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Overall and Sex-Specific Predictors of Secukinumab Effectiveness in European Patients With Psoriatic Arthritis: Results From the EuroSpA Collaboration

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ABSTRACT. ***Objective.*** Identifying patient characteristics that predict treatment response in psoriatic arthritis (PsA) may help optimize treat-to-target strategies. We aimed to explore overall and sex-specific predictors of secukinumab (SEC) effectiveness in European patients with PsA treated in routine care.

Methods. We analyzed data from 14 registries in the European Spondyloarthritis (EuroSpA) Research Collaboration. Patients aged ≥ 18 years at diagnosis, initiating SEC treatment from January 2015 to January 2021, were included. Multiple imputation was used for missing covariates at treatment start (baseline) and Disease Activity Index for Psoriatic Arthritis based on 28 joints (DAPSA28) at 6 months. Overall and sex-stratified analyses were performed by logistic and Cox regressions to identify baseline predictors of the following treatment outcomes: (1) DAPSA28 low disease activity (LDA; DAPSA28 ≤ 14) at 6 months, (2) DAPSA28 moderate response at 6 months, and (3) SEC discontinuation within 12 months.

Results. In total, 2790 patients (43% male) were included. Median age was 43 years (IQR 34-52), and SEC was the first-line biologic/targeted synthetic disease-modifying antirheumatic drug (b/tsDMARD) in 665 patients (24%). Positive predictors for both DAPSA28 LDA and DAPSA28 moderate response were male sex, fewer previous b/tsDMARDs, C-reactive protein (CRP) > 10 mg/L, and lower Health Assessment Questionnaire (HAQ) score. Absence of psoriasis, higher patient fatigue, and tender joint counts predicted SEC discontinuation within 12 months. For some outcomes, sex-specific predictors were fewer previous b/tsDMARDs and CRP > 10 mg/L among male patients and lower patient fatigue score among female patients.

Conclusion. We identified overall and sex-specific predictors of SEC effectiveness in European patients with PsA. Our findings may support personalized treatment decisions.

Key Indexing Terms: interleukin 17A inhibitors, psoriatic arthritis, rheumatology, sex, spondyloarthritis, treat-to-target

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Psoriatic arthritis (PsA) is an inflammatory joint disease characterized by variable patterns of manifestations including peripheral arthritis, axial spondyloarthritis (axSpA), enthesitis, dactylitis, and psoriasis (PsO).[1] Although the male-to-female PsA ratio is roughly 1:1,[1,2] the disease manifestations, course, and treatment response differ between male and female individuals.[2]

The potential consequences of living with PsA include pain and fatigue, as well as disability and reduced quality of life.[1] In combination with a treat-to-target (T2T) approach, the introduction of biologic (b-) and targeted synthetic (ts-) disease-modifying antirheumatic drugs (DMARDs), such as tumor necrosis factor inhibitors (TNFi) and interleukin 17A inhibitors (IL-17Ai), has improved treatment outcomes by reducing progression of structural damage and functional disability.[3-5] Secukinumab (SEC), an IL-17Ai approved for the treatment of PsA, has been shown to be effective in achieving remission and low disease activity (LDA) while being well tolerated.[6-8]

In addition to a T2T strategy, it is advocated to personalize the choice of medical treatment by targeting patient-specific manifestations.[1,5] Further improvements in management may be obtained by identifying patient characteristics that predict treatment response. Mounting evidence has already identified predictors of treatment response in patients with PsA undergoing TNFi treatment.[9-16]

However, in patients treated with SEC, the evidence regarding predictors of treatment response is limited, and existing studies have applied different study designs, as well as various definitions of treatment exposures, study populations, and measures of treatment effect.[17-20] Thus, further investigation of the predictors of treatment response among patients with PsA treated with SEC is needed. Although studies consistently identify male sex as a positive predictor of treatment response in both TNFi-treated[9-15] and IL-17Ai–treated[17,18,20] patients, to our knowledge, no previous study has investigated whether the pattern of identified predictors differs between male and female individuals.

The European Spondyloarthritis (EuroSpA) Research Collaboration Network (RCN) is a collaborative research framework aiming to study effectiveness and safety of b/tsDMARD treatments in routine care patients diagnosed with SpA, including PsA and axSpA, across Europe.[21] Currently including registries from 19 countries, the EuroSpA RCN offers a unique opportunity to carry out a large-scale study on predictors of treatment effectiveness in patients with PsA treated with SEC.[22]

Thus, using data from the EuroSpA RCN, the objectives of the present study were to explore overall and sex-specific predictors of clinical effectiveness in patients with PsA treated with SEC in routine care. Specifically, we aimed to investigate predictors of achieving LDA according to the Disease Activity Index for Psoriatic Arthritis based on 28 joints (DAPSA28) at 6 months, DAPSA28 moderate response at 6 months, and SEC discontinuation within 12 months.

