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# PREPARE: Personalised Rehabilitation via Novel AI Patient Stratification Strategies. The Case for Idiopathic Scoliosis During Growth

Carlotte KIEKENS[a,1] , Stefano NEGRINI[b], and the PREPARE Group
[a] *Laboratory of Evidence-Based rehabilitation, IRCCS Galeazzi-Sant'Ambrogio Hospital, Milan, Italy.*
[b] *Department of Biomedical, Surgical and Dental Sciences, University of Milan "La Statale", Milan, Italy*
ORCiD ID: Carlotte Kiekens https://orcid.org/0000-0001-8500-7751
ORCiD ID: Stefano Negrini https://orcid.org/ 0000-0002-1878-2747

**Abstract.** Drafting an Individual Rehabilitation Project requires precise goal-setting based on functional prognosis. However, patient stratification in rehabilitation is often hindered by the complexity of multimodal interventions. The PREPARE Rehab project, a four-year EU Horizon initiative, utilises Machine Learning and Artificial Intelligence (AI) to develop data-driven prediction tools across nine health conditions. This paper focuses on the children with idiopathic scoliosis cohort, utilising a dataset of over 21,000 patients. By standardising data through the Observational Medical Outcomes Partnership (OMOP) Common Data Model (CDM), the project aims to deliver a unified decision-support platform and AI-enhanced stratification models to prevent adult disability and optimise treatment intensity.

**Keywords.** Rehabilitation; Precision Medicine; Artificial Intelligence; Decision Support Systems, Clinical; Scoliosis.

## 1. Introduction

Rehabilitation is a multimodal, person-centred, collaborative process that includes interventions targeting a person's capacity and/or contextual factors related to performance. The goal is to optimise the functioning of people with health conditions experiencing disability [1]. In contemporary rehabilitation medicine, creating an Individual Rehabilitation Project is a complex process that requires an accurate functional prognosis to set realistic, person-centred goals [2]. Unlike acute medical fields, where outcomes are often binary (e.g., mortality or morbidity), rehabilitation focuses on the nuances of functioning and quality of life.

[1] Corresponding Author: Carlotte Kiekens, IRCCS Galeazzi-Sant'Ambrogio Hospital, Via Cristina Belgioioso 173, 20157 Milan, Italy. Email: carlotte.kiekens@isico.it

In the specific context of Idiopathic Scoliosis (IS) during growth, the primary objective of rehabilitation is the prevention of long-term disability, disease progression, and the avoidance of invasive spinal fusion surgery. Currently, clinicians face a significant challenge: the risk of over-treatment (unnecessary bracing or psychological burden) or under-treatment (allowing progression that leads to surgery). While individual clinical predictors (such as the Risser sign or Cobb angle) are well documented, they are rarely integrated into complex, multivariable models that account for the natural history of the disease.

The PREPARE Rehab project (Personalised REhabilitation via novel AI Patient stratification strategies) addresses this gap [3]. This HaDEA-Horizon project, supported by a budget of over 6.5 million euros, represents a massive collaborative effort involving 20 partners across 9 countries over four years. Central to the project's innovation is the use of real-world assemblies of routinely collected data. To maintain data security and privacy, this data is treated in a federated manner, enabling collective analysis without the need to centrally pool or share the raw data. The project utilises a sophisticated technological stack for sharing model results, including:

- The Observational Medical Outcomes Partnership (OMOP) Common Data Model (CDM) standard.
- The Observational Health Data Sciences and Informatics (OHDSI) collaborative network.

By applying prediction and stratification machine-learning strategies to this standardised rehabilitation data, PREPARE aims to deliver an Artificial Intelligence (AI)-based Clinical Decision Support System (CDSS). While this paper focuses on Children with IS (ISICO - Milan, IT), the project encompasses nine distinct rehabilitation cases and high-risk scenarios across Europe, including also:

- Hand and wrist disorders (Rotterdam, NL)
- Intermittent claudication (Nijmegen, NL)
- Lower limb loss (Ljubljana, SI)
- Parkinson's disease and Parkinsonism (Ancona, IT)
- Hip and knee replacement for osteoarthritis (Milan, IT)
- Temporomandibular joint disorders (Milan, IT)
- General spine disorders (Eurospine, CH)
- Hypertension leading to rehabilitation needs (Thessaloniki, GR)

This multi-condition approach ensures that the developed AI strategies are robust, scalable, and capable of improving the quality of life for diverse, complex patient populations. The PREPARE CDSS will empower clinicians and patients to make more precise, data-driven decisions for nine complex health conditions, with IS serving as a primary use case.

## 2. Methods

The methodology of the PREPARE project is rooted in scalability, standardisation, and high-level data science.

Data Standardisation: To facilitate multi-centre collaboration, results are shared using the OMOP CDM, enabling heterogeneous data from various clinical sites to be analysed through a unified lens.

Intervention Description: To address the "black box" problem in rehabilitation, interventions for the various clinical cases were meticulously catalogued using the GUIDE-Rehab (Reporting Guideline for Intervention Description in Rehabilitation) framework [4]. In addition, we investigated whether the rehabilitation data shared common characteristics across different health conditions and care settings within PREPARE. Therefore, seven (of the nine) rehabilitation-oriented clinical databases were analysed using the International Classification of Functioning, Disability and Health (ICF) framework. Variables were categorised as outcomes, modifiers, or baseline measurements. Commonalities and differences across data domains were identified through iterative consensus meetings among PREPARE partners [5].

