Application for the GRAPPA pilot research grant 2025 for the rheumatology-dermatology collaborative project

# Monitoring Outcomes, Variability, and Evolution in PsOriatic Disease using Functional Activity and Sensor-based Technology (MOVE-PsO-FAST)

Recruiting an inception cohort of patients across the spectrum of psoriatic arthritis to identify movement phenotypes associated with transition to PsA with an overarching aim of developing a scalable and specific screening tool to augment contemporary approaches.

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**Scientific abstract**

Psoriatic disease, encompassing psoriasis and psoriatic arthritis (PsA), is a chronic inflammatory condition affecting the skin, joints, and systemic health. Disease progression from psoriasis to PsA occurs in approximately 1 in 3 of patients and is often accompanied by musculoskeletal symptoms such as pain, fatigue, and stiffness—factors that all impair movement and physical function. Diagnostic delays, reported in up to 50% of PsA cases, exacerbate irreversible joint damage and functional impairment. Current screening tools rely on self-report questionnaires and lack specificity, leading to referral bottlenecks, poor uptake, and suboptimal identification of individuals at risk. Wearable sensors, such as accelerometers, provide an innovative solution by passively and continuously measuring human behaviours such as physical activity and sleep. These devices offer objective and sensitive metrics that can augment traditional self-reported questionnaires. Recent advances highlight the utility of wearable technology in identifying subtle movement and physiological changes associated with prodromal and progressive disease states, particularly in Parkinson's disease. Preliminary work from our team has identified an association between lower device-measured physical activity and risk of incident PsA in individuals with psoriasis. This study will establish an inception cohort of 200 participants spanning the continuum of psoriatic disease; from healthy controls, psoriasis, psoriasis at risk of transition to PsA, and confirmed PsA. Comprehensive assessments, including clinical, self-report, ultrasound, and wearable-derived measures will characterise the distinct movement phenotypes across the spectrum of psoriatic disease. Time-series machine learning models will be developed and validated to identify psoriatic disease stages.

This project integrates novel wearable technology with clinical and imaging data to address critical gaps in PsA detection, offering transformative potential for early diagnosis, personalised monitoring, and risk stratification for potential prevention strategies.

**Lay abstract**

Psoriasis and psoriatic arthritis (PsA) are long-term diseases caused by the immune system, affecting the skin, joints, and overall quality of life. Psoriatic disease typically manifests as skin psoriasis, although approximately 25% of people with psoriasis will go on to develop PsA, causing joint pain, swelling, structural damage and functional limitation. Unfortunately, PsA is often diagnosed late, which can cause permanent joint damage and make movement more difficult. Current screening methods for PsA rely upon patient-completed questionnaires but these can miss early signs of disease or mistake other joint problems for PsA. This study explores how wearable devices, such as fitness trackers, could identify the development of psoriatic disease over time. These devices automatically measure physical activity and sleep patterns without any burden to the patient. This provides a large amount of useful data that may help spot signs of PsA much earlier. Previous research by our team found that people with psoriasis who are less active, as measured by wearables, may have a higher risk of developing PsA. In this study, we will recruit 200 participants across different stages of psoriatic disease, from healthy individuals to those already diagnosed with PsA. By analysing changes in movement and activity, we aim to develop prediction models that can identify people at different stages of disease. By combining wearable technology with clinical insights, this project aims to enable early diagnosis, personalise treatment, and prevent severe complications for people with psoriatic disease.

**Background**

Psoriasis and psoriatic arthritis, collectively known as psoriatic disease, are chronic inflammatory diseases that predominantly affect the skin and joints and are associated with a range of other comorbidities. Psoriatic disease is driven by a combination of genetic, immunologic, and environmental factors and affects between 2-4% of the population worldwide [1]. Psoriatic disease is believed to exist on a spectrum that can progress from psoriasis (PsO) to psoriatic arthritis (PsA) in about 33% of patients. Psoriasis precedes the development of PsA in most people (61-82%) [2], offering a window of opportunity for screening. Significant delays in diagnosis in up to 50% of the people with PsA have been reported with some studies highlighting a median time to diagnosis from first symptoms of PsA of over 2 years [3,4]. A delay in diagnosis of even six months can lead to worse physical function and significantly more radiographic joint damage [5].

