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ASSESSMENT OF THE QUALITY OF MOVEMENT FOR PATIENTS WITH ADOLESCENT IDIOPATHIC SCOLIOSIS

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ABSTRACT

Goal of the work is to verify if there exists a significant difference in the quality of movement measured via virtual reality (VR) technology between two groups of patients diagnosed with adolescent idiopathic scoliosis (AIS). Grouping is made according to geographic regions; Group 1 is from Zagreb, Group 2 from Vukovar. Another goal of the work is to verify whether there is a significant improvement from initial to final measurements over a one year period in the results of all patients from both groups.

Hypothesis: there is no significant difference in the quality of movement between two groups of patients, as obtained through VR tests. The second hypothesis is that there is no significant difference in the results of specific VR tests for AIS between initial and final measurements of all the examinee; respectively, the conventional therapy program in both groups doesn't produce significant results in the direction of improvement.

The sample: each group is comprised of 5 patients with AIS diagnosis, between the ages of 12–18, of both genders. The patients have a double scoliotic curve with Cobb value between 37 and 46 degrees, and are being treated with classical physiotherapeutic methods for AIS, at clinics in Zagreb and Vukovar.

Methodology: VR tests for assessment of the quality of movement are a part of the *System for Diagnosis and Control in Kinesiology* (SYDACK) constructed at the Faculty of Kinesiology, University of Zagreb, as described in the dissertation: VR in physiotherapy of patients with AIS (Filipović, 2011). SYDACK is an original Croatian product, containing 4 VR tests for evaluating the quality of movement: diagonal sliding to the right, diagonal sliding to the left, sliding and hip elevation.

Results are analyzed via a t-test for small independent samples and a t-test for small dependent samples. In 93.75% cases there is no significant difference between results of the two groups, as obtained by all 4 VR tests. The analysis shows there is no geographical dependence in the quality of motion with AIS, which confirms the initial hypothesis. In 81.25% cases there is no significant difference in the results of specific VR tests between initial and final measurements. In 18.75% cases there is a significant difference in the direction of improvement.

Keywords: SYDACK; assessment; AIS

INTRODUCTION

Adolescent idiopathic scoliosis is represented as pathological postural adaptation of the body through a structural three-dimensional deformity of the vertebral column and the body in process of puberty (Filipović & Ciliga, 2010). Although scoliosis was described in detail by Hippocrates, with this condition there are still many unknowns. Theories about the origin of AIS are different, but there is a consensus about the multi factor etiology. Basic characteristics of pathological pattern of AIS are: postural asymmetry, dysfunction in proprioceptive system and abnormal postural balance. The origin of the problem points to the central nervous system (Zabjek, 2008; Filipović & Ciliga, 2010). Within the population of girls, AIS is 7 times more common than in the boys' population, and girls may be more sensitive to changes in central control during the development of the central nervous system (Lowe, 2000). Girls with AIS have insufficient balance control, which is explained as the problem of motor deficits which follow changes in vertebral torsion and rotational trunk asymmetry in relation to the vertical axis (Dalleau, 2007). Some studies suggest that through the visuomotor coordination and spatial recognition the brain uses abstract spatial information located between the sensory inputs and motor outputs (Veldhuizen, 2000). Huynh (2006) performed biomechanical analysis of patients with AIS and found that asymmetric development of the central nervous system can't be the only factor in the development of this condition since genetic background, growth and development play an important role (Schizas, 1998; Lowe, 2000). In this sense, the family history is positive in 36% of non-identical and 73% of monozygotic twins (Burgoyne, 2001). In choosing a treatment for AIS, it should be emphasized that spine reaches its maturation within 2 years after skeletal maturity (Dickson, 2004). Asymmetry in the paravertebral muscles on convex and concave sides of the scoliosis curve, measured by surface EMG, can be pointed as the central factor responsible for the progression of AIS (Cheung, 2004; Veldhuizen, 2000). However, today the asymmetry in paravertebral muscles as the origin of AIS is rejected and shown as a secondary aspect (Mahaudens, 2005; Weinstein, 2008; Filipović, 2011). The effectiveness of screening and early treatment using orthosis is an issue that is intensively discussed. Orthoses give some common non-operative approach, which has been used for 40 years, but more controlled trials of its effectiveness for AIS are necessary (Stephens Richards & Vitale, 2008; Bunge, 2008). Therapeutic evaluation of children with scoliosis is usually done by radiography. International Society on Scoliosis Orthopaedic Rehabilitation and Treatment (SOSORT) approves the method according to Cobb which is considered as the gold standard in scoliosis assessment. The biggest concern about the radiological assessment is that children at the age when their growing and development are intensive are exposed to radiation. However, Stephens Richards and Vitale (2008) emphasized that exposure to radiographic technology today is significantly lower than in the past. In order to reduce the risk of radiation exposure there are some imaging techniques which measure the deflection of the spine; scoliometry, Moire topography, integrated computer scan systems that use back contour surfaces as points for determining the direction and degree of deformation of the trunk (Mior, 1996). Pearsall (1992) states that the Cobb method does not describe fully three-dimensional deformation of the spine and associated segments. He also points out the lack of a forward bend test which is not sufficiently sensitive in measuring thoracolumbal deformities. Filipović (2003) states that

