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Research Article

Scoliosis Deformity Reduction in Adults: Structural Rehabilitation Procedures Incorporating the Engineering Concept of the 'Non-commutative Property of Finite Rotation Angles under Addition'

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Abstract

Background

Scoliosis is characterized by three-dimensional changes of the spine and is estimated to be present in 4% of the population worldwide. One of the major challenges faced by clinicians is how to incorporate 3D posture findings into the treatment plane.

Objectives

The present study will evaluate the feasibility of conducting a larger randomized trial. This pilot study is designed to investigate the hypothesis that the Structural Rehabilitation Procedures Incorporating the Engineering Concept of the 'Non-commutative Property of Finite Rotation Angles under Addition will yield short long-term improvement on scoliotic posture parameters outcomes in terms of 3D posture angulation, translation and rotational parameters.

Methods/Design

A pilot randomized clinical trial study was carried out with 12 participants (18-25 years old) with AIS in a physiotherapy laboratory at the University of Sharjah. Participants were randomly allocated to two groups. The experimental group (n=8) intervention consisted of mirror imaging exercise. The waitlist control group (n=4) will have an initial screening using the DIERS formetric machine and will not have any intervention for the 2 weeks during which the experimental group are receiving the novel treatment, after this 2 week period, they will be re-assessed and the novel intervention will be given.

Main Outcome Measures

Primary outcomes were recruitment and satisfaction rate, participation, safety and adherence to intervention. Secondary outcomes were Cobb's angle, vertebral rotation, coronal imbalance, pelvic rotation, sagittal imbalance and pelvic obliquity. Data were collected at baseline and after 2 weeks of intervention.

Results

Participant rates were 80% for the experimental group, recruitment rates were 66.6% and Satisfaction rate showed 41.6% were 'Very satisfied', 16.6% were 'somewhat satisfied', 8.3% was 'Neither Satisfied nor Dissatisfied'.

Conclusions

This pilot study demonstrated feasibility for recruitment, compliance, and safety. The outcomes provided some resources for the incorporation of 3D mirror-image functional re-training intervention compared to waitlist control group for scoliotic posture parameters.

Introduction and Background

Adolescent idiopathic scoliosis (AIS) is a lifetime, systemic condition of unknown etiology, resulting in a spinal curve or curves of ten degrees or more. Although scoliosis is commonly described in terms of spinal curvature in the coronal plane, it is a three-dimensional deformity composed of torsion, angulation, and translation simultaneously occurring in the transverse, coronal, and sagittal planes (Asher and Burton 2006). The prevalence rates of AIS worldwide, using a cut-off point of 10° cobb or more, is approximately 2% to 2.5%. The prevalence drops to 0.29% for curves greater than 20°. In addition, there is an overall female predominance, which increases substantially for larger curves (Konieczny, Senyurt, and Krauspe 2013).

A complex three-dimensional deformation of the spine in AIS results in multiple postural displacements (Trobisch, Suess, and Schwab 2010). Irrespective of the primary trigger, sustained postural imbalance can result in the establishment of a state of continuous asymmetric loading. Once established and maintained

beyond a critical threshold for weight and time, there is an inevitable tendency for progression to occur. More importantly, when the asymmetry is reversed and the unbalanced loading is thereby corrected by restoring normal posture, complete resolution of deformity can occur [1].

The effectiveness of passive treatment for the AIS has been the subject of debate for many years. passive exercise such as spinal manipulative therapy (SMT) has demonstrated poor effectiveness in preventing curve progression (Romano and Negrini 2008).

Regarding the Orthotic bracing which is the most common non-surgical treatment for AIS (Anon 2010). There is evidence that rigid brace treatment is effective in altering the natural history of AIS. However, though rigid bracing has been found to be to some extent significantly beneficial to correct posture deviations related to scoliosis, other problems exist, including psychological stress, compliance, rebound phenomena, and inappropriate mechanism of action.

While active based treatment is particularly important for spinal posture that has been demonstrated to be driven more by automatic, feed-forward schemes than voluntary control (Smania *et al*. 2008). this is one of the reasons for an active exercises approach as a stand-alone treatment or coupled with bracing according to the so-called active bracing principle (Negrini 2008).

