Original Paper

AI-Based Rehabilitation System for Congenital Muscular Torticollis: Formative Usability Evaluation

Seojin Hong[1], MS; Heewon Nam[1], BS; Seongwoo Jeong[1], MS; Hyun Choi[2], PhD; Hyosun Kweon[1], PhD

[1]Department of Clinical Rehabilitation Research, Rehabilitation Research Institute, National Rehabilitation Center, Seoul, Republic of Korea
[2]Department of Healthcare and Public Health, Rehabilitation Research Institute, National Rehabilitation Center, Seoul, Republic of Korea

Corresponding Author:

Hyosun Kweon, PhD
Department of Clinical Rehabilitation Research
Rehabilitation Research Institute, National Rehabilitation Center
58 Samgaksan-ro, Gangbuk-gu
Seoul 01022
Republic of Korea
Phone: 82 02-901-1904
Email: hskweon@korea.kr

Abstract

Background: Home-based exercise programs for congenital muscular torticollis (CMT) depend heavily on caregivers, yet adherence is often hindered by cognitive and emotional burdens.

Objective: This study conducted a formative usability evaluation of an AI-based CMT rehabilitation system comprising a clinician web interface and a caregiver mobile app to identify usability-related issues and preliminary design requirements during early development.

Methods: A formative usability evaluation was conducted with 8 clinical experts (rehabilitation physicians, nurses, and physical therapists). Participants engaged in focus group interviews (FGIs) following a demonstration of the system and completed the System Usability Scale (SUS) for the overall system, including a proxy evaluation of the caregiver mobile app. Qualitative data were analyzed using thematic analysis, and SUS scores were analyzed descriptively as a supplementary quantitative measure of perceived usability.

Results: The thematic analysis identified 2 core themes, “Usability Barriers of the CMT Rehabilitation System” and “Improvement Requirements,” encompassing 10 subthemes and 21 concepts. Key findings highlighted concerns regarding the reliability and interpretability of AI-generated feedback and the need to simplify data visualization to reduce the potential cognitive burden on caregivers. The mean SUS score for the overall system was 73.44 (SD 18.01). This result was interpreted descriptively and considered supplementary to the qualitative findings.

Conclusions: The formative evaluation identified preliminary usability strengths and areas for improvement from clinicians’ perspectives, with particular concerns regarding the reliability and interpretability of AI-generated feedback. The experts emphasized that the AI-based CMT rehabilitation system should function as a therapeutic bridge between clinicians and caregivers. As actual caregivers were not included in this evaluation, the findings represent preliminary formative design inputs based on clinicians’ proxy perspectives rather than evidence of usability for caregivers. Future iterations should incorporate the identified improvements and undergo evaluation with actual caregivers in home environments, along with separate technical verification of the accuracy of the AI feedback algorithm.

JMIR Hum Factors 2026;13:e101427; doi: 10.2196/101427

Keywords: congenital muscular torticollis; rehabilitation; formative evaluation; usability; human-centered design; mobile health; mhealth app; caregivers

Introduction

Background

Congenital muscular torticollis (CMT) is a representative musculoskeletal disorder in infancy characterized by an abnormal head and neck posture, in which the head tilts to one side while the chin rotates toward the opposite side [1]. Although CMT is relatively common during early infancy, a lack of timely intervention can lead to long-term functional impairments, such as craniofacial asymmetry, spinal deformities, and developmental delays. Consequently, early diagnosis and prompt intervention for CMT are consistently emphasized as essential elements for ensuring normal growth and functional development [2].

According to previous research, when physical therapy such as stretching and postural correction is initiated within the first month of life, approximately 98% of infants have been reported to recover a normal range of cervical motion within an average period of 1.5 months. Furthermore, initiating treatment before 3 to 4 months of age typically allows for sufficient improvement through conservative interventions alone. Conversely, after 3 to 4 months, increased resistance as infants develop head control often results in a reduced therapeutic response. Delayed diagnosis and intervention increase the likelihood of requiring invasive treatments, such as botulinum toxin injections or surgery [3]. Therefore, in the treatment of congenital muscular torticollis, it is paramount to promptly initiate conservative rehabilitation interventions including physical therapy, stretching, and postural correction based on an early diagnosis [4,5].

Rehabilitation therapy for CMT relies heavily not only on physical therapy in clinical settings but also on home exercise programs (HEP) performed repeatedly by caregivers in their daily lives [6,7]. However, in actual clinical practice, it is frequently reported that treatment adherence is compromised because caregivers often lack a sufficient understanding of the purpose and methods of the exercises, or struggle to perform them with the correct posture and intensity [8]. In particular, for rehabilitation exercises involving infants, continuity of therapy is significantly influenced not only by the physical burden on caregivers but also by psychological factors, such as anxiety and a lack of confidence in performing the exercises [9,10]. Recent studies have emphasized the necessity of designing rehabilitation programs that extend beyond simple exercise prescriptions by accounting for the emotional experiences and cognitive burdens of caregivers [3,8]. These limitations act as primary factors hindering the effectiveness of torticollis rehabilitation, suggesting an urgent need for systematic tools that support caregivers in performing rehabilitation exercises safely and accurately.

To address these limitations, the CMT rehabilitation system is being developed to support caregivers in performing rehabilitation exercises more accurately and consistently within the home environment. By integrating AI capabilities, this system aims to provide caregivers with visual and cognitive guidance throughout the exercise process, thereby enhancing both the accuracy and consistency of performance. Furthermore, the CMT rehabilitation system possesses the potential to overcome the primary challenges identified in existing practices, such as low treatment adherence, insufficient exercise accuracy, and the limitations of continuous monitoring by clinical professionals. Consequently, the system is expected to facilitate caregiver engagement in the rehabilitation process and, ultimately, contribute to achieving successful clinical outcomes for infants with CMT.

Usability

Usability in medical devices refers to the characteristics of a user interface that support users in achieving effectiveness, efficiency, and user satisfaction when operating the device within its intended use environment [11]. Particularly in software as a medical device (SaMD), usability evaluation is considered a core risk management activity that extends beyond simple improvements in user convenience; it ensures patient safety by guaranteeing that users can operate the device safely and accurately [12]. Software medical devices that fail to adequately incorporate usability principles are highly susceptible to use errors, which can lead to unintended use, improper intervention, and diminished therapeutic efficacy. Consequently, systematic usability evaluation has become an essential procedure in the development process of software medical devices.

Since the CMT rehabilitation system is designed for caregivers to directly perform interventions on infants, various human factors such as the user's level of understanding, cognitive burden, and perception of responsibility directly influence the safety and effectiveness of the product. Due to these characteristics, it is particularly crucial to conduct a formative evaluation during the early development phase to perform an in-depth exploration of the entire usage process and to identify potential use errors.

