Identifying Design Requirements for a Physiotherapist Dashboard with Decision Support for Clinical Movement Analysis of Musicians with Musculoskeletal Problems: Qualitative User Research Study

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Abstract

Background: Musculoskeletal disorders are common among musicians, requiring precise diagnostic and therapeutic approaches. Physiotherapists face unique challenges due to the complex relationship between musculoskeletal health and the demands of musical performance. Traditional methods often lack the necessary precision for this specialized field. Integrating Clinical Decision Support (CDS) tools with Clinical Movement Analysis (CMA) could improve diagnostic accuracy and therapeutic outcomes by offering detailed biomechanical insights and facilitating data-driven decision-making.

Objective: This study aimed to identify design requirements for a specialized CDS tool incorporating CMA to support physiotherapists in diagnosing and treating musculoskeletal disorders in musicians, thereby improving diagnostic accuracy, therapy effectiveness, and patient outcomes.

Methods: A qualitative user research study was conducted, utilizing Human Factors Engineering methods from problemdriven research, user-centered design, and decision-centered design. Data collection included a domain-specific literature review, workflow observations, and focus group discussions with domain experts, including three musicians' physiotherapists and a movement scientist. This qualitative data was triangulated to characterize the domain, identify the CMA workflow, user needs, key cognitive tasks, and decision requirements. These insights were translated into concrete design requirements for a CDS tool.

Results: A workflow for integrating musician-specific CMA into physiotherapy was established. Twenty-one user requirements, seven key cognitive tasks, and five key decision requirements were defined, along with forty-nine design seeds, which informed the design requirements for the CDS tool. Key features identified include: (1) efficient integration of musician-specific biomechanical findings into therapy; (2) combining heterogeneous data types for holistic assessment; (3) providing an adaptive overview of patient-related information; (4) utilizing adequate visual representations and interaction techniques; (5) facilitating efficient visual-interactive analysis of findings and treatment results; (6) enabling preparation and export of therapy findings and analysis results. Additionally, eleven technical prerequisites and fourteen decision support recommendations were identified. These requirements will guide the design and development of a CDS tool featuring advanced visualization tools, interactive data exploration capabilities, and contextual integration of clinical and biomechanical data.

Conclusions: A specialized CDS tool incorporating CMA data holds significant potential to enhance decision-making in musicians' physiotherapy. By addressing cognitive demands and integrating advanced visualization techniques, the tool can support physiotherapists in making more accurate assessments, potentially improving patient outcomes, reducing injury recurrence, and supporting musicians' career longevity. Ongoing research is essential to refine the tool and validate its clinical effectiveness. Future studies should incorporate advanced analytics and explore broader therapeutic applications to enhance its impact.

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Identifying Design Requirements for a Physiotherapist Dashboard with Decision Support for Clinical Movement Analysis of Musicians with Musculoskeletal Problems: Qualitative User Research Study

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Keywords
Clinical Decision Support, Physical Therapy; Clinical Movement Analysis; Performing Artists; Performance-related Musculoskeletal Disorders; Human Factors Engineering; Design Study Methodology; Problem-Driven Research; User-Centered Design; Decision-Centered Design

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Conclusion: A specialized CDS tool incorporating CMA data holds significant potential to enhance decision-making in musicians' physiotherapy. By addressing cognitive demands and integrating advanced visualization techniques, the tool can support physiotherapists in making more accurate assessments, potentially improving patient outcomes, reducing injury recurrence, and supporting musicians' career longevity. Ongoing research is essential to refine the tool and validate its clinical effectiveness. Future studies should incorporate advanced analytics and explore broader therapeutic applications to enhance its impact.

1. Introduction

1.1. Background

Musculoskeletal disorders are common among musicians due to repetitive movements, muscle strain, poor posture, and intensive practice, affecting their ability to perform and sustain careers [1–3]. At least 50% of musicians suffer from *performance-related musculoskeletal disorders (PRMDs)*, experiencing pain and other symptoms that impair performance [4–6]. However, targeted therapy is underused, and specialized assessment and treatment strategies are needed (cf. [7,8]).

Musician-specific physiotherapy is beneficial for identifying and treating these issues, focusing on aspects of posture, movement behavior, and musical expression that affect health [8–10]. Effective treatment requires a thorough understanding of musician-specific characteristics and identification of functional disorders in the musculoskeletal system through clinical neuro-orthopedic examinations and analyses of the musician’s movement while performing [11].

In physiotherapy, clinical reasoning is essential for decision-making, often using a hypothetical-deductive method [12]. Accurate diagnostics are crucial to prevent misjudgments [13], and comprehensive information gathering is vital for effective therapy planning [14,15]. Technology-driven assessments can enhance diagnostic accuracy, moving beyond subjective methods and trial-and-error approaches [16].

Clinical Movement Analysis (CMA) provides objective, quantifiable data on functional disorders, supporting personalized medicine [11,17] and offering physiotherapy applications that conventional assessments cannot achieve [18,19]. As an apparatus-based biomechanical analysis for individualized functional diagnostics, CMA employs techniques such as motion capture and electromyography (cf. [20,21]). It helps evaluate complex movements during performance, allowing for the identification of aberrant postures and movements contributing to PRMDs in musicians [22–24]. Thus, CMA aids in diagnosing functional disorders, planning individualized therapy, and monitoring therapeutic measures [17,19,25], minimizing the risk of false results [26,27].

The *RefLabPerform* project [28] aims to develop a reference laboratory for PRMD assessment in musicians, integrating CMA with physiotherapeutic assessments, which will be implemented at the *Institute for Applied Physiotherapy Osnabrück (INAPO)*. Advanced instruments will be used by specialists for musician-specific CMAs, with results provided to physiotherapists for further clinical evaluation.