Although many physiotherapy scoliosis specific exercise programs methods are now used to treat scoliosis, many have been criticized for lacking patient specificity, and not being truly three-dimensional (Noh *et al*. 2014) (Borysov *et al*. 2015). The majority of traditional exercises are based on outdated concepts, related to a time when the 3D nature of AIS and neurophysiological basis were rarely considered or incorporated into brace design.

The nature of challenges faced by clinicians is derived from the underlying structural and functional problems with scoliosis that go beyond the 3D deformation of the spine, particularly postural disorganization, neuro-musculoskeletal dysfunction and unsynchronized growth patterns. Mostly ignored in the current rehabilitation program (Smania *et al.* 2008).

Building upon this logic, We used the CBP mirror image structural rehabilitation which is individually tailored according the individual 3D posture assessment as an a approach to reducing scoliotic posture Guided by the engineering concept of Non-commutative Property of Finite Rotation Angles under Addition that different order of thoracolumbar posture while performing scoliotic posture correction will lead to different posture outcomes this concept was first taught at semi annual seminar in Reno, Nevada 1997.

To our knowledge, this would be the first true experimental study to investigate the effectiveness of this 3d mirror image approach. Accordingly, the purpose of this pilot study was to evaluate the feasibility of the methods proposed to conduct a full RCT to assess the effectiveness of the Structural Rehabilitation Procedures Incorporating the Engineering Concept of the 'Non-commutative Property of Finite Rotation Angles under Addition.

Method

Study Design

This is a pilot study of a randomized control trial, in this study we will be concerned mainly with feasibility outcomes, with some emphasis on causal relationships between our main variables. In addition, this true experimental design will allow us to control the threats for the internal validity of this research that was carried out between January 2019 and March 2020. This study was approved by the Research Ethics Committee of university of Sharjah.

Setting

This study was held in one of the physiotherapy labs at the University of Sharjah.

Recruitment Process

Study brochures were given to a big number of students in the medical campus of UOS and posted on multiple universities Facebook groups across Dubai, Sharjah, and Ajman, as well as different social media platforms such as WhatsApp and Facebook in a random manner and through word of mouth.

Selection of Subjects

Adolescent 20 patients with idiopathic scoliosis from both genders were participated in the study after signing institutionally approved consent form prior to data collection (appendix I). Their age ranged from 16-22 years old, their height ranged from 155 to 175cm with mean height (165± 5.6), and their weight ranged from 50 to 70Kg with mean weight (60 ±7.5).

The patients were eligible to participate in the study under specific criteria:

Exclusive Criteria

• True leg length discrepancy.

• Previous spinal surgery.

• Associated pathologies that may interfere with maintaining an erect standing posture such as cerebellar or inner ear disorders.

• Associated pathologies of lower limbs that may interfere with the global posture as foot, knee and hip deformities.

• Obese subjects as obesity might interfere with surface topography imaging.

Inclusive Criteria

• Having a mild to moderate scoliotic curve (Cobb angle ranged from 10 to 30 degree).

• Having a significant translational and/or rotational deformities of the thoracolumbar spine with point value ranged from (11-20) according to posture index scale.

Randomization

The subjects will be randomly assigned to the intervention (n=8) group or the waitlist control group (n=4) by an independent party that will select numbers from preserved envelopes by a random number generator. The randomization will be restricted to permuted block randomization where participants will be randomly allocated to their groups. Each random permuted block is transferred to a sequence of consecutively numbered, sealed, opaque envelopes that were stored in a locked drawer until required. As each participant formally enters the trial, the researcher will open the next envelope in the sequence in the presence of the patient.

Block randomization works by randomizing participants within blocks such that an equal number is assigned to each treatment. For example, given a block size of 4, there are 6 possible ways to equally assign participants to a block. Allocation proceeds by randomly selecting one of the orderings and assigning the next block of participants to study groups according to the specified sequence. Note that repeated blocks may occur when the total sample size is greater than the block size times the number of possible orderings. Furthermore, the block size must be divisible by the number of study groups [2].

The participants in the intervention group will receive 3D mirror imaging assessment using DIERS formetric machine, followed by initial treatment using rotational and transitional sequences that would oppose their abnormal curve in order to correct it, a follow up will be done for each participant in 2 weeks.

The participants in waitlist control group will have an initial screening using the DIERS formetric machine and will not have any intervention for 2 weeks, after the 2 weeks they will be re-assessed, and intervention will be given.

