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Original Research Article

Effectiveness of telerehabilitation versus physical rehabilitation on postural angles in adolescent girls: a cluster randomized controlled trial

Pallavi S. Wakode[1]*, Janhvi V. Dongre[2]

[1]Symbiosis School of Sports Sciences, Symbiosis International (Deemed University), Pune, Maharashtra, India
[2]Smt. Kashibai Navale College of Physiotherapy, Pune, Maharashtra, India

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***Correspondence:**
Dr. Pallavi S. Wakode,
E-mail: pal.wakode@gmail.com

ABSTRACT

Background: Postural deviations such as forward head posture and rounded shoulders are increasingly prevalent among adolescents. Despite growing interest in corrective interventions, limited evidence exists regarding their effect on objectively measured postural angles. This study compares the effectiveness of tele-rehabilitation and physical (in-person) rehabilitation on Postural angles in adolescent girls.

Methods: A cluster randomized controlled trial was conducted among school-going adolescent girls aged 12-16 years. A total of 120 participants were recruited and allocated into three groups: telerehabilitation (n=40), physical rehabilitation (n=40), and control (n=40). Due to attrition, 114 participants were included in the final analysis. Interventions were delivered three times per week for eight weeks. Postural angles cervical angle, sagittal head angle, and shoulder angle were assessed using photogrammetry. Statistical analysis was performed using a generalized linear model (GLM) adjusting for baseline values. The intervention in tele rehabilitation group was given on an online video platform and physical rehabilitation was given in person in school.

Results: Both telerehabilitation and physical rehabilitation demonstrated significant improvements in all postural angles compared to the control group ($p<0.001$). Physical rehabilitation showed significantly greater improvements in sagittal head angle and shoulder angle compared to telerehabilitation ($p<0.001$), whereas no significant difference was observed between the two interventions for cervical angle ($p=0.214$).

Conclusions: Both physical rehabilitation and telerehabilitation significantly improved cervical posture, sagittal head angle, and shoulder angle compared to no treatment. Physical rehabilitation consistently demonstrated the greatest improvement across all measures.

Keywords: Telerehabilitation, Posture, Adolescent, Photogrammetry, Rehabilitation

INTRODUCTION

In a normal posture, the line of gravity (LOG) passes via the external auditory meatus, the cervical spine's bodies, the acromion, and anterior to the thoracic spine. In contrast, postural misalignments may require increased internal forces to offset the external torque produced by gravity, which is made worse by the LOG's altered position.[1] Other misalignments throughout the body, like rounded shoulders and higher thoracic kyphosis, may arise from the head not aligning with the vertical axis of the body to compensate for the shifting position of the LOG. The term "slouched posture" or "slumped posture" refers to a combination of all three postural abnormalities.[2]

Posture can be quantified by measuring variables such as postural angles. The use of goniometry, photography, photogrammetry, and radiography to assess various postural angles has been documented in the literature.[1,3,4] The most popular non-invasive technique for measuring postural measurements is photogrammetry, which does not involve printing images and does not expose users to the dangerous radiation that comes with the radiography method.[1] In a clinical environment, the authors frequently employ a variety of postural angles like thoracic kyphosis angle, sagittal head tilt, sagittal shoulder-C7 angle, and craniovertebral (CV) angle for patients who have biomechanical defects.[1]

Using photogrammetry to measure these angles yields objective, repeatable data that can be stored and examined at a later time. The thoracic kyphosis angle indicates the degree of kyphosis of the thoracic spine, the sagittal head tilt gauges the posture of the upper cervical spine, the sagittal shoulder-C7 angle indicates the roundness of the shoulders, and the CV angle gauges the head's position with respect to the neck.[1,5]

As the proportion of people using smartphones or personal computers rises, so does the propensity to spend a lot of time sitting down. This may result in abnormal posture, including a forward head posture (FHP) or a rounded shoulder, by altering the spine's alignment.[6] FHP, or the forward positioning of the head with respect to the shoulder, may be altered by neck flexion. Higher FHP has been associated with deficiencies in cervical range of motion, namely in neck flexion and rotation.[7]