However, interpreting CMA data requires expertise and time, presenting challenges for clinical practice, highlighting the need for efficient, intuitive presentation for analysis and decision making [11,29,30]. Current tools for biomechanical analysis lack guidance for musicians' physiotherapy, leading to concerns about accuracy and usability [30,31].

A tailored health technology for musicians’ physiotherapy is essential to efficiently record, process, provide, analyze, and interpret musician-specific CMA data for routine use. Hereby, a *Clinical Decision Support (CDS)* tool can improve diagnostics by integrating CMA findings, facilitating comprehensive decision-making and effective therapies [32]. Adapting research approaches from health while considering physiotherapy-specific conditions will ensure the tool aligns with the clinical workflow, balancing perceived benefit, effort, and costs [16,33].

1.2. Human factors and CDS design

Human Factors Engineering (HFE) is crucial for designing CDS tools, focusing on usability and workflow integration for decision support (cf. [34–36]). Effective CDS requires speed, efficiency, meaningful alerts, consistency, and logical grouping with intuitive interface design [37–40]. Hence, designing CDS must address user needs, working environments, cognitive demands, decision-making requirements, and advanced interactive visualizations for data analysis.

Three HFE approaches – *Design Study Methodology (DSM)*, *user-centered design (UCD)*, and *decision-centered design (DCD)* – provide guidance for this. DSM is a problem-driven research paradigm focused on creating innovative visualization solutions through iterative collaboration with domain experts to address real-world problems [41]. UCD emphasizes understanding user tasks, goals, and needs by involving users from the beginning, which informs the specification of user requirements and guides the design process [42]. DCD aims to improve decision-making in critical scenarios, such as medical diagnosis, by enhancing human decision-making [43,44]. Cognitive task analysis identifies key cognitive demands and translates them into decision requirements, guiding the design process to improve clinical performance [45]. These approaches share a human-centered, iterative, and multi-stage methodology, leveraging in-depth analysis and expert contributions, while each addresses distinct aspects of the design process.

1.3. Objectives

The study aimed to identify design requirements for a CDS tool, specifically a physiotherapist dashboard, to assess musculoskeletal problems in musicians within the *RefLabPerform* project. This involved considering the working environment, clinical procedures, and user needs from the beginning, and gathering detailed information on how decision-making in musicians' physiotherapy can be supported technically, especially with the integration of CMAs.
To achieve this, requirements elicitation methods from three HFE approaches—DSM, UCD, and DCD—were followed to comprehensively describe the domain and the underlying problem, resulting in well-informed requirements and recommendations. This approach is expected to enhance usability and acceptance, improve user efficiency and accuracy, and reduce the cognitive workload of the future CDS tool.

2. Methods

2.1. Overall procedure

This qualitative user research study followed a problem-driven research paradigm and was part of the initial *domain characterization and analysis* phase within a larger design study incorporating aspects from DSM, UCD, and DCD (see Figure 1). The requirements elicitation procedure incorporated aspects from the first four steps of DSM (*learn*, *winnow*, *cast*, and *discover*) [41], the initial two phases of UCD (*understanding context of use* and *specifying user requirements*) [42], and the first three stages of DCD (*preparation*, *knowledge elicitation*, and *analysis and representation*) [44]. The approaches were merged and subdivided into three stages: *precondition and preparation*, *knowledge acquisition and characterization*, and *analysis and representation*, with subsequent phases planned for future work.
The main author (EW) conducted the work-flow observations and moderated the focus groups in German in March and April 2021. His researcher characteristics are the following: “gender: Male”, “experience: six years research experience in health informatics, main focus in physiotherapy and movement analysis projects”, “degree: M.Sc. in Computer Science”, “occupation: Research assistant”.