the Cobb method has no statistical significance in order to assess the function of the spine, where it only indicates the degree of curvature. Dickson (1999) explains that scoliosis is usually estimated by the Cobb method because it simply took root among clinicians, but the disadvantage is its non-linearity compared to increasing the size of curvature. Cobb angle is not an arithmetic size and can't be used as a descriptive statistic, while the reliability of the method according to Cobb, measured by multiple examiners, ranges between 3.2° and 9.6° error (Mior, 1996). However, no better approach was developed for the measurement of scoliosis. Lehnert-Schroth (1992) concludes through empirical research that the degree of scoliosis, measured using radiographs, is less important to patients – they want to see how the hump on their back decreases. Wong and Wong (2008) made a study on the use of "intelligent clothes" in assessing posture. Guided by the principle of therapeutic posture through continuous training and feedback control, and learning good postural habits, these authors constructed special clothing with built-in accelerometers and devices for the detection of postural curvature in the sagittal and coronal planes. Filipović (2006) provides a view of information technology application of virtual reality (VR) in the form SYDACK (System for Diagnosis and Control in Kinesiology), to the functional assessment of AIS, as well as in the physiotherapy for a variety of other disorders of the musculoskeletal system.

PURPOSE

Goal of the research is to verify if there exists a significant difference in the quality of movement measured via VR technology on specific tests named SYDACK between two groups of patients diagnosed with AIS. Another goal of the research is to check whether there is a significant improvement from initial to final measurements over a one year period in the results of all patients from the two groups. Grouping is made according to geographic regions; Group 1 is from Zagreb, Group 2 from Vukovar. Hypotheses are that there is no significant difference in the quality of movement between two groups of patients, as obtained through VR tests and that there is no significant difference in the results of VR tests for AIS between initial and final measurements of all examinee.

METHODS

The examinee sample is comprised of two groups. Each group is comprised of 5 patients with AIS diagnosis, between the ages of 12–18. The first group consists of three girls and two boys from Zagreb, the second of three girls and two boys from Vukovar. The patients have a double scoliotic curve with Cobb value between 37 and 46 degrees, and are treated with classical physiotherapeutic methods for AIS, at clinics in Zagreb and Vukovar respectively. VR tests for evaluating the quality of movement are a part of the SYDACK system constructed at the Faculty of Kinesiology, University of Zagreb, as described in the dissertation *VR in physiotherapy of patients with AIS* (Filipović, 2011). 4 VR tests were applied: diagonal sliding to the right, diagonal sliding to the left, sliding and hip elevation. Assessment of postural status was done once a month during the one year for both groups. All participants took up VR tests for the first time in this study. SYDACK

system is consisted of the following elements: **a)** Animated Avatar head model performs specific physiotherapeutic exercises on the computer screen (Figure 1) which include four VR tests; **b)** A set of two sensors tracks movements of postural segments, shoulder and pelvic girdle, in relation to the x-axis (forward and backward movement) and the y-axis (left and right movement); **c)** SYDACK consists of four applications: a program for viewing therapeutic exercises (continuous red lines on the computer screen), a program for displaying information from sensors that monitor the patient movement (intermittent lines), the application for the registration of data in a database and program for Avatar head model animation. The Avatar animation program is taken as an animation tool with the name Pozer-4, while the animation process is a combination of video recording of the physiotherapist motion and Pozer-4. SYDACK is an original Croatian product and the result of the scientific project VR in kinesiology and scientific research "Virtual reality in physiotherapy for adolescent idiopathic scoliosis" (Filipović, 2006).

