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# Psoriasis Characteristics for the Early Detection of Psoriatic Arthritis

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*ABSTRACT.* ***Objective.*** Delays in the diagnosis and treatment of psoriatic arthritis (PsA) are common. These delays contribute to impairments in quality of life and joint damage. This study aims to calculate the incidence rate of PsA over time and identify clinical features that may be used for PsA prediction in patients with psoriasis (PsO).

***Methods.*** The study population for PsA incidence analysis included 1128 participants enrolled in the Utah Psoriasis Initiative between 2002 and 2014. Clinical evaluation and medical record review were performed to identify new cases of PsA after enrollment. To identify PsO features associated with PsA, the population was restricted to 627 participants who did not have PsA before PsO phenotyping and had been followed up for subsequent PsA diagnosis. We conducted Cox proportional hazard regressions to estimate the HR of PsA associated with PsO characteristics and other health-related features.

***Results.*** PsA incidence rate increased for > 60 years following PsO onset (trend $P < 0.0001$). There was a significant association between PsA and induration severity in untreated lesions ($P < 0.001$, HR 1.46), history of fingernail involvement ($P < 0.001$, HR 2.38), pustular PsO ($P < 0.001$, HR 3.32), fingernail involvement at enrollment ($P < 0.001$, HR 2.04), and Koebner phenomenon ($P < 0.001$, HR 1.90). Multivariate analysis yielded a model that included a history of fingernail involvement ($P < 0.001$, HR 2.16) and untreated induration ($P < 0.001$, HR 1.41).

***Conclusion.*** Risk of PsA increases steadily for > 60 years following PsO onset. Patient-reported history of PsO characteristics has greater predictive power than physician-measured features at enrollment visits. The characteristics identified in this study provide guidance for screening for PsA risk in patients with PsO.

*Key Indexing Terms:* cohort studies, inflammation, longitudinal studies, psoriasis, psoriatic arthritis, survival analysis

Psoriasis (PsO) is a chronic disease characterized by patches of raised, red, scaly skin. It is multifactorial and known to be both genetically and immunologically mediated. Psoriatic arthritis (PsA) occurs in up to 30% of patients with PsO and is characterized by inflammation in joints, tendons, and ligaments.[1,2] The development of effective and consistent methods to screen for high-risk individuals and diagnose those in the early stages of PsA is critical to preserving the quality of life and mitigating irreversible joint damage in these populations.[3,4] Existing screening strategies for PsA in patients with PsO are infrequently used in routine clinical practice because of challenges with feasibility and predictive performance.[5]

Previous research has identified patient characteristics associated with PsA, including PsO severity, obesity, psoriatic nail involvement, and exposure to physical trauma.[6,7,8,9,10] However, consistent evidence is lacking which elucidates which PsO

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severity measurements (induration, erythema, desquamation, investigator global assessment [IGA], body surface area affected by PsO (BSA), and the product of IGA and BSA [IGA×BSA]) have the best predictive value for subsequent onset of PsA in individuals with PsO. Although patient-reported worst-ever BSA has a reported association with PsA,[11] there has not been a comparison between the maximum BSA since PsO onset and the BSA measured at the time of study enrollment. Additionally, PsO severity measured at enrollment may be affected by treatment and therefore may not be ideal for subsequent PsA prediction. Investigation into the association between the erythema, desquamation, and induration severity of untreated PsO lesions and PsA onset has not been previously undertaken. Further, a previous study showed that PsA risk does not dissipate for up to 20 years after the diagnosis of PsO,[8] but the risk in patients with PsO duration longer than 20 years remains unknown.

This study aimed to answer these questions and provide guidance for designing and applying effective screening strategies for PsA. We also evaluated the predictive performance of a wide range of clinical features for PsA screening tool development.

## METHODS

*Patient population.* The Utah Psoriasis Initiative (UPI) is a registry and tissue bank of 1379 patients with PsO enrolled between 2002 and 2014. UPI participants were adult patients seen at the University of Utah Health who had been diagnosed with PsO by a dermatologist. Upon enrollment in the UPI, participants completed a questionnaire regarding their historical PsO characteristics, PsA diagnosis, and other comorbidities. A dermatologist reviewed and reconciled the questionnaire and conducted a detailed exam of PsO conditions. The University of Utah institutional review board approved this study (IRB00010681).

