DOI: 10.7860/JCDR/2026/82905.22494

Original Article

Physical Medicine and Rehabilitation Section

Effects of Telerehabilitation versus Physical Rehabilitation on Kyphotic Index in Adolescent Girls: A Randomised Controlled Study

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ABSTRACT

Introduction: One of the major concerns during adolescence is the development of postural deviations and musculoskeletal disorders, particularly affecting the cervical, thoracic, and lumbar spine. Thoracic kyphosis is characterised by an excessive anterior curvature of the thoracic spine. The Kyphotic Index (KI) is a quantitative indicator representing the ratio of thoracic width to thoracic length.

Aim: To compare the effectiveness of telerehabilitation and physical (in-person) rehabilitation on KI in adolescent girls.

Materials and Methods: The present Randomised Controlled Trial (RCT) was conducted among adolescent girls studying in peri-urban schools located in Dhayri and Khadakwasla, Pune, Maharashtra, India. Schoolgirls between 12 and 16 years of age who were beginning puberty were selected. Girls with protracted shoulders and a forward head posture were included. Girls with documented musculoskeletal, neurological, or cardiopulmonary diseases, as well as those with functional or structural scoliosis or visual impairment, were excluded from the study. The KI was used as a quantitative metric to assess the degree of thoracic spinal curvature. A total of 114 schoolgirls were selected and divided into three groups: telerehabilitation, physical rehabilitation, and control. The intervention was conducted over eight weeks with three sessions per week, and KI was measured pre- and postintervention. Strengthening exercises for the rotator cuff, scapular stabilisers, and cervical muscles, along with stretching for the pectoral and neck muscles, were administered in the intervention groups. The telerehabilitation group received sessions via an online video platform, whereas physical rehabilitation was delivered in person at school. Post-hoc comparisons using the Bonferroni adjustment were conducted to examine differences in postintervention KI (Post_Kyp) between treatment groups.

Results: Physical rehabilitation produced the greatest improvement (adjusted mean=9.59) compared to telerehabilitation (10.26) and control (10.65). These results indicate that both physical rehabilitation and telerehabilitation significantly reduced postintervention KI compared to the control group, with physical rehabilitation showing a greater reduction than telerehabilitation (p-value <0.001).

Conclusion: The telerehabilitation group significantly reduced KI in adolescent girls; however, physical rehabilitation showed a greater reduction than telerehabilitation.

Keywords: Adolescent, Female, Kyphosis, Posture, Telemedicine

INTRODUCTION

Adolescence is an important stage of development marked by rapid growth, hormonal changes, and musculoskeletal adaptations. These factors can contribute to postural problems [1]. Girls usually begin puberty between ages 8 and 13, and early growth spurts can affect posture and spinal alignment. Many school-aged children experience musculoskeletal pain during this time due to prolonged sitting, poor-quality school furniture, and heavy schoolbags [2-5]. Poor posture is common and leads to improper spinal loading and discomfort. This includes slouching, forward head posture, and rounded shoulders [6].

The KI is a validated and widely used clinical measure that quantifies thoracic curvature. It provides a non invasive, reliable, and cost-effective way to identify postural issues in adolescents. The degree of thoracic kyphosis is measured by assessing the length and depth of the thorax with a flexi-curve ruler [7]. Sedentary lifestyles, long screen time, and poor ergonomic practices have all been linked to higher KI values in teenage girls [8]. Excessive thoracic kyphosis during adolescence can lead to long-term problems such as persistent musculoskeletal pain, worsening spinal deformities, and decreased lung function [9,10].

According to epidemiological studies, children and adolescents frequently experience upper quadrant pain and spinal posture abnormalities [11,12]. If untreated, these postural issues can negatively impact both physical and mental health, even in adulthood. Preventive and corrective treatments are essential in school settings because of increasing electronic device use and sedentary behaviour during this crucial growth period [13,14].

Exercise-based rehabilitation has been proven beneficial in managing adolescent musculoskeletal pain by combining stretching, strengthening, and ergonomic education [15,16]. In periurban and rural schools, access to conventional physiotherapy services is often a challenge due to limited infrastructure and transportation. Hence, the inclusion of telerehabilitation into school-based health programs may offer a suitable strategy to overcome these limitations [16-18]. Telerehabilitation refers to the use of digital platforms to provide structured exercise and posture-correction programs remotely. However, success and patient satisfaction in telerehabilitation interventions depend on effective communication and active engagement to enhance adherence throughout postural rehabilitation in adolescents [19].

