European advances in digital rheumatology: explainable insights and personalized digital health tools for psoriatic arthritis

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eClinicalMedicine
2025;84: 103243
Published Online xxx
https://doi.org/10.1016/j.eclinm.2025.103243

Summary

The shift from traditional to technology-based diagnosis and management of psoriatic arthritis (PsA) represents a significant evolution in patient care. Traditionally, PsA was diagnosed and managed through clinical evaluations, physical examinations, and basic imaging techniques. With the evolution of digital technologies, the PsA care is transforming, giving rise to the field of digital rheumatology. In this vein, Europe has invested in research initiatives, like iPROLEPSIS, that could accelerate this transformation and redefine PsA care within a digital world. In this *Viewpoint* we present the current clinical PsA landscape, highlight the PsA patients' interaction with the digital world, and showcase the novel iPROLEPSIS digital offerings. The latter scaffold digital rheumatology by identifying PsA key drivers. Moreover, they support personalized PsA risk prediction and improve early PsA detection. Furthermore, they enable precise PsA treatment strategies and digital therapeutics within a novel digital health ecosystem.

Keywords: Psoriatic arthritis; Digital rheumatology; iPROLEPSIS European research initiative; Novel digital biomarkers; Explainable AI models; Digital therapeutics

Introduction

Digital health applications are revolutionizing medical practice.[1–3] They are particularly beneficial for chronic diseases with straightforward treatment targets, like hypertension, which can be monitored using biosensors.[4] However, their effectiveness in managing diseases with more complex treatment targets, such as psoriatic arthritis (PsA), remains unproven. PsA is a multifactor disorder characterized by aberrant immune responses in genetically susceptible individuals coupled with the presence of additional (environmental, occupational, lifestyle) factors, including changes in

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microbiota/diet.[5,6] In this vein, a multiscale-multifactorial disease model is needed to shed light upon the health-to-PsA transition and contribute to the efficient clinical and self-management of the disease. Despite years of effort towards such a direction, this need remains unmet.[7]

Over the past decade, digital advancements have significantly influenced rheumatology, targeting the improvement of diagnostics, patient monitoring, and personalized treatment strategies. The digital rheumatology landscape encompasses tools like electronic health records (EHRs), telemedicine, symptom checkers, and mobile health. Emphasis was placed on using machine learning (ML) models to assist in early diagnosis of rheumatoid arthritis, leveraging large-scale EHR data to identify patterns in disease progression.[8] However, factors such as access to care, noise in the EHR data, missingness, and indication bias pose significant hurdles. Moreover, surveys highlight global challenges in tele-rheumatology,[9] primarily due to organizational issues, such as training needs, high costs, and reimbursement gaps, rather than clinical barriers. So far, significant efforts have been made to develop digital health applications based on simplified patient-reported outcomes (PROs), yet focusing on rheumatoid arthritis patients.[10–12] However, these tools often capture only a snapshot of the disease spectrum. Research indicates substantial room for improvement, particularly in creating tools for comprehensive self-evaluation of disease activity and enhancing patient-physician interaction.[13] Wearable devices combined with smartphone apps have also been developed,[14,15] though they are rarely used to monitor disease activity. Transferability to the case of PsA and evaluating PROs via smartphone apps remain crucial.

In recent years, Europe has significantly invested in digital advancements in rheumatology, recognizing the potential of AI, wearable technologies, and data-driven healthcare to improve patient outcomes. In this viewpoint, we provide insights into how digital technology supported by Europe will offer new opportunities for PsA understanding and management within an evolving digital rheumatology world.

Current clinical PsA landscape

PsA is a chronic immune-mediated inflammatory disease, affecting the peripheral and axial skeleton alongside skin complications, with a severe impact on patients' quality of life; it is estimated that 1–2% of the general population has PsA.[16] PsA is associated with psoriasis (PsO) and up to 30% of people living with PsO, i.e., at least 100 million people worldwide are expected to develop PsA.[17] As a chronic inflammatory disease, PsA involves immune system dysregulation transitions from phenomenologically healthy towards a pro-inflammatory state transiting to an acute inflammatory phase. Although the mechanisms of inflammation that allow for the progression of PsA are well understood, the mechanisms that tip the balance of immunity to initiate inflammation are not understood. It is difficult to diagnose PsA at an early stage due to the heterogeneity in disease manifestation and lack of diagnostic tests.[16] Much of this difficulty relates to establishing the presence of inflammation in joints and tendon-entheses. Musculoskeletal inflammation is the main hallmark for diagnosing PsA in PsO patients,[18] and, also, for disease exacerbations in PsA. Nevertheless, evidence from the literature suggests that a single variable does not adequately predict the transition from PsO to PsA, but rather that a complex interaction of multiple features underlies this evolution.[19]