Intervention

A prospective, randomized, controlled study will be conducted at a physiotherapy laboratory of the University of Sharjah. Recruitment will begin after approval will be obtained from our local institutional review board. Those who meet initial criteria and express continued interest in participating will be asked to bring a copy of their medical record where the exclusion criteria can be checked.

Mirror image postural stress radiographs for analysis of thoraco-lumbar scoliotic curve reduction and flexibility include a combination of the movements of thoracic lateral translation, thoracic lateral bending and thoracic Y-axis rotation. It's critically important to state that the patient's posture must be assessed in detail prior to the performance of mirror image screening. [reference number]

A list of possible mirror image postural stress radiograph follows:

1. Single movement: side bending Y-axis rotation and lateral translation, this will be performed in upright position.

2. Double combination movement: any sequence of lateral bending Y-axis rotation and lateral translation.

3. Triple combination movement: any combined sequence of lateral bending Y-axis rotation and lateral combination.

Initially, the procedure carried out for the experimental group started by observation, physical assessment, analysis of the patients postures in detail for rotational and translational displacements of the thoracic region relative to the pelvis, any posture deviations were noted. Pain history was recorded, and recent medical reports such as X-rays or MRIs were reviewed.

The patients performed the combination of movements that would be potentially given later before they were prescribed for the sake of practice. Then, they were screened using the DIERS 4D formetric machine in their natural stance, unclothed in upper to mid-bodies, and barefooted. Following that, they were given combinations of different rotational and transitional sequences. For combined postural movements we made sure that the first movement given is held prior to and upon adding the second or third movement to it. this may have required pelvic stabilization by one of the therapists at first. After quantifying the complex 3D nature of scoliotic posture specifically in the thoraco-lumbar region, these data were incorporated into the exercise program, which was done by adjusting the spine into the reverse posture of the scoliotic curve, incorporating the angulations, translation and rotation simultaneously. After finding the sequence of movement that straightened the scoliotic curve best, the patient was instructed to maintain the given position in sitting or standing while stabilizing the pelvis against a stable surface, for minimum of two minutes, and gradually increase the duration to reach an end goal of five minutes, then, to progress with the treatment, maintain the same given position while performing activity of daily living, at least for 20 minutes per day, up to two weeks. In addition to that, patients were instructed to hold the corrective sequences while walking at approximately 2-3 miles per hour. This active adjusting program was continued till the next follow up took place.

After a 2-weekfollow up, participant's scoliotic curve was re-evaluated to check for any changes, and accordingly the sequence of the treatment may or may not be changed based on the obtained changes as a result to the priory-given sequence. Participants were instructed to not perform any loading exercises that would interfere with the result such as weightlifting.

Data Collection and Outcome Assessment

Primary outcomes were feasibility of recruitment, randomization, and assessment procedure. And secondary outcome measures were Cobb's angle, sagittal imbalance, coronal imbalance, pelvic rotation, pelvic obliquity and vertebral rotation.

Primary Outcomes

Measurement of Safety

According to this trial protocol, at least one researcher was present throughout the check up and follow up sessions to make sure the participant is performing the exercises safely, also they were advised to contact us

if any undesirable pain or discomfort occurred while executing the home program. We also asked them about any pain, discomfort or nausea while performing the corrective exercises. These adverse events were recorded weekly, if present, during the intervention period, and at every 2 weeks during the follow up period via phone or text message.

Measurement of Recruitment and Randomization

Recruitment rate was defined as the number of individuals recruited from those who expressed interest. Measurement completion rate was defined as the number of participants able to complete each outcome measure at baseline and follow-up. Loss to follow-up was defined as participants who withdrew or dropped out due to various reasons. (Figure 1) is a flow chart illustrating this process.

