxation exercise, postural correction training, circulatory exercise, respiratory exercise, shoulder range of motion exercise, and ambulation.Thus, helping in the recovery process **(Lieberman *et al.*, 2011).**

CONCLUSION

Congenital heart disease remains a significant challenge for affected children, with long-term developmental and functional impairments following surgery. Early interventions like cardiac rehabilitation and innovative technologies such as VR can play a critical

role in enhancing recovery, improving quality of life, and addressing both physical and psychological deficits. VR, in particular, is a promising tool for rehabilitation, providing engaging, game-like environments that support both recovery and emotional well-being.

Conflict of interest

The authors have declared no conflict of interest.

Compliance with Ethics Requirements

Ethical Committee Approval of the Faculty of Physical Therapy, Cairo University will be obtained before preceding the procedures of the study. In addition, a written consent form will be obtained from children or their parents before starting the study procedures.

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الواقع الافتراضى فى اعادة تأهيل القلب بعد جراحة القلب المفتوح عند الأطفال: مقالة مراجعة

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يُعد عيوب القلب الخلقية من أكثر العيوب الخلقية شيوعًا، حيث تؤثر على 0.8-0.95٪ من الولادات في جميع أنحاء العالم. تسبب مجموعة من الأعراض بدءًا من التعرق الزائد والإرهاق وصولاً إلى المضاعفات الأكثر خطورة مثل فشل القلب وارتفاع ضغط الدم الرئوي. على الرغم من أن الجراحة قد حسنت معدلات البقاء على قيد الحياة، فإن العديد من الأطفال يعانون من إعاقات عصبية وحركية وتطويرية مستمرة بعد التصحيح الجراحي حتى بعد الجراحة الناجحة، يعانى الأطفال الذين يعانون من عيوب القلب الخلقية أعراضًا مثل الألم وصعوبات التنفس وضعف القدرة الوظيفية وتأخر النمو البدني. في بعض الحالات، قد تتطلب العيوب المعقدة عمليات زرع قلب.

لقد ثبت أن إعادة التأهيل القلبي تحسن بشكل كبير التعافي الجسدى والنفسي والاجتماعي للأطفال بعد الجراحة. إعادة التأهيل يمكن أن يبدأ خلال 24-48 ساعة من الجراحة ويعتبر أمرًا بالغ الأهمية. تركز المرحلة الأولية من إعادة التأهيل القلبي على التحفيز وإدارة الألم، بينما تهدف المراحل اللاحقة إلى تحسين القوة والقدرة على التحمل.

الواقع الافتراضي في إعادة التأهيل للأطفال: الواقع الافتراضي هو بيئات تشبه الألعاب التي تحسن التحفيز والتركيز. هو أداة جديدة وقوية لإعادة تأهيل الأطفال. يمكن أن يساعد في تقليل الألم والقلق، ويقدم كل من التشتت والفوائد العلاجية أثناء إعادة التأهيل. يوفر الواقع الافتراضي بيئة نفسية وفسيولوجية تصحيحية.