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Original Article

Orthopaedics Section

Comparative Analysis of Cervical Range of Motion Assessment in Mechanical Neck Pain using Conventional Techniques versus Artificial Intelligence Approaches: A Cross-sectional Observational Study

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ABSTRACT

Introduction: A significant percentage of the world's population suffers from Mechanical Neck Pain (MNP), a widespread and incapacitating ailment that highlights the need for precise diagnosis and treatment approaches. In order to manage MNP, cervical Range of Motion (ROM) measurement is essential. The conventional procedures for this are goniometry and inclinometry. However, these techniques often face limitations concerning accuracy and inter-rater reliability.

Aim: To compare the efficiency of conventional techniques with Artificial Intelligence (AI)-based technologies while evaluating cervical ROM in patients with MNP.

Materials and Methods: This was a cross-sectional observational study where 31 MNP patients participated in a comparative analysis. The duration of study was four months (From March 2024 to June 2024). The study was conducted in Physiotherapy Out Patient Department, SGT Hospital and Research Institute, Gurugram, Haryana, India. Traditional goniometry and an AI-driven system (PhyTrackTM version 1.2) were used to measure cervical ROM. Two sessions of assessment were required for each subject to undergo measurements of flexion, extension, and lateral flexion. Paired t-tests were used to analyse differences between the two methods.

Results: A total of 31 MNP patients participated in this study. The results of the ROM assessments for cervical flexion (p=0.133), extension (p=0.876), and lateral flexion (p=0.086) using the manual and AI approaches did not show any statistically significant differences. This implies that assessments conducted using AI are similar to those conducted using manual methods.

Conclusion: AI-driven solutions show potential for providing accuracy and reliability comparable to conventional techniques for measuring cervical ROM in MNP patients, although further research with larger sample sizes is needed to confirm these findings. AI integration into clinical practice may improve ROM evaluation accuracy, consistency, and efficiency, which would benefit patients. Future research ought to investigate how AI-based evaluations affect clinical outcomes and decision-making over the long run.

Keywords: Artificial intelligence, Conventional techniques, Rehabilitation

INTRODUCTION

The MNP is a prevalent and disabling condition, affecting a substantial portion of the global population. MNP refers to neck pain without a clearly identifiable pathoanatomic cause. It is often classified as non-specific neck pain due to the absence of a direct structural pathology. MNP typically develops gradually and arises from multiple contributing factors, including poor posture, forward head posture, crossed neck syndrome, psychological factors such as anxiety and depression, as well as various occupational and sports-related activities [1]. According to the GBD 2019 Diseases and Injuries Collaborators (2020), MNP contributes significantly to the global burden of musculoskeletal disorders [2]. The high prevalence, coupled with its profound impact on individuals' quality of life, underscores the necessity for effective diagnostic, management, and treatment strategies [3]. MNP is a prioritised condition in the realm of musculoskeletal health due to its potential to cause psychological discomfort, functional restrictions, and chronic pain.

Cervical ROM assessment is an essential part of the clinical evaluation of MNP. Precise assessment of ROM is crucial for diagnosing the condition as well as monitoring the course of treatment and choosing the best course of action. In clinical settings, goniometry and inclinometry have historically been the most often utilised techniques for ROM assessment. Goniometry uses a tool similar to a protractor to measure joint angles, whereas inclinometry uses gravity-based inclinometers to determine the cervical spine's inclination [4]. These techniques are widely used, but they frequently face difficulties with measurement accuracy, inter-rater reliability, and the requirement for high levels of clinical skill [5]. These limitations emphasise the need for ROM evaluation methods that are more accurate, dependable, and approachable.

Recent developments in AI offer new opportunities to enhance the assessment of musculoskeletal conditions, including MNP [6]. AI technologies, especially those powered by machine learning algorithms, have shown promise in improving predictive analytics and diagnostic accuracy in a number of healthcare fields [7]. When it comes to ROM assessment, AI-based systems have an edge over traditional manual procedures in that they are more accurate, impartial, and consistent. Large datasets can be analysed by machine learning algorithms, which can also reveal correlations and trends that human observers would overlook. This results in more accurate and consistent ROM measurements [8]. The subjectivity and variability present in traditional approaches can be greatly reduced by these technologies, which will ultimately result in judgments that are more dependable.

Studies indicate that up to 70% of people may suffer from MNP at some point in their lives, making it a very common condition [9]. There is an immediate need for effective and trustworthy techniques for both diagnosis and treatment due to these high incidence rates.

Developing precise ROM assessments is essential in creating successful treatment regimens. Nonetheless, there are issues with the subjectivity and unpredictability of conventional techniques like goniometry. Studies have demonstrated that goniometry can display significant inter-rater variability, which compromises the accuracy of its readings [4].