Clinical examination is currently the most common way of assessing inflammation. However, there is limited use of quantitative screening strategies for PsA development among PsO patients, as it requires specialist training for the general practician and dermatologist. While screening questionnaires have been implied, their gain in identifying those who have inflammation is limited.[20] Currently, no established biomarkers or clinical algorithms can predict PsA onset and correlate it with the development of bone or joint damage in patients with PsA.

Recently, new pharmaceutical treatments and recommendations for PsA have emerged,[21] targeting diverse molecular pathways. Drugs licensed for PsA include: (1) conventional synthetic (cs) disease-modifying antirheumatic drugs (DMARDs), such as methotrexate (MTX), sulfasalazine and leflunomide; (2) biological (b) DMARDs targeting tumor necrosis factor (TNF), the interleukin (IL)-$_{12/23}$ or IL-$_{23}$ pathway, and the IL-$_{17}$A and IL-$_{17}$A/F pathway; and (3) targeted synthetic (ts) DMARDs that inhibit Janus kinases or phosphodiesterase 4. For mild PsA, non-steroidal anti-inflammatory drugs are recommended for short-term monotherapy, while oral glucocorticoids are generally avoided. In cases of peripheral arthritis, early initiation of csDMARDs is advised, with methotrexate as the preferred option. If treatment goals are not met, a bDMARD should be introduced, without prioritizing a specific mode of action. For PsO-related symptoms, bDMARDs targeting IL-$_{23p40}$, IL-$_{23p19}$, IL-$_{17}$A, and IL-$_{17}$A/F inhibitors are recommended. Despite the available pharmaceutical treatments, the overall response rates still have not shown improvement.[22] Early non-pharmacological treatments, such as physical therapy, psychosocial interventions, self-management programs, and lifestyle adjustments, are considered potentially beneficial. However, their regimen should be personalized to each patient's needs and disease stage. So far, fragmentation has been noticed in the PsA models of care, affected by the

different referral pathways that depend on the severity of the disease at onset and the rapidity with which patients seek medical attention.

Living with PsA in a digital world

Modern lifestyles, characterized by increased sedentary behaviour, poor dietary habits, and high stress levels, have significantly impacted patients living with PsA. Historically, PsA patients often engaged in more physically active routines, which naturally helped manage symptoms through regular movement and exercise. However, the shift towards a more sedentary lifestyle has exacerbated PsA symptoms. This sedentary behaviour is linked to increased inflammation and joint stiffness, worsening the overall disease burden.[19] Additionally, the rise in high-stress occupations and poor dietary habits, including the consumption of processed foods, has further contributed to the deterioration of PsA symptoms.[23] These lifestyle changes have also led to higher rates of obesity and cardiovascular diseases among PsA patients, complicating their condition and treatment.[18]

From the PsA patient's perspective, nowadays, several needs remain unmet despite advancements in medical treatments. Many patients continue to struggle with the daily management of pain and fatigue, which significantly impacts their quality of life. There is also a notable lack of support systems that address the emotional and psychological toll of living with a chronic condition. Patients often report feelings of isolation and misunderstanding, underlying the need for better mental health support and community resources. Furthermore, there is a demand for more personalized treatment plans that consider the unique lifestyle factors and comorbidities of each patient.[22,24] Addressing these unmet needs is crucial for improving the overall well-being and quality of life for PsA patients. This notion is reflected in the latest recommendations for PsA assessment centred on a holistic consideration of disease activity, physical functioning, and impact from a patient perspective, implementing shared decision-making.[25] Although treat-to-target in PsA management is suggested,[25] requiring standardized assessments, inconsistent clinical decision-making, and lack of regular disease activity evaluations pose major obstacles. Clearly, there is a need for the patient to participate in disease management, not only in treatment decision-making but also in disease activity assessment, incorporating patient-reported outcomes (PROs). The latter include patients' self-assessment of disease activity, pain, physical function, remission, flare, and self-management reports.