Focus group interviews (FGIs) are a qualitative research method applicable at any stage of the medical device lifecycle, offering the advantage of comprehensively exploring user experiences, perceptions, design issues, and usage contexts [13]. In particular, through interactions among participants with diverse professional backgrounds, FGIs can provide insights that are difficult to elicit in individual interviews. Therefore, FGIs are a highly appropriate methodology for investigating early-stage usability issues in medical devices with complex usage contexts, such as the CMT rehabilitation system [14].

Aim

The aim of this study was to conduct a formative usability evaluation of a prototype AI-based CMT rehabilitation system, comprising a clinician web interface and a caregiver mobile app, from the perspectives of clinical experts. Through FGIs and a usability assessment, we sought to identify usability-related issues, potential use errors, and preliminary design requirements to guide further system development. As caregivers were not included in this study, the caregiver-facing app was evaluated from clinicians' proxy perspectives, with the findings intended to inform future evaluation with actual caregivers.

Methods

Study Design

This study used a formative usability evaluation that included FGIs and a survey with 8 clinical experts, including rehabilitation medicine physicians, nurses, and physical therapists. The evaluation was designed to identify usability-related issues, potential use errors, and areas for improvement in the prototype CMT rehabilitation system from the perspectives of clinical experts. Rehabilitation medicine physicians and nurses provided perspectives relevant to the clinician-facing web interface, while physical therapists contributed domain expertise in CMT rehabilitation. The caregiver-facing mobile app was evaluated from the clinical experts' proxy perspectives, as actual caregivers were not included in this study. The findings were used to derive preliminary formative design inputs to guide subsequent iterations of the system rather than to establish the usability of the caregiver-facing app for actual caregivers.

Materials

The CMT rehabilitation system used in this study was developed to facilitate the provision of rehabilitation exercises for infants under 12 months of age diagnosed with CMT. The system enables caregivers to perform rehabilitation interventions for their infants using a mobile app. The CMT rehabilitation system consists of a web interface for clinical staff and a mobile app for the infant and caregiver. The intended users of the web interface are health care professionals (physicians and nurses), while the mobile app is intended for caregivers.

Health care professionals access the web interface to diagnose infants who require CMT rehabilitation, prescribe appropriate exercises, and manage or supervise the treatment process. Caregivers use the mobile app to follow guided exercise videos, enabling them to provide direct rehabilitation therapy to the infant. The treatment interface within the mobile app provides AI-based feedback intended to support caregivers during exercise performance. Furthermore, the app allows for the recording of participation and adherence upon completion of each session.

Participants

The formative usability evaluation was designed with reference to the usability engineering process outlined in IEC 62366-1:2015+ AMD1:2020 [15]. For the focus group interviews, we aimed to recruit 5 to 8 clinical experts, including rehabilitation medicine physicians, nurses, and physical therapists involved in the diagnosis, treatment, or outpatient support of patients with CMT, to obtain multidisciplinary perspectives on the clinical workflow [16]. A total of 8 clinical experts participated in the study: 2 rehabilitation medicine physicians, 2 nurses, and 4 physical therapists.

This formative evaluation was limited to clinical experts; caregivers, who are the intended users of the caregiver-facing mobile app, were not recruited. Accordingly, the clinicians evaluated the caregiver-facing app from a proxy clinical perspective, and the usability of the app from the perspective of actual caregivers was not assessed in this study.

The inclusion criteria were as follows: (1) clinical experience in the diagnosis, treatment, or outpatient support of CMT; (2) sufficient proficiency in Korean and English to understand the terminology used in the system; and (3) provision of informed consent to participate in the evaluation. Individuals who did not meet the inclusion criteria or did not provide informed consent were excluded.

Data saturation was not used as a criterion for determining the sample size because the number and composition of participants were predefined for this formative usability evaluation.

Procedure

The FGIs for the formative usability evaluation were conducted in a single session for each group. Participants were organized into 2 groups to capture complementary clinical perspectives based on their professional roles and experience with CMT care: group A consisted of 2 rehabilitation medicine physicians and 2 nurses involved in the clinical management and outpatient support of patients with CMT, and group B consisted of 4 physical therapists with expertise in CMT rehabilitation (Figure 1). Both groups comprised clinical experts, and no caregivers participated in the evaluation.

The formative evaluation procedure began with a briefing for participants regarding the purpose, overview, and methodology of the CMT rehabilitation system. Following the acquisition of informed consent, a preinterview survey was conducted to collect demographic and professional characteristics. The interviews were conducted based on a pre-established scenario and included a live demonstration of the system. Participants were provided with opportunities to interact directly with the product as necessary, while the evaluation facilitator observed and recorded the proceedings. Postinterview surveys were administered to gather additional feedback, and a standardized set of interview questions was applied to both focus groups (Table 1). The question protocol was designed to explore usability-related issues and potential areas for improvement from the participating clinical experts' perspectives, in accordance with the evaluation scenario. Each FGI session lasted approximately 100 minutes (Table 2).

Table 1. Formative evaluation procedures, involving practitioners and evaluators.

Composition	Details	Time (min)
Orientation	• The facilitator introduces the concept of formative evaluation to participants who are unfamiliar with it. • The facilitator explains the target product, purpose, overview, methodology, and other relevant aspects of formative evaluation to the participant.	30
Guidance on consent	• The facilitator provides the participant with detailed instructions regarding recording and transcription procedures. • The facilitator ensures that the participant fully comprehends the evaluation content and voluntarily provides written consent to participate in formative evaluation.	10
Conduct FGI[a]	• The facilitator conducted user training, demonstrations, and interviews according to a predetermined script. • The participants observed the demonstrations, responded to interview questions, and were allowed to operate the product if necessary.	40
Perform SUS[b]	• An observer documented the entire interview process. • After completing the FGI, the facilitator administered the SUS to assess perceived usability of the overall CMT[c] rehabilitation system, including a proxy evaluation of the caregiver-facing mobile app.	20

[a]FGI: focus group interview.
[b]SUS: System Usability Scale.
[c]CMT: congenital muscular torticollis.

Table 2. List of focus group interview questions.

Items	Statement
Opening questions	• General characteristics (age, sex, years of clinical experience, and experience using similar medical devices or providing related treatments)
Transition questions	• Are you currently providing treatment for improving torticollis in children? • Could you describe your clinical experience in treating or rehabilitating torticollis? • What types of rehabilitation treatments have you provided for neonates and infants with torticollis? • In your opinion, what are the most important considerations in the rehabilitation of neonates and infants with torticollis? • What factors should be considered when developing a torticollis rehabilitation system?
Key questions	• The following questions relate to the torticollis rehabilitation system currently under development: • (Instruction manual provided) Do you have any comments on the instruction manual (eg, content structure, length, and clarity)? • (Oral explanation and demonstration provided) Are there any difficulties or areas for improvement when using the clinician web interface of the torticollis rehabilitation system? • Are there any difficulties or areas for improvement when using the child-oriented mobile app of the torticollis rehabilitation system?
Closing questions	• Do you have any additional comments regarding the torticollis rehabilitation system? • Please share any additional considerations that should be taken into account in the development of the torticollis rehabilitation system.