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A key research priority in psoriatic disease is to develop methods to identify individuals at risk of transition from psoriasis to PsA earlier in the disease course to enable timely referral and early intervention [6]. The European Alliance of Associations for Rheumatology (EULAR) has identified features such as arthralgia, joint and entheseal pain, synovitis, enthesitis, and dactylitis as potential markers of early disease [7]. Recent work from GRAPPA has highlighted a significant unmet need for effective screening tools to identify individuals at risk for PsA [8]. Existing screening tools, such as the Psoriatic Arthritis Screening Tool (PEST) questionnaire, while useful, do not capture all individuals at risk, emphasising the need for new approaches to bridge this gap. Ultrasound imaging has emerged as a sensitive method for identifying subclinical inflammation, with studies demonstrating its potential predictive value in identifying PsA[9,10]. Ultrasound, however, is resource-intensive, dependent on specialised equipment, and often confined to academic centres, making it unsuitable for population screening in a primary care setting. As a result, there is an unmet need for scalable, objective, and sensitive screening approaches used to augment existing approaches.

Wearable technology offers a transformative opportunity to address these limitations. By passively and continuously capturing metrics such as physical activity and sleep, wearable devices provide real-world, objective data that can enhance early disease detection. Insights from neurology have demonstrated the potential of wearable sensors in identifying prodromal disease states, as seen in Parkinson's disease [11,12]. Emerging work from our team has highlighted the potential added benefit of device-measured physical activity over traditional risk models for cardiovascular disease [13]. We have also developed approaches to classifying prodromal states in Parkinson's disease from accelerometer-captured walking data alone [in press]. Psoriatic disease offers a rich source of characteristic physical activity patterns including lower walking cadence, gait speed, stride length, and swing phase compared with healthy controls [14,15]. Our preliminary work has identified an association between lower physical activity, as measured by accelerometers, and a higher risk of PsA in individuals with psoriasis (submitted to GRAPPA congress 2025). Furthermore, in a pilot study of patients with PsA, we have demonstrated associations between lower accelerometer-derived physical activity level and higher disease activity and physical function [16].

Despite advances in understanding the course of progression in psoriatic disease, significant gaps remain that hinder early detection and risk stratification for PsA. **Firstly**, the association between physical activity patterns and distinct stages of psoriatic disease, including subclinical inflammation, has not been characterised. **Secondly**, the utility of wearable-derived measures compared to traditional assessments like ultrasound and questionnaires remains poorly understood. **Thirdly**, the feasibility of applying novel machine learning approaches to wearable data for accurate classification of psoriatic disease stages has not been explored. This study aims to address these critical gaps through a combination of clinical, imaging, and wearable-derived assessments.

## Aims

1. To characterise how wearable-derived measures of physical activity (e.g. step count and cadence) and sleep (e.g. sleep duration) vary across clinical stages of psoriatic disease
2. To compare wearables vs ultrasound vs questionnaires in their ability to cross-sectionally differentiate between distinct PsA states
3. To classify different stages of psoriatic disease based solely on unique walking signatures measured from a wrist-worn accelerometer

## Methods

We will recruit a target population of 200 participants across 4 sub-groups. Groupings will be based upon consensus definitions from EULAR, PAMPA and the Scher proposal including healthy controls, isolated cutaneous psoriasis, individuals with psoriasis and musculoskeletal symptoms not explained by another diagnosis, and established PsA [7,17,18]. We will employ stratified random sampling to ensure balanced demographics (e.g., age and sex) across clinical subgroups. We will recruit participants with psoriasis and PsA from local rheumatology and dermatology clinics. We will also utilise the HPOS cohort, leveraging its database of over 1,500 patients with psoriasis in the UK to identify participants. We will recruit biologic-naïve patients with psoriasis to reduce the confounding effect of treatment on subclinical enthesitis.