Despite growing interest in digital health, the effectiveness of telerehabilitation in treating postural issues in adolescent girls remains insufficiently explored. Moreover, adolescent girls are at high risk of developing postural deviations such as thoracic kyphosis due to rapid growth spurts, academic demands, and increased screen exposure. The current study was therefore novel in its design, as it attempts to evaluate the impact of an eight-week telerehabilitation program compared to a physical rehabilitation program on the KI in adolescent girls. This study fills a significant gap and provides new insights into improving postural health by incorporating structured exercise programs delivered remotely through telerehabilitation, and by comparing their effectiveness with a conventional, in-person physical rehabilitation program in adolescent girls.

MATERIALS AND METHODS

A cluster, single-blinded Randomised Controlled Trial (RCT) was conducted among adolescent girls studying in schools located in Dhayri and Khadakwasla, Pune, Maharashtra, India, in which the assessor was blinded. The sampling frame comprised a list of eligible schools in the western Maharashtra region. The study was conducted from June 2023 to August 2024. Institutional Ethics Committee approval was obtained from Symbiosis International (Deemed University), Pune, with IEC registration number (SIU/IEC/586), and the researcher complied with the ethical standards and guidelines outlined in the Helsinki Declaration of 1975, revised in 2013. Participant confidentiality was maintained throughout the study. Assent and informed consent were obtained from all adolescent girls and their parents, who were informed of their right to withdraw at any time without consequences.

Inclusion criteria: School girls at the onset of puberty aged between 12 and 16 years were included in the study. To ensure homogeneity related to postural deviations, adolescent girls showing signs of forward head posture (defined as a cervical angle less than 50°) [20] and girls with protracted shoulders (defined as a shoulder angle less than 52°) [20] were included in the study.

Exclusion criteria: Adolescent girls with any acute injury, illness, or history of surgery, those diagnosed with musculoskeletal, neurological, or cardiopulmonary disorders, adolescent girls with functional or structural scoliosis and those with visual deficits were excluded from participation to avoid confounding factors affecting posture were excluded from the study.

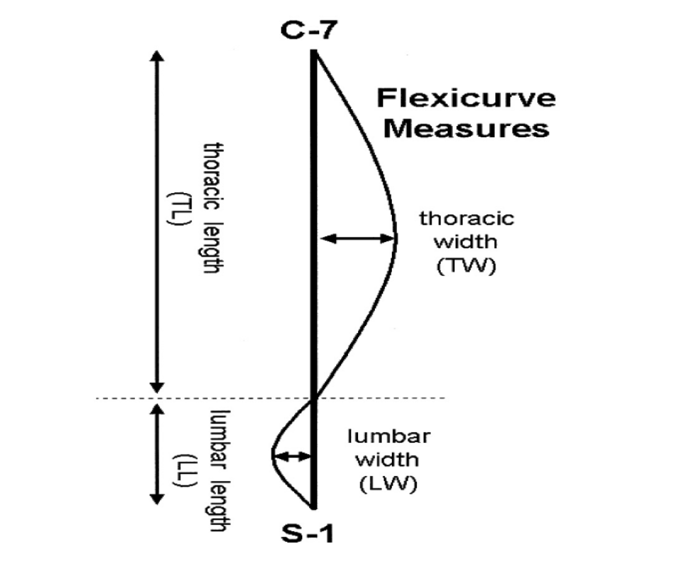
Sample size estimation: The sample size estimation was carried out using the formula for comparing means between groups, based on values obtained from a previous study by Ruivo RM et al., 2017, with mean values of Group-1 and Group-2 being 13.4 and 17.5, respectively [21]. Parameters used included a 95% confidence interval, 80% power, and an equal allocation ratio across groups. Using these parameters, the sample size per group was calculated to be 35 participants. Extending the calculation to a three-group design (control, physical rehabilitation, and telerehabilitation for 8 weeks with no follow-up), the sample size requirement remained 35 participants per group to maintain equivalent power and confidence levels. Thus, the total sample size required was 105 participants. Considering 10% dropouts from each group, the final sample size was set at 120 (40 participants per group × 3 groups).