Adolescents and children frequently experience musculoskeletal neck pain. Of the children and adolescents who participated in the study by Fares et al in 2017, musculoskeletal neck discomfort was diagnosed in over 87% (180 out of 207) of children and adolescents. Deformed neck alignment when sitting, studying, and watching television, as well as bending the head, neck, and shoulders over cell phones and other portable electronics, can cause gradually increasing cervical spine stresses.[8] According to a review by Brink and Louw, there are five aspects of sitting that are linked to upper quadrant musculoskeletal discomfort in children and adolescents: dynamism, postural angles, and activities while sitting, and sitting duration.[9]

There is compelling evidence that the prevalence of pain rises with age during the adolescent stage, typically occurring slightly sooner in girls, maybe coinciding with puberty, and that girls are more likely than boys to experience it.[10] The precise balance of the vertebral column is well known, and any alteration to one area will be offset by other areas. Large breasts appear to affect the lumbar and thoracic portions of the spinal column. Breast size appears to have a considerable impact on posture, notably the angles of lumbar lordosis and thoracic kyphosis.[11]

Towards the end of adolescence, the prevalence of musculoskeletal pain approaches that of adults. An increased likelihood of chronic pain in adulthood is associated with persistent musculoskeletal discomfort in adolescents. School and school-related activities play a significant role in life and have a big influence on kids' and teens' growth and prospects for the future.[12] Research indicates that telerehabilitation may be just as successful as or even more successful than conventional rehabilitation methods in treating musculoskeletal disorders.[13,14] Telerehabilitation aids in pain management and enhances physical function. Furthermore, osteoarthritis of the knee, low back pain, and complete hip and knee joint replacement can all benefit from telerehabilitation.[15]

Although the efficacy of numerous conservative treatments has been assessed for adult populations, a child or adolescent's spine differs physiologically from an adult's (i.e., in terms of ligamentous laxity, bone composition, and muscle mass) and may react differently to different loading, movements, and interventions.[16] Despite the fact that exercise therapies seem to be promising in treating Low back pain in children and adolescents, There is dearth in literature about studies on posture correction and its effect on postural angles. The aim of this study was to find out effectiveness of telerehabilitation and physical rehabilitation on postural angles in adolescent girls.

METHODS

Study design

A cluster single-blinded randomized controlled trial was carried out among adolescent girls attending schools in peri-urban areas of Pune, with the outcome assessor remaining blinded throughout. The sampling frame included a list of eligible schools from the western Maharashtra region. Ethical clearance was obtained from the Institutional Ethics Committee of Symbiosis International (Deemed University), and the study adhered to the principles of the Helsinki declaration (1975, revised 2013). The study was undertaken from June 2023 to August 2024.

Participant confidentiality was maintained at all stages. Assent from the adolescents and informed consent from their parents were secured, with clear communication of their right to withdraw at any point without repercussions. The data presented in this manuscript are drawn from a larger study; however, this paper represents a separate analysis focused on a distinct research question and reports previously unpublished findings.

Eligibility criteria

Adolescent schoolgirls aged 12-16 years, at the onset of puberty, were included. To maintain homogeneity with respect to postural deviations, participants exhibiting forward head posture (cervical angle <50°) and protracted shoulders (shoulder angle <52°) were selected.

Exclusion criteria comprised any history of acute injury, illness, or surgery, as well as diagnosed musculoskeletal, neurological, or cardiopulmonary conditions.

In addition, girls with functional or structural scoliosis or visual impairments were excluded to minimize potential confounding influences on posture.

Sample size estimation

The sample size was estimated using the formula for comparison of means between independent groups, based on values reported by Ruivo et al (2017), where the mean outcomes for group 1 and group 2 were 13.4 and 17.5, respectively.[18] The calculation assumed a two-tailed significance level of 5% (95% confidence interval), 80% statistical power, and equal allocation across groups. This yielded a required sample size of 35 participants per group for detecting a significant difference. The estimate was extended to a three-arm parallel design comprising Control, physical rehabilitation, and telerehabilitation groups over an 8-week intervention period without follow-up, with the requirement remaining 35 participants per group to preserve statistical power and confidence. Thus, the total minimum sample size was 105 participants. To account for an anticipated 10% dropout rate, the sample size was inflated to 120 participants, with 40 participants allocated to each group.

Postural angles measurement

The following postural angles were calculated with the help of photogrammetry: the sagittal head angle (SHA) is the angle formed by the intersection of a horizontal line that passes through the tragus of the ear and a line that connects the tragus of the ear and the external canthus of the eye. The angle of the cervical region (CA) Using the cervical angle, the forward posture is assessed. It is the angle formed when a horizontal line that passes through the spinous process of C7 joins a line to the tragus of the ear. The angle formed by the intersection of the line connected to the spinous process of C7 and the horizontal line that passes through the midpoint of the humerus is known as the shoulder angle (SA).