Several global initiatives have emerged to address the aforementioned needs, focusing on developing digital tools that enhance the monitoring and management of rheumatic diseases, including PsA. These efforts aim to bridge gaps in standardized assessments and PROs by integrating advanced technologies that support self-evaluation, treatment optimization, and improved patient-physician communication. Some of the key worldwide initiatives in this field include:

1) The Psorcast research study (https://psorcast.org) aimed at enhancing the early detection and management of PsA. Leveraging a smartphone application for digital symptom data collection through active tests (i.e., photos of hand, feet, and psoriatic skin areas, 30-s walk test, and digital jar opener) and PROs, Psorcast aimed to predict treatment response and flare-remission cycles.
2) The IHI-AUTOPIX European-funded project (https://www.autopix-project.eu) aims to enhance the diagnosis, treatment decisions, and monitoring of major rheumatic diseases, specifically rheumatoid arthritis, PsA, and axial spondylarthritis, by leveraging artificial intelligence to make clinical imaging more interpretable and accessible. More specifically, the key goals include: i) developing AI and machine learning tools to transform unstructured medical images into quantitative biomarkers, ii) creating accessible imaging strategies, such as remote monitoring and robotic-powered point-of-care ultrasound exams, to mitigate the shortage of qualified personnel and improve diagnostic precision, and iii) enhancing the sustainability and efficiency of imaging, minimizing the burden associated with imaging procedures, and making interpretation more efficient and objective.
3) The IMI2 IDEA-FAST European-funded project (https://idea-fast.eu) aims to identify and validate digital biomarkers that can reliably measure fatigue, sleep disturbances, and daily functioning in people with neurodegenerative disorders and immune-mediated inflammatory diseases, including rheumatoid arthritis. Physical activity and mobility data, sleep patterns, and cognitive and behavioral data collected via wearable devices and smartphone applications, along with self-reported fatigue levels, IDEA-FAST tries to define new digital endpoints that can be applied in clinical trials and routine care.

Within a similar context, Europe has funded a new European Research and Innovation Programme within the Horizon Europe Framework, namely iPROLEPSIS (2023–2027, www.iprolepsis.eu). Unlike other initiatives, iPROLEPSIS is specifically designed to investigate the health-to-PsA transition, advancing both diagnostic approaches and personalized care options for individuals with psoriatic arthritis. In contrast, Psorcast relies exclusively on active tests, whereas iPROLEPSIS integrates passive data collection for continuous disease tracking. IHI-AUTOPIX focuses solely on imaging data and does not directly address PsA, while iPROLEPSIS

takes a comprehensive approach, incorporating multiple data modalities to enhance understanding of disease progression. Similarly, IMI2 IDEA-FAST concentrates on digital biomarkers for specific symptoms rather than targeted monitoring of PsA and its evolution, as iPROLEPSIS does. As explained next, these distinctions position iPROLEPSIS as a holistic and specialized initiative addressing unmet needs in PsA diagnosis and patient management.

The iPROLEPSIS digital offerings

To address the aforementioned shortcomings and needs, the iPROLEPSIS project sets an overarching aim to explain the health-to-PsA transition and advance PsA diagnosis and care by adopting a patient-centred perspective. It follows a trustworthy and inclusive approach to orchestrated explainable AI (xAI) development,[26] based on multidisciplinary expertise and broad stakeholder engagement. We anticipate that via iPROLEPSIS, the key actionable factors leading to personalized PsA inflammation risk assessment and disease progression prognosis will be identified, guiding novel personalized prevention interventions.

A key element of iPROLEPSIS is that it operates at the intersection of advanced technology and personalized healthcare. The iPROLEPSIS concept and digital offerings (Fig. 1) are summarized below:

A. **Knowledge discovery from extended, multi-sourced digital databases**. Grounded on a dual data collection process, it acquires extended knowledge by bringing together retrospective with prospective data. In particular, the retrospective dataset is formed from data already acquired from previous studies and are accessible by iPROLEPSIS stakeholders. These data come from multiple sources, e.g., real-world data (RWD) from human studies, including medical, clinical, well-being, and lifestyle data, providing a holistic sensing of the various manifestations of PsA. Additionally, prospective data are acquired via the four iPROLEPSIS well-powered multicentre clinical human studies. The latter have 22–36-month duration with a follow-up phase and incorporate clinical and dynamic data from smart sensors and apps (Table 1) used by the iPROLEPSIS community, including more than 4000 participants. iPROLEPSIS will explore the possibility of a partnership with another European-funded project, namely HIPPOCRATES,[22] to incorporate extended digital data drawn from a subset of the 25,000 PsO patients recruited to the HIPPOCRATES Prospective Observational Study (HPOS) for evaluation and validation.