METHODS

Design and data sources. The following 14 registries participating in the EuroSpA RCN could contribute data at the time of the data upload: Anti-TNF Treatment in Rheumatoid Arthritis (ATTRA; Czech Republic), Spanish Registry for Adverse Events of Biological Therapy in Rheumatic Diseases (BIOBADASER; Spain), Slovenian Biologics Register (Biorx.si; Slovenia), DANBIO (Denmark), Estonian Spondyloarthritis and Biologics Treatment Register (ERSBTR; Estonia), Italian Group for the Study of Early Arthritis (GISEA; Italy), Icelandic Nationwide Database of Biologic Therapy (ICEBIO; Iceland), Norwegian Disease-Modifying Antirheumatic Drugs Register (NOR-DMARD; Norway), Rheumatic Diseases Portuguese Register (Reuma.pt; Portugal), National Register for Antirheumatic and Biologic Treatment in Finland (ROB-FIN; Finland), the Romanian Registry of Rheumatic Diseases (RRBR; Romania), Swiss Clinical Quality Management in Rheumatic

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Diseases (SCQM; Switzerland), Swedish Rheumatology Quality Register (SRQ; Sweden), and TURKBIO (Türkiye). Data had been collected prospectively by the individual registries according to their respective protocols. The process of data transfer from the registries to the RCN included the following 3 steps: (1) data managers from each registry created pseudonymized datasets including predefined variables, (2) datasets were securely uploaded to the EuroSpA server, and (3) datasets were harmonized and pooled.

Patients and visits.

- *Inclusion criteria.* Patients aged ≥ 18 years at the time of PsA diagnosis were included if they initiated their first SEC treatment after January 1, 2015. Secukinumab treatments starting between January 1, 2015, and January 3, 2021, were included and all patients were followed for up to 12 months.
- *Inclusion of data associated with clinical visits.* Baseline was defined as the start of SEC treatment. For baseline and follow-up visits, the following visit selection criteria were applied: baseline visit (from 30 days prior to 30 days after treatment start), 6-month follow-up (90-270 days after treatment start), and 12-month follow-up (271-450 days after treatment start). For patients with > 1 visit occurring within the same time window, priority was given to the visit including the highest number of patient-reported outcomes, and secondly, to the visit closest to the date of baseline, 6-month follow-up, and 12-month follow-up (day 0, 283, and 365, respectively).

Outcomes. The primary outcome was achievement of LDA at 6 months, defined as a score ≤ 14 on DAPSA28.[23] Secondary outcomes included achievement of DAPSA28 moderate response, defined as a 75% improvement at 6-month follow-up (as previously defined for DAPSA based on 66/68 joint counts[24]), as well as drug discontinuation within 12 months of follow-up.

Statistical analysis. Descriptive statistics included median with IQR for continuous variables and counts with percentages for categorical variables. All analyses were conducted in a pooled cohort of patients from the participating registries.

- *Regression analyses.* Logistic regression analyses were performed to identify baseline predictors of DAPSA28 LDA and DAPSA28 moderate response at 6 months. Cox proportional hazards regression analyses were carried out for predictors of drug discontinuation within 12 months. These analyses were conducted for the overall cohort, as well as stratified by sex. Odds ratios and hazard ratios, along with 95% CIs, were estimated by logistic and Cox regression analyses, respectively. For the outcome of drug discontinuation, patients were censored according to the first occurrence of either treatment stop for reasons other than adverse events or loss of effect, death, or end of follow-up.
- *Baseline covariates.* We explored 17 baseline demographic and clinical characteristics as potential predictors. The selection of variables was based on previous study findings in TNFi-treated PsA populations, as well as on data availability. Categorial independent variables included sex, smoking status (current vs never/previous), concomitant conventional synthetic DMARDs (csDMARDs; yes vs no), C-reactive protein (CRP; ≤ 10 vs > 10 mg/L), and presence of the following conditions during the disease course (ever vs never): cardiovascular disease (CVD), type 1 or 2 diabetes mellitus (DM), or PsO. Age at treatment start, time since diagnosis (years), BMI (calculated as weight in kilograms divided by height in meters squared), number of previous b/DMARDs, patient pain score (0-10 integer scale), patient fatigue score (0-10 integer scale), physician global assessment (0-10 integer scale), Health Assessment Questionnaire (HAQ; 0-3), swollen joint count of 28 joints (SJC28; 0-28) and tender joint count of 28 joints (TJC28; 0-28) were included as continuous variables. Patient global assessment was not included in the set of baseline covariates for the prediction models, as it was assumed that patient pain and fatigue were associated with and affecting patient global assessment.[25]
- *Missing values.* Multiple imputation by chained equations (MICE) was used to impute missing baseline covariates and missing DAPSA28 values at 6 months to account for attrition.[26] The number of imputed datasets (n = 35) was decided based on the missingness of values in the original data, considering all baseline covariates and follow-up variables (Supplementary Material S1, available with the online version of this article).
- *Variable selection of covariates.* We used purposeful selection to evaluate and derive significant predictors and statistical confounders for the final prediction models.[27,28] This method was applied in both logistic regression[27] and Cox regression models.[28] Here we provide a brief description of the method; a more detailed description is given in Supplementary Material S2 (available with the online version of this article).