Figure 1. Performance of task scenarios by evaluation participants.



FGI

FGIs are a qualitative research method designed to collect data through in-depth discussions with purposefully selected participants centered on specific topics [16,17]. Information gathered through FGIs is instrumental in identifying potential areas for further exploration or in clarifying themes that may be difficult to capture using other research instruments. The interactive and synergistic nature of focus groups allows participants to refine or elaborate on their thoughts by

engaging with the opinions of others. This process often yields richer and more expansive insights than those typically obtained through one-on-one interviews [13].

In this study, FGIs were used to identify usability-related issues, potential use errors, and areas for improvement in the CMT rehabilitation system, thereby deriving preliminary formative design inputs to guide subsequent system development. The question protocol for the FGIs was structured to facilitate meaningful interaction among participants and to elicit comprehensive feedback based on the system's operational scenarios. Following the framework proposed by Krueger and Casey, the interview guide was organized into distinct phases: opening, introductory, transition, key, and concluding questions. The final question set was determined through rigorous deliberation between the evaluation facilitators and the product development team, ensuring that the design promoted robust participant engagement. The key interview questions used for data collection are presented in Table 2.

System Usability Scale

The System Usability Scale (SUS) is an evaluation instrument used to assess the overall usability of a system [18]. The SUS consists of 10 items rated on a 5-point Likert scale (Textbox 1), which are aggregated to produce a composite score ranging from 0 to 100. The scoring procedure involves converting individual item responses to values in the range of 0 to 4 and multiplying the sum of these values by 2.5 to obtain a total score between 0 and 100. Specifically, for odd-numbered items, the score contribution is calculated by subtracting 1 from the participant's response; for even-numbered items, the contribution is determined by subtracting the participant's response from 5 [19].

Textbox 1. System Usability Scale items.

- I think that I would like to use this system frequently
- I found the system unnecessarily complex
- I thought the system was easy to use
- I think that I would need the support of a technical person to be able to use this system
- I found the various functions in this system were well integrated
- I thought there was too much inconsistency in this system
- I would imagine that most people would learn to use this system very quickly
- I found the system very cumbersome to use
- I felt very confident using the system
- I needed to learn a lot of things before I could get going with this system

Ethical Considerations

This study was approved by the Institutional Review Board of the National Rehabilitation Center (NRC-2025-05-036). All participants were provided with a comprehensive explanation regarding the research objectives and methodology prior to the study, and they voluntarily provided written informed consent. Participants were informed that their involvement in the study was entirely voluntary and that they reserved the right to withdraw from the research at any stage without prejudice. To ensure the protection of personal information and the maintenance of confidentiality, all collected data were anonymized and processed in accordance with ethical standards.

Data Analysis

The FGIs were video- and audio-recorded. Two researchers (SH and HN) independently transcribed the recordings verbatim and cross-checked their transcripts against each other. Any discrepancies were reviewed against the original recordings and resolved through discussion, resulting in a finalized transcript for qualitative analysis.

The qualitative data were analyzed using thematic analysis following Braun and Clarke's approach [20]. The analysis involved familiarization with the data, generation of initial codes, identification and organization of recurring patterns into candidate themes, review and refinement of the themes, and definition of the final themes. Two researchers independently reviewed and categorized the finalized transcripts. The coding and categorization results were then cross-checked to identify agreements and discrepancies. Disagreements regarding coding, categorization, or theme interpretation were resolved through discussion and consensus. The final themes reflected recurring usability-related issues and design considerations identified across the FGIs. QualCoder was used to manage and organize the qualitative data throughout the analysis.

The SUS was used as a supplementary quantitative measure of perceived usability. SUS scores were summarized using the mean and SD. Given the small sample size (n=8), the SUS results were interpreted descriptively and considered supplementary to the qualitative findings.

Results

Participant Information

In this study, 8 participants who met the inclusion criteria were recruited. Analysis of the participants' demographic characteristics revealed the following age distribution: 1 in their 20s, 2 in their 30s, 1 in their 40s, and 4 in their 50s. Regarding professional experience, 2 participants had 10 years or less, 2 had 20 years or less, 1 had less than 30 years, and 3 had 30 years or more of clinical experience. Examination of participants' experience with CMT rehabilitation indicated that the 2 rehabilitation medicine

physicians had experience with outpatient assistance, while the 2 nurses had experience with treatment observation and/or outpatient assistance. All 4 physical therapists had experience in providing CMT treatment (Table 3).

Table 3. General characteristics of participants.

ID	Sex	Age (y)	Occupation	Experience in CMT[a] rehabilitation		
				Clinical experience	Clinical experience	Treatment method
P1	Male	29	Rehabilitation physician	Outpatient assistance	4 mo	Outpatient clinic observation and assistance
P2	Female	32	Rehabilitation physician	Outpatient assistance	6 mo	Outpatient clinic observation and assistance
P3	Female	53	Nurse	Treatment observation	30 y	Ward rounds and observation of medical consultation and treatment
P4	Female	53	Nurse	Outpatient assistance	30 y	Ward rounds and observation of medical consultation and treatment
P5	Female	35	Physical therapist	Physical therapy	13 y	Provision of treatment based on assessment of the child's condition
P6	Female	53	Physical therapist	Physical therapy	30 y	Treatment involving stretching of shortened muscles combined with postural education
P7	Female	52	Physical therapist	Physical therapy	28 y	Provision of treatment based on assessment of the child's condition
P8	Male	44	Physical therapist	Physical therapy	19 years	Instrument-assisted physical therapy (stretching and caregiver education)

[a]CMT: Congenital muscular torticollis.

Qualitative Findings: Focus Group Themes

In this study, the data collected through the FGIs were analyzed and categorized according to the thematic analysis framework proposed by Braun and Clarke [20]. The thematic analysis ultimately identified 2 core themes, 10 subthemes, and 21 coded concepts. The inconveniences and areas for improvement regarding the CMT rehabilitation system are summarized in Table 4.

Table 4. Outcomes of qualitative analysis.