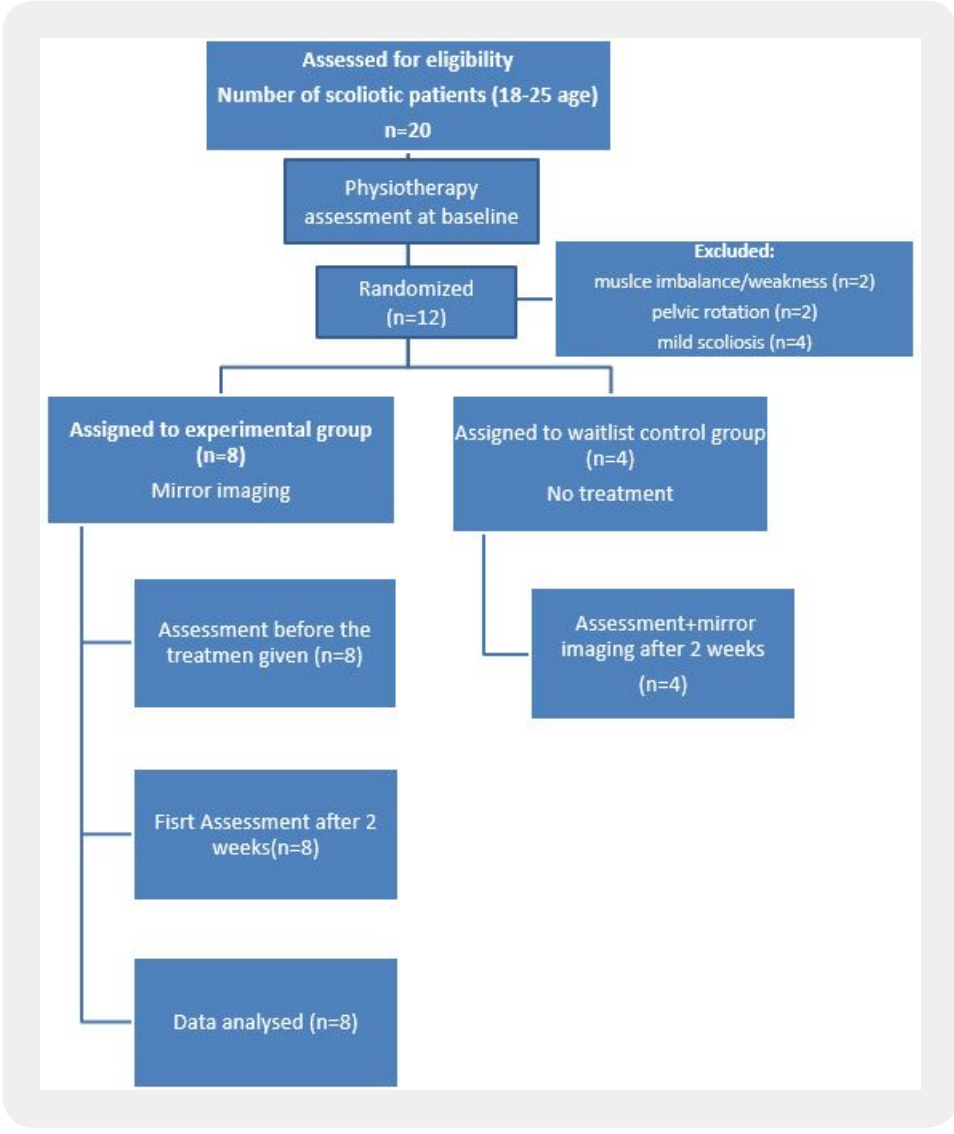


Figure 1: *Flow and progression of participants throughout the study*

Measurement of Participation

According to the current trial protocol, participants in the experimental group were required to perform all physical therapy intervention at home (mirror imaging) and attend the follow up assessments every 2 weeks. If a participant did not attend a session or an assessment, the number of daily physical therapy intervention that were given to perform at home, and all assessment sessions each participant attended was recorded by one of the researchers.

Measurement of Adherence

According to the current trial protocol, each participant in the experimental group was required to perform mirror imaging with a different combination of movements, started by instructing them to maintain the given position while performing active movements for two minutes, and gradually increase the duration to reach an end goal of 5 minutes. Throughout the intervention period, information regarding adherence to the intervention which was instructed to the participants to follow at the same time, was recorded by the researcher at follow-up sessions. The number of daily physical therapy interventions, where the participant completed at home and the reasons for not completing it were acquired and recorded.

