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Longitudinal assessment of changes in psychosocial functioning of patients with adolescent idiopathic scoliosis using virtual reality before, during and after treatment: a quantitative and qualitative study

Ewa Misterska
The University of Safety, Department of Pedagogy and Psychology
https://orcid.org/0000-0001-9726-9214
Corresponding author: emisterska1@wp.pl

Maciej Głowacki
Department of Pediatric Orthopaedics and Traumatology, Poznan University of Medical Sciences, Poland
https://orcid.org/0000-0002-9932-670X

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ABSTRACT

This project aims to longitudinally assess changes in the psychosocial functioning of females with adolescent idiopathic scoliosis before and after completion of surgical treatment and implementation of cognitive-behavioural therapy. The planned study is a longitudinal randomised trial with 1-year follow-up. The cross-sectional aspect of the research concerns differences in perception of body shape from the perspective of the patients, their doctors, and healthy female adolescents. This study will recruit 106 patients treated at the Department of Pediatric Orthopaedics and Traumatology, Poznan University of Medical Sciences, their doctors and 106 healthy female controls. It will be the first study to use biometric self-avatars in virtual reality to investigate changes within body representation in scoliosis. The study findings will inform the development of guidelines for interdisciplinary rehabilitation of scoliosis patients following surgical treatment.

General information

The project entitled „Longitudinal assessment of changes in psychosocial functioning of patients with adolescent idiopathic scoliosis before, during and after treatment. Quantitative and qualitative study" was was founded by the National Science Centre, Poland within Opus 14 competition (grant number 2017/27/B/NZ5/02109). The project is planned for 36 months, and it is run by the Department of Pedagogy and Psychology, The University of Safety, Poland, in the cooperation

with the Department of Pediatric Orthopaedics and Traumatology, Poznan University of Medical Sciences, Poland. The head of the project is Ewa Misterska, M.Sc, Ph.D, and the principal investigator is Maciej Głowacki, M.D, Ph.D. The total grant value is 579761 PLN. The study was approved by the ethics committee at the Poznan University of Medical Sciences (Decision No. 695/18).

Research Project Objectives

The aim of the project, designed as a randomized trial with a 1 year follow-up, is a longitudinal assessment of changes in the psychosocial functioning of female patients with adolescent idiopathic scoliosis (AIS) before and after completion of surgical treatment and implementation of cognitive-behavioral therapy (CBT) interventions. A control group of healthy females will also be was selected for comparative purposes.

This is the first project planning to use biometric self-avatars in virtual reality (VR) to investigate body image in AIS. This method will allow performing a realistic manipulation of body shape of personalized avatars and investigating perception of other bodies in a well-controlled way by changing the identity of the avatar while keeping the underlying body shape identical. Specifically, a stereoscopic virtual reality life-size stereo display, a three-dimensional (3D) body scanner and a body model will allow for body shape manipulations of photo-realistic virtual avatars and naturalistic mirror-scenario presentation of these avatars. Importantly, this technology will also enable to create artificial other persons that have the participant's body shape.

In recent years, VR generated both excitement and confusion [1]. The first healthcare applications of VR started in the early '90s due to the need of medical staff to visualize complex medical data, particularly during surgery and for surgery planning [2]. In behavioural sciences, where immersive devices are used by more than 50% of the applications, VR is described as"an advanced form of human-computer interface that allows the user to interact with and become immersed in a computer-generated environment in a naturalistic fashion" [3]. During the exposing, patients can thus experience the feeling of being there" [1]. All these definitions underline two different focuses of VR in medicine: VR as a simulation tool and VR as an interaction tool. For physicians and surgeons, the simulation focus of VR prevails over the interaction one: the ultimate goal of VR is the presentation of virtual objects to every human sense in a way identical to their natural counterpart [9]. For clinical psychologists and rehabilitation specialists the ultimate goal is different [4,5]. They use VR to provide a new human-computer interaction paradigm in which users are no longer simply external observers of images on a computer screen but active participants within a computer-generated 3D virtual world (VW). VR was verified in the treatment of six psychological disorders, e.g. panic disorders with agoraphobia [6], body image disturbances [7] or binge eating disorders [8].