Themes and categories	Concepts
Usability barriers of the CMT[a] rehabilitation system	
Lack of visual readability in the user manual	• Small font size
Insufficient video tutorial structure for understanding the use of mobile apps for children	• Insufficient structure for providing tutorial videos based on treatment prescriptions • Video content within the tutorial video • Insufficient tutorial video structure
Limitations of the provision of treatment information and reliability of mobile apps for children	• AI treatment feedback reliability limitations
Inefficiency of medical staff web pages	• EMR[b] integration not possible • Inefficiency of UI[c] sorting criteria per patient
Limitations of clinical use of web pages for medical professionals	• Inability to verify medical staff's treatment performance data
Improvement requirements of the CMT rehabilitation system	
Strengthening information delivery in the user manual	• Improved visual readability • Provide sufficient information
UI and functional improvements for performing treatment in children's mobile apps.	• Advancing AI treatment feedback • Treatment settings and screen UI configuration • Treatment performance log recording function • Treatment continuous mode
Improving the structure of tutorial videos for children's mobile apps	• Video composition • Playback control • Providing tutorial videos based on treatment prescriptions
Added ability to access treatment performance data on the medical staff web page	• Verification of medical staff treatment performance data
Strengthening the integration and management of clinical information on medical staff web pages.	• EMR integration • Flexibility in treatment prescriptions • Patient clinical information records • Patient-tailored UI structure and visibility improvements

[a]CMT: congenital muscular torticollis.

[b]EMR: electronic medical record.
[c]UI: user interface.

Usability Barriers of the CMT Rehabilitation System

Limited Visual Readability of the User Manual

Participants reported that although the text in the user manual was visually recognizable, the small font size made it difficult to intuitively identify key information. This reduced overall visual readability and interfered with rapid information recognition:

> *I can see it, but the letters are small, so it's not intuitive*. [P3]

> *It seems like the font became small because everything was put onto 1 page*. [P4]

Inefficiency of the Clinician Web Interface

Participants indicated that entering a patient registration number in the clinician web interface did not result in electronic medical record (EMR) linkage, making it impossible to verify actual clinical information. This reduced the practical significance of entering patient numbers and highlighted the need for a separate comment section to document medical history or special notes.

Additionally, the dashboard displayed patients based on registration date within a limited time frame, which was perceived as clinically unhelpful. Participants suggested that patient lists should be sortable based on clinically meaningful criteria, such as the most recent prescription date, or should allow clinicians to customize sorting preferences. These limitations were considered to restrict efficient management and use of patient information in clinical contexts:

> *Why do we enter a patient number if it's not linked to the EMR?* [P4]

> *I don't think it would be useful if the patient list in the dashboard is sorted only by registration date*. [P2]

Limitations in Clinical Use of the Clinician Web Interface

Participants stated that summary treatment data alone were insufficient to verify inappropriate movements or to provide specific corrective feedback to caregivers. Without access to treatment videos or objective evidence of incorrect movements, AI feedback was perceived as lacking credibility. Indicators such as "participation" or "How was the treatment?" were considered to have limited clinical significance. Consequently, participants indicated that clinicians would face difficulty identifying areas requiring caregiver education or ensuring the clinical appropriateness of the prescription, potentially reducing clinical applicability:

> *If clinicians could see the exercise videos performed by caregivers or receive more detailed AI feedback, it would be more trustworthy. As it stands, I don't think AI feedback alone is reliable*. [P2]

> *If caregivers could provide detailed information about how the child responded, what was difficult, or which posture was challenging, that would be meaningful. But it seems functionally impossible right now*. [P2]

Inadequate Tutorial Video Structure for Supporting the Use of the Mobile App

Participants reported that the tutorial video structure could increase cognitive burden rather than support understanding. Specifically, although only certain exercises were prescribed, caregivers were required to watch all tutorial videos, which was perceived as unnecessary and distracting.

Mandatory viewing upon each login disrupted workflow continuity. The segmented structure of multiple required tutorials was also perceived as interfering with caregivers' ability to understand the rehabilitation process as a cohesive sequence.

Additionally, short video length, fast playback speed, and insufficient guidance regarding movement direction and method were reported as barriers to accurate observation and replication:

> *The tutorial videos are too short, and since only a few exercises are prescribed, I wonder if we really need to watch all of them*. [P2]

> *The environment in the video felt distracting, and the child's clothing movement was uncomfortable to watch*. [P3]

> *The video speed is too fast, and the voice guidance keeps repeating. It's confusing*. [P5]

Limitations in Treatment Information Provision and Reliability of AI Feedback

Participants questioned whether the AI-generated recognition of therapeutic movements and the accompanying visual feedback adequately reflected the accuracy and clinical relevance of the actual treatment movements. In particular, they perceived that different neck movements were recognized in a similar manner and that the criteria underlying the feedback were not clearly specified. As a result, participants anticipated that caregivers might have difficulty determining the appropriateness of therapeutic movements based solely on AI-generated feedback. These characteristics were perceived as creating a structure in which caregivers could not independently verify whether the movement they were performing aligned with the intended therapeutic action,

leading to the perception that participants raised concerns regarding whether the interpretability and reliability of the AI feedback were sufficient to support caregivers' assessment of treatment performance:

> *Since the AI only recognizes the nose and shoulder line, it feels difficult to clearly distinguish whether the movement is left lateral neck flexion or left head rotation. So I'm not sure how meaningful the AI feedback would be for caregivers.* [P2]

> *Regarding the green feedback shown on the treatment screen, I don't trust that just because it turns green it necessarily indicates good performance. Also, if the movement is not shown in green, there is no guidance on how to improve, so it's hard to trust it.* [P2]

> *Even if the AI feedback appears in green, I question whether that truly means the caregiver is performing the movement correctly.* [P4]

Improvement Requirements of the CMT Rehabilitation System

Strengthening Information Delivery in the User Manual

Participants indicated that key information and safety-related content in the user manual should be conveyed more clearly and intuitively. They suggested increasing font size or using color emphasis to visually distinguish important information, and presenting safety-related content—such as fall risks—using warning colors or graphical illustrations.

For procedures that caregivers may find challenging, such as account registration and entry of child information, participants emphasized the need for explanations accompanied by actual screen examples. In addition, information that may affect user flow—such as rules for rewatching treatment tutorials and the range of prescribable items—should be clearly specified in the manual.

Overall, the user manual was interpreted as requiring enhancement beyond text-centered explanations, with greater emphasis on visual and safety-oriented information grounded in specific interface screens and usage contexts:

> *Important precautions would be more intuitive and visually clear if presented with illustrations. If possible, including pictures or photographs would be helpful.* [P3]

> *I think the fall-risk information in the patient user manual is important, so it should be highlighted in pink.* [P5]

> *In section 3 of the application user manual, which covers preparation for the child and caregiver, the steps for account registration and entering basic information are explained only in text. However, there are more people than expected who have some level of anxiety about using mobile devices. It would be helpful to include example screenshots showing what those screens look like and which parts need to be checked, including the registration screen and the child information entry screen.* [P8]

> *When reading a manual, people often don't actually read the safety information. So if there were colors that signal 'this must be read' or warning icons such as a fall-risk symbol, it would likely increase awareness and make people look at it again.* [P8]