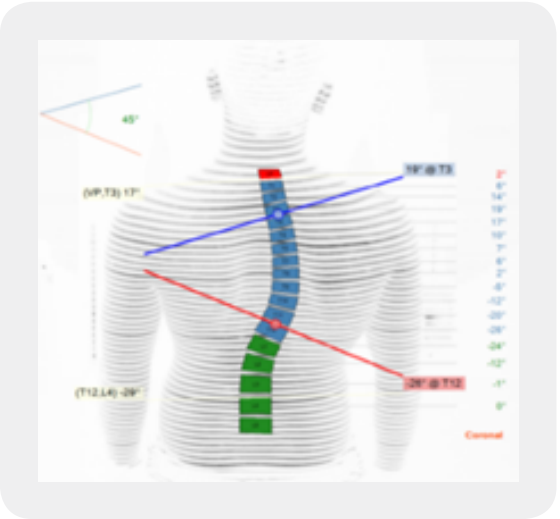
Global Satisfaction with Care

Global satisfaction with care was measured by answering the question "Over the course of treatment for your scoliosis in this study, how would you rate your overall medical care?" Answers to the acceptability questions were scored on a 6-point Likert scale ranging from very dissatisfied to very satisfied on a 5-point Likert scale ranging from extremely dissatisfied to extremely satisfied (5 - Very Satisfied 4 - Somewhat Satisfied 3 - Neither Satisfied nor Dissatisfied 2 - Somewhat Dissatisfied 1 - Very Dissatisfied).

Secondary Outcomes

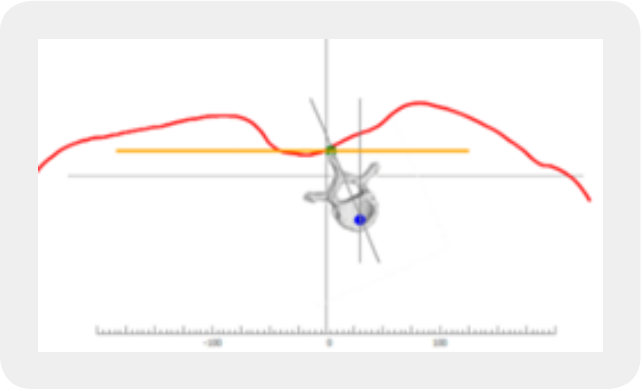
The Cobb's Angle

Cob's angle of scoliosis is an important index. The classical approach is used to assess the upper / lower end vertebras on the entire anteroposterior spine. A vertical line on the upper / lower end of the vertebra end line and the angle of the two vertical lines used is the Cobb angle.



Vertebral Rotation

Describes the axial rotation of vertebral Spinous process location (Cobb method) used clinically to measure the degree of vertebral rotation. The method of Cobb divides the vertebral body into six sections; the area of alignment of the spinous process defines the assigned grade.



Pelvic Torsion

Is calculated from the reciprocal torsion of the surface normal on the two lumbar dimples (vertical components). If the difference angle is positive, then the normal on the right dimple is up more than on the left dimple.

Pelvic Obliquity (tilt)

Pelvic tilt refers to a difference in height of the lumbar dimples, based on a horizontal plane (transverse section). Right dimple higher than left dimple if the angle is positive.

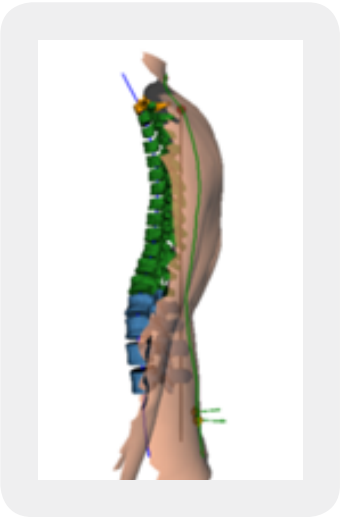
Coronal Imbalance (Lateral Deviation)

This parameter describe the total deviation of the spine midline from the spinal prominence to DM line in the frontal plane, i.e. the maximum deflection on the right plus the maximum deflection on the left.

Sagittal Imbalance

1) kyphotic angle: this is the maximum kyphotic angle, measured between the surface tangents of the upper inflection point ICT in the vicinity of the VP and the thoracic-lumbar inflection point.

2) lordotic angle: this is maximum lordotic angle, measured between the surface tangent of the thoracic-lumbar inflection point and the lower lumbar-sacral inflection point.