The aim of the project is related to the core hypothesis which assumes that CBT interventions should prevent AIS patients from sustained body image and mental health disturbances following operative treatment. Therefore, the following questions will be investigated:

- Do women with AIS after CBT intervention differ in their body-shape estimation, body image disturbances and mental health as compared to scoliosis patients not subjected to this intervention?
- Do women with AIS overestimate perception of scoliosis-related body deformity before and after surgical treatment?
- How do women with AIS differ from controls with regard to their desired body?
- Are estimated own body shape or desired body shape correlated with scoliosis-related parameters, e.g. Cobb angle, apical translation or rib hump angle? Furthermore, to investigate the influence of a scoliosis-related body deformity on perception of other persons' body shape, we will conduct another experiment asking.
- Do shape estimates and most attractive body shape change when patients refer no longer to the own body but to another person who is matched in body shape? Finally, we will assess the following issues.
- Will scoliosis patients vary their behavior toward female avatars based on their body image disturbances?.
- Is there any difference between patients and their doctors in esthetic evaluation of patient's

body shape at various stages of surgical scoliosis treatment?
- Is there any difference, depending on the stage of surgical treatment, in the patients' drawings of the body shape, as well as quantitative evaluation of BID and mental health disturbances?
- Is there any relationship between the qualitative and VR-related evaluation of desired body shape before and following AIS surgical treatment?

Research Plan and Basic Concept

Work plan

In order to realize detailed goals listed above, the planned study concerns evaluation of changes within body image and mental health of AIS patients subjected (CBT scoliosis sample) or not (control scoliosis sample) to psychotherapeutic intervention, at three time points:

- before operative treatment, at the Department of Pediatric Orthopaedics and Traumatology, Poznan University of Medical Sciences, Poland (1st A study phase);
- within 2 weeks following operative treatment, at the Department of Pediatric Orthopaedics and Traumatology, Poznan University of Medical Sciences, Poland (1st B study phase);
- minimum 12 months after operative treatment, after spondylodesis (spinal fusion) has stabilized and natural compensatory mechanisms have emerged, in relation to the area affected by fusion, via correspondence (2nd study phase).

The cross-sectional aspect of the research concerns differences in perception of body shape from the perspective of the patients, their doctors, and healthy female adolescents.

Study design

Considering the study design, the random assignment to treatment groups aims to ensure that the characteristics of the participants, which may affect the results, are balanced [10].

Both scoliosis samples (experimental and control) will be fully informed of the study type. To prevent contamination, the groups will be asked not to mention the intervention to anyone outside of the group until the study was completed.

For the requirements of this project, no patients will be required to return to the clinic. Participation will be voluntary and the patient and their carer can withdraw from the study at any point, without this affecting their right to pursue further treatment at the same Clinic. The protocol of the study will be described in details to all subjects at the time of recruitment. After hospital discharge, continuity of care and support through telecommunication devices (e-mail, chat, and telephone as preferred) will be offered to each patient. Contacts will not scheduled and will depend only on each patient's needs.

Research Methodology

Considering radiological and clinical research methodology, X-rays of the patient in a standing position including the pelvis from a posterior-anterior angle will be taken before and after surgery. Parameters submitted for analysis will include i.e. the value of Cobb angle, apical translation, the range of instrumentation and percent of scoliosis correction after operative treatment. Sociodemographic data will be assessed as well.

Considering psychological quantitative evaluation, patients and healthy controls will be assessed using the Polish versions of: the Trunk Appearance Perception Scale (TAPS), Spinal Appearance Questionnaire-for patients (SAQ for patients), the Strengths and Difficulties Questionnaire-25 for patients (SDQ-25 for patients) and The Trunk Aesthetic Clinical Evaluation (TRACE). Doctors will be assessed using the TRACE. Concerning qualitative analysis, participants will be assessed using the Draw a Person Test (DAP). They will be asked to draw themselves, then a female and a male body. The scoring of the DAP will be performed using the Koppitz's Human Figure Drawing Scoring System with our original modification [11-22].

Concerning virtual reality tasks, based on a three-dimensional (3D) body scan, realistic virtual 3D bodies (avatars) for each participant that will be varied through a range of ± 20% of the participants' Cobb angle, will be created. Avatars will be presented in a virtual reality mirror scenario. Participants will identify their actual and their desired body shape.

The cognitive-behavioral therapy for the experimental group will consist of eight sessions, each of two hours duration and will be aimed at supporting patients in accepting their actual

body shape, and in feeling positive about cosmetic results of surgical treatment.

Patients and samples

Patient sample

Recruitment to the study will be in accordance with the inclusion criteria (females; aged 12–18 years; qualified to surgical treatment due to AIS by means of anterior or posterior spinal fusion) and the exclusion criteria (previous spinal surgery; previous diagnosis of mental impairment). Specifically, a simple random sampling will be chosen as random allocation process. In this case, a full list of patients qualified for surgical treatment due to AIS (sample basis) and fulfilling the inclusion criteria will be available, and we will randomly select individuals using a table of random numbers, either to the CBT scoliosis sample (experimental group, n = 53) or control scoliosis sample (n = 53). Simple randomization can be trusted to generate similar numbers in the two trial groups and to generate groups that are roughly comparable in terms of known (and unknown) prognostic variables.