B. **Explainable insights in PsA via xAI-based data mining and predictive modelling.** The wealth of diverse acquired data feeds into a sophisticated data harmonization and xAI-based data mining and modelling module.[26] Data harmonization is used to standardise the structure and content of all available data and enable efficient analyses of the harmonized data to produce reliable evidence. The Observational Medical Outcomes Partnership (OMOP) Common Data Model[27] is adopted for data

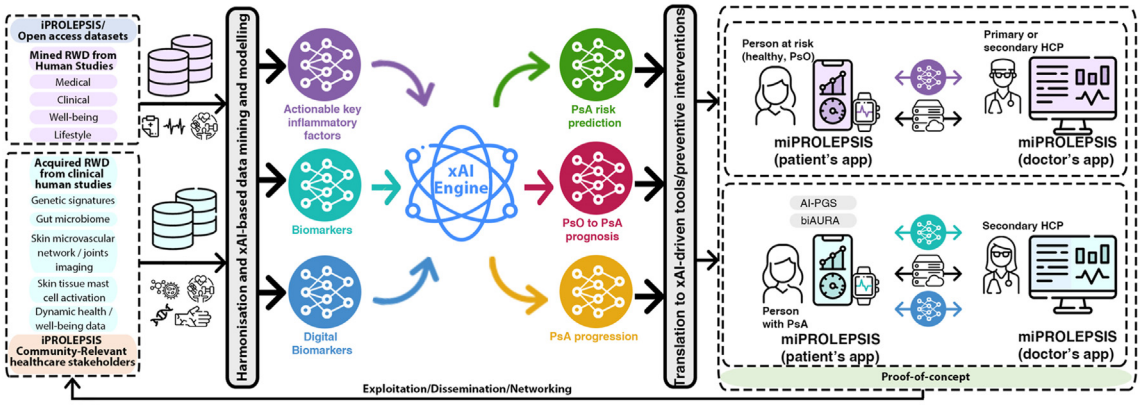

Fig. 1: **The trajectory from research to innovation and progress in PsA after iPROLEPSIS. The acquisition of currently available retrospective data leads, via harmonization and xAI-based data mining and modelling, to the identification of actionable key inflammatory factors and the introduction of new clinical/digital biomarkers. These feed an xAI-based engine that outputs novel PsA risk prediction models, PsO to PsA prognosis models, and PsA progression models. By the time the iPROLEPSIS project is completed in 2027, we aim to have refined these models and translate them to xAI-driven tools/preventing interventions, validated in multiple, large cohorts via prospective multicentre clinical studies and partnerships, informing the related stakeholders. This approach should yield new ways of understanding the health-to-PsA pathway and clinically and self-managing the disease.** PsA, psoriatic arthritis; PsO, psoriasis; RWD, real world data, xAI, explainable artificial intelligence; HCP, healthcare professional, AI-PGS, AI-based personalised serious game suite app; biAURA, binaural-based app for pain soothing and sleep quality enhancement; miPROLEPSIS: the iPROLEPSIS core app.

Digital measure(s)	Data source	Target(s)
Joint range of motion scores	Videos captured from smartphone's camera	Joint stiffness and pain (PSAID-1, PSAID-5)
		Disease activity scores (MDA, PASDAS, DAPSA)
		Disease impact score (PEST)
		Disease change (GCRQ)
Joint swelling score	Photographs captured from smartphone's camera	Swollen Joint Count (SJC66)
Nail psoriasis detection	Photographs captured from smartphone's camera	CASPAR-Nail dystrophy
Typing dynamics	Typing events from smartphone's keyboard	Disease activity scores (DAPSA, PASDAS)
		Joint discomfort (PEST)
		Pain (PSAID-1)
		Fatigue (PSAID-2)
		Hand function (66/68JC)
Physical activity level (sedentary/light/MVPA) and gait characteristics (Coarse type)	Data from smartphone's IMU sensors	Disease activity scores (MDA, DAPSA, PASDAS)
		Disease impact scores (PSAID, PEST)
		Pain (PSAID-1)
		Functional capacity (PSAID-5)
		Hand function (66/68JC)
Physical activity level (sedentary/light/MVPA) and gait characteristics (Fine type)	Data from smartwatch's accelerometer sensors	Disease activity scores (MDA, DAPSA, PASDAS)
		Disease impact scores (PSAID, PEST)
		Hand function (66/68JC)
		Pain (PSAID-1)
		Sleep (PSAID-7)/Skin (PSAID-3)
		Functional capacity (PSAID 5)
		Morning stiffness (BASDAI-5)
Intestinal motility scores	EGG and bowel sound signals acquired from PLUX's smart belt	Disease activity (MDA)
		Gastrointestinal health status (Crohn's Disease Activity Index, Mayo score)
Digital inflammation response index	BBI from smartwatch's PPG sensor(s)	DAPSA-CRP
Garmin's smartphone all-day metrics	Produced by the proprietary algorithms of Garmin processing the sensors of Garmin's smartwatches	Disease activity scores (MDA, DAPSA, PASDAS)
Body battery		Pain (PSAID-1)
Stress level		Fatigue (PSAID-2)
Sleep measures		Functional capacity (PSAID 5)
Wellness measures		Sleep (PSAID-7)/Skin (PSAID-3)
		Morning stiffness (BASDAI-5)
		Happiness (European social survey C1)
		Joint discomfort (PEST)