Addition of Access to Treatment Performance Data on the Clinician Web Interface

Participants indicated that the information provided on the clinician web interface was limited to AI-generated results, making it difficult to fully understand the actual pattern of treatment performance. In particular, beyond the duration classified as "good posture," no detailed information was provided regarding which inappropriate movements had been performed, thereby limiting clinicians' ability to deliver specific corrective feedback. Accordingly, participants expressed the need for detailed treatment performance records or full treatment videos to be transmitted to the clinician web interface, enabling clinicians to directly review patients' actual performance and provide informed feedback. In addition, summary indicators such as participation rates should be accessible on the web interface so that clinicians can reference treatment progress. These findings suggest the necessity of incorporating treatment performance data access functions to support clinicians' clinical judgment and interventions:

> *In addition to AI feedback, it would be helpful to have information about how the remaining time—outside of the 'good posture' period—was spent, so that clinicians can determine whether any movements were performed incorrectly.* [P4]

> *It would be beneficial if the treatment videos performed by caregivers could be transferred to the clinician web interface, allowing clinicians to review them and provide feedback.* [P1]

> *It would also be helpful if the participation records completed by caregivers after each treatment session could be shared with us, so that we can refer to how actively the session was carried out.* [P2]

Strengthening the Integration and Management of Clinical Information on the Clinician Web Interface

Participants indicated that the clinician web interface should be improved to allow integrated management of patient information, prescription settings, and treatment performance summaries within a single screen. They expressed the need

for EMR-based medical history and basic patient information to be automatically synchronized through entry of the patient's name or registration number, thereby eliminating redundant data entry. In addition, participants emphasized the need for a comment function that would allow clinicians to record clinical context, such as the direction of torticollis, feeding direction, and relevant medical history. They also requested a function enabling frequently used prescription durations and items to be saved as default or previous settings for reuse. Furthermore, participants suggested that the patient list screen should allow intuitive identification of clinical information—such as torticollis direction and treatment performance summaries (eg, success status or duration)—through color coding or simple visual indicators. Overall, clinicians preferred an integrated management environment that would enable simultaneous review of core clinical information and treatment status on a single screen, rather than navigating across multiple separate pages:

> *It would be helpful if the dashboard patient list clearly indicated which side the child has torticollis. Also, when registering a patient ID, it would be good to have a space to enter information about the child, such as feeding direction.* [P5]

> *Medical staff are very accustomed to looking at patient lists and clinician web interfaces, so even if the screen appears complex, it wouldn't be a problem. We're used to complexity. In fact, it may be better to display as much information as possible. Instead of clicking on a patient's name and navigating to a separate detailed page, it would be more convenient if a panel opened beside the list showing that patient's details, without the current screen disappearing. Since the amount of information isn't excessive, there may be no need to divide it across multiple pages. Even if it includes information such as age, sex, diagnosis, recent condition, and attending physician, although it may look complex, clinicians are accustomed to reviewing such information and may actually prefer it. Having the detailed information displayed alongside the list rather than moving to another page would likely make it more convenient to use.* [P8]

> *It would be ideal if patient information could be directly synchronized with the EMR through the patient's name. If linked properly, there would be no need to manually enter medical history or basic information. Simply entering the patient's name and registration number should automatically retrieve and populate the corresponding information.* [P8]

> *Clinicians usually have specific time durations or prescription items that they frequently use. It would be helpful if they could save their commonly used settings. For example, having a default setting, or recalling the most recent setting and adjusting only the time slightly, would be convenient. It would be beneficial to have functions that allow the previous settings, default settings, or user-saved settings to be easily recalled without having to modify everything manually.* [P8]

UI and Functional Improvements to Support Treatment Performance in the Mobile App

Participants indicated that overall improvements in the user interface and functionality of the caregiver-facing mobile app were necessary to more effectively support treatment performance. In particular, they noted that the current AI recognition method primarily based on the nose and shoulder line was insufficient to adequately distinguish between different therapeutic movements. Accordingly, the need for more sophisticated sensor recognition and enhanced AI-based treatment feedback was emphasized.

Beyond simple visual indicators such as green markings, participants requested reward-based feedback mechanisms such as visual effects that promote a sense of achievement or motivational elements like point accumulation to enhance engagement.

In addition, participants suggested that the treatment settings screen should be improved in terms of font size and information density to allow users to grasp key information at a glance. The need for a practice mode, enabling caregivers to rehearse movements and receive feedback before performing actual treatment sessions, was also raised. Furthermore, participants highlighted the importance of allowing guide videos on the treatment screen to be adjusted or hidden as needed.

Finally, the ability for caregivers to document the treatment process in text form and share this information with clinicians was identified as important for supporting understanding and management of treatment performance:

> *After the AI feedback on the treatment screen is completed, only the time classified as 'good posture' is shown, which may leave caregivers wondering what they are supposed to do next. It would be helpful if more detailed information were provided so they could better understand their performance.* [P3]

> *It might also be useful if caregivers could write something like a treatment log and keep it as a record to share when they meet with the clinician.* [P3]

> *Since certain angles should not be exceeded during exercise therapy, perhaps the AI sensors could be made more precise to capture those limits in greater detail.* [P4]

> *Currently, the AI feedback is limited to red and green lines. It would be good to include motivational features so that when the green indicator appears, there are visual effects like fireworks and mileage accumulation, allowing the child to reach a target point and feel a sense of achievement and enjoyment.* [P8]

If caregivers want to start treatment immediately, they should be able to do so, but sometimes they may just want to practice the movement first. It would be good to have a practice mode where they can rehearse the movement and receive feedback, so that after understanding how to perform it properly, they can then begin the actual treatment. Having separate 'Practice' and 'Start' buttons would be helpful. [P8]

Improvement of the Tutorial Video Structure in the Mobile App

Participants indicated that tutorial videos should be presented in a more intuitive and controllable format to enable caregivers to accurately replicate the therapeutic movements applied to the child. They emphasized the need to improve the filming method (eg, clothing and posture), clarify movement presentation direction (eg, left-right distinction and mirror mode), and include visual aids such as subtitles or arrows highlighting the muscle being stretched.

In addition, participants requested playback control functions, including adjustable playback speed, pause, and repeat options, so that caregivers could sufficiently review and follow specific segments as needed. The ability to automatically select or display guide videos according to the child's affected side (left or right) and prescribed exercises was also identified as an important improvement requirement.