For each of the outcomes, any covariate with a significant univariable test at a 0.25 level was selected as a candidate and included in multivariable analysis. Next, covariates were removed from the multivariable model if they were neither statistically significant, nor a (statistical) confounder by an iterative selection process, where significance was evaluated at the 0.05 alpha level and confounding as a change in any remaining parameter estimate > 15%, as compared to the initial multivariable model. At the end of this iterative process of refitting, verifying, and deleting, the model contained the significant predictors and confounders. Afterward, any covariates without a significant univariable test were added back one at a time in the multivariable model containing the already selected significant predictors and confounders. All significant covariates at a 0.1 level were inserted into the model, and the model was iteratively reduced as before but only for the covariates that were additionally added. At the end of this step, the final multivariable model was derived.

Gross domestic product (GDP) per capita based on purchasing power parity (in international dollars, $) was a priori forced into all multivariable models to adjust for socioeconomic differences between countries (registries).[29] Calendar year of SEC start was additionally forced into all multivariable models as a continuous variable. Thus, GDP and calendar year were not evaluated as potential predictors or confounders in the change-in-estimate approach.

Purposeful selection was adequately adapted to the multiply imputed data by repeated use of Rubin rules,[30] which involved

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fitting the model under consideration to all imputed datasets and combining estimates across imputed datasets in each step of the model selection.

- *Performance.* The concordance index (C-index), which is defined as the proportion of concordance between predicted and observed outcomes,[31] of the final multivariable models was assessed by internal validation on multiply imputed data.[32] The chosen validation strategy combined multiple imputation and bootstrapping by drawing 100 bootstrap samples from the 35 imputed datasets. For logistic regression models, the C-index is equivalent to the area under the receiver-operating curve (AUROC).[33]

Statistical analyses were performed with R version 4.2.2.[34]

RESULTS

In total, 2790 patients with PsA initiated SEC treatment and were eligible for analysis. Table 1 shows the baseline patient characteristics for the overall cohort and stratified by sex; 43% of patients were male, SEC was the first ever b/tsDMARD treatment in 24%, and 40% received concomitant treatment with csDMARDs. Median age at diagnosis and initiation of SEC treatment was 43 (IQR 34-52) years and 52 (IQR 44-60) years, respectively. As compared to male patients, female patients were older, more frequently smokers, had fewer comorbidities, and less often increased CRP, as well as higher scores on patient pain, patient fatigue, and DAPSA28.

In the imputed data, the overall outcome rates at 6 months for DAPSA28 LDA and DAPSA28 moderate response were 48% and 13%, respectively, and the retention rate for SEC at 12 months was 74.3% (95% CI 72.6-76.1). Stratified by sex, 42% of female individuals and 57% of male individuals achieved DAPSA28 LDA at 6 months, whereas 10% female individuals and 17% male individuals achieved DAPSA28 moderate response. The 12-month retention rates were 71.9% (95% CI 69.5-74.3) for female individuals and 77.6% (95% CI 75.0-80.1) for male individuals.

The data availability and the number of patients from the 14 registries are shown in Supplementary Tables S1 and S2 (available with the online version of this article).

Primary outcome: DAPSA28 LDA at 6 months. Table 2 shows

Table 1. Baseline patient characteristics in the overall cohort and stratified by sex.