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*Exposures*

Demographic and clinical information will be recorded including age, sex, comorbidities, disease duration and past therapies. Disease activity and impact will be carefully assessed using standard clinical measurements including, but not limited to:

- Tender and swollen joints counts, enthesitis assessment and dactylitis counts
- Psoriasis area and severity index (PASI) and body surface area (BSA) of skin psoriasis
- International Dermatology Outcomes Measures Musculoskeletal-Questionnaire (IDEOM MSK-Q)
- Physical function assessment questionnaires

*Musculoskeletal power Doppler ultrasound (PDUS) assessment*

To align with contemporary imaging approaches and the ongoing PAMPA trial, musculoskeletal inflammation will be assessed using the PsASon13 score—a validated composite measure incorporating grey-scale and Doppler findings across key joints and entheses [6]. We will also scan at patellar, quadriceps and Achilles tendon insertions bilaterally.

*Wearable data collection*

Participants will be required to wear an Axivity AX6 tri-axial accelerometer continuously on their dominant wrist for 7 days. Open-source self-supervised machine learning algorithms will be applied to the raw data to generate summary statistics on walking, sleep, sedentary behaviour, light physical activity, and moderate-to-vigorous physical activity (MVPA) [19,20].

*Statistical analyses*

Descriptive statistics will summarise demographic and clinical characteristics across the four psoriatic disease subgroups. Multivariable logistic regression models will examine associations between key digital measures and clinical status (e.g. HC vs PsO vs subclinical PsA vs PsA), adjusting for covariates including age, sex, BMI, and comorbidities. We will also explore the associations between PsASon22 ultrasound score and wearable-derived features. From our previous pilot work, we identified differences in PA levels between individuals in remission vs active disease with a sample size of 19 [16]. Further work in rheumatoid arthritis has identified distinct activity phenotypes associated with disease state in a sample size of 11 participants [21]. Based on our prior data, a sample size of 200 participants (50 per group) provides 85% power to detect a difference in physical activity measures of at least 10% between clinical stages of psoriatic disease. This calculation assumes a more conservative effect size to that observed in our own preliminary work.

In an exploratory analysis, we will apply a human activity recognition (HAR) pipeline with the aim of classifying subgroups from raw accelerometer data alone. Active walking windows—defined by periods classified as both walking and moderate-to-vigorous activity—will be extracted using open-source models developed by our team. These windows will be passed into a deep learning classifier trained to distinguish psoriatic disease stages based on gait dynamics. During training, each walking window will be labelled according to the participant's clinical group: healthy control (HC), psoriasis (PsO), preclinical PsA, or established PsA. An 80/20 train-test split will be used to evaluate performance, ensuring that no participant contributes data to both training and validation sets. Using these features, we will evaluate the feasibility of a machine learning classifier to identify "PsA-like gait" patterns. This model will output classification probabilities across each psoriatic subgroup providing foundational insights into gait-based phenotyping.

**Expected results and significance for psoriatic disease**

This study will deliver a deep phenotyping approach across psoriatic disease, integrating clinical, ultrasound, and objective mobility measures. We expect to identify distinct movement phenotypes and explore associations between physical activity and subclinical inflammation. Exploratory machine learning models will assess whether active walking patterns can differentiate clinical subgroups using wearable data. This pilot will evaluate the feasibility of novel digital phenotyping methods, laying the groundwork for future large-scale risk prediction research. Findings will inform a planned PhD fellowship focused on validating wearable-derived markers of psoriatic disease progression in population-scale datasets. By leveraging wearable technology, this research aims to **address the significant unmet need for effective screening tools** to identify individuals at risk for PsA.

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