Kyphotic Index (KI) Measurement

Excessive anterior-posterior curvature of the thoracic spine, which frequently results in a pronounced rounded upper-back posture, is an indicator of kyphosis. The KI is a quantitative metric used to assess the degree of thoracic spinal curvature, specifically evaluating kyphosis severity. The KI is calculated using the following formula [22]:

Kyphotic Index (KI) = (Width/Length) ×100

Hinman MR, stated that width is the greatest horizontal distance between the apex of the thoracic curve and a vertical reference line derived from the spinous process line, and length is the linear distance along the spinal segment measured from the first thoracic vertebra (T1) to the twelfth thoracic vertebra (T12). This ratio offers a consistent means of expressing the relative protrusion of the thoracic curvature, facilitating comparisons between individuals and over time. A higher KI indicates a more pronounced kyphotic curve [Table/Fig-1] [23].



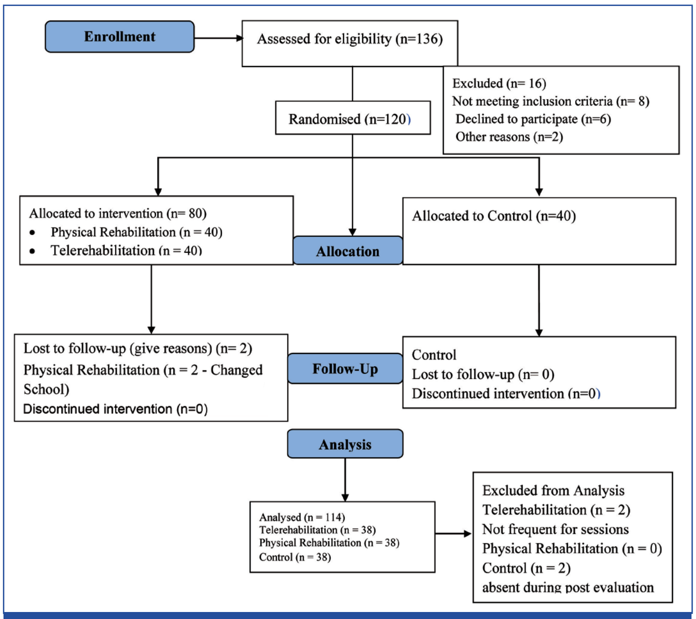
[Table/Fig-1]: Flexicurve measurement technique (Adapted from Hinman MR [23]).

Reliability and validity: The Intraclass Correlation Coefficient (ICC) is widely used to assess the reliability of measurement tools. The ICC for KI has been documented as 0.87, indicating high consistency between repeated measures and across different raters [24]. Studies evaluating KI have reported good to excellent reliability [25-27].

Intervention

A purposive sampling technique was used to select the schools for the study. Three schools were selected. Randomisation of clusters (schools) into two intervention groups (telerehabilitation and physical rehabilitation) and one control group was performed using a computer-generated random sequence to ensure allocation concealment. Forty adolescent girls were included in each intervention group and control group. The intervention was conducted over eight weeks, with three sessions per week, and KI was measured pre- and postintervention. Strengthening of the rotator cuff, scapular stabilisers, and cervical muscles, along with stretching of the pectorals and neck muscles, was provided in both intervention groups.

In the telerehabilitation group, the intervention was delivered using an online interactive video platform, while physical rehabilitation was provided in person at school [Table/Fig-2]. However, due to



[Table/Fig-2]: CONSORT flow chart.

demanding academic schedules at the schools, further follow-up could not be conducted.

STATISTICAL ANALYSIS

Data were analysed using a one-way ANCOVA with baseline values (Pre_Kyp) as the covariate to adjust postintervention KI scores (Post_Kyp). Prior to analysis, assumptions of ANCOVA were tested. Since these assumptions were not satisfied, a Generalised Linear Model (GLM) with a Gamma distribution and log link function was employed to account for heteroscedasticity and non homogeneous slopes. The Wald Chi-square test was used to assess whether the group variable had a significant overall effect on Post KI, considering all treatment groups together. Post-hoc comparisons using the Bonferroni adjustment were conducted to examine differences in Post KI between treatment groups.

RESULTS

[Table/Fig-3] shows that age, height, weight, and BMI were comparable across all three groups (physical rehabilitation, telerehabilitation, and control). The p-values for all parameters were >0.05, indicating no statistically significant differences between groups at baseline. This suggests that the groups were well matched demographically, and any postintervention changes can be more confidently attributed to the interventions rather than baseline differences.