	Overall, N = 2790	Male, n = 1201	Female, n = 1589
Male sex	1201 (43)	–	–
Age at diagnosis, yrs	43 (34-52)	41 (33-50)	44 (35-53)
Time since diagnosis, yrs	7 (3-12)	7 (3-13)	6 (3-12)
Time since symptoms onset, yrs	11 (6-18)	11 (6-18)	12 (6-18)
Age at SEC treatment start, yrs	52 (44-60)	51 (43-59)	53 (45-61)
BMI, kg/m^2	27.4 (24.2-31.2)	27.5 (24.8-30.6)	27.0 (23.6-31.5)
Current smokers	397 (19)	145 (16)	252 (21)
Concomitant csDMARD[a]	1122 (40)	478 (40)	644 (41)
Cardiovascular disease	295 (29)	152 (33)	143 (25)
DM type 1 or 2	138 (14)	65 (14)	73 (13)
Psoriasis	609 (84)	291 (89)	318 (81)
No. of previous b/tsDMARD treatments			
Biologic-naïve	665 (24)	328 (27)	337 (21)
1 prior b/tsDMARD	682 (24)	310 (26)	372 (23)
≥ 2 prior b/tsDMARDs	1443 (52)	563 (47)	880 (55)
SEC dose at initiation			
150 mg	303 (52)	140 (53)	163 (51)
300 mg	283 (48)	126 (47)	157 (49)
Year of SEC initiation			
2015-2017	1255 (45)	535 (45)	720 (45)
2018-2021	1535 (55)	666 (55)	869 (55)
CRP > 10 mg/L	507 (29)	239 (31)	268 (27)
Patient pain score (0-10)	7 (5-8)	6 (4-8)	7 (5-8)
Patient fatigue score (0-10)	7 (5-8)	6 (5-8)	8 (6-9)
Physician global assessment (0-10)	4 (2-6)	4 (2-6))	4 (2-6)
SJC28	1 (0-4)	1 (0-4)	2 (0-4)
TJC28	4 (1-8)	4 (1-8)	5 (1-9)
HAQ (0-3)	1.1 (0.6-1.6)	1.0 (0.5-1.4)	1.2 (0.8-1.8)
DAPSA28	25.8 (16.7-37.2)	24.4 (15.9-35.6)	26.2 (17.5-38.4)

Values are presented as n (%) or median (IQR). [a] Methotrexate, sulfasalazine, leflunomide, or others. b/tsDMARD: biologic/targeted synthetic DMARD; CRP: C-reactive protein; csDMARD: conventional synthetic DMARD; DAPSA28: Disease Activity Index for Psoriatic Arthritis using 28 joints; DM: diabetes mellitus; DMARD: disease-modifying antirheumatic drug; HAQ: Health Assessment Questionnaire; SEC: secukinumab; SJC28: swollen joint count of 28 joints; TJC28: tender joint count of 28 joints.

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the identified predictors of DAPSA28 LDA at 6 months based on the purposeful covariate selection. Adjusted for GDP per capita and year of treatment start, the multivariable logistic regression yielded 7 significant baseline predictors of DAPSA28 LDA at 6-month follow-up: male sex, CRP > 10 mg/L, lower number of previous b/tsDMARDs, nonsmoking status, lower patient pain score, lower HAQ score, and lower TJC28. One covariate, patient fatigue score, fulfilled the criterion for being a statistical confounder and was included in the multivariable model for adjustment.

Secondary outcomes. For the outcome of DAPSA28 moderate response at 6 months, the adjusted multivariable analysis yielded 6 predictors. Four of the predictors corresponded to those of the DAPSA28 LDA outcome, which were male sex, lower number of previous b/tsDMARDs, CRP > 10 mg/L, and lower HAQ score (Table 2). In contrast to the DAPSA28 LDA outcome, for which lower TJC28 was a predictor and SJC28 was not a predictor, here both higher TJC28 and higher SJC28 were predictors of DAPSA28 moderate response instead. CVD, DM, and patient pain and fatigue scores were identified as statistical confounders.

Regarding SEC discontinuation within 12 months, the final adjusted model included absence of PsO, higher patient fatigue score, and higher TJC28 as predictors of this outcome (Table 2).

Sex-stratified analyses. Table 3 shows the results of the sex-stratified multivariable analyses for all outcomes. Stratification by sex revealed that male-specific predictors for the achievement of DAPSA28 LDA at 6 months were lower number of previous b/tsDMARDs and CRP > 10 mg/L. Current smoking was no longer a predictor (in either sex). In accordance with the overall analysis for DAPSA28 LDA at 6 months, lower patient pain score, lower HAQ score, and lower TJC28 were predictors shared by both sexes. Patient fatigue score remained a statistical confounder in both sexes.