Conversely, AI-based systems use large datasets and sophisticated algorithms to provide accurate and consistent readings. According to Sharma M et al., these systems are capable of analysing intricate movement patterns and minute ROM changes that conventional approaches might miss [8]. AI technology can also help with remote monitoring and tele-rehabilitation, which enables patients to receive fast and accurate assessments without having to visit a clinic. In the current healthcare environment, where there is a growing need for effective resource use and access to care, this competence is especially pertinent.

AI can improve the objectivity and accuracy of ROM assessments, and has potential to revolutionise physical therapy practice. AI can give physical therapists accurate, unbiased data to guide treatment decisions by reducing the subjectivity and variability that define traditional techniques. AI's ability to provide real-time feedback and conduct remote monitoring also makes it possible to continuously assess and modify treatment programs, resulting in interventions that are more individualised and successful. According to Jiang F et al., this may eventually lead to improved patient outcomes by enabling more individualised treatment plans [7].

Even though AI has a lot of potential for use in physical therapy, it is crucial to carefully compare proven conventional techniques with AI-based technologies. By conducting a comparative analysis of cervical ROM assessments in MNP patients using both manual traditional procedures and AI-driven technologies, this study aims to address this gap. This study tries to ascertain if AI can enhance the clinical care of MNP and lead to better patient outcomes by comparing the precision, dependability, and effectiveness of these two different approaches.

MATERIALS AND METHODS

This was a cross-sectional observational study where 31 MNP patients participated in a comparative analysis. The duration of study was four months (From March 2024 to June 2024). The study was conducted in Physiotherapy OPD, SGT Hospital and Research Institute, Gurugram. The assessment was conducted using conventional goniometric methods and PhyTrack (T) version 1.2, an AI-driven Computer Vision engine developed by Digital Darwin®. Ethical clearance was taken from Faculty of Physiotherapy, SGT University, Gurugram, SGTU/FPHY/2024/351A.

Inclusion criteria: The study included participants aged 18 years and older, all of whom were diagnosed with MNP. (Clinical findings included localised cervical pain, restricted and painful ROM, and muscle tenderness without significant neurological deficits. Diagnosis was primarily clinical, with imaging reserved for ruling out structural or neurological pathology.) Subjects were recruited from the Physiotherapy Outpatient Department (OPD) at SGT Hospital and Research Institute, Budhera, Gurugram, Haryana, India.

Exclusion criteria: Participants with a history of spine surgery, traumatic injuries, neurological disorders affecting cervical ROM, or any other medical conditions that could impact ROM assessments were excluded.

Study Procedure

Participants underwent cervical ROM assessments using both conventional methods (goniometry) and AI-driven technologies (PhyTrack). PhyTrack is Digital Darwin's proprietary computer vision model trained to assist physiotherapists in digital evaluation of patients (https://www.digitaldarwin.ai/OurTools/PhyTRACK.html). Two separate assessment sessions were conducted for each participant, with a rest period between sessions to reduce carryover effects.

Conventional methods: Participants were positioned in a standardised posture for cervical ROM assessment using a goniometer. The physiotherapist measured angular ROM for cervical flexion, extension, and lateral flexion, ensuring consistency in positioning and technique [Table/Fig-1-3].

[Table/Fig-1]: Cervical flexion.

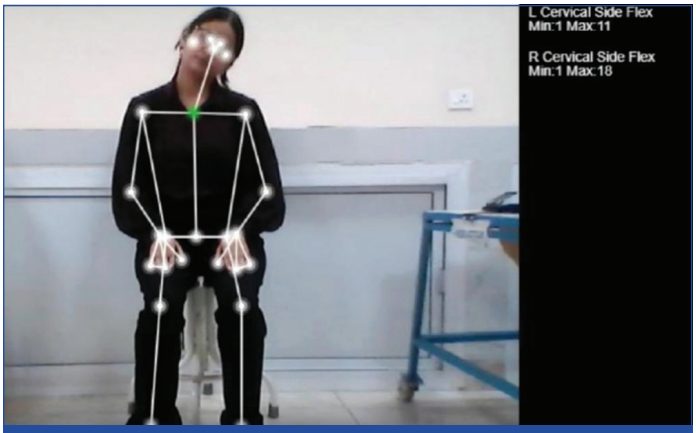
[Table/Fig-2]: Cervical extension.

[Table/Fig-3]: Cervical side flexion.

AI-driven technologies: The AI-driven PhyTrack system captured three-dimensional motion data during cervical movements. The data were processed using AI algorithms to calculate precise ROM values. This technology provided an advanced and objective method of measuring cervical mobility [Table/Fig-3-6].