*Variables.* The outcome variable was PsA diagnosis. Patients were followed forward in time for PsA diagnosis after enrollment. UPI participants were invited to complete a rheumatologic study evaluation that included diagnostic classifications of PsA. Diagnostic codes indicative of PsA diagnosis were also collected from electronic medical record (EMR) data within the Electronic Data Warehouse (EDW) at the University of Utah Health and at Intermountain Healthcare. Approximately 85% of the Utah population is represented in these EDWs.

Participants were classified into 3 categories with respect to their PsA status: Definitive PsA, Uncertain PsA, and No PsA. Definitive PsA classification required PsA diagnosis by a rheumatologist, defined by (1) patient-reported diagnosis of PsA from a rheumatologist, (2) PsA diagnosis reported by a UPI study rheumatologist after an evaluation with the patient, or (3) a diagnosis code for PsA or ankylosing spondylitis (AS) by a rheumatologist in an EMR (International Classification of Diseases, 9th revision [ICD-9] codes 696.0 and 720.0; ICD-10 codes L40.5 and M45.9). Uncertain PsA are those not classified as Definitive PsA who also have a (1) patient-reported PsA or AS diagnosis from a nonrheumatology provider, (2) diagnosis code for PsA by a nonrheumatologist, (3) diagnosis code for rheumatoid arthritis, or (4) uncertain diagnosis reported by the study rheumatologist after a face-to-face evaluation. The study rheumatologist's classification overrode previous reports if they were in contradiction. Patients who did not meet the criteria for Definitive PsA or Uncertain PsA were classified as No PsA, denoted by cutaneous-only psoriasis (PsC).

Exposure variables included PsO characteristics and additional health-related features such as comorbidities and BMI. These variables included patient-reported features collected through questionnaires and investigator-reported features collected through a physician examination. All phenotypes were assessed at the time of enrollment. Patients also reported their PsO characteristics prior to enrollment. The questionnaire included the following questions about BSA: (1) "Please estimate the total percentage of your BSA that is covered with psoriasis right now. The palm of your hand is approximately 1% of your BSA. If you were to push all lesions together, how many palms would it take to cover your psoriasis?" and (2) "If you are currently being treated for your psoriasis, your BSA is likely not at its worst. Using the above-described method, please estimate your BSA affected by psoriasis when it was at its worst ever."

For patient-reported erythema, desquamation, and induration, we asked patients to score the severity of their typical untreated lesions. Patients were provided with an induration card (provided by the National Psoriasis Foundation) and photographs as reference points for the possible scores they could give their typical untreated lesions. This is in contrast to the scores given to them by the physician at enrollment, which may reflect response to treatment.

*Statistical analysis.* To calculate the PsA incidence rate since the first PsO symptom, we excluded patients with uncertain PsA status, missing PsO onset time, and PsA diagnosis prior to PsO onset. Person-years (PY) at risk were calculated from patient-reported onset date of the first PsO symptoms to the date of PsA diagnosis, or the date of the patient's last clinical encounter documented in their medical records, whichever came first. The incidence rate of PsA was calculated as the number of PsA diagnoses divided by the number of PY at risk. We used Poisson regression to model the increased risk of incident PsA over the course of the disease from PsO onset. This model included an effect for time since onset within 10-year categories and an offset for the time at risk within each category.[12]

To identify PsA-predicting PsO characteristics and health-related features assessed at UPI enrollment, we further excluded patients with a PsA diagnosis prior to enrollment, patients lacking follow-up data for PsA diagnosis after enrollment, and patients with survey responses with ≥ 50% missing data. Descriptive statistics of patient characteristics were reported as mean and SD for quantitative variables and as number of observations and percentage for categorical variables. Rare ($n < 5$) phenotypes were not described given uncertainty due to the small sample size. In total, 36 variables were analyzed. Raw comparisons between PsA and PsC were carried out by Kruskal-Wallis test for quantitative variables and chi-square test for categorical variables.

We performed multiple imputation using the MICE package in R with 25 rounds of imputation with 20 iterations each.[13] This ensures valid inference if the data is missing-at-random (given the observed data, the data values, and missingness pattern are independent). No variables assessed had ≥ 50% missingness. We did not perform imputation for IGA×BSA since this variable was calculated from IGA and BSA.