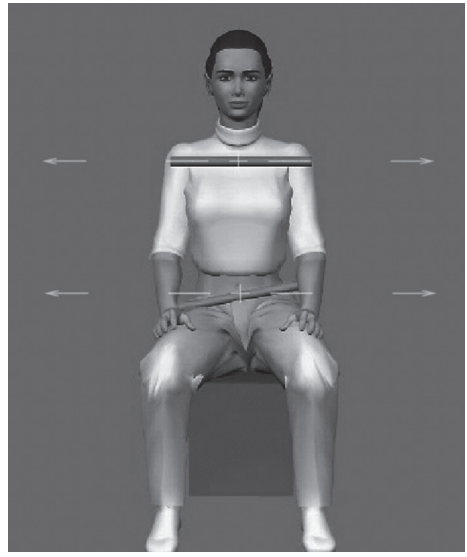

Figure 1. Avatar animated head model (Filipović, 2006)

Data are figures of deviations in angles from zero position to the end range of motion, and these are variances from y-axis and x-axis (the higher the score the higher deviation). Data analysis is based on monitoring and comparing the symmetry or asymmetry of motion in the initial and the final measurement. It analyzes the movements of the shoulder and pelvic girdle and at each there are sensors as labels that record angles in two dimensions (y-axis and x-axis). Analysis of postural status provides conclusions based on the results from analysis of variance of the initial to final measurements of these segments of the body. Therefore, selected shoulder and pelvic girdle movements are followed.

VR tests

Sliding test requires translation of the shoulder girdle in the frontal plane from side to side with a stable pelvis (Figure 2).

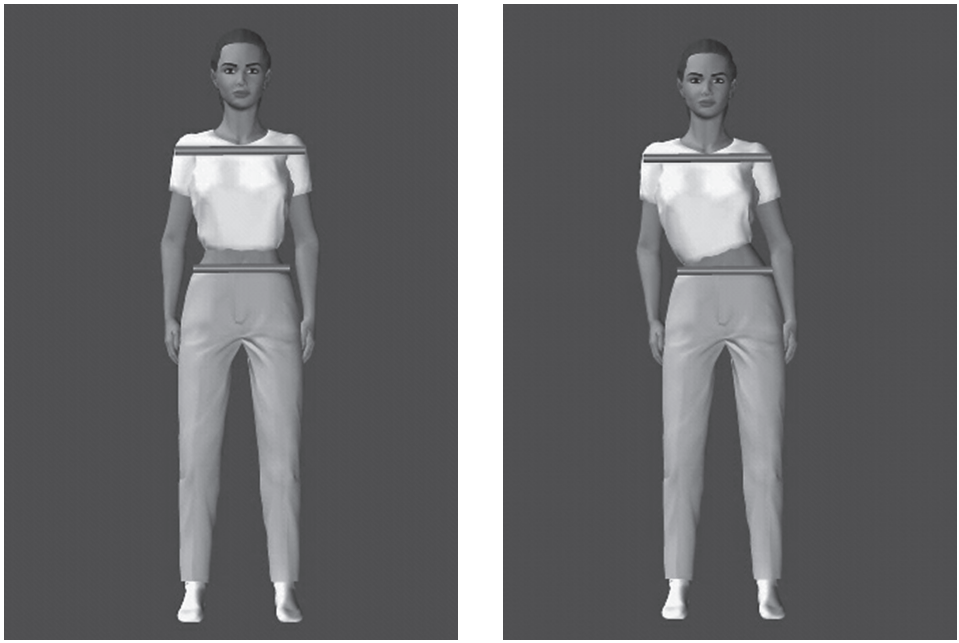

Figure 2. Sliding test (Filipović, 2006)