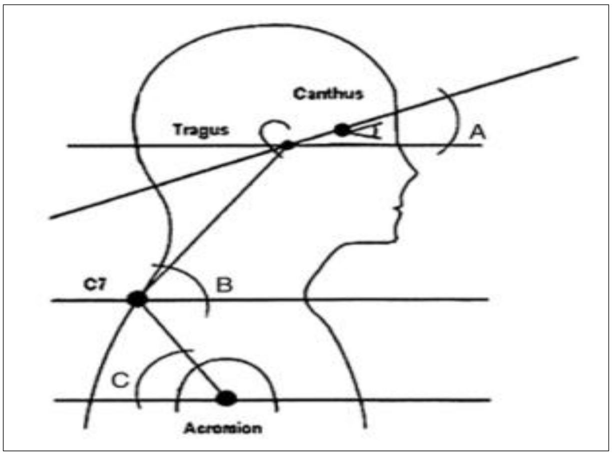

Figure 1: Postural angle measurement.[18]

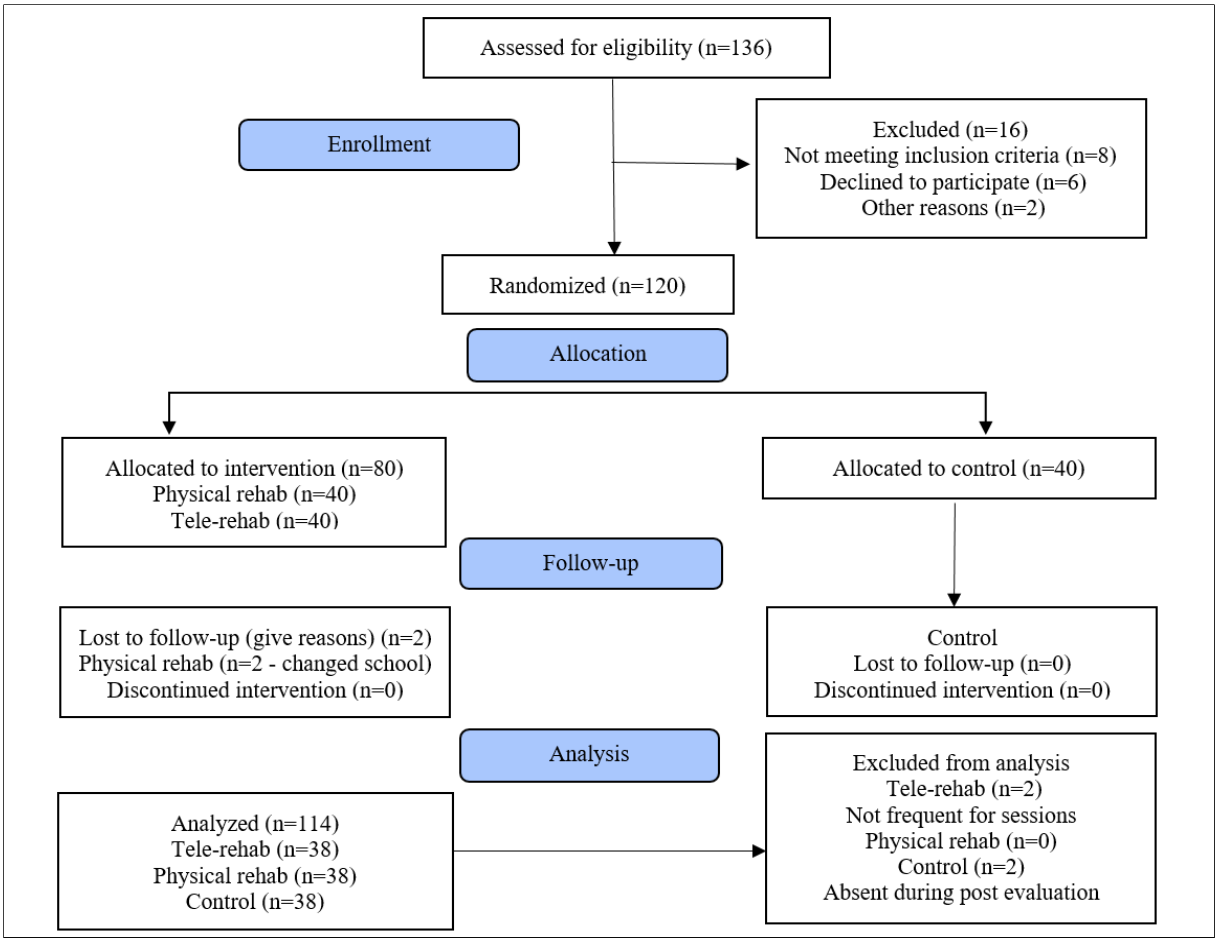

Figure 2: Consort flow chart.

Intervention

A purposive sampling method was employed to select three schools for the study. These clusters were then randomly assigned to either the telerehabilitation group, the physical rehabilitation group, or the control group using a computer-generated random sequence to ensure allocation concealment.

A total of 120 adolescent girls were included, with 40 participants allocated to each group. The intervention was conducted over a period of 8 weeks, with three sessions per week, and postural angles were assessed at baseline and post-intervention. Both intervention groups received a structured exercise program comprising strengthening of the rotator cuff, scapular stabilizers, and cervical musculature, along with stretching exercises targeting the pectoral and neck muscles.

The telerehabilitation group received the intervention through an interactive online video platform, whereas the physical rehabilitation group underwent supervised, in-person sessions at school.

RESULTS

Statistical analysis

Analysis was performed on 114 participants who completed the study (per-protocol analysis), as 6 participants were lost to follow-up. The cervical, sagittal head, and shoulder angles were tested for normality using the Shapiro-Wilk test. Owing to significant analysis of covariance (ANCOVA) assumptions being broken, a generalized linear model (GLM) was employed to assess treatment effects while adjusting for baseline measurements. Since there were differences in the associations between the pre- and post-intervention data across groups, the assumption of homogeneity of regression slopes was violated for the cervical angle, indicating that ANCOVA was unacceptable. Similarly, the SHA necessitated the use of GLM due to the non-normality of residuals, uneven variances, and non-parallel slopes across groups, among other ANCOVA assumptions that were not met. Estimated marginal means were calculated to compare adjusted group outcomes and post hoc pairwise analysis was performed to determine which specific group differed significant from one another.