Furthermore, participants suggested that structurally different types of videos—such as therapeutic movement tutorials, device explanations, and diagnostic guidance—should be integrated or reorganized into a simplified framework distinguishing between mandatory and optional tutorials:

It would be helpful to include a function that allows the playback speed to be slowed down. In addition, the video could include subtitles or arrows indicating which muscle is being stretched and along which axis. For example, it could show messages such as, 'It has stretched this much,' or 'Stretch only to this point,' to guide users more clearly while they follow along. [P6]

When following the movements on the screen, it would be helpful if the direction of the instructor's explanation and my own direction were clearly specified. [P7]

I don't think the mandatory tutorial needs to be divided into four separate videos. It could simply be combined into one mandatory tutorial that plays continuously. I find myself wondering why it was split into multiple parts. It would be better to have one tutorial for the exercise movements, one for device instructions, and one for diagnosis guidance, and then classify them as either mandatory or optional. Overall, I think the tutorials should be simplified and grouped more clearly. [P8]

The pacing of the video and the narration are both too fast. This makes it difficult for caregivers to understand. There is separate explanatory text beside the video, but instead, it might be better to enlarge the video and include subtitles directly within it. It would also be helpful if arrows or other visual indicators were provided to intuitively guide the current movement status. [P8]

Quantitative Findings: SUS

The mean SUS score for the overall CMT rehabilitation system, including the clinician web interface and a proxy evaluation of the caregiver mobile app, was 73.44 (SD 18.01) (Table 5). Given the small sample size (n=8) and variability in the scores, the SUS result was interpreted descriptively as a supplementary measure of perceived usability and should be considered alongside the qualitative findings.

Table 5. System Usability Scale (SUS) results (n=8; unit: point).

Item	Min-max	Mean (SD)	Scaled mean (SD)
Total	—[a]	2.94 (0.37)	73.44 (18.01)
Q1	2.00-5.00	3.63 (1.06)	65.63 (24.80)
Q2	1.00-3.00	2.00 (0.53)	75.00 (12.50)
Q3	2.00-5.00	3.88 (0.83)	71.88 (19.52)
Q4	1.00-4.00	2.00 (1.07)	75.00 (25.00)
Q5	2.00-5.00	3.63 (0.92)	65.63 (21.42)
Q6	1.00-3.00	2.00 (0.53)	75.00 (12.50)
Q7	4.00-5.00	4.38 (0.52)	84.38 (12.10)
Q8	1.00-3.00	1.75 (0.71)	81.25 (16.54)
Q9	3.00-5.00	3.88 (0.64)	71.88 (14.99)
Q10	1.00-4.00	2.25 (0.89)	68.75 (20.73)

[a]Not applicable.

Discussion

Principal Findings

This formative evaluation identified several usability-related issues and preliminary design requirements for the prototype AI-based CMT rehabilitation system from the perspectives of clinical experts. The qualitative findings highlighted 3 main areas: the need to reduce the potential cognitive burden associated with caregiver-delivered rehabilitation, the need to improve the reliability and interpretability of AI-generated feedback, and the need to strengthen coordination between the clinician-facing web interface and caregiver-facing mobile app. The mean SUS score was 73.44 (SD 18.01); however, given the small sample size and variability in scores, this result was interpreted as a supplementary descriptive measure rather than as definitive evidence of overall system usability. Importantly, because caregivers did not participate in this study, findings concerning caregiver experience represent clinicians' proxy perspectives and require confirmation through direct evaluation with actual caregivers.

The qualitative findings identified usability-related concerns that were not adequately represented by the overall SUS score alone. These included the clarity of instructions, delineation of roles between clinicians and caregivers, feedback during exercise performance, and understanding of the system's intended scope of use. Thus, the SUS findings should be regarded as supplementary to the qualitative findings rather than as evidence that the system has achieved an acceptable level of usability. These findings also suggest that usability issues in caregiver-delivered rehabilitation may extend beyond interface operability or functional arrangement to broader human factors considerations associated with the context in which caregivers perform therapeutic exercises with infants.

Human Factors Considerations in Caregiver-Delivered Rehabilitation

The usability issues identified by the clinical experts were less related to basic interface elements, such as button placement, and more closely related to the potential cognitive demands placed on nonprofessional caregivers who are expected to perform therapeutic exercises in home settings. Unlike medical devices operated primarily by trained health care professionals, the caregiver-facing component of the CMT rehabilitation system requires caregivers to perform exercises with infants while simultaneously interpreting instructions and system feedback. From a human factors perspective, this dual role as both system user and provider of home-based exercises may create cognitive and emotional demands that should be considered during system design.

Previous research has indicated that caregivers' disease awareness, level of understanding, and trust in treatment can influence adherence [10]. Consistent with these findings, clinical experts in the present study anticipated that caregivers may experience fear or uncertainty when directly performing therapeutic exercises and may have difficulty simultaneously performing the exercises and interacting with the mobile app. Similarly, Stitt and Operacz [8] reported that caregivers of infants with torticollis may experience psychological stress during home exercise programs because of concerns about causing pain to the child, which may negatively affect adherence. However, the cognitive and emotional burdens identified in the present study were based on clinicians' proxy perspectives and were not directly reported by caregivers.

These findings suggest that the design of CMT rehabilitation software should consider not only basic operability but also the potential cognitive and emotional demands associated with caregiver-delivered rehabilitation. Clear visual materials, comprehensible safety information, and step-by-step guidance may help caregivers understand how exercises should be performed and when corrective action may be necessary. Rather than positioning caregivers as independent clinical decision-makers, the system should support them in performing clinician-prescribed exercises within clearly defined boundaries. From a human factors perspective, these considerations represent preliminary design inputs for reducing potential cognitive burden and use-related errors.

Clear and interpretable feedback may be particularly important when caregivers are expected to determine whether an exercise is being performed appropriately. Subtle aspects of exercise performance, such as movement angle and direction, may be difficult for nonprofessional users to judge without adequate guidance. Clinical experts therefore emphasized the need for visual feedback that communicates exercise performance in an understandable manner. Such feedback may help reduce reliance on subjective judgment and support caregivers in identifying when an exercise requires correction.

In addition, the clinical experts emphasized the importance of clearly defining conditions under which caregivers should discontinue an exercise or seek assistance from a clinician. Home-based rehabilitation requires caregivers to respond appropriately to changes in an infant's condition during exercise. If warning signs, stopping criteria, or safety information are unclear, caregivers may have difficulty determining whether an observed response requires intervention. Accordingly, presenting concrete and observable safety information, including appropriate exercise discontinuation criteria, may represent an important human factors consideration for subsequent system development.

Reliability and Interpretability of AI-Generated Feedback

A particularly important finding was the clinical experts' concern regarding the reliability and interpretability of AI-generated feedback. Participants questioned whether the feedback provided by the prototype could reliably distinguish appropriate from inappropriate exercise performance and whether caregivers would receive sufficient information to understand and correct inappropriate movements. These concerns are particularly relevant in infant rehabilitation, where inaccurate or insufficiently interpretable feedback could contribute to inappropriate exercise performance and potentially increase the risk of harm.

These concerns are consistent with previous research emphasizing the importance of explainability and transparency in medical AI for supporting user understanding and trust [21]. Recent privacy-preserving and interpretable AI approaches for pose-based rehabilitation [22] also provide a useful framework for considering transparent and correction-oriented feedback. Future iterations of the CMT rehabilitation system could therefore explore feedback mechanisms that communicate not only whether a movement is considered appropriate but also why it was classified as such and how an inappropriate movement could be corrected.