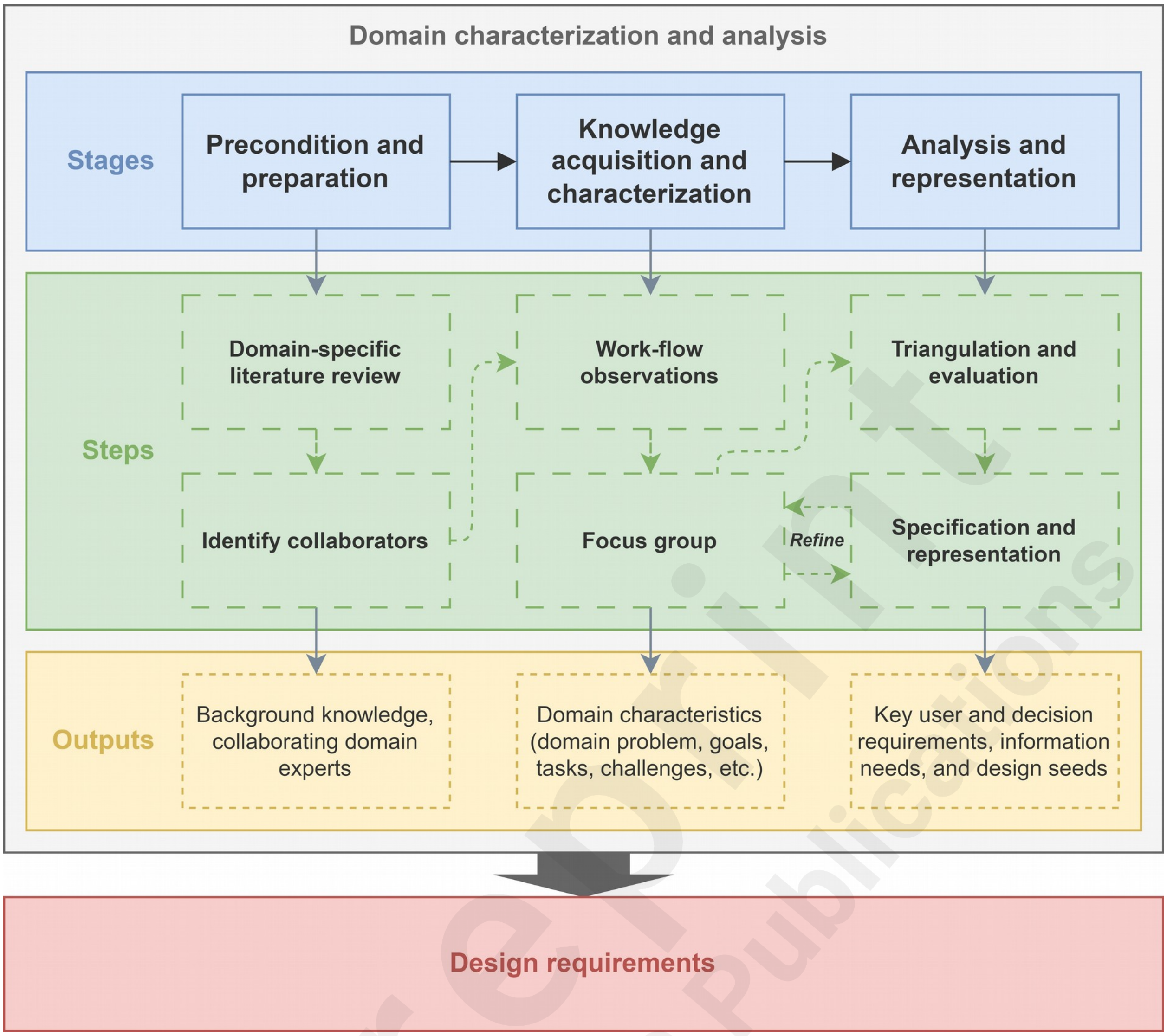

Figure 1. Initial domain characterization and analysis phase involved three stages including steps and outputs to identify design requirements for the CDS tool.

2.2. Precondition and preparation

2.2.1. Domain-specific literature review

Domain-specific literature from physiotherapy, clinical biomechanics, and movement analysis of musicians was reviewed to gather background information about the domain and user group characteristics and to become familiar with relevant terms and jargon (e.g., [6,8–11,13–15,17,19,21,21,23,29,31,46–57]). Previously articulated task descriptions, such as clinical reasoning and functional diagnostics, were examined to gain domain understanding and to initially identify cognitively complex components.

2.2.2. Identify collaborators

The INAPO, a specialized facility for treating neuromusculoskeletal disorders, served as a cooperation partner. INAPO has specialized in the treatment of musicians in close cooperation with the "Institute for Music" at Osnabrück University of Applied Sciences. Admitted patients receive tailored treatment and exercise programs. INAPO emphasizes staying updated with scientific progress in musicians' health and movement sciences, using modern therapy methods. As part of the *RefLabPerform* project, a CMA lab was established at INAPO, equipped with optoelectronic motion capture, surface electromyography sensors, and force plates. Requirements were gathered based on the CMA lab and INAPO's clinical practice needs.

Three musicians' physiotherapists from INAPO (one male and two female) and one movement scientist and professor for “clinical reasoning and applied biomechanics” from the University of Applied Sciences Osnabruck were selected face-to-face as domain experts for systematic collaboration during requirements elicitation. We used purposive sampling to ensure inclusion of a representative sample of practicing physiotherapists with extensive experience in managing musicians with musculoskeletal problems.

2.3. Knowledge acquisition and characterization

2.3.1. Work-flow observations

We employed contextual inquiry to observe the workflow of physiotherapists treating musicians with musculoskeletal problems at INAPO prior to the focus group discussion. Contextual inquiry, a qualitative user research method, involves observing and interviewing potential users in their work environment as they perform actual tasks [58], i.e., watching them perform tasks while asking questions about their actions and thought processes. This method uncovers tacit knowledge, reveals detailed work practices, and provides reliable, relevant information about user needs and behaviors. The goal was to identify and gather domain experts' needs and preferences for a CDS tool concerning their (cognitively challenging) tasks and daily data encounters. Additionally, we asked the experts about their thoughts on the integration of musician-specific CMAs into the diagnostic process and the application in clinical decision-making.

EW observed three physiotherapists experienced in treating musicians with musculoskeletal problems, previously selected for collaboration, during their daily work routines over one week. Each session lasted about two hours, allowing for detailed observation and discussion. Observations continued until thematic saturation was reached. Workflow diagrams were created from observation notes and presented at the focus group meeting to facilitate discussion on workflow processes.

2.3.2. Focus group

We conducted an online focus group [59] lasting approximately 270 minutes (4.5 hours), comprising seven participants: the four collaborating domain experts, two computer scientists, and one user experience designer. Video and audio recordings were made using Zoom (Zoom Video Communications, Inc., USA). The focus group aimed to gain a deeper understanding of the domain, exploring the working environment, clinical procedures, user needs, and decision-making processes in musicians' physiotherapy, providing essential information for the tool's design. The primary goal was to establish a common understanding of the domain and address the following questions for the specific setting:

- What are the goals of musicians’ physiotherapy?
- What skills and competences are needed to achieve these goals?
- What barriers can hinder the achievement of the goals?
- What collaborations are needed to achieve the goals?
- What tools and equipment are used?
- What is the general workflow, and which work steps are performed at which point in time?
- What are the objectives of each work step?
- What information and tools are needed for each work step?
- What are the activities within each work step?
- What are the results of each work step?
- What could the workflow in the motion analysis lab look like?
- How could the physiotherapists interact with the motion analysis lab?

Given the lack of standardized procedures for focus group data collection and analysis, which depend on the research question and timeframe, we opted to organize the results into a mind map during the discussion to facilitate consensus-building. Following the focus group session, the research team held a debriefing session to review the discussions and identify key points.