Group	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m²)
Physical rehabilitation (n=38)	13.20±0.8	134±11.84	46.45±3.86	20.59±6.49
Telerehabilitation (n=38)	13.45±1.2	130±14.32	43.68±5.48	20.34±5.52
Control (n=38)	13.49±1.5	132±10.52	44.12±4.25	21.27±4.66
p-value	0.325	0.429	0.238	0.350

[Table/Fig-3]: Baseline characteristics of study participants (Mean±SD).

[Table/Fig-4] presents descriptive statistics for KI. Baseline KI means were similar across groups: physical rehabilitation (10.73±0.47), telerehabilitation (10.64±0.35), and control (10.26±0.16). After intervention, the physical rehabilitation group showed a significant reduction in KI (9.63±0.33), while the telerehabilitation group showed a smaller reduction (10.33±0.27), compared to the control group (10.35±0.22).

Group	n	Preintervention (Mean±SD)	Postintervention (Mean±SD)	t value	p-value
Physical rehabilitation	38	10.732±0.467	9.628±0.330	11.89	<0.001
Telerehabilitation	38	10.637±0.351	10.326±0.272	4.33	0.0048
Control	38	10.258±0.162	10.353±0.219	-2.16	0.334

[Table/Fig-4]: Descriptive statistics of Kyphotic Index (KI) (Mean±SD).

Intragroup comparisons were performed using paired sample t-tests. The control group showed no significant difference (p-value=0.334), whereas the physical rehabilitation group showed a statistically significant reduction in KI (p-value <0.001). The telerehabilitation group also showed a smaller but significant reduction in KI (p-value=0.0048).

As shown in [Table/Fig-5], the Wald Chi-square test yielded a significant result: χ^2 (2)=245.992, p-value <0.001. This indicates a statistically significant difference in postintervention KI values among the three groups, even after adjusting for baseline KI. The physical rehabilitation group had the lowest mean postintervention KI value (9.59), indicating the greatest reduction in KI. Telerehabilitation also showed improvement (mean=10.26), but less than the physical rehabilitation group. The control group had the highest post-intervention KI (10.65), indicating minimal change.

As shown in [Table/Fig-6], all pairwise comparisons demonstrated statistically significant differences (p-value <0.001) after Bonferroni correction. The physical rehabilitation group had significantly lower postintervention scores than both the control and telerehabilitation groups. The telerehabilitation group also performed significantly better than the control group, but not as well as the physical rehabilitation group. Mean differences were as follows: control vs. physical rehabilitation showed the largest difference (1.06 units), control vs. telerehabilitation showed a moderate difference (0.39 units), and physical rehabilitation vs. telerehabilitation showed a substantial difference (0.67 units).

Group	Mean	Std. Error	95% Wald Confidence interval
Physical rehabilitation	9.59	0.037	9.52 - 9.66
Telerehabilitation	10.26	0.037	10.19 - 10.34
Control	10.65	0.077	10.50 - 10.80

[Table/Fig-5]: Wald Chi-square test for Kyphotic Index (KI) by estimated marginal means.
Note: Covariate adjusted for baseline Kyphotic Index (KI) (Pre_Kyp = 10.54)

Post-hoc pairwise comparisons confirmed that physical rehabilitation was significantly more effective in reducing KI compared to both telerehabilitation and control. Telerehabilitation was also significantly better than the control, supporting its value as a viable alternative, though slightly less effective than in-person care.

DISCUSSION

The present study aimed to evaluate the effects of telerehabilitation versus physical rehabilitation on KI in adolescent girls and revealed significant differences between the groups. All pairwise comparisons demonstrated statistically significant improvement after Bonferroni corrections. The physical rehabilitation group showed the greatest reduction in KI compared to both the telerehabilitation and control groups. Although the telerehabilitation group showed significant improvement compared to the control group, the extent of improvement was less than that seen in the physical rehabilitation group. The current study showed that physical rehabilitation is highly effective in reducing KI, as the protocol was designed to restore normal balance between opposing muscle groups. These changes may be attributed to direct supervision and real-time correction of faulty movement patterns, which facilitate better learning and performance of the prescribed exercises.

The findings of the present study align with previous research on postural alignment and kyphosis in adolescents [15,21]. During the COVID-19 pandemic, a cohort study by Andrade RM et al., examined the impact of telerehabilitation and conventional in-person rehabilitation on teenagers with idiopathic scoliosis by measuring the spine's Cobb angle. According to the study, both rehabilitation techniques improved the spine's Cobb angle, suggesting that telerehabilitation may be a useful substitute for conventional rehabilitation in the treatment of adolescent spinal abnormalities. Telerehabilitation ensures that teenagers complete exercises correctly by providing real-time feedback and guidance, which improves spinal curvature and associated symptoms [28].