Sample Size Calculation

To determine the required sample number in this study, estimates of mean difference and standard deviation for scoliotic angle were collected from Harrison and Oakley previous study. The mean difference value and standard deviation were estimated as 5.1 and 3.9 respectively, a 2-tailed test, an alpha level of 0.05, and a desired power of 95%. These assumptions generated a sample size of 50 patients per each group. As a pilot study we will start by 20% of the initial estimated sample to account for drop-out rates, the sample size will increase to 10%.

Data Collection Method

Study will be conducted at a physiotherapy laboratory of the University of Sharjah. Recruitment will begin after approval will be obtained from our local institutional review board. All of the participants will be conveniently selected from the university student population. The primary investigator will start the recruitment process from the University community using social media platforms and word of mouth. The students will participate in the study after signing an informed consent prior to data collection. Those who

meet the inclusion criteria and express continued interest in participating will be asked to bring a copy of their medical record where the exclusion criteria can be checked. Participants were scanned by using the DIERS formetric 4D, which is a surface topographical scan of the back, for static standing posture analysis. With each scan, the surface topography instrument calculates defined shape parameters based on angles, distances, rotations, and deviations of the spine and pelvis, that appear from the surface indentations and elevations.

Participants removed all clothing except for a pair of shorts so that the entire surface of the back was exposed, then they were positioned on a platform 2 m from the DIERS formetric 4D projection unit. The heels of their bare feet were placed on the platform. Although the foot placement was required to be in line with an arrow drawn at a specific distance from the projection unit, we made sure the placement instruction did not produce any unnatural hip movement. After foot placement, the participants were asked to stand in a relaxed, neutral position. Participants were scanned first in neutral position then with 8 different combinations of spine curvature [3].

Data Management

All the information obtained from patients remained strictly confidential. Results of the study remained anonymous. All data kept in a locked file in the physiotherapy department of the University of Sharjah and remained there until the end of the study. In addition to that, all electronic data kept in a password protected file by one of the co-researchers for future use that is not indicative of subject's identity, as stated in the consent form.

Data Analysis

Primary Outcome Result

Recruitment

The time span required to recruit the number of patients was the period from January 2020 to March 2020. Inclusion criteria were missed in 40% of all persons interested in study participation, and our recruitment rate was 60%. A diagram of the patients' retention and randomization throughout the study is shown in figure 1. A total of 20 scoliotic individuals were initially screened. After the screening process, 12 patients were found to be eligible to participate in the study. In total, 66.6% completed the first follow-up after 2 weeks of treatment. No patients were excluded because of lack of compliance with or intolerance to either treatment regimen. The demographic characteristics of the patients are shown in Table 1.

Table 1: *The demographic characteristics of the patients*

Characteristics	Value
Number of Patients	12
Mean Age	19.3

Gender	
Female	9
Male	3
Diagnosis	
Adolescent idiopathic scoliosis	10
Congenital	2

Adherence and Participation

On average, participants complied with 98% of the required visits and 80% of the participants attended all study visits. Major reasons for missed sessions were due to class and study time conflict (98%) and illness (2%). More than 85% adhered to the minimum performance of ≥ 80% of scheduled home program exercises.

Safety

One subject in the experimental group complained of nausea during the home exercise session. The subject was near completion of the exercise session at the time of the incident and reported minimal nutritional intake before the home exercise session. The incident was reported to the subject's orthopedist and was managed accordingly. This subject had no further difficulties completing the multimodal treatment program. No adverse events were reported by study participants in any group.

Satisfaction Rate

Satisfaction with the study group intervention was high (5 patients: 41.6% were 'Very satisfied', 2 patients 16.6% were 'somewhat satisfied', 1patient: 8.3% was 'Neither Satisfied nor Dissatisfied', and 0% were 'Somewhat Dissatisfied or "Very Dissatisfied").

Waitlist Control group did not receive treatment program in the designated time due to pandemic COVID-19 so satisfaction rate could not be recorded.

Secondary Outcome Result

All data will be analyze using SPSS version 20.0 software (SPSS Inc., Chicago, IL) with normality and equal variance assumptions ensured prior to the analysis. Descriptive statistics were calculated to describe baseline data. The normal distribution of variables was determined using the Shapiro-Wilk Test, expressing continuous data as means with standard deviation (SD) in the text and tables. The nonparametric $\chi 2$ test and the Mann-Whitney U test or parametric t test were conducted to determine whether the 2 groups differed on demographic variables.