The descriptive statistics for postural variables across the three groups are presented in Table 1. At baseline, the control, physical rehabilitation, and telerehabilitation groups demonstrated comparable mean values for CA, SA, and SHA. Following the intervention period, both the physical rehabilitation and telerehabilitation groups showed noticeable improvements in postural alignment, reflected by increased cervical and shoulder angles and reduced sagittal head angle, whereas the control group exhibited minimal changes or slight deterioration across most parameters.

To evaluate the effectiveness of the interventions on postural outcomes, GLM analysis was conducted with baseline (pre-intervention) values included as covariates to control for initial group differences. Post hoc pairwise comparisons with Bonferroni adjustment were performed to examine between-group differences. Table 2 presents the adjusted mean differences, standard errors, and corresponding p values, providing a detailed comparison of CA, SHA, and SA across the control, physical rehabilitation, and telerehabilitation groups. The results demonstrated significant differences among the groups after adjusting for baseline values (covariates). Estimated marginal means (EMMs) were calculated to provide group comparisons after controlling for pre-intervention scores, thereby reducing baseline variability and offering a more accurate estimate of treatment effects.

For CA, both the physical rehabilitation and telerehabilitation groups showed significantly higher adjusted post-intervention means compared to the control group ($p<0.001$), with no significant difference between the two intervention groups. In terms of SHA, both intervention groups demonstrated significant reductions compared to control, indicating improvement in forward head posture, with the physical rehabilitation group showing significantly greater improvement than telerehabilitation ($p<0.001$). Similarly, for SA, both intervention groups showed significantly higher adjusted means than control ($p<0.001$), and the physical rehabilitation group demonstrated significantly greater improvement compared to telerehabilitation ($p<0.001$).

Table 1: Descriptive statistics for postural variable.