2.4. Analysis and representation

2.4.1. Triangulation and evaluation

The qualitative data was triangulated and evaluated to determine how the tool can address the domain problem and user needs, and support decision-making. First, the insights from workflow observations and the focus group were organized and contextualized with domain-specific literature to understand and describe the domain characteristics. Further evaluation of the findings revealed key user needs, as well as cognitively challenging tasks, strategies, difficulties, and critical aspects in musicians' physiotherapy.

2.4.2. Specification and representation

Based on the prior findings, the solution's characteristics were specified. First, a workflow for integrating musician-specific CMA was established and visualized. Key user requirements, cognitive tasks, decision requirements, and associated information needs were then derived and formulated. Subsequently, design seeds to support decision-making were created. These findings were organized in tabular form.

In a second online focus group discussion, which lasted approximately 180 minutes (3 hours), the identified domain characteristics, specified user and decision requirements, and design ideas were revisited with the same group of experts and researchers. During this session, these elements were discussed in detail and refined based on their feedback.

Finally, incorporating knowledge and conditions from the theoretical background and domain, concrete design requirements were specified, including key features, technical prerequisites and decision support recommendations.

3. Results

3.1. Characteristics of the domain

To describe the domain, the characteristics were categorized under the following themes: domain problem; goals, skills and competences, work equipment, and barriers; and tasks, routines, and challenges.

3.1.1. Domain problem

The unresolved domain problem is integrating musician-specific CMA into musicians’ physiotherapy and offering visual-interactive access to aggregated findings and treatment data for decision support.

Musicians' physiotherapy, an integral component of "musicians' medicine", specializes in the assessment and treatment of neuromusculoskeletal disorders prevalent among musicians. This specialty employs standard physiotherapeutic tools along with musician-specific questionnaires and CMAs to enhance diagnostic precision and facilitate data-driven therapeutic decisions. Post-intervention, the collection of relevant patient questionnaires and repeated CMAs is crucial for effective therapy evaluation. However, an efficient technical solution for the comprehensive integration and analysis of clinical and biomechanical data tailored to musicians' physiotherapy remains absent. The primary beneficiaries of such a solution would be physiotherapists, with musicians gaining from improved, targeted therapies. Additionally, specialized physiotherapists or movement scientists trained in musician-specific CMAs, would benefit from enhanced integration of CMA into the therapeutic process.

Documentation, typically on paper, should be electronic for comprehensive evaluation. Integrating CMAs adds complexity, requiring standardized data processing and effective communication between physiotherapists and movement labs. Current software for biomechanical analysis is not user-friendly for physiotherapists, lacking advanced visualization, interactive data exploration, and contextualization of clinical and biomechanical data. A new solution is needed to simplify data analysis and visualization for therapists, with requirements evolving during implementation.

3.1.2. Goals, skills, competences, equipment, and barriers

Table 1 summarizes the goals, skills, competences, work equipment, and (potential) barriers cited by domain experts. The primary goal of physiotherapists is to provide high-quality patient care to enhance or maintain sensorimotor self-determination. This requires addressing the patient's main problems and goals efficiently to implement effective, targeted therapies. It is crucial to assess the effectiveness of therapeutic measures continuously, aligning interventions with the patient's condition and goals. Achieving these outcomes demands extensive skills and competences, particularly in CR, which is central to effective therapy [57].

Domain experts highlight the importance of a solid background in (patho-)anatomy, physiology, normative and comparative values, and evidence-based assessments, tests, and interventions. Clinical experience is also vital for developing communication and manual skills, refining techniques, interpreting tests, and recognizing clinical patterns. Further general requirements for physiotherapists are outlined in the literature (cf. [57]). Domain experts identified several tools used in therapy, including musician-specific patient questionnaires, body tables, numerical rating scales, goniometers, and algometers.

Physiotherapists face several barriers that can impede therapeutic objectives, including insufficient background knowledge, limited clinical experience, and shifts in knowledge due to ongoing education. Patient-related barriers include compliance issues and unrealistic expectations. Additionally, legal, or institutional barriers, such as limited examination and treatment time, and insufficient financial, technical, or spatial resources, also pose significant challenges.

Table 1. Domain-specific goals, skills and competences, work equipment, and barriers.

GOALS	SKILLS AND COMPETENCIES	EQUIPMENT	BARRIERS
- Enhancing or maintaining sensorimotor self-determination - Improving the main problem - Addressing patient goals	*Background knowledge:* - Anatomy and physiology • Patho-anatomy and physiology (clinical patterns, clinical picture, musician-specific traits) • Reference values (standard, individual, musician-specific - Scientific evidence for assessments, tests, interventions *Clinical experience:* - Communication skills - Manual skills - Recognizing clinical patterns - Techniques - Test interpretation	- Patient questionnaires - Diagnostic questionnaires - Body tables - Numerical rating scale - Measuring instruments (e.g., goniometer, algometer)	*Physiotherapist:* - Lack of background knowledge - Lack of clinical experience - Shift in knowledge and beliefs, e.g., through further education and training - Premature judgments *Patient:* - Compliance • Background (cognitive, social, educational) • Negative experiences • Unreasonable expectations *General conditions:* • Legal: Limited time, lack of resources (e.g., financial) • Institutional: Limited time, lack of resources (e.g., premises, measuring instruments), availability of qualified therapists

3.1.3. Tasks, routines, and challenges

The cyclical CR process consists of eight main phases: Looking, Collecting, Processing, Deciding, Planning, Acting, Evaluating, and Reflecting [12]. These phases are interrelated and often overlap. The technical solution should explicitly assist the therapist in five of these steps:

- *Collecting:* Recording all subjective and objective findings
- *Processing:* Analyzing and interpreting the findings
- *Deciding:* Assessing the findings for diagnosis and planning
- *Evaluating:* Assessing the intervention(s) based on the repeat findings
- *Reflecting:* Assessment of therapy effectiveness

The diagnostic process in physiotherapy involves examination, evaluation, and reassessment of findings and therapy measures under significant time pressure. Therapists must extract relevant information to make accurate treatment decisions, recognizing anomalies and changes in data [60].