The required sample size suitable for the study was determined using the following general formula: n = N/(1+(4d^2(N-1))/uAlfa^2), where ualfa = 0,05, estimation error d = 0.10 and N = 180000 (based on the epidemiological data, revealing that scoliosis is diagnosed in 2–3% of children and adolescents and on GUS report indicating 6000000 children and adolescents in Poland; therefore, the population of AIS in Poland is about 180000) [23]. Based on this formula, a sample size of 96 patients was deemed suitable. In addition, sample size will be increased by 10% to compensate for potential nonresponses (refusals/losses) [24]. Finally, ecruitment to the study will take place with 106 patients who were qualified for operative treatment due to scoliosis, at the Department of Pediatric Orthopaedics and Traumatology, Poznan University of Medical Sciences, their doctors and 106 healthy female controls. Simple random sampling will be chosen as random allocation process.

Healthy controls

The following entry criteria to the healthy controls will be applied: (1) females; (2) age range of 12 to 18; and (3) no scoliosis or other spinal deformities confirmed in the clinical examination. Healthy controls will be matched at a 1:1 ratio for (i) sex and (ii) age corresponding to the minimum 1-year follow-up for the scoliosis patients. The school attended by the students in the control group will be chosen at random, as will be the class tutors to whom we will send study participation request containing information for students and parents. Adams forward bend test will be used to assess suspected scoliosis, according to the methodology proposed by Santos [25]. The evaluator will be positioned behind the student and will ask the child to undertake a trunk flexion, inclining the head and allowing the arms to fall towards the ground. The evaluator will observe the symmetry of the thoracic and lumbar spine in order to identify the presence of spinal deformity. Gibbosity will be defined as the condition of over-curvature opposed to a contralateral flattening. The possible results for this test would be: suspicion of scoliosis (gibbosity presence) or absence of scoliosis (gibbosity absence) [25].

Data analysis

Quantitative data analysis and processing methods: In terms of descriptive statistics of quantitative features, the following will be determined: mean, median, minimum and maximum values, standard deviation, 95% confidence interval. To compare differences in results between the three time points, a Friedman two-way ANOVA will be utilized. Significant omnibus tests will be followed-up using multiple Wilcoxon signed-rank tests with a Bonferroni adjustment to protect against Type I errors. Spearman's rank correlation coefficient will be used for calculating correlations between quantitative variables. The Mann- Whitney test or the Kruskal-Wallis test will be used to determine dependencies between quantitative and qualitative characteristics. The accepted border level of statistical significance will be p = 0.05 and, therefore, any test results where the p value exceeded this level will be treated as insignificant.

Qualitative data analysis and processing methods: In respect to the descriptive statistics of the qualitative features, the number of units that belong to the described categories of a giv-

en feature and their relative percentage values will be given. The scoring of the DAP will be performed using the Koppitz's Human Figure Drawing Scoring System [21] by two independent evaluators [E1,E2].

VR tasks analysis and processing methods: from the different experimental tasks, we will extract for all experiments:

- the degree of inaccuracy/distortion of the estimated body shape as compared to participants' actual body shape at the time of the experiment (1AFC and MoA),
- the desired body shape change (MoA),
- the discrepancy between desired and actual body shape (MoA).

To quantify the degree of distortion, we will analyze the over- or underestimation relative to actual individual body shape.

Measurable Effects and Expected Results

This would be the first study to use biometric self-avatars in virtual reality to investigate changes within body representation in scoliosis. This method will allow performing a realistic manipulation of body shape of personalized avatars and investigating perception of other bodies in a well-controlled way by changing the identity of the avatar while keeping the underlying body shape identical. Specifically, a stereoscopic virtual reality life-size stereo display, a three-dimensional (3D) body scanner and a body model will allow for body shape manipulations of photo-realistic virtual avatars and naturalistic mirror-scenario presentation of these avatars. Importantly, this technology will also enable to create artificial other persons that have the participant's body shape.

It is important to underline that VW is an exciting area offering opportunities in every healthcare areas, from teaching to clinical interventions [1]. The results of the referred study may have a significant contribution to development of guidelines for interdisciplinary rehabilitation of scoliosis patients following surgical treatment. Considering future research implications, the current set of virtual reality could be used in exposure-based treatments. Such methods may inform the development of interventions to reduce stigmatized beliefs about persons with easily recognizable body deformities, difficult to modify through more traditional therapeutic approaches.

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Conflict of interest statement
The authors declare no conflict of interest.

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