Variables	Groups	N	Pre (mean±SD)	Post (mean±SD)
Cervical angle	Control	38	46.39±4.96	43.17±4.85
	Physical rehab	38	41.98±2.38	53.58±2.54
	Telerehab	38	44.69±2.78	52.41±3.01
Shoulder angle	Control	38	54.24±2.95	50.42±2.77
	Physical rehab	38	53.95±2.18	68.11±3.90
	Telerehab	38	54.31±2.85	62.70±3.64
Sagittal head angle	Control	38	24.82±3.36	22.98±2.70
	Physical rehab	38	24.23±2.92	16.22±3.81
	Telerehab	38	23.99±2.14	20.57±1.64

Table 2: Pairwise comparison for postural variables.

Variables	Comparison	Mean difference	SE	P value	Interpretation
Cervical angle	Physical rehab versus control	+12.27	0.85	<0.001	Significant increase
	Telerehab versus control	+10.67	0.67	<0.001	Significant increase
	Physical rehab versus telerehab	+1.61	0.89	0.214	Not significant
Sagittal head angle	Control versus physical rehab	+6.36	0.64	<0.001	Significant reduction
	Control versus telerehab	+1.85	0.71	0.027	Significant reduction
	Physical rehab versus telerehab	+4.51	0.61	<0.001	Significant reduction
Shoulder angle	Control versus physical rehab	-17.78	0.71	<0.001	Significant increase
	Control versus telerehab	-12.27	0.67	<0.001	Significant increase
	Physical rehab versus telerehab	+5.50	0.77	<0.001	Significant increase

Overall, these findings indicate that both intervention approaches were effective in improving postural alignment when baseline differences were controlled, with physical rehabilitation consistently demonstrating superior outcomes compared to telerehabilitation across most variables.

DISCUSSION

Both the physical rehabilitation and telerehabilitation group significantly increased postural CA when compared to the control group, according to the results of the GLM, which adjusted for baseline CA. Strong treatment effects were indicated by the estimated marginal means for the physical rehabilitation and telerehabilitation groups being significantly higher than those of the control group. These results are consistent with past research demonstrating the effectiveness of both conventional and remotely delivered therapy in enhancing cervical alignment and promoting proper forward head posture.[19,20]

The physical rehabilitation and telerehabilitation groups showed a slightly greater mean improvement in CA (mean difference=1.61°), but the difference was not statistically significant (p=0.214). This indicates that telerehabilitation may be nearly as effective as in-person therapy for addressing cervical posture in adolescent populations. These findings support the growing body of evidence that telerehabilitation is a viable alternative for those who struggle to get in-person physical treatment.[21,22]

The present study demonstrated that both physical therapy and telerehabilitation therapies were effective in reducing the post-SHA in adolescents when compared to the control group. Results showed that the physical rehabilitation group had the largest correction (mean=16.22°), followed by the telerehabilitation group (mean=20.73°), and the control group had the least improvement (mean=22.58°). The physical rehabilitation group may have performed better because they received real-time tactile and visual correction during in-person sessions and more immediate feedback from the therapist. Nonetheless, the statistically significant improvement in the telerehabilitation group underscores the intervention's potential as a scalable and accessible solution, especially in settings with insufficient physical therapy infrastructure.[22,23]

Pairwise comparisons revealed that all group differences were statistically significant for sagittal head angle. Both interventions' outcomes were significantly better than the Control group's (physical rehab versus control: mean difference=6.36°, p<0.001; telerehab versus control: mean difference=1.85°, p=0.027), and physical rehabilitation outperformed telerehabilitation with a mean difference of 4.51° (p<0.001). These findings are consistent with earlier studies that demonstrated the effectiveness of posture correction methods in reducing sagittal misalignment and enhancing forward head posture in adolescents.[1,24]

A controlled trial comparing postural instruction (PE) and corrective exercise programs (CEPs) for young adults was carried out by Titcomb et al in 2023. After four weeks, the cranio vertebral angle of both exercise groups increased significantly compared to PE alone, indicating that stretching and strengthening led to better improvements in sagittal alignment.[25] A 2020 randomized clinical trial by Elabd et al on individuals with chronic low back pain who combined cervical posture correction with lumbar stabilization revealed greater increases in cranio vertebral angle compared to lumbar stabilization alone, further supporting the cross-segmental effect of cervical exercise on sagittal posture. The notion that certain cervical-focused exercises lead to notable improvements in sagittal head alignment is supported by all of these studies.[26]

Post shoulder angle was analyzed using a GLM and the results showed that both telerehabilitation and physical rehabilitation produced statistically significant improvements in comparison to the control group. When the estimated marginal means were adjusted the physical rehabilitation group (mean=68.21°) showed the greatest improvement, followed by the telerehabilitation group (mean=62.62°), while the control group displayed the lowest post-intervention SA (mean=50.36°).