We performed a univariate survival analysis using a Cox proportional hazards regression model to determine risk for PsA associated with each psoriatic phenotypic or health-related feature. We included sex as a covariate because of reported sex-related phenotypes of PsA[14] and an association in our dataset between sex and PsA. Duration of PsO at enrollment was treated as the left-truncation time. All tests were 2-sided. HRs and 95% CIs of PsA risk after PsO onset were calculated from multiple imputations using Rubin's rule.[13,15,16,17] Using the Bonferroni method to control family-wise type I error, the significance threshold was 0.0014.[18] Using imputed data, multivariate analysis was performed by backward stepwise regression.

Sensitivity analyses were performed to explore (1) an analysis strategy without using multiple imputation, and (2) a relaxed classification of PsA status (i.e., including patients diagnosed with PsA by a nonrheumatologist in the Definitive PsA category, rather than the Uncertain PsA category).

All statistical analyses were performed in R version 3.6.0 (R Foundation for Statistical Computing).

## RESULTS

The UPI included 1379 participants. After excluding 232 patients with Uncertain PsA status, 8 with missing PsO onset time, and 11 with a PsA diagnosis prior to PsO onset, there were

*Table 1*. Demographic and clinical characteristics of study participants.

| | PsC (n = 499)[a] | PsA (n = 128)[a] | Missing (%) | *P** |
|---|---|---|---|---|
| Age at study entry, yrs | 45.8 (± 17.0) | 47.3 (± 12.9) | 0 (0.0) | 0.46 |
| Male sex | 270 (54.1) | 57 (44.5) | 0 (0.0) | 0.07 |
| Race | | | | |
| White | 447 (90.3) | 108 (85.7) | 6 (1.0) | 0.18 |
| Non-White | 48 (9.7) | 18 (14.3) | | |
| Follow-up time, yrs | 8.2 (± 5.0) | 6.0 (± 4.4) | 0 (0.0) | 0.39 |
| PsO age of onset, yrs | 28.1 (± 17.3) | 29.2 (± 14.9) | 0 (0.0) | 0.8 |
| Yrs with PsO at study entry | 17.7 (± 14.4) | 18 (± 13.4) | 0 (0.0) | 0.47 |
| BMI at age 18 yrs | | | | |
| Normal (< 25) | 380 (79.7) | 101 (80.8) | 25 (4.0) | 0.93 |
| Overweight (25–30) | 75 (15.7) | 18 (14.4) | | |
| Obese (> 30) | 22 (4.6) | 6 (4.8) | | |
| Worst BSA | | | | |
| Mild (< 3%) | 94 (19.4) | 19 (15.2) | 17 (2.7) | 0.17 |
| Moderate (3–10%) | 213 (43.9) | 49 (39.2) | | |
| Severe (> 10%) | 178 (36.7) | 57 (45.6) | | |
| IGA at enrollment | 1.95 (± 1.01) | 2.04 (± 0.99) | 16 (2.6) | 0.24 |
| IGA×BSA at enrollment | 16.5 (± 33.0) | 20.4 (± 38.1) | 34 (5.4) | 0.52 |

* Chi-square test for categorical variables or Kruskal-Wallis test for continuous variables. [a] Values are expressed as n (%) for categorical variables or mean (± SD) for continuous variables. BSA: body surface area (% affected by psoriasis); IGA: investigator global assessment; IGA×BSA: the product of IGA and BSA; PsA: psoriatic arthritis; PsC: cutaneous-only psoriasis; PsO: psoriasis.

1128 subjects for PsA incidence rate calculation. The annual PsA incidence increased from 0.0137 during the first 20 years to 0.0312 in > 60 years after PsO onset (Figure 1). Test for trend of incidence rates yielded an estimate of the rate ratio of 1.028 for each year increase in PsO duration (95% CI 1.021–1.036, $P < 0.0001$).