Work-flow observations and focus group discussion provided a deeper understanding into the therapeutic and diagnostic processes in musicians' physiotherapy. Before the first consultation, patients complete musician-/problem-specific questionnaires, and the results guide the subjective examination, including background information and symptoms. This information helps generate diagnostic hypotheses tested during a physical examination, often using tools like goniometers. The results confirm or reject these hypotheses, leading to a physiotherapeutic diagnosis and a customized treatment plan. Treatment effectiveness is evaluated regularly, with reassessments before each follow-up to adjust or stop treatment as needed.

3.2. Specification and representation

The findings from the prior domain characterization were further examined and discussed with the domain experts. This process aimed to address the integration of musician-specific CMA into physiotherapy, identify user requirements, and determine key cognitive tasks and decision requirements.

3.2.1. Integrating musician-specific CMA into physiotherapy

Based on the domain experts' input, the integration of musician-specific CMA into physiotherapy was designed. It is crucial to incorporate CMA efficiently, providing valuable information on a musician's dysfunction. The timing, execution, and result delivery are critical for high clinical benefit and rapid transfer from the movement analysis lab to the therapist. The CMA aims to test diagnostic hypotheses and evaluate therapeutic measures' effectiveness. Biomechanical data should be classified and interpreted within the clinical context, structured as additional findings, and made available to therapists.

Figure 2 proposes integrating CMA into the assessment process alongside the physical examination. Clinical reasoning underpins CMA use, starting with a clear question based on a working hypothesis, guiding the selection of muscles, starting positions, testing types, and biomechanical characteristics. This procedure is referred to as a movement analysis protocol based on Kontaxis et al. [61].

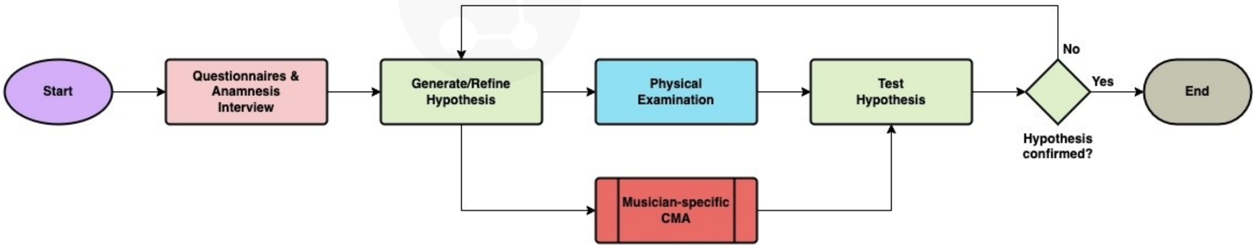

Figure 2. Flowchart of the revised diagnostic process incorporating CMA as an additional objective diagnostic tool alongside the physical examination (own illustration).

In addition to utilizing CMA for functional diagnostics during the initial assessment, a subsequent CMA is conducted post-treatment, as depicted in Figure 3. This allows for a pre-post comparison to evaluate the effectiveness of the treatment interventions.