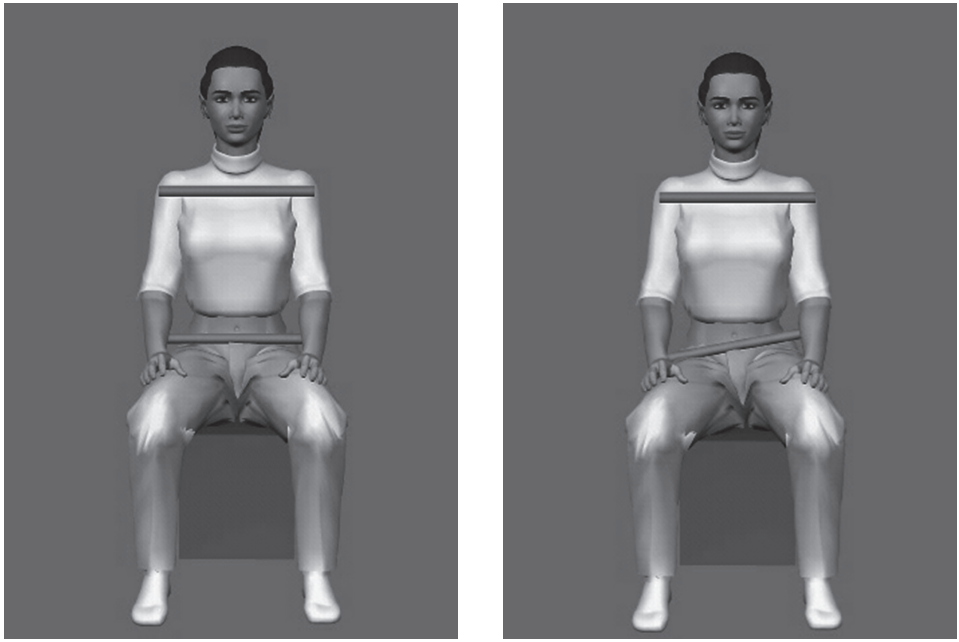

Figure 3. Hip elevation test (Filipović, 2006)

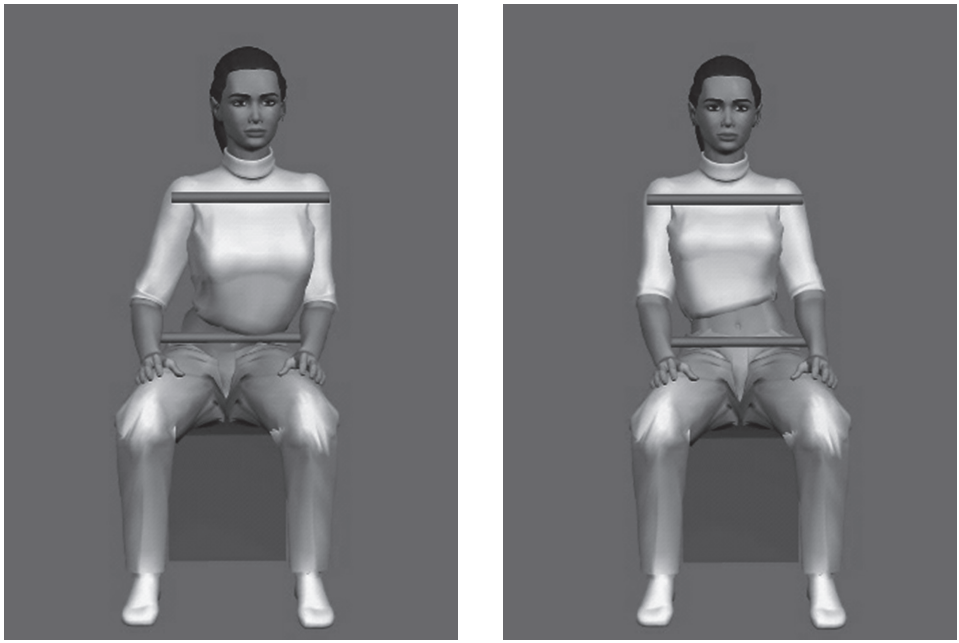

Figure 4. Diagonal sliding to the right test (Filipović, 2006)