Importantly, the present study evaluated clinical experts' perceptions of AI-generated feedback and did not assess the technical accuracy, reliability, or clinical validity of the underlying AI algorithm. Therefore, neither the SUS results nor the qualitative usability findings should be interpreted as evidence of AI performance. Separate technical verification is required to determine whether the algorithm can accurately identify exercise performance and provide reliable feedback. The usability findings presented here should instead be considered preliminary design inputs for improving how AI-generated information is communicated to users.

Integration Within the Clinical Workflow

From the perspective of clinical workflow, participants emphasized the importance of caregiver education before system use and clear delineation of the respective roles of clinicians and caregivers. Clearly defining caregivers' responsibilities and limitations, as well as the circumstances in which clinician monitoring or intervention is required, may help reduce uncertainty and support safer use of the system. In this context, usability should be considered not only in relation to individual interface components but also in relation to how the system fits within the broader rehabilitation workflow.

The clinical experts also requested functions that would allow clinicians to review patient exercise performance, including recorded videos and detailed movement-related data, and suggested potential integration with EMR systems. In CMT management, professional clinical intervention and caregiver education are both important components of rehabilitation [3]. The findings, therefore, suggest that closer coordination between the clinician-facing web interface and caregiver-facing mobile app may facilitate communication and continuity of rehabilitation between clinicians and caregivers. In this sense, the integrated system has the potential to function as a therapeutic bridge between clinical care and caregiver-delivered home rehabilitation.

Methodological Implications

In this study, combining FGIs with the SUS provided complementary qualitative and quantitative information during the formative evaluation. Whereas the SUS provided a descriptive measure of perceived usability, the FGIs enabled more detailed exploration of usability-related concerns involving role perception, perceived responsibility, safety information, AI-generated feedback, and the context of caregiver-delivered rehabilitation. The multidisciplinary composition of the clinical expert groups, including rehabilitation medicine physicians, nurses, and physical therapists, also enabled the system to be considered from different professional perspectives relevant to CMT care.

Given the early developmental stage of the prototype, these findings should be interpreted as preliminary formative design inputs intended to guide subsequent iterations of the system. They should not be interpreted as evidence that usability has been established for actual caregivers or that the system is ready for clinical implementation. Direct evaluation with caregivers will be necessary to determine whether the issues anticipated by clinical experts correspond to caregivers' actual experiences during system use.

Limitations and Future Research

Several limitations should be acknowledged. First, this study included only eight clinical experts, and actual caregivers—the intended users of the caregiver-facing mobile app—did not participate. Therefore, findings concerning caregiver-related usability issues reflect clinicians' proxy perspectives and should not be interpreted as direct evidence of caregivers' experiences or the usability of the caregiver-facing app. Future evaluations should directly involve caregivers to examine their actual interactions with the system, perceived cognitive and emotional demands, and use-related difficulties.

Second, the small sample size and variability in SUS scores limit the precision and generalizability of the quantitative findings. Accordingly, the SUS results were interpreted descriptively and as supplementary to the qualitative findings rather than as a definitive assessment of overall system usability.

Third, the prototype was evaluated in a controlled setting rather than in actual home environments. Consequently, contextual factors that may influence caregiver interaction with the system during home-based rehabilitation, including environmental distractions, simultaneous caregiving demands, and repeated use over time, were not directly assessed. Future studies should therefore evaluate the system with caregivers under realistic home-use conditions following iterative design refinement.

Finally, this study examined clinical experts' perceptions of AI-generated feedback but did not assess the technical accuracy, reliability, or clinical validity of the underlying AI algorithm. Separate technical verification of the AI feedback algorithm is therefore required before its performance can be established. Following iterative design refinement and technical verification, subsequent usability evaluations involving actual caregivers in representative use environments will be necessary to further assess the safety and usability of the system and to inform progression toward summative evaluation.

Conclusions

This study conducted a formative usability evaluation of an AI-based CMT rehabilitation system from the perspectives of clinical experts. The evaluation identified preliminary usability strengths and areas for improvement, while the

mean SUS score of 73.44 (SD 18.01) was interpreted as a supplementary descriptive measure alongside the qualitative findings. The FGIs highlighted several usability-related issues and preliminary design requirements for subsequent system development.

The primary areas for improvement included (1) enhancing the readability of the user manual and visualization of safety information; (2) optimizing the tutorial structure of the caregiver-facing mobile app and improving the reliability and interpretability of AI-generated feedback; and (3) improving clinical workflow efficiency, including potential integration of the clinician web interface with hospital EMR systems. In particular, clinical experts raised concerns regarding whether AI-generated feedback accurately reflected patients' exercise performance and emphasized the need for clinicians to review patient performance videos and detailed movement-related data. These findings highlight the importance of separately verifying the technical accuracy and reliability of the AI feedback algorithm.

The findings suggest that the AI-based CMT rehabilitation system has the potential to support communication and continuity of rehabilitation between clinicians and caregivers. However, because actual caregivers were not included in this study, the findings regarding the caregiver-facing app represent clinicians' proxy perspectives and should be regarded as preliminary formative design inputs rather than evidence of usability for caregivers. Future research should incorporate iterative design refinements based on these findings, evaluate the system with actual caregivers in home environments, and separately verify the technical performance of the AI feedback algorithm.

Acknowledgments

This study was supported by the National Rehabilitation Center Rehabilitation Research & Development Support Program, funded by the Ministry of Health and Welfare (NRCRSP-25TB01, 26TB01).

Generative AI Use

Generative AI tools (eg, ChatGPT or other large language models) were not used in the generation of this manuscript. All content was authored and reviewed by the listed authors.

Funding

The authors declared no financial support was received for this work.

Data Availability

The datasets generated during and/or analyzed during this study are available from the corresponding author upon reasonable request.

Authors' Contributions

Conceptualization: SH, HN, SJ, HC, HK
Data collection: SH, HN
Formal analysis: SH, HN;
Methodology: SH, HN, SJ
Supervision: HC, HK
Writing – original draft: SH, HN
Writing – review & editing: SH, HN, SJ

Conflicts of Interest

None declared.