[Table/Fig-4]: Cervical flexion.

[Table/Fig-5]: Cervical extension.



[Table/Fig-6]: Cervical side flexion.

Each participant completed two assessment sessions: one using conventional goniometry and the other using AI-driven technologies. The order of assessments was randomised to prevent potential bias. Prior to each session, participants were given detailed instructions on performing cervical movements, including flexion, extension, and lateral flexion, to their maximum comfortable range. A qualified physiotherapist conducted both assessments, ensuring standardised procedures and techniques across sessions. Consistency in positioning and measurement protocols was strictly maintained for all participants.

The primary outcome measures were cervical ROM values obtained through both conventional goniometry and the AI-driven PhyTrack system. Comparisons were made between the two methods to determine accuracy (The measurements using the AI system and conventional goniometry were performed simultaneously ensuring consistency in head positioning and movement), reliability (Repeated measurements taken by the same examiner at different times to test intra-rater reliability, measurements conducted by different examiners to test inter-rater reliability), and potential advantages of using AI-based technology for ROM assessments.

STATISTICAL ANALYSIS

Data was analysed using IBM Statistical Package for Social Sciences (SPSS) software. For the statistical analysis, paired t-tests were performed to compare cervical ROM measurements obtained from conventional goniometric methods and AI-driven technologies (PhyTrack). This comparative analysis aimed to identify any significant differences in ROM between the two assessment methods. The paired t-test was chosen to account for the repeated measures design, as each participant underwent both assessment methods. A p-value of less than 0.05 was considered statistically significant for determining whether the observed differences were not due to random variation but reflected true differences between the methods.

RESULTS

Descriptive statistics, including means, standard deviations, and frequency distributions, were employed to summarise participant demographic characteristics [Table/Fig-7].

Variables	Mechanical Neck Pain (MNP)
Number of patients	31
Mean age (years)	38.27±14.63

[Table/Fig-7]: Demographic details.

No statistically significant differences were observed when comparing cervical ROM measurements between the conventional manual method and the AI-based approach for the variables of cervical flexion, extension, and side flexion [Table/Fig-8].

Variables	Manual Mean±SD	AI Mean±SD	t-value	p-value
Cervical flexion	52.74±16.69	48.38±9.15	1.545	0.133^{NS}
Cervical extension	37.26±19.18	36.71±16.53	0.157	0.876^{NS}
Side flexion	26.06±7.58	23.29±6.75	1.774	0.086^{NS}

[Table/Fig-8]: Comparison of Range of Motion (ROM) measured by Manual method and Artificial Intelligence (AI).
NS: Non-significant

Cervical flexion: The p-value for cervical flexion was 0.133, indicating no significant difference between the two methods. However, a slightly lower mean ROM was noted with the AI approach (48.38±9.15) compared to the manual goniometric measurement (52.74±16.69). Although the difference was not statistically significant, the AI method showed a tendency to yield marginally lower ROM values [Table/Fig-8].

Cervical extension: The mean values for cervical extension were almost identical between the two methods, with the manual approach recording 37.26±19.18 and the AI method recording 36.71±16.53. The high p-value of 0.876 further confirms that there was no significant difference between these measurements, indicating strong agreement between the manual and AI methods for assessing cervical extension [Table/Fig-8].

Side flexion: For side flexion, the AI-based method recorded a slightly lower mean ROM (23.29±6.75) compared to the manual method (26.06±7.58). Although the p-value of 0.086 is closer to the significance threshold, it still falls short of indicating a meaningful difference between the two methods. This suggests that, while the AI system may produce slightly more conservative ROM estimates, the overall measurements are comparable [Table/Fig-8].

Overall, the absence of significant differences across all variables suggests that the AI-driven technology is as reliable as the conventional manual method for measuring cervical ROM. These results could be used to support the potential use of AI-based systems as an alternative or complementary tool for ROM assessment in clinical practice.

DISCUSSION

This study aimed to compare the efficiency of AI-driven technologies with traditional manual methods for determining cervical ROM in

people who suffer from MNP. Given the high prevalence of MNP and the importance of a precise ROM evaluation in its management, this comparison is crucial. Although conventional manual methods are still commonly used, they are often criticised for issues with accuracy, dependability, and efficiency. AI-based technologies offer a promising alternative that could enhance the precision and consistency of ROM assessments.

The results of this study show that manual techniques and AI-driven techniques are equivalent when assessing cervical ROM in people with mechanical neck discomfort. This finding will have a big impact on clinical practice, especially in the field of physical therapy and rehabilitation. We can potentially improve the ROM measures' accuracy, reliability, and efficiency by integrating AI technology into clinical assessments. This will help to overcome many of the drawbacks of traditional approaches.