From the remaining 1128 patients with PsO, we further excluded 148 patients with a PsA diagnosis prior to enrollment, 345 patients lacking follow-up data for assessing PsA diagnosis after enrollment, and 8 patients with survey responses containing ≥ 50% missingness, resulting in 627 individuals for PsA-predicting feature identification. Among these participants, 128 (20%) developed PsA after enrollment and had a PsA diagnosis from a rheumatologist, whereas 499 had PsC without PsA as of their most recent encounter in the medical system. Patients with PsC and PsA were comparable with regard to race, BMI at age 18 years, PsO age of onset, duration of PsO at enrollment, follow-up time, and PsO severity at enrollment (Table 1). The mean and maximum follow-up times since enrollment were 7.7 and 16 years, respectively.

By Cox proportional hazards regression adjusted for sex, variables associated with a statistically significant increased risk of PsA include pustular PsO (HR 3.32, 95% CI 1.91–5.77), a history of fingernail involvement (HR 2.38, 95% CI 1.64–3.45), fingernail involvement at time of enrollment (HR 2.04, 95% CI 1.40–2.95), Koebner phenomenon (KP; HR 1.90, 95%

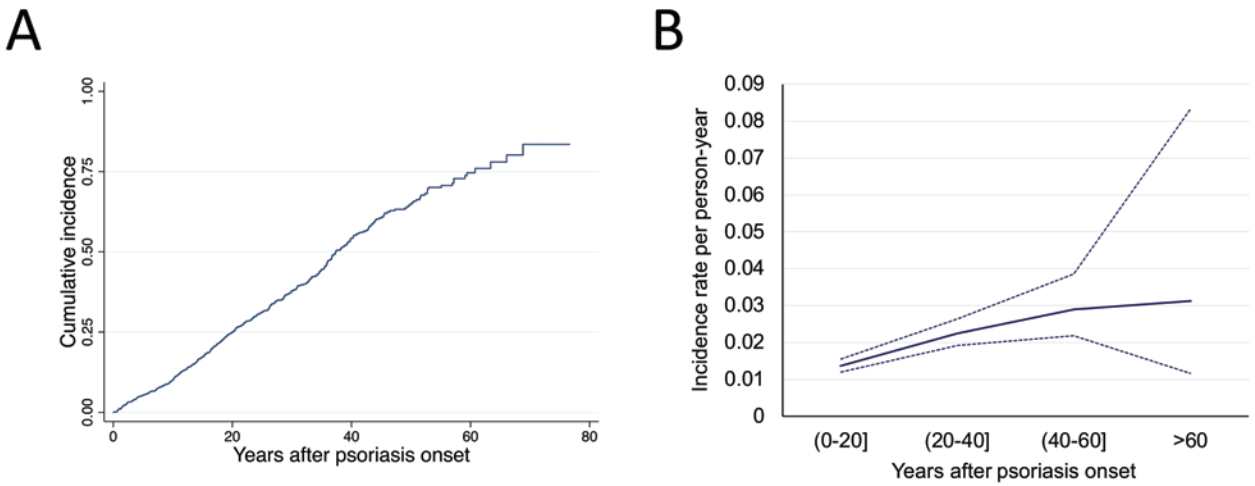


*Figure 1*. Incidence of PsA following psoriasis onset. (A) Cumulative incidence of PsA; and (B) psoriasis duration-dependent incidence rate of PsA. Solid blue line is incidence, dotted lines are 95% CIs. PsA: psoriatic arthritis.

*Table 2.* Association between PsO characteristics and PsA risk.