Data for the scoliosis arm of the study were extracted from a specialised tertiary care database, including:

- Demographic details and clinical outcomes.
- Patient-Reported Outcome Measures (PROMs) collected at 4–6 months intervals.
- Comparative natural history data from untreated patients to act as a baseline for Machine Learning (ML) models.

The project employs ML strategies to identify patterns in patient stratification and treatment response. These strategies are validated through demonstration studies to ensure that the AI outputs are clinically actionable and relevant to the treating physician.

## 3. Results

The analysis of the case data on "Children with IS" is supported by a robust dataset that represents one of the largest specialised cohorts in the field. We analysed data from 21,026 patients (16,438 females; mean age 12.6 ± 2.58 years). The cohort presented a mean Cobb angle of 25.6° and a mean Angle of Trunk Rotation (ATR) of 8.3°. Treatment modalities included bracing for 9,704 patients and Scoliosis Specific Exercises (SSE) for 7,854 patients. Reported Quality of Life mean scores were ISYQOL (n=6,377) 61.60 and SRS-22 (n=9,174) 4.1.

### *3.1. Intervention description*

To ensure descriptive precision, rehabilitation interventions were characterised according to the GUIDE-Rehab framework [4]. While the aggregate of these programs spanned the full spectrum of the classification system, individual programs lacked comprehensive coverage. Interventions primarily addressed 'Body Functions and Structures' (n=6), whereas 'Participation' and 'Contextual Factors' received less attention. Notably, the application of similar components—such as bracing and SSE—varied across the theoretical frameworks of the interventions. Additionally, pharmacological and surgical components were found to be fundamental elements of the holistic rehabilitation process.

### *3.2. Commonalities in rehabilitation data across seven databases*

The comparative analysis of the included rehabilitation databases revealed significant heterogeneity regarding data granularity and categorical focus. While outcomes such as

pain levels and quality of life were consistently tracked, participation-centric metrics and discharge statuses were notably underrepresented. Modifiers were primarily dominated by pharmacological, orthotic/prosthetic, and exercise-based interventions. Furthermore, although all seven databases provided standardised baseline data on diagnosis and demographics, there was no consensus regarding the documentation of functional independence, specifically in gait and daily living activities [5].

### *3.3. Envisioned final results*

The final results of the project will be

1. A Decision-Support Platform: A federated platform for secure, big-data access.
2. Stratification Models: AI-enhanced tools that predict patient progression and treatment response.
3. Regulatory Roadmap: A strategic guide for the integration of these tools as Software-as-a-Medical-Device (SaMD).

## 4. Discussion

The PREPARE Rehab project demonstrates that integrating AI into rehabilitation is not merely about computational power, but about contextualising data. By merging clinical data with socio-behavioural research, the models account for the "whole person" rather than just the spine.

A significant strength of this approach is the use of the OMOP CDM, which allows the AI to learn from diverse datasets that were previously siloed, thereby providing a more holistic understanding of the determinants of treatment.

This study validates the GUIDE-Rehab reporting guideline as a rigorous framework for characterising the complexity of rehabilitation interventions. Through its application to the seven heterogeneous pilot cases, including IS, within the PREPARE project, we successfully translated diverse clinical practices—spanning the continuum from acute surgical recovery to chronic care—into a cohesive, comparable architecture. Our results demonstrate a vital synergy between GUIDE-Rehab and the ICF. ICF standardises health outcomes, GUIDE-Rehab serves as the 'missing link' by elucidating intervention theories and active components. Such transparency is foundational for the AI-driven stratification and predictive modelling at the core of the PREPARE initiative. To address the resource-intensive nature of manual reporting, future efforts should prioritise the automated extraction of these clinical 'ingredients' via Natural Language Processing and their integration into electronic health records.

The comparison of variables across the included databases showed that, despite some overlapping domains, rehabilitation data collection remains fragmented. This fragmentation highlights an urgent need for standardisation. While biomedical data is well-represented, the systematic integration of psychosocial and contextual factors remains insufficient. Addressing these gaps is a prerequisite for developing sophisticated predictive models and delivering truly personalised rehabilitation strategies.

However, the transition from data models to clinical practice requires a rigorous regulatory framework. Developing a Software-as-a-Medical-Device roadmap is essential to ensure these AI tools are used safely and ethically in a clinical setting.

## 5. Clinical Implications or Impact

The impact of the PREPARE project on the clinical management of IS is twofold:

Precision Rehabilitation: Clinicians will be able to move away from "one-size-fits-all" protocols. By using AI-driven stratification, a physician will identify patients at high risk of progression early, enabling more aggressive intervention (e.g., bracing) while sparing low-risk patients from unnecessary treatment.

Improved Long-term Outcomes: By optimising the Individual Rehabilitation Project during growth, the project aims to significantly reduce the incidence of adult disability and the need for surgical fusion.

Ultimately, the PREPARE framework provides a blueprint for applying AI to other complex health conditions, facilitating a move toward a more reliable, personalised, and holistic healthcare system.

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