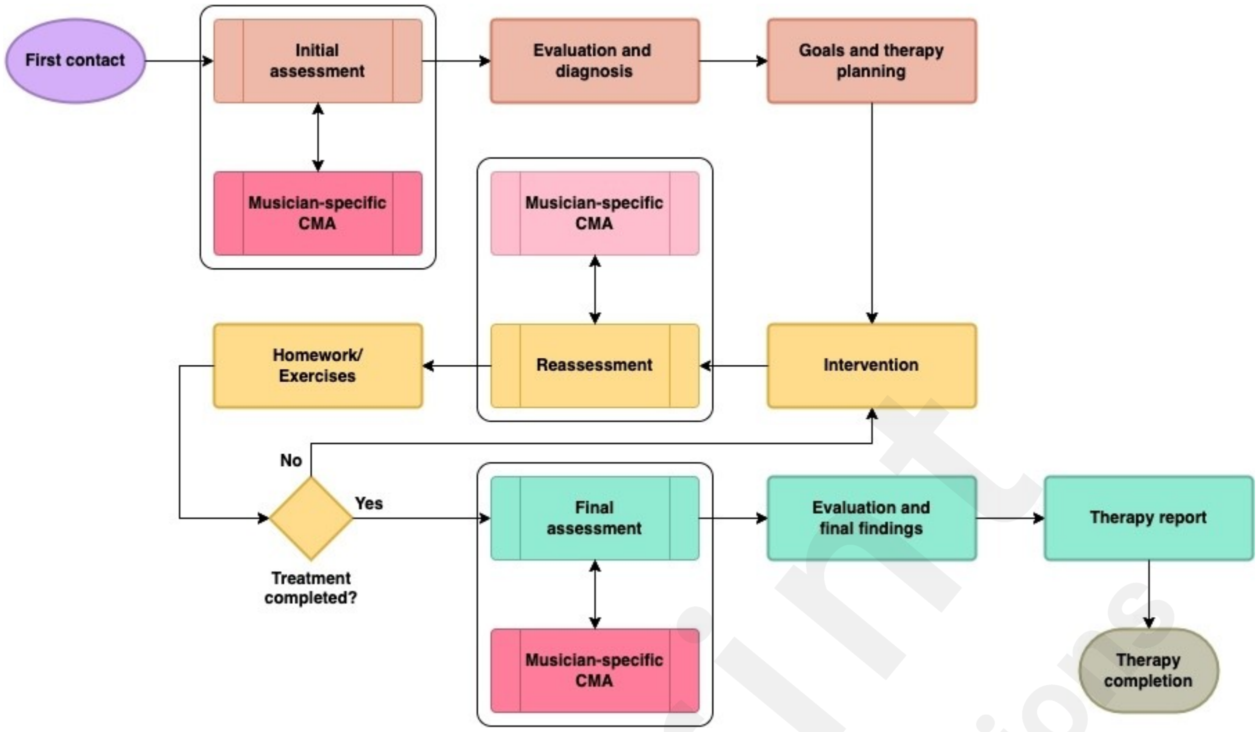

Figure 3. Flowchart illustrating the modified clinical procedure with integrated CMA post-treatment (own illustration).

3.2.2. User requirements

Contextual analysis, informed by the domain-specific literature, workflow observations, and focus groups, revealed user needs concerning the solution's characteristics. In total, **21** user stories were defined based on these needs, reflecting the users' expectations of a CDS tool's functionality [62]. These user stories pertain to clinical findings and treatment documentation, CMA, analysis and evaluation, and reporting. The full list of user requirements is available in Error: Reference source not found.

3.2.3. Key cognitive tasks and decision requirements

First, cognitively challenging activities were identified, such as diagnostics, treatment planning, and therapy evaluation, informed by task descriptions from literature and the findings from knowledge acquisition and characterization. For each activity, we identified critical cues used by experts, potential errors, and procedures to meet cognitive demands. Physiotherapists generate and test hypotheses by interviewing patients and conducting or commissioning examinations, continuously integrating, and interpreting the information. Each activity is a cognitively challenging demand, requiring decisions on what information to gather and when to stop, as well as determining the next steps in treatment.

Finally, seven key cognitive tasks were identified: (1) querying specific patient questionnaires, (2) subjective examination of the patient, (3) testing diagnostic hypotheses, (4) consolidating and evaluating the information relevant to therapy, (5) planning the adapted therapy, (6) treating a patient's specific problem in an iterative approach, and (7) evaluating the therapy results. The final list of key cognitive tasks and the associated strategies, (potential) errors or difficulties, and critical hints of the domain experts can be found in Error: Reference source not found.

In coordination with the domain experts, key decision requirements were extracted from these activities, focusing on planning, and assessing examinations and treatments while considering musician-specific CMA. Information needs for each decision were defined, specifying the clinical information needed. This approach led to design recommendations for decision support, offering early HCI concepts for organizing and visualizing information.

Five key decision requirements were identified incorporating musician-specific CMA in the context of physiotherapeutic diagnostics: (1) plan functional diagnostic examination, (2) assess CMA findings, (3) prepare overall finding and, if necessary, report of findings, (4) compare results of reassessments and evaluate treatment effectiveness and (5) evaluate therapy results and success. Based on the key decision requirements and associated information needs, a total of **49** design seeds were identified. The final list can be found in Error: Reference source not found.

Physiotherapists must decide if, when, and how to perform a CMA for a patient, considering basic patient information, contributing factors, symptoms, previous CMA parameters, and time and number of previous treatments. They must quickly evaluate findings to plan next steps, gaining an overview of the patient's problem, identifying patterns, and confirming diagnostic hypotheses to formulate a physiotherapy diagnosis. They must determine which data are therapy-relevant to create an overall finding or report.

Throughout treatment, physiotherapists continuously assess findings and treatment effectiveness, deciding if measures positively impact the patient's problem or need adjustment. They review therapy-relevant information before and after treatments to identify trends and changes. They reflect on therapy outcomes and their actions, assessing whether therapy was successful and identifying key factors. They monitor achievement of therapy and patient goals using data from baseline and follow-up findings, treatment results, and relevant questionnaires, including post-intervention CMA results.

3.3. Design requirements

The findings from the *domain characterization and analysis* informed concrete design requirements for the CDS tool. Key features and recommendations were specified, considering the user needs and requirements for decision support. The use case established framework conditions and technical prerequisites to enable the system.

3.3.1. Key features

Based on the insights gained, we identified six key features (K_F) that form the basic pillars of the tool and must be fulfilled during design and implementation:

K_{F1} *Provision of biomechanical findings:* Musician-specific CMAs should be efficiently integrated into therapy to give physiotherapists valuable insights into a patient's dysfunction. Biomechanical data must be processed, modeled, and stored to produce a report with relevant characteristics for further analysis.

K_{F2} *Integration of heterogeneous data types and sources:* For a holistic inspection and assessment of all available information from the subjective and objective examinations of a patient's problem, it is necessary to combine different types of data from different data sources. This includes clinical findings and treatment data from physiotherapy documentation, results from online questionnaires and biomechanical findings data from movement analysis.

K_{F3} *Adaptive overview:* A simplified aggregated overview is essential for quick and clear inspection and monitoring of patient-related information. This should include basic therapy data, recent findings, and treatments, as well as relevant individual patient details. Information should be adaptive and patient-specific, allowing physiotherapists to manually add or remove data. Detailed views should be accessible via a drill-down function.

K_{F4} *Adequate visual representations and interaction techniques:* Efficient visualizations, such as lists, tables, diagrams, and illustrations, should be chosen to aid physiotherapists in effective decision-making. Therapists should be able to manually arrange and configure these elements and use familiar interaction techniques like drag-and-drop, sorting, searching, and filtering.

K_{F5} *Efficient visual-interactive analysis of findings and treatment results:* Physiotherapists need an efficient solution for interactive visual analysis of findings and treatment results to identify abnormalities, trends, and patterns in clinical and biomechanical data. Established visual analytics methods will be used to explore and compare multivariate and time-oriented data.