| | | Report by | PsC, n = 499 | PsA, n = 128 | HR (95% CI) | *P*[*] |
|---|---|---|---|---|---|---|
| PsO phenotypes | | | | | | |
| History of fingernail PsO | | P | 206 (41.4) | 81 (63.8) | 2.38 (1.64–3.45) | < **0.001** |
| Pustular PsO | | I | 15 (3.1) | 15 (12.0) | 3.32 (1.91–5.77) | < **0.001** |
| Fingernail PsO | | I | 213 (44.1) | 77 (62.6) | 2.04 (1.40–2.95) | < **0.001** |
| Koebner phenomenon | | P | 178 (37.9) | 67 (56.3) | 1.90 (1.31–2.76) | < **0.001** |
| PPPP | | I | 9 (1.9) | 8 (6.4) | 3.30 (1.57–6.97) | 0.002 |
| GPP | | I | 6 (1.2) | 7 (5.6) | 3.12 (1.42–6.85) | 0.005 |
| Guttate PsO | | I | 54 (11.2) | 9 (7.3) | 0.62 (0.31–1.22) | 0.17 |
| Erythrodermic PsO | | I | 4 (0.8) | 3 (2.4) | 1.96 (0.60–6.44) | 0.27 |
| Inverse PsO | | I | 132 (27.6) | 39 (31.5) | 1.23 (0.84–1.80) | 0.29 |
| History of scalp PsO | | P | 366 (73.5) | 100 (79.4) | 1.25 (0.81–1.93) | 0.31 |
| PsO age of onset, mean (SD) | | P | 28.1 (17.33) | 29.2 (14.94) | 1.05 (0.94–1.19) | 0.38 |
| Palmoplantar PsO | | I | 30 (6.2) | 5 (4.0) | 0.69 (0.28–1.71) | 0.42 |
| PsO severity | | | | | | |
| Untreated induration[a] | 0 | P | 35 (7.3) | 4 (3.2) | 1.46 (1.27–1.68) | < **0.001** |
| | 1 | | 141 (29.3) | 25 (19.8) | | |
| | 2 | | 165 (34.2) | 40 (31.7) | | |
| | 3 | | 88 (18.3) | 31 (24.6) | | |
| | 4 | | 37 (7.7) | 18 (14.3) | | |
| | 5 | | 16 (3.3) | 8 (6.3) | | |
| Untreated desquamation[a] | 0 | P | 3 (0.6) | 0 (0.0) | 1.22 (1.05–1.42) | 0.008 |
| | 1 | | 50 (10.4) | 8 (6.4) | | |
| | 2 | | 117 (24.2) | 31 (24.8) | | |
| | 3 | | 136 (28.2) | 23 (18.4) | | |
| | 4 | | 120 (24.8) | 37 (29.6) | | |
| | 5 | | 57 (11.8) | 26 (20.8) | | |
| Untreated erythema[a] | 0 | P | 1 (0.2) | 0 (0.0) | 1.25 (1.06–1.48) | 0.009 |
| | 1 | | 26 (5.4) | 5 (4.0) | | |
| | 2 | | 107 (22.2) | 24 (19.0) | | |
| | 3 | | 178 (36.9) | 33 (26.2) | | |
| | 4 | | 125 (25.9) | 43 (34.1) | | |
| | 5 | | 46 (9.5) | 21 (16.7) | | |
| Induration at enrollment[a] | 0 | I | 65 (13.7) | 11 (8.7) | 1.21 (1.02–1.44) | 0.03 |
| | 1 | | 193 (40.7) | 50 (39.7) | | |
| | 2 | | 142 (30.0) | 41 (32.5) | | |
| | 3 | | 48 (10.1) | 19 (15.1) | | |
| | 4 | | 26 (5.5) | 5 (4.0) | | |
| | 5 | | 0 (0.0) | 0 (0.0) | | |
| Desquamation at enrollment[a] | 0 | I | 32 (6.8) | 9 (7.2) | 1.16 (0.99–1.37) | 0.07 |
| | 1 | | 164 (34.6) | 39 (31.2) | | |
| | 2 | | 158 (33.3) | 37 (29.6) | | |
| | 3 | | 77 (16.2) | 33 (26.4) | | |
| | 4 | | 38 (8.0) | 6 (4.8) | | |
| | 5 | | 5 (1.1) | 1 (0.8) | | |
| Erythema at enrollment[a] | 0 | I | 22 (4.6) | 4 (3.2) | 1.14 (0.96–1.35) | 0.13 |
| | 1 | | 72 (15.2) | 25 (19.8) | | |
| | 2 | | 179 (37.8) | 37 (29.4) | | |
| | 3 | | 143 (30.2) | 39 (31.0) | | |
| | 4 | | 52 (11.0) | 19 (15.1) | | |
| | 5 | | 6 (1.3) | 2 (1.6) | | |
| Worst-ever BSA, mean (SD) | | P | 17.9 (24.24) | 23 (27.57) | 1.00 (1.00–1.01) | 0.22 |
| BSA at enrollment, mean (SD) | | I | 6.3 (9.41) | 8.2 (14.55) | 1.01 (1.00–1.02) | 0.09 |
| IGA at enrollment, mean (SD) | | I | 2 (1.01) | 2 (0.99) | 1.15 (0.96–1.38) | 0.12 |
| IGA×BSA at enrollment, mean (SD) | | I | 16.5 (33.04) | 20.4 (38.06) | 1.00 (1.00–1.01) | 0.22 |
| Comorbidities | | | | | | |
| Depression | | P | 96 (19.5) | 42 (33.6) | 1.78 (1.22–2.59) | 0.003 |
| Inflammatory bowel disease | | P | 4 (0.8) | 5 (4.0) | 3.51 (1.40–8.78) | 0.007 |
| High blood pressure | | P | 130 (26.2) | 44 (35.2) | 1.40 (0.97–2.02) | 0.07 |
| Asthma | | P | 55 (11.1) | 20 (16.0) | 1.47 (0.91–2.38) | 0.11 |