The research should use an intention-to-treat approach to interpret outcomes. With repeated steps, the comparative treatment results of the two alternative therapies will be investigated over the duration of the procedure using 2-way variance analysis (ANOVA). The models should include a separate factor (group), a repeated measure (time) and a factor of interaction (group time). If correlations ($P < .05$) are observed, paired

and independent t tests will be conducted as post hoc analyses. The baseline value of the test as covariates will be used for assessing discrepancies between classes. A significance level alpha=.05 will be used for all analyses.

Ethics

We got ethical approval from research ethics committee in University of Sharjah. Participants were given informed consent that explains the procedure, the therapists have been alerted to the privacy and confidentiality rights of the patient, also to have limited access to personal information. Also, make sure that that data is saved in a secure location and to have secure codes that no one knows about except for the therapists.

Discussion

This report presented the application of the engineering concept non-commutative property of finite rotation 5 angles under addition to the spine as a special form of CBP mirror imaging methods in the treatment of idiopathic adolescence scoliosis, and it was a pilot study that recruited 12 subjects out of 20 individuals with AIS who expressed their interest in participating. In accordance with the objectives of this study, it was verified that a large-scale RCT is in fact feasible.

One could make a reasonable argument that the conservative treatment landscape of AIS is underdeveloped in several areas, as the effectiveness of conservative methods in the treatment of AIS has been the subject of debate for many years. This landscape, up to date, is marked by two main methods that dominate most prescriptions: therapeutic stretching and strengthening exercises, and orthotic bracing. Each of the two methods possesses some advantages and disadvantages stated earlier in this text. On the opposing end, is our proposed novel mirror imaging technique.

The mirror imaging technique that we are looking into was addressed earlier in a case study done by Deed E. Harrison and Paul A. Oakley and published in 2017. “Five adult patients who had lumbar/thoraco-lumbar scoliosis and back pain, and at least two prominent thoracic postural abnormalities according to Harrison’s rotations and translations of thoracic postures” were included. “For each patient, one stress film was taken using the order of mirror image movements with the largest displacement followed by the second largest (primary + secondary) and one stress film was taken in the opposite order (secondary + primary)” and they chose the sequence that best straightened the scoliotic curvature to be incorporated into the treatment program. The result was that “all patients had a reduction of curvature concomitant with a reduction in pain levels”. They concluded that “this unique treatment approach offers a patient-specific, targeted structural rehabilitative procedure to stress the spine towards a more straightened configuration. Adult lumbar and thoraco-lumbar curves can be reduced and improved by these non-invasive CBP methods”.

It is worth noting that their study design is suited for exploration purposes, in other words, it can provide promising grounds for the justification of further hypothesis generation and research, but not for generalization of the results onto a larger population. For this novel treatment to be integrated into the current treatment landscape, a full randomized clinical trial that yields permitting results must be done. For this reason, we

have taken a different approach with our pilot study, to pave the way for an RCT, which is the highest level of clinical evidence.

The novel treatment proposed in our study manages to overcome a significant number of the aforementioned points of criticism and others in the previous treatments. For example, it manages to not only be patient specific, but also treatment-phase-specific when the prescribed corrective combinations are changed based on the response to previous combinations. In other words, it enables the positive segmentation of the treatment into phases. It also works on the correction of posture on a subconscious level, something that is achieved upon the progression of treatment when subjects are instructed to perform the corrective combinations while being engaged in other activities, which takes into account the growing interest in the hypothesis that the defects in proprioceptive postural control are closely linked to the etiology of AIS and formation of the scoliotic curve, which is further exacerbated by biomechanical factors. It also takes into account the complex 3D nature of the deformity, by incorporating rotational and translational moments.

The outcome of our measurement of safety deems a large-scale future RCT quite safe to perform. Regardless of the course of action taken to ensure safety of the subjects, the mirror imaging treatment and prerequisite assessment (formetric 4D), in and of themselves, are completely safe and noninvasive, the same cannot be said for other treatment regimens that include exposure to potentially carcinogenic X-rays for assessment purposes. Therefore, optimal safety levels could be achieved in our assessment and treatment with minimal measures.