PSAID, PSoriatic Arthritis Impact of Disease; MDA, Minimal Disease Activity; PASDAS, Psoriatic ArthritiS Disease Activity Score; DAPSA, Disease Activity index for PSoriatic Arthritis; PEST, Psoriasis Epidemiology Screening Tool; CASPAR, ClASsification criteria for Psoriatic ARthritis; SJC, Swollen Joint Count; JC, Joint Count; MVPA, Moderate to Vigorous Physical Activity; IMU, Inertial Measurement Units; EGG, Electrogastrogram; PPG, Photoplethysmography; BBI, Beat-to-Beat Interval; CRP, c-Reactive Protein; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index.

Table 1: **Summary of the digital measures along with the respective data sources and targeted clinical and patient-reported outcomes.**

harmonization. Then, xAI-based data mining and orchestrated multiscale and multifactorial modelling approaches[26] are applied to the harmonized data to identify actionable key inflammatory factors and introduce new clinical/digital biomarkers (dBMs) (Table 1). The latter relate to a wide range of PsA manifestations. These include changes in the skin microvascular network and molecular tissue changes at the entheses captured via optoacoustic imaging with Raster-Scan Optoacoustic Mesoscopy (RSOM)[28] and Multispectral Optoacoustic Tomography (MSOT).[29] Joint inflammation is captured by videos and photos from a smartphone camera. Tissue mast cell activation is captured by histopathology image analysis. Alterations in health and well-being due to inflammation in daily life are captured by wearables, wellness measures, and PROs (Table 1). Additional information is captured

on several fronts, namely: a) sampled genetic signature, b) gut microbiome alterations through stool analysis, c) environmental and pollution data via location-aware web services, and d) occupational stressors from self-reported data. The insights generated by this module inform an xAI-based engine that predicts PsA inflammation risk, transition prognosis from PsO to PsA,[30] and the progression of PsA itself. These predictions are translated into tangible tools and actions through xAI-based tools and related preventive intervention modules.

C. **Personalized digital health tools for PsA-related stakeholders.** One of the project's key deliverables is the miPROLEPSIS app, designed to empower individuals at risk of PsA and those already diagnosed (current version available at https://play.google.com/store/apps/details?id=com.iprolepsis.patient.app&hl=en). It will allow users to quantitatively track their PsA risk, receive explainable insights, and access personalized projections of PsA activity status, combined with their PROs e-diary. Healthcare professionals (HCPs), both non-experts like general practitioners and experts, such as rheumatologists and dermatologists, will benefit from specialized versions of the miPROLEPSIS app. They can identify at-risk individuals, track patients' status, view projections of PsA evolution, and tailor treatment plans accordingly. In addition, the miPROLEPSIS app will include functionalities for personalized intervention to prevent and reduce inflammation. In particular, a lifestyle AI-driven recommendation engine will be available to the user to facilitate healthy nutrition and an active lifestyle. This will be based on an ensemble of AI agents, ontologies, fuzzy systems, and an inference mechanism. It will effectively combine the experts' knowledge with the collected patients' data and export a set of appropriate recommendations based on the personalized needs of the users. Moreover, an AI-based personalised serious game suite (AI-PGS app) will offer user-adapted gamified activities. This suite includes: a) ExerGames, b) DietaryGames, c) EmoGames, d) BreathingGames, e) NoPainGames, and f) SensorimotorArtGames. These serious games aim to improve movement, fitness, and mood, using biofeedback and art for stress and pain relief. Additionally, a pain soothing and sleep quality improvement intervention (biAURA app), will use binaural beats through earphones to improve sleep by inducing slow brain waves. It will monitor sleep data (heart rate, movement, temperature) from smart sensors to detect and address sleep disturbances. The biAURA app can also positively affect stress/pain/fatigue management during day.[31] The clinically validated tools and outcomes of iPROLEPSIS will be disseminated to stakeholders, e.g., Group for Research and Assessment of Psoriasis and Psoriatic Arthritis (GRAPPA)[18] and GRAPA-EU,[32] the European Alliance of Associations for Rheumatology (EULAR),[21] and the wider iPROLEPSIS community for broader impact and utilization.