K_{F6} *Preparation and export of findings and analysis results:* Physiotherapists should be able to summarize and export therapy findings as a report for discussion with colleagues and patients, or for continued treatment elsewhere. The report should be presented in a clear, customizable format.

3.3.2. Technical prerequisites

Technical prerequisites (P_T) must be established to enable the tool (see Table 2). The system must allow physiotherapists to view a patient's data and case history (P_{T1}). Data from anamnesis, physical examinations, and treatment courses must also be available (P_{T2}). Additionally, patients should complete validated musician-related questionnaires online, with results included in the findings overview (P_{T3}). Biomechanical data from a musician-specific CMA must be available as biomechanical findings (P_{T4}). Functional diagnostics are conducted in a CMA lab within a physiotherapy practice, staffed by specialists. To initiate an exam, physiotherapists must submit an electronic order with relevant CMA information like patient ID, instrument group, and symptoms (P_{T5}). The lab needs an order management system to handle these requests and update CMA status (P_{T6}), as well as a data management system for recorded measurements (P_{T7}). Instrument-specific protocols should standardize CMAs (P_{T8}), and existing measuring instruments and software should be integrated (P_{T9}). Data processing and calculation should be partially automated (P_{T10}), and the resulting characteristics should be provided as biomechanical findings (P_{T11}).

Table 2. Overview of the technical prerequisites (P_T) to enable the CDS tool for musicians' physiotherapy.

CATEGORY	TECHNICAL PREREQUISITES	
Integration of therapy-related patient data	**P_{T1}**	Integration of patient and case data
	P_{T2}	Integration of clinical findings and progress data
	P_{T3}	Integration of the online questionnaire results
	P_{T4}	Integration of the biomechanical findings data
Laboratory system	**P_{T5}**	Electronic order entry
	P_{T6}	Laboratory order management
	P_{T7}	Laboratory data management
	P_{T8}	Standardized motion analysis protocols
	P_{T9}	Integration of existing biomechanical measuring instruments/systems and analysis software
	P_{T10}	(Partially) automated processing and calculation of relevant features
	P_{T11}	Providing data from clinical movement analysis as biomechanical findings

3.3.3. Decision support recommendations

The user needs and design seeds addressing decision requirements formed the basis for specifying concrete decision support recommendations (DS_R), particularly for supporting clinical decision-making (see Table 3).

For planning musician-based diagnostics, it is helpful to have a note indicating if such an examination is possible for the patient (DS_{R1}). The tool should remind the physiotherapist to conduct pre- and post-interventional exams if possible (DS_{R2}). Additionally, suggested configuration parameters should be provided when creating an examination order to save time (DS_{R3}).

To efficiently query and inspect findings and treatment results, essential data should be preselected for the overview (DS_{R4}). Information should be summarized in aggregated elements and presented in suitable display formats (DS_{R5}). Relevant therapy events should be shown on a timeline (DS_{R6}). Additionally, visual cues should highlight significant data changes to reduce cognitive load and speed up decision-making (DS_{R7}).

For interpreting findings, integrating normative and comparative values is desirable (DS_{R8}). Therapists should be able to create interactive annotations (DS_{R9}), marking specific data values or time intervals. To support diagnosis, findings and annotations should be linked to diagnostic hypotheses, showing which data support or refute them (DS_{R10}). Additionally, marking applicable or inapplicable hypotheses interactively should be possible (DS_{R11}).

For therapy evaluation, directly comparing baseline and final findings is essential (DS_{R12}). An interactive review of patient and therapy goals helps determine therapy success, requiring target parameters for goal achievement (DS_{R13}). Preselecting relevant entries and suitable presentation forms aids in report preparation (DS_{R14}).

Table 3. Overview of the decision support recommendations (DS_R) for the CDS tool.

CATEGORY		DECISION SUPPORT RECOMMENDATION
Planning musician-specific examinations for functional diagnostics	**DS_{R1}**	Indicate if musician-specific examinations are possible for the patient.
	DS_{R2}	Remind physiotherapists to conduct pre- and post-interventional examinations.
	DS_{R3}	Provide suggested configuration parameters for examination orders to save time.
Query and inspection of diagnostic findings and treatment results	**DS_{R4}**	Preselect essential data for efficient querying and inspection.
	DS_{R5}	Summarize information in aggregated elements and suitable display formats.
	DS_{R6}	Map relevant events on a timeline.
	DS_{R7}	Use visual cues to highlight abnormal data or significant changes.
Analysis and interpretation of the findings data	**DS_{R8}**	Integrate normative and comparative values for interpreting findings.
	DS_{R9}	Allow interactive annotations for specific data values or time intervals.
	DS_{R10}	Link findings and annotations to working hypotheses.
	DS_{R11}	Mark working hypotheses as applicable or not with appropriate presentation.
Therapy evaluation and reporting	**DS_{R12}**	Enable direct comparison of baseline and final findings for therapy evaluation.
	DS_{R13}	Facilitate an interactive review of patient and therapy goals, with target parameters for goal achievement.
	DS_{R14}	Preselect relevant entries and use appropriate presentation formats for report preparation.

4. Discussion

4.1. Principal Findings

We proposed and applied a novel HFE process model to inform the design of a CDS tool for managing musculoskeletal problems in musicians' physiotherapy, using methods, and addressing aspects from DSM, UCD, and DCD. Following this model, we first identified and thoroughly described the characteristics of the domain and problem area. We explored user needs, cognitively challenging tasks, information needs, and decision-making challenges faced by physiotherapists treating musicians with musculoskeletal conditions. We then proposed design seeds for CDS, translating user and decision requirements into concrete design requirements, including key features, technical prerequisites, and recommendations for decision support.