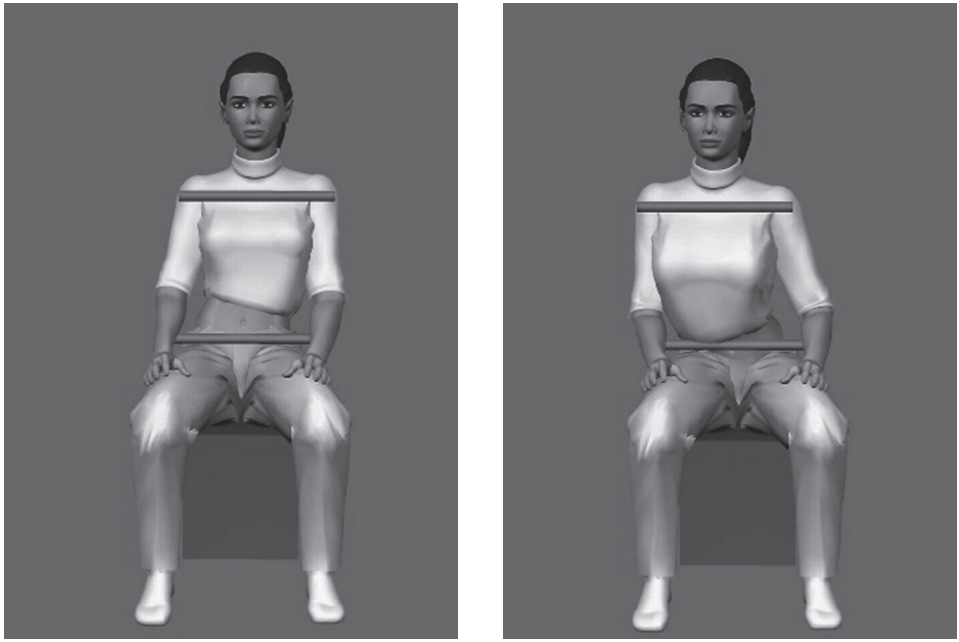

Figure 5. Diagonal sliding to the left test (Filipović, 2006)

Hip elevation test requires an alternating elevation of the pelvis in the frontal plane to the right and left with a stable shoulder girdle (Figure 3).

Diagonal sliding to the right test requires translation of the shoulder girdle and spine in the transverse plane right forward and left back with a stable pelvis (Figure 4).

Diagonal sliding to the left test requires translation of the shoulder girdle and spine in the transverse plane left forward and right back with a stable pelvis (Figure 5).

Each subject was individually assessed using an anamnestic questionnaire with questions on age, gender, city of living, body weight, body height, place and the time of making the AIS diagnosis, possible problems during their mother's pregnancy and their birth, family history and questions about the type and intensity of exercise, school and out-of school activities, and performing sports. Each examination was performed using SYDACK measurement systems and data were recorded on the same computer in the same conditions once a month. Measurement was individualized and continually carried out by the same examiner for a one year period. The first and last measurements were performed in 3 sets of 10 repetitions for each of the 4 VR tests with every subject. From the second to the eleventh measuring session, the participants performed a series of 10 repetitions for each of the 4 VR tests. SYDACK system is tested for its metric properties (Viskić-Štalec, 2006) and as a measuring instrument has high reliability and validity. Results are analyzed via a t-test for small independent samples and a t-test for small dependent samples, in the Statistical Package for the Social Sciences (SPSS), version 15.0.

RESULTS

In order to compare the results of each VR test for the subjects from Zagreb and Vukovar, a t-test for small independent samples was used – between small groups of Zagreb (N = 5) and Vukovar (N = 5) respectively.

Table 1. Comparison of initial and final results of the examinees from Zagreb and Vukovar on each variable of VR tests

	M	SD	t	df	P		M	SD	t	df	P
1axr group1	1.24	2.18	–0.43	8	>0.05	2axr group1	0.78	0.54	–0.5	8	>0.05
1axr group2	1.74	1.35				2axr group2	0.99	0.78			
1axz group1	0.58	0.26	–1.93	8	>0.05	2axz group1	1.42	1.43	–0.4	8	>0.05
1axz group2	2.43	2.13				2axz group2	1.80	1.17			
1ayr group1	2.37	2.01	–0.76	8	>0.05	2ayr group1	3.66	2.27	0.09	8	>0.05
1ayr group2	3.76	3.56				2ayr group2	3.47	3.69			
1ayz group1	2.93	2.45	0.31	8	>0.05	2ayz group1	3.10	2.96	–0.79	8	>0.05
1ayz group2	2.46	2.26				2ayz group2	4.74	3.51			