The aforementioned iPROLEPSIS concept is materialized via the architecture and data flow depicted in Fig. 2. Due to the nature of the PsA, iPROLEPSIS implements highly interdisciplinary research and development activities that are organized in an architecture deployed with multiple sub-systems and components (Fig. 2-(a–c)), taking into consideration the health-to-PsA transition phases (Fig. 2-(0–4)). It involves the iPROLEPSIS community (Fig. 2-(0, 1): Preclinical Stage), identified people at PsA risk (Fig. 2-(2, 3): Prodromal Stage), diagnosed people with PsA assisted with symptoms monitoring (Fig. 2-(4): Clinical Stage) and personalized preventive interventions (Fig. 2-(5): Clinical Stage). iPROLEPSIS outcomes would increase physicians' proficiency, provide new healthcare recommendations (Fig. 2-(6)), and increase people's health literacy and empowerment (Fig. 2-(7)).

From iPROLEPSIS's initial conception, patients' voices are always present and amplified via the formed "patient researchers panel". Utilizing user-centred co-creation and agile scrum methodology,[33] iPROLEPSIS involves the constant engagement of patients and stakeholders in design, development, and testing processes. Agile principles, i.e., collaboration, iterative progress, adaptability, and continuous improvement through regular feedback and team communication, are adopted by the iPROLEPSIS consortium, allowing for shorter development cycles ("Sprints") to accommodate ethics and evolving user needs. This incremental approach ensures that technology aligns with real user needs and achieves high acceptability and satisfaction.

The models and tools developed within iPROLEPSIS, arising from a wide range of retrospective data, will be validated in multiple, large cohorts through prospective multicentre clinical studies and partnerships, ensuring the reliability and generalizability of the findings across diverse patient populations from Europe (e.g., Greece, the UK, the Netherlands, Portugal). Under the "P4 medicine" (Preventative, Predictive, Personalized, and Participatory) approach, which involves health professionals, caregivers, and people at risk/living with PsO/PsA, iPROLEPSIS will consist of real-world data collection mechanisms and a powerful hybrid xAI-based decision support system to provide efficient and clinically validated personalized treatment and care plans for PsA patients. We will report specific metrics for PsA classification performance (e.g., accuracy, sensitivity, specificity, F1 score, ROC-AUC), PsA symptoms prediction (e.g., calibration plot, net benefit), the efficiency of new digital biomarkers (e.g., correlations with standardized clinical scores and care practices), and user