References

1. Pradhan P, Norceide DJ, Connolly M, Garayo T, Herman MJ. Congenital muscular torticollis: a current concept review. SurgiColl. 2025;3(1). [doi: 10.58616/001c.126718]
2. Sargent B, Kaplan SL, Coulter C, Baker C. Congenital muscular torticollis: bridging the gap between research and clinical practice. Pediatrics. Aug 2019;144(2):e20190582. [doi: 10.1542/peds.2019-0582] [Medline: 31350358]
3. Rodríguez-Huguet M, Rodríguez-Almagro D, Rosety-Rodríguez MÁ, Vinolo-Gil MJ, Ayala-Martínez C, Góngora-Rodríguez J. Effectiveness of the treatment of physiotherapy in the congenital muscular torticollis: a systematic review. Children (Basel). Dec 20, 2023;11(1):8. [doi: 10.3390/children11010008] [Medline: 38275429]
4. Kaplan SL, Coulter C, Sargent B. Physical therapy management of congenital muscular torticollis: a 2018 evidence-based clinical practice guideline from the APTA academy of pediatric physical therapy. Pediatr Phys Ther. Oct 2018;30(4):240-290. [doi: 10.1097/PEP.0000000000000544] [Medline: 30277962]
5. Durguti Z, Murtezani A, Spahiu L, Durguti T, Gara E. Management of infants with congenital muscular torticollis. J Pediatr Neurol. Aug 2019;17(4):138-142. [doi: 10.1055/s-0038-1660829]

6. Kwon DR, Cho SC. Efficacy of intensive inpatient therapy in infants with congenital muscular torticollis involving the entire sternocleidomastoid muscle. Children (Basel). Jun 20, 2023;10(6):1088. [doi: 10.3390/children10061088] [Medline: 37371319]
7. Keklicek H, Uygur F. A randomized controlled study on the efficiency of soft tissue mobilization in babies with congenital muscular torticollis. J Back Musculoskelet Rehabil. 2018;31(2):315-321. [doi: 10.3233/BMR-169746] [Medline: 28946532]
8. Stitt A, Operacz R. A qualitative investigation of parent perceptions of home exercises for congenital muscular torticollis. Children (Basel). Jun 5, 2024;11(6):689. [doi: 10.3390/children11060689] [Medline: 38929268]
9. Oledzka MM, Sweeney JK, Evans-Rogers DL, Coulter C, Kaplan SL. Experiences of parents of infants diagnosed with mild or severe grades of congenital muscular torticollis. Pediatr Phys Ther. Oct 2020;32(4):322-329. [doi: 10.1097/PEP.0000000000000738] [Medline: 32991556]
10. Rabino SR, Peretz SR, Kastel-Deutch T, Tirosh E. Factors affecting parental adherence to an intervention program for congenital torticollis. Pediatr Phys Ther. 2013;25(3):298-303. [doi: 10.1097/PEP.0b013e318298eb92] [Medline: 23797401]
11. Wiklund ME, Kendler J, Strochlic AY. Usability Testing of Medical Devices. 2nd ed. CRC press; 2015. URL: https://www.taylorfrancis.com/books/9781466595897 [Accessed 2026-02-24]
12. Kim J, Kim J, Kim J, Jung M. Development of guideline for heuristic based usability evaluation on SaMD [Article in Korean]. J Biomed Eng Res. 2023;44(6):428-442. [doi: 10.9718/JBER.2023.44.6.428]
13. Kitzinger J. Qualitative research. Introducing focus groups. BMJ. Jul 29, 1995;311(7000):299-302. [doi: 10.1136/bmj.311.7000.299] [Medline: 7633241]
14. Bae YS, Kim KH, Choi SW, Ko T, Lim JS, Piao M. Satisfaction and usability of an information and communications technology-based system by clinically healthy patients with COVID-19 and medical professionals: cross-sectional survey and focus group interview study. JMIR Form Res. Aug 26, 2021;5(8):e26227. [doi: 10.2196/26227] [Medline: 34254946]
15. "IEC 62366-1: 2015+ AMD1: 2020," Medical Devices – Part 1: Application of Usability Engineering to Medical Devices. Vol 1. International Electrotechnical Commission (IEC); 2020. URL: https://webstore.iec.ch/en/publication/67220 [Accessed 2026-11-06]
16. Guest G, Namey E, Taylor J, Eley N, McKenna K. Comparing focus groups and individual interviews: findings from a randomized study. Int J Soc Res Methodol. Nov 2, 2017;20(6):693-708. [doi: 10.1080/13645579.2017.1281601]
17. Powell RA, Single HM. Focus groups. Int J Qual Health Care. Oct 1996;8(5):499-504. [doi: 10.1093/intqhc/8.5.499] [Medline: 9117204]
18. Brooke J. SUS - a quick and dirty usability scale. In: Jordan PW, Thomas B, Weerdmeester BA, McClelland IL, editors. Usability Evaluation in Industry. CRC Press; 1996. URL: https://www.taylorfrancis.com/chapters/edit/10.1201/9781498710411-35/sus-quick-dirty-usability-scale-john-brooke [Accessed 2026-11-06]
19. Lewis JR, Sauro J. Item benchmarks for the System Usability Scale. J Usability Stud. 2018;13(3):158-167. URL: https://dl.acm.org/doi/10.5555/3294033.3294037 [Accessed 2026-11-06]
20. Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol. Jan 2006;3(2):77-101. [doi: 10.1191/1478088706qp063oa]
21. Artificial intelligence index report 2025. AI Index Steering Committee, Institute for Human-Centered AI, Stanford University; 2025. URL: https://hai-production.s3.amazonaws.com/files/hai_ai_index_report_2025.pdf [Accessed 2026-11-06]
22. Bačić B, Vasile C, Feng C, Ciucă MG. Towards nation-wide analytical healthcare infrastructures: a privacy-preserving augmented knee rehabilitation case study. In: Mukhopadhyay SC, Senanayake S, Prasad PWC, editors. Innovative Technologies in Intelligent Systems and Industrial Applications: CITISIA 2024 - Volume 1. Vol 1512. Springer; 2026:378-387. [doi: 10.1007/978-3-032-10898-2_32]

Abbreviations

CMT: congenital muscular torticollis
EMR: electronic medical record
FGI: focus group interview
HEP: home exercise program
SaMD: software as a medical device
SUS: System Usability Scale

Edited by Adeola Bamgboje-Ayodele; peer-reviewed by Jong-hee Lee, Yihan Hu; submitted 15.May.2026; initial comments to author 29.Sep.2026; final revised version received 19.Oct.2026; accepted 29.Oct.2026; published 19.Nov.2026

Please cite as:
Hong S, Nam H, Jeong S, Choi H, Kweon H
AI-Based Rehabilitation System for Congenital Muscular Torticollis: Formative Usability Evaluation
JMIR Hum Factors 2026;13:e101427
URL: https://humanfactors.jmir.org/2026/1/e101427
doi: 10.2196/101427

© Seojin Hong, Heewon Nam, Seongwoo Jeong, Hyun Choi, Hyosun Kweon. Originally published in JMIR Human Factors (https://humanfactors.jmir.org), 19.Nov.2026. This is an open-access article distributed under the terms of the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR Human Factors, is properly cited. The complete bibliographic information, a link to the original publication on https://humanfactors.jmir.org, as well as this copyright and license information must be included.