1bxr group1	2.22	1.47	–0.24	8	>0.05	2bxr group1	1.25	0.53	–0.88	8	>0.05
1bxr group2	2.51	2.27				2bxr group2	1.74	1.12			
1bxz group1	2.01	2.11	–0.62	8	>0.05	2bxz group1	1.33	0.62	–0.65	8	>0.05
1bxz group2	3.07	3.11				2bxz group2	1.82	1.55			
1byr group1	6.22	4.34	0.22	8	>0.05	2byr group1	2.6	2.36	–0.39	8	>0.05
1byr group2	5.67	3.46				2byr group2	2.65	1.58			
1byz group1	2.93	2.14	–2.28	8	>0.05	2byz group1	2	1.71	–1.7	8	>0.05
1byz group2	9.30	5.84				2byz group2	5.14	3.73			
1cxr group1	1.95	1.02	1.03	8	>0.05	2cxr group1	1.58	1.84	0.32	8	>0.05
1cxr group2	1.38	0.69				2cxr group2	1.27	1.02			
1cxz group1	2.71	3.12	–0.23	8	>0.05	2cxz group1	1.85	1.70	–0.15	8	>0.05
1cxz group2	3.06	0.93				2cxz group2	2	1.29			
1cyr **group1**	3.17	1.55	***–2.84***	8	**<0.05**	2cyr group1	4.41	3.51	–1.16	8	>0.05
1cyr **group2**	9.41	4.65				2cyr group2	8.08	6.08			
1cyz group1	1.91	1.41	–1.33	8	>0.05	2cyz group1	2.85	1.63	–2.05	8	>0.05
1cyz group2	5.23	5.35				2cyz group2	5.95	2.95			
1dxr group1	0.93	1.13	–1.26	8	>0.05	2dxr group1	0.32	0.20	–1.85	8	>0.05
1dxr group2	2.05	1.62				2dxr group2	0.97	0.74			
1dxz group1	2.50	3.12	–0.22	8	>0.05	2dxz group1	5.40	2.73	1.03	8	>0.05
1dxz group2	2.85	1.54				2dxzgroup2	3.58	2.82			
1dyr group1	2.43	1.06	–1.51	8	>0.05	2dyr group1	5.83	6.13	0.02	8	>0.05
1dyr group2	5.14	3.85				2dyr group2	5.76	4.28			
1dyz group1	1.68	1.48	–1.06	8	>0.05	2dyz group1	4.62	3.40	0.41	8	>0.05
1dyz group2	2.58	1.16				2dyz group2	3.90	1.89			

Legend: 1 – initial measurement; 2 – final measurement; x – axis with a tilt forward and back; y – axis with a tilt left and right; r – shoulders; z – pelvis; a – sliding test; b – hip elevation test; c – diagonal sliding to the right test; d – diagonal sliding to the left test; M – mean; SD – standard deviation; t – t-test; p – reliability

T-test shows that the difference between the arithmetic mean of the first and second group of patients isn't statistically significant ($p > 0.05$) for all of the variables, except the *1cyr* variable (initial tests measuring diagonally sliding to the right on the y-axis in the shoulder girdle) where a statistically significant difference exists between means ($p < 0.05$). With the exception of the variable *1cyr*, the hypothesis that there is no statistically significant difference in the quality of movement between two groups of patients in specific VR tests for AIS is confirmed. Between 32 analyzed parameters (initial and final tests) 31 didn't show a statistically significant difference in the results (96.87%). Between 16 initial variables, 15 of them didn't show a statistically significant difference in the results (93.75%). It is possible to conclude with statistical significance that there is no geographical and regional dependence between the two groups of patients with the

diagnosis of AIS, according by place of living, in results of 4 VR tests that evaluate the quality of motion of two postural body segments, the shoulder girdle and pelvis.

In response to the second problem including initial and final measurement, a t-test for small dependent samples was used, for all subjects in total (N = 10).