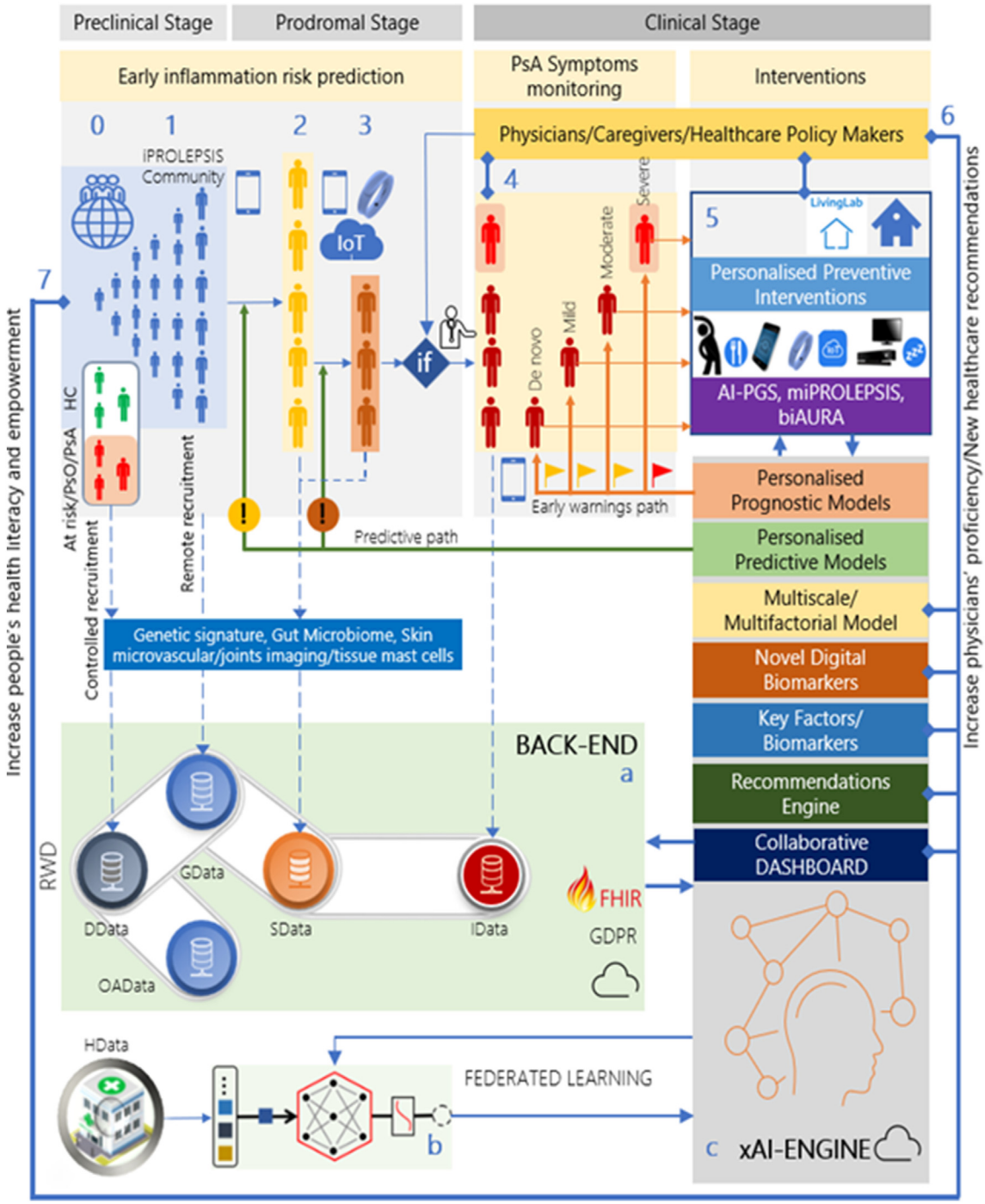

Fig. 2: **iPROLEPSIS system architecture (a: Back-end; b: Federated learning from historical data at hospitals; c: xAI-Engine components), and data flow across health-to-PsA stages (0: healthy→4: PsA) involving the iPROLEPSIS community (0, 1), identified people at PsA risk (2, 3), diagnosed people with PsA assisted with symptoms monitoring (4) and personalized preventive interventions (5). iPROLEPSIS outcomes would increase physicians' proficiency, provide new healthcare recommendations (6), and increase people's health literacy and empowerment (7).** #Data: H, Historical; OA, Open Access; D, Development; G, General; S, Specific; I, Intervention. HC, Healthy Controls; FHIR, Fast Healthcare Interoperability Resources; GDPR, General Data Protection Regulation.

experience (e.g., System Usability Scale). Moreover, the EU MAFEIP tool (https://tool.mafeip.eu) will be adopted to evaluate the cost-effectiveness of the iPROLEPSIS, ensuring that the findings can be effectively integrated into routine clinical care to address the unmet needs of PsA patients.

Overview and the way forward

Europe has been actively developing policies to address chronic rheumatic diseases within the framework of digital rheumatology. The EULAR has been at the forefront, promoting the integration of digital health technologies to improve patient outcomes, emphasizing the importance of PROs and the use of digital tools to enhance patient engagement and adherence to treatment protocols.[21,34] Incorporating advanced digital technologies, such as wearable devices, smartphone apps, and xAI-driven data mining and modelling, within research initiatives presents a unique opportunity to propel the field of PsA research forward and utilize this technology for evidence-based care within the digital rheumatology perspective.[34]

Advancements in digital rheumatology are increasingly shaping the way PROs contribute to clinical decision-making and personalized care. By leveraging multi-sourced RWD, researchers and clinicians can develop multidimensional, longitudinal measures that provide a more comprehensive understanding of disease progression in natural settings. These approaches help uncover complex patterns that may improve early diagnosis, treatment optimization, and long-term PsA management. To maximize the potential of these advancements, digital health solutions must optimize the extraction of vital clinical and behavioral data from patient cohorts, shedding light on the factors that underpin the health-to-PsA transition. Developing xAI-based diagnostic and prognostic tools can also enhance predictive capabilities, providing a foundation for personalized interventions and treatment strategies.