Recruitment of subjects was found to be 60% of the scoliotic patients who expressed interest in our study. This percentage was achieved due to fulfillment of our inclusion criteria, the patients who were not recruited did not have any exclusion criteria, nor did we encounter any exclusion criteria throughout our study. Lack of recruitment was due to unfulfillment of inclusion criteria, which was very expected in such a small sample, that is being due to our limited access as students to a large population, due to our lack of large-scale recruitment resources.

Our measurement of participation found that, on average, participants complied with 98% of the required visits, and 80% of the participants attended all study visits. Major reasons for missed sessions were due to class and study time conflict (98%) and illness (2%). Such findings are quite promising for the feasibility of a full-scale RCT, but some participation-enhancing factors that enabled us to get such results might be specific to this population, such as the fact that it was easy to reach our lab since our subjects attend lectures in the same, or a nearby building. We also speculate that the young age of our subjects, and the fact that the vast majority of them were medical student might also have been participation enhancing factors, as they could play a role in enhancing awareness of the condition, and enthusiasm to participate in the sessions.

More than 85% adhered to the minimum performance of ≥ 80% of scheduled home program exercises, which is considered to be quite satisfactory given the difficulty of some of the corrective sequences. Such adherence rates could be attributed to the fact that we made sure patients understood the novelty of the treatment and its elaborate mechanism of action. Other factors were consistent communication and ensuring personally that patients followed their prescribed exercises and corrective sequences. As we took these measures, and various others, we were able to obtain high satisfaction rates (5 patients: 41.6% were 'Very satisfied',

2 patients 16.6% were 'somewhat satisfied', 1 patient: 8.3% was 'Neither Satisfied nor Dissatisfied', and 0% were 'Somewhat Dissatisfied or "Very Dissatisfied") [4-9].

Limitations

Obtaining and assessing the clinical outcome of our new proposed method was not applicable due to various reasons, nor was it our priority since this is a pilot study for feasibility assessment purposes. Among the limiting factors were limited or confined population, limited space and human resources that accommodate a larger sample, limited researcher's clinical experience that required the PI to be present at various points during the sessions. Limitations evoked by cultural and religious intergender barriers were also present with regards to undressing and physical contact. Limitations due to machine error were also present, as we found that the DIERS 4D formetric machine produced images that were easily distorted by suboptimal conditions, such as high percentages of subcutaneous fat, and the presence of skin surface appendages like hairs and moles. The reliability and validity of the machine is in fact substantiated in the literature. However, the problem that remains is the underperformance under suboptimal, yet frequently encountered conditions.

Recommendation for Future Studies

We recommend conducting a full-scale randomized clinical trial with a larger sample to confirm the efficacy of this novel treatment, and produce generalizable data.

Conclusion

This demonstrated feasibility for recruitment, compliance, and safety. Provided some resources for the incorporation of 3D mirror-image functional re-training intervention compared to waitlist control group for scoliotic posture parameters.

Bibliography

1. Deed E. & Harrison, J. W. (2007). Lumbar Scoliosis: CBP® Approach to Clinical Assessment & Management.

2. Degenhardt, B., Starks, Z., Bhatia, S. & Franklin, G. (2017). Appraisal of the DIERS method for calculating postural measurements: An observational study. *Scoliosis and Spinal Disorders, 12*(28).

3. Henry Knipe, A. P. (n.d.). Coronal balance.

4. Gabrielle Lam, C., *et al.* (2008). Vertebral rotation measurement: a summary and comparison of common radiographic and CT methods. *Scoliosis, 3,* 16.

5. Jimmy Effird (2010). Blocked randomization with randomly selected block sizes. *Int J Environ Res Public Health., 8*(1), 15-20.

6. Med, J. C. (2009). The relationship between pelvic torsion and anatomical leg length inequality: a review of the literature. *J Chiropr Med., 8*(3), 107-118.

7. Melvin Makhni, C., *et al.* (2018). Restoration of sagittal balance in spinal deformity surgery. *J Korean Neurosurg Soc., 61*(2), 167-179.

8. Thaler, R. L. (2016). Comparison of two- and three-dimensional measurement of the Cobb angle in scoliosis. *International Orthopaedics, 41,* 957-962.

9. Wang, J. Z., *et al.* (2018). Measurement of scoliosis Cobb angle by end vertebra tilt angle method. *J Orthop Surg Res., 13*(1), 223.