Table 2. Comparison of the results achieved in all patients at each initial and final VR test

	M	SD	t	df	P
pair 1 1axrM – 2axrM	0.60	1.74	1.09	9	>0.05
pair 2 1axzM – 2axzM	–0.10	2.11	–0.16	9	>0.05
pair 3 1ayrM – 2ayrM	–0.49	4.79	–0.32	9	>0.05
pair 4 1ayzM – 2ayzM	–1.22	4.79	–0.80	9	>0.05
pair 5 1bxrM – 2bxrM	0.87	1.86	1.47	9	>0.05
pair 6 1bxzM – 2bxzM	0.96	2.04	1.49	9	>0.05
pair 7 **1byrM – 2byrM**	3.32	4.48	***2.33***	9	**<0.05**
pair 8 **1byzM – 2byzM**	2.54	2.94	***2.73***	9	**<0.05**
pair 9 1cxrM – 2cxrM	0.24	1.24	0.61	9	>0.05
pair 10 1cxzM – 2cxzM	0.96	1.81	1.67	9	>0.05
pair 11 *1cyr*M – 2cyrM	0.04	6.01	0.02	9	>0.05
pair 12 1cyzM – 2cyzM	–0.82	5.17	–0.50	9	>0.05
pair 13 1dxrM – 2dxrM	0.84	1.42	1.87	9	>0.05
pair 14 1dxzM – 2dxzM	–1.81	3.59	–1.59	9	>0.05
pair 15 1dyrM – 2dyrM	–2.01	6.81	–0.93	9	>0.05
pair 16 **1dyzM – 2dyzM**	–2.12	2.07	***–3.24***	9	**<0.05**

There is no significant difference between arithmetic means ($p > 0.05$) in most of the pairs (81.25%). The exceptions are the following tests in which there is a significant difference ($p < 0.05$):

– pair 7 (initial and the final assessment of the *byr* variable: hip elevation on the y-axis of the shoulder girdle),

– pair 8 (initial and the final assessment of the *byz* variable: hip elevation on the y-axis of the pelvis),
– pair 16 (initial and the final assessment of the *dyz* variable: diagonal sliding to the left on the y-axis of the pelvis).

For these pairs, three of them 16 (18.75%) there is a significant difference in the results of specific VR tests assessment between initial and final measurements.

DISCUSSION

The intention of the physiotherapeutic evaluation of patients with AIS measured via VR technology was to check whether there is a significant difference in the results of examinees from Zagreb and Vukovar in the quality of movement. Pathology length in patients from diagnosis to initial measurements using SYDACK system is from 6 months to 2 years. The presence of male patients in the sample confirms the characteristics of AIS by Lowe (2000) although the clinical experience of authors is not 7:1 ratio for girls, but the AIS increases in frequency among boys and the age of the patients decreases. The patient sample has the range of the AIS curve according to Cobb of an angle from 18° to 38°, which means that tested candidates are not in the category suitable for surgery. There was no statistically significant difference between the results of the two analyzed groups measured via VR technology for assessment of the quality of movement. Results of initial tests obtained in 15 of the 16 variables (93.75%) indicate that the groups don't vary in territorial characteristics (lifestyle, environmental conditions, etc.). The only exception is represented by the initial measurement of the shoulder girdle motion through diagonal sliding to the right test, for the y-axis (variable *1cyr*), which shows significant variation in the direction of better results in the first group (patients from Zagreb). The final measurement of the same exercise as well as all other final measured tests, shows no statistically significant difference between two groups. According to these results it is possible to assume that there is no geographical dependence for the obtained results. In tests *1axz* (initial assessment of the exercise-test sliding on the x-axis of the pelvis), *1byz* (initial assessment of the exercise-test hip elevation on the y-axis of the pelvis) and *2cyz* (final assessment of the exercise-test diagonal sliding to the right on the y-axis of the pelvis) the difference is close to significance, also in the direction of better results in the first group. During the assessment some of the patients characteristics were perceived, related with their approach and expectations of the treatment. It has been shown that patients from Vukovar have less opportunity for active exercise, for continuous monitoring of physiotherapist or for sports activities, in relation to patients from Zagreb, who were all involved in an activity and have a wider choice of places and modules for AIS treatment. Through conventional methods of clinical AIS treatment, physiotherapy is limited to an average of 10 sessions and the intensity of the therapy depends on the patients themselves; their parents, motivation, desire, and persistence. Possible relation between patients according to AIS conventional physiotherapy in clinics is determined by chance of choice. The type of sport that the patients are involved in is also very important; how intensely and for how long are they doing it, because some sports activities such as tennis, volleyball, badminton and other sports that use a dominant hand (Gielen & Van der Eede, 2008) adversely affect