*Table 2.* Continued.

| | Report by | PsC, n = 499 | PsA, n = 128 | HR (95% CI) | *P*˚ |
|---|---|---|---|---|---|
| Ever smoked | P | 187 (37.7) | 49 (39.2) | 1.29 (0.90–1.85) | 0.17 |
| Stroke | P | 13 (2.6) | 1 (0.8) | 0.30 (0.04–2.15) | 0.23 |
| Eczema | P | 58 (11.8) | 12 (9.5) | 0.78 (0.43–1.42) | 0.42 |
| Cancer | P | 33 (6.7) | 8 (6.3) | 1.21 (0.58–2.52) | 0.61 |
| Skin cancer | P | 38 (7.7) | 9 (7.2) | 0.90 (0.45–1.80) | 0.77 |
| Strep throat | P | 34 (6.9) | 9 (7.3) | 0.92 (0.46–1.81) | 0.8 |
| High cholesterol | P | 102 (20.6) | 27 (21.6) | 0.96 (0.62–1.48) | 0.86 |
| BMI at age 18 yrs, mean (SD) | P | 22.3 (4.10) | 22.2 (4.60) | 1.00 (0.96–1.05) | 0.86 |
| Diabetes | P | 47 (9.5) | 10 (8.0) | 0.95 (0.50–1.82) | 0.89 |
| Myocardial infarction | P | 18 (3.6) | 4 (3.2) | 1.01 (0.37–2.76) | 0.98 |

Values shown in the table are n (%) unless otherwise indicated. ˚ Bolded *P* values cross the threshold of 0.0014 for significance by Bonferroni correction. [a] The 3 components of the IGA analysis (erythema, induration, and desquamation) are on a 0–5 scale, with 0 representing phenotype absence and 5 being the most severe. BSA: percent of body surface area affected by psoriasis; I: investigator; GPP: Generalized pustular PsO; IGA: Investigator's Global Assessment; IGA×BSA: the product of IGA and BSA; P: patient; PPPP: palmoplantar pustular psoriasis; PsA: psoriatic arthritis; PsC: cutaneous-only psoriasis; PsO: psoriasis.

CI 1.31–2.76), and patient-reported untreated plaque induration (HR 1.46, 95% CI 1.27–1.68; Figure 2 and Table 2). Patient-reported untreated erythema and desquamation were nominally significant (Table 2 and Supplementary Figure 1, available with the online version of this article). For induration, desquamation, and erythema, history of severity in untreated lesions was associated with higher HRs and lower *P* values than the investigator-reported severity measured at enrollment (Table 2). The same was also observed for fingernail involvement (Table 2). Multivariate Cox regression yielded a model with history of fingernail PsO (HR 2.16, 95% CI 1.49–3.15) and patient-reported untreated induration (HR 1.41, 95% CI 1.22–1.62; Table 3). Neither induration at enrollment nor fingernail PsO at enrollment were nominally significant in the multivariate analysis (data not shown).

We also performed a sensitivity analysis without imputing missing data, which yielded concordant results (Supplementary Table 1, available with the online version of this article). These variables had similar HRs in non-White individuals including Black, Native American, Latino, Asian, Oceania, and admixed (HR 2.38, 95% CI 0.95–5.93 for history of fingernail involvement and HR 2.29, 95% CI 0.94–5.56 for untreated induration ≥ 3) but statistically nonsignificant *P* values ($P = 0.06$ for fingernail involvement at enrollment and $P = 0.07$ for untreated induration ≥ 3). Sensitivity analyses that additionally included PsA cases diagnosed by a nonrheumatologist demonstrated a multivariate result similar to our primary analyses (Supplementary Tables 2 and 3).