Beyond individual research initiatives, the broader integration of PROs into routine clinical practice has the potential to enhance patient engagement, refine therapeutic strategies, and improve healthcare outcomes. By incorporating xAI-driven analytics, wearable technologies, and mobile health applications, PROs can facilitate continuous monitoring, allowing for timely interventions and more adaptive treatment approaches. Additionally, large-scale validation efforts across diverse patient populations ensure these tools are reliable, generalizable, and effectively implemented in real-world healthcare settings to address the unmet needs of PsA patients. As digital health solutions continue to evolve, refining PROs and AI-assisted disease monitoring will play a crucial role in bridging the gap between research and clinical application, ultimately leading to more precise, patient-centred care in rheumatology.

While we outline an integrated research initiative for PsA within digital rheumatology, we also encourage future research to further deepen and extend its core pillars. To begin with, the potential of xAI-based model generalization and clinical translation of human-centric AI could be further explored.[35] Moreover, adopting knowledge transfer by utilizing or refining large-scale, general-purpose foundation models with limited data or investigating training methods like model distillation or contrastive learning tailored for low-data scenarios may be proven efficient alternatives. Finally, exploring the potential of digital health tools in digital rheumatology as digital therapeutics[36] is important. The exploration must consider obstacles, such as the absence of a unified regulatory framework, concerns regarding trust and security, and reimbursement policies. Addressing such challenges could facilitate the integration of digital solutions into clinical practice. Digital health tools could emerge as a novel therapeutic modality for preventing, managing, or treating chronic, behaviour-modifiable, rheumatic diseases.

Contributors

L.J.H. conceived the article, wrote the first draft, and reviewed all subsequent drafts and the final version; S.B.D. reviewed all drafts and provided substantial contributions to the content and design of the article; V.C. S.H, G.A., G.D., I.K., and H.S. provided technical insights; A.K., N.-A.F., F. L.-S., T.D., A.M.R., L.C.C., J.L., and I.T. provided clinical insights. All authors reviewed and accepted the final version of the paper and agreed to the decision to submit it. All authors reviewed and accepted the final version of the paper, were not precluded from accessing data in the study, and they accepted responsibility to submit for publication. LJH and SBD have accessed and verified the data.

Declaration of interests

The authors declare no competing interests.

Acknowledgements

The authors wish to acknowledge all members of the iPROLEPSIS consortium, comprising of partners from the ARISTOTLE UNIVERSITY OF THESSALONIKI (Greece), ERASMUS UNIVERSITAIR MEDISCH CENTRUM ROTTERDAM (The Netherlands), UNIVERSITY OF OXFORD (UK), FACULDADE DE MOTRICIDADE HUMANA (Portugal), THE HEBREW UNIVERSITY OF JERUSALEM (Israel), TECHNISCHE UNIVERSITAET MUENCHEN (Germany), CENTER FOR RESEARCH & TECHNOLOGY HELLAS-CERTH (Greece), STICHTING CICERO-COLLECTIEF INITIATIEF VOOR CREATIEF EN EDUCATIEF REUMA ONDERZOEK (The Netherlands), SOCIEDADE PORTUGUESA DE REUMATOLOGIA (Portugal), NETCOMPANY-INTRASOFT SA (Luxembourg), AINIGMA TECHNOLOGIES (Belgium), SMARTSOL SIA (Latvia), DBC EUROPE (Belgium), PLUX - WIRELESS BIOSIGNALS S.A. (Portugal), and WELLICS LTD (UK). iPROLEPSIS has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101095697. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or European Health and Digital Executive Agency. Neither the European Union nor the European Health and Digital Executive Agency can be held responsible for them. Moreover, L.J.H. acknowledges support from Khalifa University of Science and Technology, Abu Dhabi, UAE, Provost's Office Grant. The funding sources had no role in the writing of the manuscript or the decision to submit it for publication.

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