Key features include efficient integration of biomechanical data, combining heterogeneous data types, and providing adaptive overviews for quick data inspection. The tool should present patient data in a suitable form and facilitate interactive visual analyses using familiar techniques like filtering, highlighting, and annotating. Summarizing and exporting findings for communication is also essential. User and decision requirements led to specific decision-support recommendations: the tool should indicate if musician-specific diagnostics are possible, remind physiotherapists of exams, suggest efficient configuration parameters, preselect essential data, highlight significant changes, integrate normative values, support interactive annotations, compare baseline and final findings, and provide tools for reviewing patient goals and preparing reports. To enable the tool technical prerequisites must be met: include access to patient data (anamnesis, exams, treatments, and musician-related questionnaires), biomechanical data from musician-specific CMAs, support for electronic diagnostic orders, and management of these orders and CMA statuses. The system should use standardized protocols, integrate with existing tools, and automate data processing to present biomechanical findings.

The integration of CDS into physiotherapy, incorporating CMA, presents both opportunities and challenges. Our study emphasizes the need to tailor CDS to real clinical environments and therapists' workflows. Ensuring these technologies are perceived as useful is crucial, as the balance between perceived benefits and implementation effort significantly affects adoption. Developing a CDS tool for diagnosing and treating musculoskeletal disorders in musicians requires a multidisciplinary approach, combining biomechanics, computer science, and clinical practice. Collaboration with domain experts ensures the tool meets practical needs. Requirements were elicited through problem-driven research, ensuring that real-world problems were addressed, as well as UCD and DCD approaches, considering user needs, cognitive demands, and decision requirements, aiming to enhance the usability and usefulness of the solution.

The proposed CDS tool addresses a gap in current biomechanical analysis software, which often lacks user-friendliness for physiotherapists, advanced visualization, interactive data exploration, and contextualization of clinical and biomechanical data. While other researchers have developed visualization and CDS solutions for physiotherapy, such as Ploderer et al.'s [63] dashboard for visualizing upper limb movement to support rehabilitation and Liakopoulou et al.'s [64] interactive dashboard for monitoring patients' training progress, no known solution is specifically tailored to musician physiotherapy that integrates musician-specific CMA into the diagnostic process.

Additionally, our study contributes to the existing literature by detailing a methodology for requirements elicitation, comprehensively describing the domain of musicians' physiotherapy, and identifying requirements for the successful use of a CDS tool. Our findings also support previous research indicating that HFE is crucial for designing CDS technologies [34,35], emphasizing aspects such as speed, efficiency, user needs anticipation, workflow integration, meaningful alerts, consistency, logical grouping, interface design, and design simplicity [37–40].

In conclusion, successful CDS implementation depends on alignment with clinical workflows, ease of use, and demonstrable benefits in diagnostic accuracy and treatment efficiency. Insights from this study provide a solid foundation for designing a CDS tool for physiotherapists, incorporating CMA for musicians with musculoskeletal demands, aiming to improve patient outcomes and support clinical decision-making. Iterative feedback from domain experts during design and development should ensure the tool addresses real-world problems, is validated through practical application, and is continuously refined based on user insights. The involvement of musicians' physiotherapists and movement scientists from initial design to validation is pivotal.

4.2. Limitations

Despite promising findings, several limitations must be acknowledged. First, the study focused specifically on physiotherapists working with musicians, which may limit the generalizability to other clinical populations. Second, the small sample size of participating physiotherapists and domain experts may not capture the full spectrum of user needs and preferences. Additionally, the diversity of participants in terms of experience and expertise was limited. Third, personalized clinical decision support features considering individual patient characteristics were overlooked. Machine learning algorithms could improve precision and relevance [65]. Finally, the evolving nature of clinical practices and data types presents ongoing challenges for maintaining the tool's relevance. Continuous updates are needed to keep pace with advancements in clinical knowledge and technology, which can be resource intensive. Addressing these limitations in future research will enhance the tool's usability, adaptability, and impact on clinical decision-making.

4.3. Conclusion

This work contributes to HFE, physiotherapy and CDS by combining rigorous research methods with practical insights from domain experts. The proposed process model aids healthcare administrators, designers, developers, and providers in identifying user needs and information for decision-making at point of care. A specialized CDS tool incorporating CMA can significantly enhance physiotherapists' ability to diagnose and treat musculoskeletal conditions in musicians. The tool aims to improve diagnosis accuracy and therapy effectiveness by presenting patient data in an interactive and visual format, enhancing clinical decision-making. It will support visual inspection and interactive analysis, improving the therapist's workflow and ensuring clinical relevance. Such a tool can enhance patient outcomes, reduce injury recurrence, and support musicians' career longevity. Future research should validate the CDS tool's clinical effectiveness, explore advanced analytics, and consider broader applications across various therapeutic domains.

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Conflicts of Interest

None declared.

Authors' contributions

Eduard Wolf conceptualized the study, recruited participants, collected, and analyzed data, and wrote the manuscript. Prof. Dr. Karsten Morisse contributed to the study's conceptualization and reviewed the final manuscript, while Prof. Dr. Sven Meister reviewed and finalized it.

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Supplementary Files

Multimedia Appendixes

User requirements (UR) formulated as user stories based on user needs for decision support.
URL: http://asset.jmir.pub/assets/642b2811143e336d59d2e9bc79e91dfe.docx

Cognitive tasks and the associated strategies, (potential) errors or difficulties, and critical hints of the domain experts.
URL: http://asset.jmir.pub/assets/8323feff3cfd63899f2a36f32c3fbbb8.docx

Key decision requirements (DR), associated information needs and design seeds (S) to support decision-making.
URL: http://asset.jmir.pub/assets/cda88aa09ae7561116a541ae9cee1586.docx