## DISCUSSION

This time-to-event analysis revealed PsO characteristics associated with subsequent PsA onset. Various characteristics have been reported in previous studies to associate with PsA risk, including investigator-assessed characteristics measured at the time of a clinical visit (e.g., IGA, fingernail involvement).[1,19,20,21] We assessed both patient-reported and investigator-assessed variables and found that some of the strongest associations occurred with patient-reported variables. Specifically, we discovered an association with patient-reported untreated plaque induration severity. Compellingly, our data demonstrated that patient-reported untreated induration has a stronger association with PsA than induration assessed by providers at the time of enrollment. Similarly, a patient-reported history of fingernail involvement was found to be a superior predictor for PsA than provider-reported fingernail involvement at the time of enrollment. Select patient-reported disease features that account for the patient's entire psoriatic history may be more predictive of future PsA onset than investigator-assessed outcomes that are limited to a snapshot of disease state at a single timepoint.

The large sample size and long follow-up period in this study enabled the discovery of associations with uncommon phenotypes (< 5% in PsC) such as pustular PsO. The predictive association between pustular PsO and PsA risk has not been identified previously. With KP, our results were similar to other studies that reported an association between patient-reported history of the KP and PsA risk.[22] Further investigation into the specific associations between these characteristics and PsA is necessary to further elucidate the risk they pose. In contrast to other studies, we did not find associations between PsA risk and inverse PsO or scalp PsO.[19,20]

Importantly, we demonstrated a steadily increasing risk of PsA onset for > 60 years after PsO onset. This is consistent with results from another prospective PsO registry reporting a steady increase in PsA risk over time.[8] This is important for reinterpreting previous studies that defined PsC by a 10-year cutoff after PsO onset, and for appropriate design of future studies.[2,4,23]

Strengths of our study include the detailed PsO phenotyping data and a time-dependent analysis that evaluates development of PsA after the initial phenotyping, rather than reporting associations between phenotypes and prevalent PsA. The inclusive classification of patients with PsA and PsC provides a comprehensive real-world approach to defining study populations. Our conclusions are strengthened by a strict correction for multiple testing by Bonferroni and additional stepwise multivariate regression analysis.