the postural pattern and raise progression of scoliosis. Well selected sports significantly increase lung function in patients with AIS. Sports with high axial loads, such as lifting weights or those where there are extreme forms of hyperlordosis, especially those that raise resistance in spastic tissues may be potentially harmful in the treatment of AIS. Negrini et al. (2008) showed that physical therapy exercises can have a positive effect on the function of breathing, strength and postural balance and are useful in reducing the specific difficulties for patients with AIS. They state that specific and personalized treatment could be more effective than conventional physical therapy in order to reduce the progression of scoliosis. A small sample is one of the drawbacks of this research. Difficulty was also in motivating patients to the continuous arrival on examination once a month. Patients were involved in the conventional program for scoliosis physiotherapy at clinics and there is an evident lack of a specific individual therapeutic approach to their treatment. On the basis of these results, possibilities for new research are opening, with larger samples and variables. Possible problems that are imposed here are the psychological characteristics of children with AIS, lifestyle, hereditary factors, timely diagnosis and individualized physiotherapy with the goal of postural reeducation of pathological pattern.

CONCLUSION

Despite various theories about the origin, etiopathogenesis of AIS is not fully evidenced and still remains unknown. There is a consensus about the multi factor etiology of AIS. Comprehensiveness and thoroughness of the assessment is fundamental for any treatment of pathology. The goal of the research is to verify if a significant difference in the quality of movement measured via VR technology on specific tests named SYDACK between two groups of patients diagnosed with AIS exists. Grouping is made according to geographic regions; Group 1 is from Zagreb, Group 2 from Vukovar. Another goal of the work is to verify whether there is a significant improvement from initial to final measurements over a one year period in the results of two groups of patients. The hypothesis is that there is no significant difference in the quality of movement between the two groups of patients, as obtained through VR tests, and no geographical dependence. The second hypothesis is that there is no significant difference in the results of specific VR tests for AIS between initial and final measurements of all patients, from Zagreb and Vukovar; it points that the conventional therapy program in both groups doesn't produce significant results in the direction of improvement. The sample consists of two groups of 5 patients with AIS diagnosis, between the ages of 12–18, of both genders. Subjects were diagnosed with double scoliotic curve with Cobb value between 37 and 46 degrees, and are being treated with classical physiotherapeutic methods for AIS, at clinics in Zagreb and Vukovar respectively. SYDACK system for evaluating and analyzing the postural status was constructed at the Faculty of Kinesiology, University of Zagreb. It consists of four applications: a program for viewing therapeutic exercises, a program for displaying information from sensors that monitor the patient's movement, the application for the registration of data in a database and a program for the animation of the Avatar head model. Results are analyzed via a t-test for small independent samples, in the Statistical Package for the Social Sciences (SPSS), version 15.0. Results obtained in 15 of the 16 variables (93.75%)

indicate that there is no statistically significant difference between patients from Zagreb and patients from Vukovar on specific initial assessment of AIS via VR tests. From a total of 32 analyzed variables (initial and final tests) 31 didn't show a statistically significant difference in the results (96.87%). Results indicate a more favorable initial status of patients from Group 1, and almost negligible significance of differences in the final status. That suggests greater success applying AIS exercises for patients from Group 2. It is possible that the explanation of these indicators lies in the regional conditionality and impact of the social environment. The t-test for small dependent samples in all patients (Group 1 and Group 2 together) for three of the 16 cases (18.75%) shows a significant difference in the results of specific VR tests assessment between initial and final measurements, in the direction of improvement. One of the drawbacks of this research is a small sample. The reason for this is the difficulty of measuring which had to be individualized and continuous over a period of one year, on the same instrument, in the same conditions, and that had to be done by the same examiner. There is a need for new research with the requirement for analysis of psychological, sociological factors of causality and an analysis of individual and targeted physiotherapy for AIS.

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