According to pairwise comparisons, every group difference was statistically significant. Compared to the control group (mean difference= -17.78°, p<0.001) and the telerehabilitation group (mean difference=5.50°, p<0.001), physical rehabilitation was substantially more successful. Similarly, telerehabilitation performed significantly better than the control group (mean difference= -12.27°, p<0.001). These results are in line with past studies that demonstrated the effectiveness of organized shoulder retraction and postural training programs in enhancing scapular alignment and addressing rounded shoulder posture.[27]

Even though in-person physical therapy produced the best results, the telerehabilitation group's notable improvements further demonstrated the efficacy of remote therapies, particularly in setting with limited resources or in remote locations.

These findings align with recent studies showing telerehabilitation can yield outcomes comparable to those of physical therapy in musculoskeletal rehabilitation.[22,23] In a randomized controlled study for young people with upper-crossed syndrome, Jeong et al (2024) compared two telerehabilitation treatments over a 4-week period: shoulder stabilization exercises alone versus stabilization+diaphragmatic breathing. The combined intervention group showed significantly greater improvements in shoulder tilt, round shoulder posture, and craniovertebral angle (CVA), suggesting better alignment effects from integrative respiratory-postural therapy.[28]

An 8-week selected corrective exercises (SCE) program that combined targeted stretching (e.g., pectoralis minor, levator scapulae) and strengthening (e.g., middle/lower trapezius, serratus anterior) was used in a clinical study on adolescents by Heydari et al in 2022. This resulted in improvements in shoulder and craniovertebral angles that were clinically meaningful. Therapeutic activities, particularly those that emphasize scapular retraction and pectoral stretching (such as the Kendall protocol), are beneficial in correcting rounded shoulder posture and forward head tilt, according to another study conducted in 2002 by Roddey et al round shoulders are addressed by using chest stretches and scapular stabilizer strengthening, which affects both shoulder and cervical alignment.[29,30]

Eight weeks of remotely supervised spine stabilization exercises and in-clinic therapy for persistent nonspecific neck pain were compared in randomized research conducted by Onan et al in 2023. Functional capacity, neck awareness, pain reduction, and disability indices showed similar improvements in both groups, indicating that telerehabilitation can achieve results that are equal to those obtained in-person.[31] According to a 2018 systematic review by Sheikhhoseini et al therapeutic activities, particularly those that emphasize strengthening and stretching, significantly increase CVA in patients with forward head posture.[32] Eftekhari et al conducted a systematic study in 2024 that compared telerehabilitation to in-person physiotherapy and found that both improve posture and function for a variety of musculoskeletal problems.[33]

The physiological effects of focused neuromuscular training are reflected in the improvement of cervical posture, SHA, and shoulder alignment during rehabilitation. These three areas are crucial for upper body postural control. In order to restore cervical spine alignment and lessen forward head position, physical rehabilitation programs usually incorporate supervised activities such scapular stability, thoracic extension training, and deep cervical flexor strengthening.[34] Improvements in SHA and SA can be attributed to increased muscle strength, proprioceptive input, and motor control in the deep neck flexors and scapulothoracic musculature.[35]

The larger improvements seen in the physical rehabilitation group, especially in SHA and SA, however, imply that real-time supervision, therapist input, and hands-on correction might offer further advantages for neuromuscular re-education. Tactile cueing and accurate exercise correction are made easier by physical rehabilitation, which probably improves postural stabilizer activation and fosters long-term motor pattern adaptation.[36,37]

Limitations

The study had few limitations as the study was carried out on adolescent girl participants which might limit the generalizability to the broader adolescent population. Due to participants demanding academic schedule, extended monitoring was affected and led to lack of follow up. The relatively short duration of treatment may have constrained the extent of observable postural difference. Cluster-level effects were not explicitly modelled, which may influence variance estimates.

CONCLUSION

Cervical posture, sagittal head angle, and shoulder angle were all markedly improved by both physical rehabilitation and telerehabilitation as compared to no treatment. Out of all the measurements, physical rehabilitation consistently showed the biggest improvement. Sagittal head and shoulder angles showed significant differences between physical rehab and telerehab, although the improvement in cervical angle, while greater in physical rehab, was not statistically significant.

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