Limitations of our study include the retrospective nature

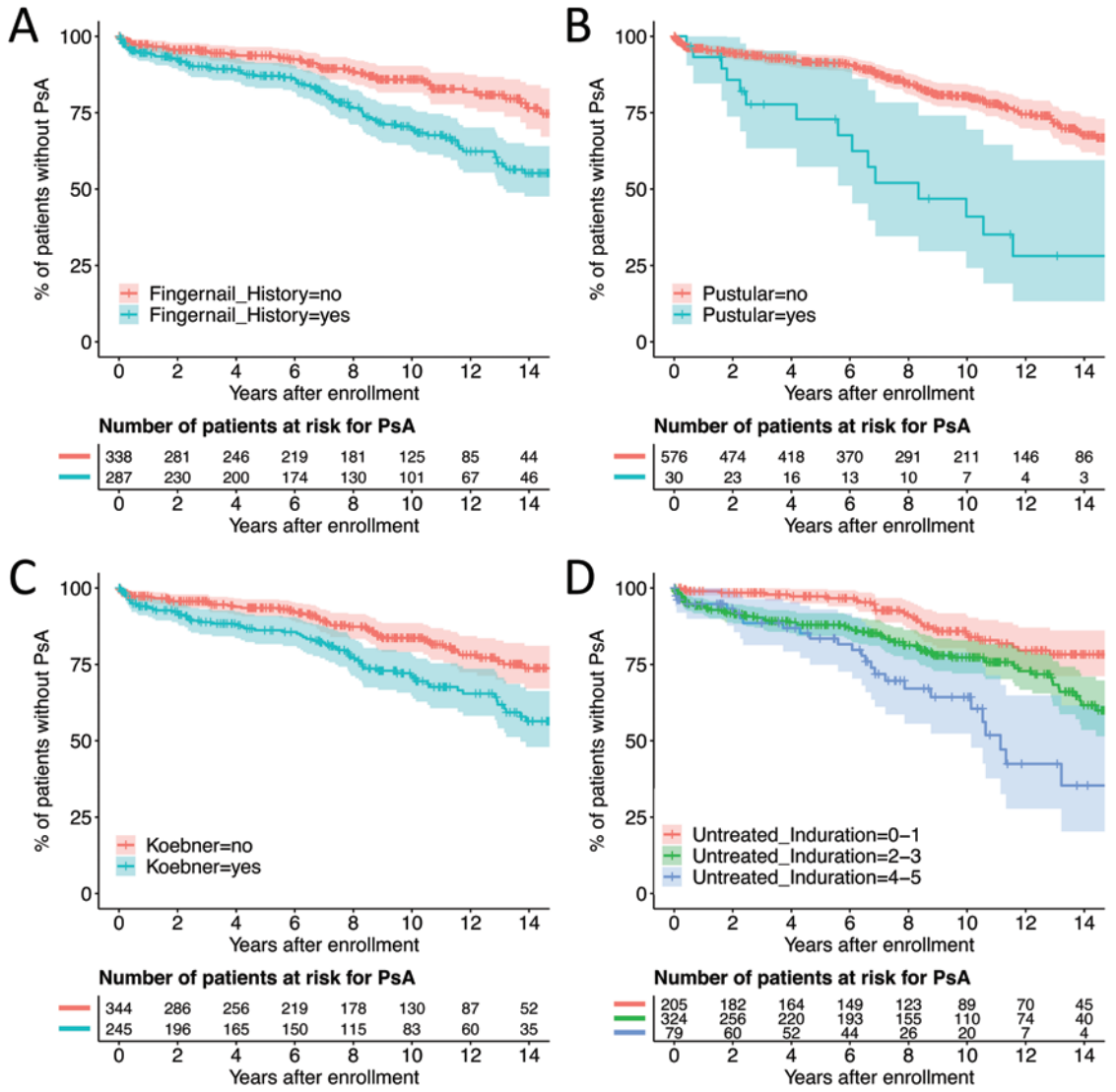


*Figure 2.* Kaplan-Meier curves for PsA development stratified by PsO characteristics. (A) history of fingernail PsO; (B) pustular PsO; (C) Koebner phenomenon; and (D) untreated induration. Induration was measured on a 0–5 scale, 0 being not present and 5 being the most severe. The X-axis is time in years from enrollment. The Y-axis is the cumulative probability of not developing PsA. Semitransparent coloring represents CIs. PsA: psoriatic arthritis; PsO: psoriasis.

*Table 3.* Multivariate Cox proportional hazards regression results.

| PsO Characteristic | HR (95% CI) | *P* |
|---|---|---|
| Untreated induration | 1.41 (1.22–1.62) | < 0.001 |
| History of fingernail PsO | 2.16 (1.49–3.15) | < 0.001 |
| Female sex | 1.65 (1.15–2.37) | 0.006 |

PsO: psoriasis.

of patient-reported variables as they may be subject to recall bias. The number of patients at risk for PsA after 60 years was small and may reflect selection bias as > 75% of patients in the cohort had developed PsA (Figure 1A). Further, ICD codes and patient-reported diagnoses of PsA are imperfect markers of PsA diagnosis. The study cohort includes a low proportion of non-White individuals. This may contribute to the lack of statistical significance when stratified by race and is prohibitive in undertaking higher resolution analyses with subsets from different racial groups. Additionally, multivariate model data should be interpreted cautiously. In particular, the selective inference reported for the multivariate model after variable selection by a low *P* value cutoff is expected to be slightly optimistic (i.e., the "true" *P* values are slightly greater than the reported *P* values).

In conclusion, we demonstrate that PsA risk in patients with PsO increases steadily for > 60 years following PsO onset. Untreated plaque induration severity, pustular PsO, history of fingernail involvement, fingernail involvement at time of enrollment in this study, and KP are significantly associated with an elevated risk for PsA. The predictive value of untreated plaque induration and history of fingernail involvement persisted through the multivariate analysis, suggesting that they are strong

indicators of future development of PsA. These findings can assist researchers with developing PsA screening and referral strategies and can aid clinicians in assessing individuals' risks for PsA.


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## ONLINE SUPPLEMENT

Supplementary material accompanies the online version of this article.

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