The results of the present study are also consistent with Abd-Eltawab AE and Ameer MA, who investigated general physical activity compared to Theraband exercises on thoracic kyphosis in females. Their study showed that both methods were beneficial in lowering the KI, with Theraband exercises having a more beneficial effect [29]. These findings support the present results, demonstrating that structured resistance exercises with direct supervision and feedback are more effective in reducing thoracic kyphosis.

A narrative review by Yang S et al., suggested that exercise programs are a potentially beneficial therapeutic option for reducing adolescent thoracic kyphosis and improving poor posture [30]. Similarly, Ogourtsova T et al., reinforced that telerehabilitation is a viable option when in-person care is limited. It works better than having no treatment at all, performs on par with regular care, and

Group (I)	Group (J)	Mean Difference (I-J)	Std. error	df	p-value (Bonferroni)	95% CI for difference
Physical rehabilitation	Control	-1.06	0.085	1	<0.001	-1.26 - -0.86
Physical rehabilitation	Telerehabilitation	-0.67	0.052	1	<0.001	-0.80 - -0.55
Telerehabilitation	Control	-0.39	0.085	1	<0.001	-0.59 - -0.18
Telerehabilitation	Physical rehabilitation	0.67	0.052	1	<0.001	0.55 - 0.80
Control	Physical rehabilitation	1.06	0.085	1	<0.001	0.86 - 1.26
Control	Telerehabilitation	0.39	0.085	1	<0.001	0.18 - 0.59

[Table/Fig-6]: Post-hoc pairwise comparisons of Post_Kyp (Bonferroni-Corrected).
Note: The p-value was significant at the 0.05 level.

paediatric rehabilitation may benefit from a combination of in-person and telerehabilitation techniques [31].

In the present study, adolescent girls' KI improved with both telerehabilitation and conventional physical rehabilitation. Traditional therapy provides hands-on instruction and direct supervision. In contrast, telerehabilitation offers greater accessibility and flexibility, making it a good option, especially when attending in-person sessions is challenging. Individual preferences, resource availability, and specific clinical concerns may all influence which treatment is most suitable [32-35].

Future research should focus on blended programs combining in-person rehabilitation and telerehabilitation specifically targeting adolescents' postural issues. Incorporating wearable technology and digital feedback systems could enhance adherence and outcomes [36]. Expanding these approaches in school-based settings may promote correction of postural abnormalities and positively impact long-term musculoskeletal health [37-39].

Overall, the findings indicate that physical rehabilitation remains the gold standard for postural correction due to its supervised nature and hands-on approach, which provides real-time feedback. However, the significant improvements observed through telerehabilitation indicate that it is an accessible alternative and may be incorporated in situations where in-person access is limited. Thus, telerehabilitation ensures continuity of care and supports postural health among adolescents.

Limitation(s)

The study was carried out exclusively on adolescent girls, which may limit generalisability to the broader adolescent population. Due to the participants' demanding academic schedules, extended monitoring and follow-up could not be performed. The relatively short treatment duration may have constrained the extent of observable postural differences. Future studies with varied population groups and longer intervention periods are recommended.

CONCLUSION(S)

Kyphotic posture improved in both telerehabilitation and physical rehabilitation groups. The KI in adolescent girls decreased significantly more in the physical rehabilitation group compared to the telerehabilitation group. The greater effectiveness of physical rehabilitation may be attributed to direct supervision and real-time correction of faulty movement patterns, whereas telerehabilitation lacked tactile feedback and continuous supervision, relying primarily on visual feedback. Therefore, telerehabilitation represents a promising secondary strategy involving remote monitoring to engage adolescents in posture correction.

Acknowledgement

Authors sincerely thank all participants who consented and took part in the study.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Oct 03, 2025
- Manual Googling: Nov 22, 2025
- iThenticate Software: Nov 24, 2025 (5%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes/No
- Was informed consent obtained from the subjects involved in the study? Yes/No
- For any images presented appropriate consent has been obtained from the subjects. Yes/No

Date of Submission: **Sep 11, 2025**
Date of Peer Review: **Oct 09, 2025**
Date of Acceptance: **Nov 26, 2025**
Date of Publishing: **Mar 01, 2026**