The results align with the growing body of literature supporting the integration of AI in healthcare. According to Javaid M et al., AI systems are capable of analysing intricate datasets and identifying patterns that human assessors could find challenging [10]. This capacity is especially pertinent to ROM examinations, where precision is necessary for a proper diagnosis and efficient treatment planning.

Additionally, compared to conventional approaches, AI-driven solutions can offer more reliable and reproducible assessments, according to the study by Palmieri M et al., Variability in manual measurements is frequently caused by variations in technique and inter-rater dependability [11]. In contrast, AI technologies standardise the evaluation procedure, minimising inconsistencies and guaranteeing more accurate data. Standardised measurements are critical for monitoring patient development and making well-informed healthcare decisions in clinical settings [7].

Topol EJ discussed the transformative potential of AI in healthcare, particularly in diagnostics and personalised management [12]. The integration of AI in ROM assessments can facilitate more precise and individualised treatment plans for patients with MNP. By providing objective and accurate measurements, AI can help therapists identify specific limitations and improvements in a patient's ROM, thereby enhancing the effectiveness of therapeutic interventions.

Furthermore, according to Karalis VD, AI-driven assessments may considerably cut down on the amount of time needed for evaluations, allowing therapists to devote more time to patient care. This increase in efficiency is especially helpful in busy clinical settings environment where patient care may suffer due to time restraints. Rapid and accurate ROM assessment provided by AI may result in more prompt interventions and better patient outcomes [13].

The idea that AI can improve clinical decision-making is further supported by the study's findings. AI systems can assist therapist in creating more individualised and successful treatment plans by supplying comprehensive and reliable ROM data. The management of chronic illnesses, such as MNP, necessitates continual evaluation and modification of treatment programs to get the best possible results [14].

It's critical to recognise the need for additional research despite these encouraging findings. Although this study shows that AI and manual approaches are comparable in ROM evaluation, more research is needed to determine the long-term effects of AI-driven assessments on patient outcomes. Additionally, studies should investigate the applicability of AI technologies across diverse populations and settings to ensure their generalisability.

The findings of this study indicate that AI-driven technologies are as reliable as conventional goniometry for assessing cervical ROM in patients with MNP. This has several important clinical implications like AI-driven systems reduce the subjectivity associated with manual measurements, ensuring more consistent and objective data. This is critical for accurate diagnoses and individualised treatment planning, helping clinicians better track patient progress and adjust therapeutic interventions accordingly. AI-based ROM assessment methods offer quicker, more streamlined evaluations, allowing clinicians to dedicate more time to direct patient care. This is particularly advantageous in high-demand settings where efficient time management is crucial. AI systems like PhyTrack could facilitate remote monitoring, enabling patients to receive reliable ROM assessments without frequent in-person clinic visits. This opens new possibilities for tele-rehabilitation, especially beneficial for individuals with limited access to in-clinic care due to geographical or logistical constraints.

Future studies should investigate if AI-driven ROM assessments lead to lasting improvements in pain management and function in chronic conditions like MNP. Research is needed to assess AI-based ROM tools' effectiveness in various demographic groups to ensure they are inclusive and generalisable in musculoskeletal care. Evaluating the financial implications of integrating AI into clinical practice, including setup and maintenance costs, is essential to determine its economic feasibility and benefits over traditional methods. Efforts to integrate AI training into physical therapy education will be vital, ensuring that practitioners feel prepared and confident using AI-based tools in clinical settings.

Limitation(s)

The study included a relatively small number of participants, which may limit the generalisability of the findings. A larger sample size across varied demographics would provide more robust data. Only a few ROM movements (e.g., cervical flexion, extension, lateral flexion) were assessed. Expanding the study to include other cervical movements or functional assessments would offer a more comprehensive evaluation. The reliability of the AI assessments heavily depends on the algorithm used further research is needed to refine algorithms for improved precision and applicability. This study primarily focused on measurement accuracy without directly assessing patient-centered outcomes like pain relief, functional improvement, or patient satisfaction, which are crucial for evaluating clinical utility.

CONCLUSION(S)

In conclusion, this study offers compelling evidence that AI-driven solutions are just as accurate in evaluating cervical ROM as manual techniques. AI has several benefits, such as increased consistency and efficiency, thus there is a lot of promise that these technologies may improve clinical practice in the treatment of mechanical neck discomfort. We can enhance the precision and consistency of ROM measurements by incorporating AI into clinical evaluations, which will result in more informed clinical judgments and better patient outcomes. The vast uses of AI in musculoskeletal examinations and its long-term effects on patient treatment should be the main areas of future research.

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