In the sex-stratified analyses on predictors of DAPSA28 moderate response at 6 months, lower number of previous b/tsDMARDs was a male-specific predictor, whereas female-specific predictors were higher TJC28 and lower patient fatigue score, although the latter was nonsignificant. Consistent predictors of the outcome that were shared by male and female individuals were CRP > 10 mg/L, higher SJC28, and lower HAQ score. Selected confounders were CVD, DM, and patient fatigue score in male individuals, and patient pain score in female individuals.

In the sex-stratified analyses on drug discontinuation within

Table 2. Baseline predictors at 6 months for DAPSA28 LDA and moderate response, and drug discontinuation within 12 months. Results of univariable and multivariable logistic and Cox regression analyses based on a multiple imputed cohort of patients with PsA from the EuroSpA collaboration.

Predictors	DAPSA28 LDA at 6 Months		DAPSA28 Moderate Response at 6 Months		Drug Discontinuation Within 12 Months	
	Univariable Analyses, OR (95% CI)	Multivariable Analysis[a], OR (95% CI)	Univariable Analyses, OR (95% CI)	Multivariable Analysis[a], OR (95% CI)	Univariable Analyses, HR (95% CI)	Multivariable Analysis[a], HR (95% CI)
Age at SEC start	0.99 (0.98-1.00)		0.99 (0.98-1.00)		1.00 (0.99-1.00)	
Years since diagnosis	1.00 (0.99-1.01)		1.00 (0.98-1.02)		1.00 (0.99-1.01)	
Male vs female sex	1.87 (1.58-2.21)	1.31 (1.07-1.61)	1.80 (1.38-2.34)	1.52 (1.13-2.04)	0.76 (0.65-0.89)	
BMI, kg/m^2, per unit	0.98 (0.96-1.00)		0.99 (0.97-1.02)		1.00 (0.98-1.02)	
Current smoking vs never/ previous	0.79 (0.61-1.02)	0.75 (0.56-1.00)	0.68 (0.46-1.00)		1.08 (0.87-1.35)	
Concomitant csDMARDs vs none	1.02 (0.85-1.22)		1.40 (1.09-1.80)		0.78 (0.66-0.91)	
No. of previous b/tsDMARDs, 0/1/≥ 2	0.84 (0.80-0.89)	0.90 (0.84-0.97)	0.81 (0.74-0.90)	0.86 (0.77-0.95)	1.09 (1.05-1.14)	
CVD vs never	0.80 (0.60-1.06)		0.70 (0.48-1.01)	[b]	0.98 (0.69-1.39)	
DM type 1 or 2 vs never	1.04 (0.69-1.58)		0.76 (0.51-1.13)	[b]	0.60 (0.37-0.97)	
Psoriasis vs never	1.56 (1.15-2.12)		1.53 (1.10-2.14)		0.58 (0.42-0.80)	0.67 (0.50-0.91)
CRP > 10 mg/L vs ≤ 10 mg/L	1.00 (0.80-1.25)	1.33 (1.03-1.72)	2.21 (1.67-2.93)	2.05 (1.48-2.85)	0.80 (0.64-1.00)	
Patient pain score, 0-10	0.76 (0.73-0.80)	0.84 (0.78-0.91)	0.95 (0.90-1.00)	[b]	1.06 (1.02-1.11)	
Patient fatigue score, 0-10	0.79 (0.75-0.84)	[b]	0.91 (0.86-0.97)	[b]	1.09 (1.04-1.15)	1.08 (1.04-1.14)
PGA, 0-10	0.89 (0.86-0.92)		1.08 (1.02-1.15)		1.01 (0.97-1.05)	
HAQ, 0-3	0.40 (0.33-0.48)	0.65 (0.51-0.84)	0.78 (0.61-0.99)	0.58 (0.43-0.80)	1.10 (0.96-1.27)	
SJC28	0.93 (0.90-0.95)		1.12 (1.08-1.15)	1.09 (1.05-1.14)	1.01 (0.98-1.03)	
TJC28	0.89 (0.87-0.91)	0.92 (0.89-0.94)	1.04 (1.02-1.06)	1.05 (1.02-1.08)	1.02 (1.01-1.04)	1.02 (1.00-1.04)
C-index		0.75 (0.73-0.77)		0.74 (0.70-0.77)		0.63 (0.60-0.65)

[a] Multivariable analyses a priori adjusted for GDP per capita and year of SEC initiation (2015-2021). [b] Variables estimated to be statistical confounders during the purposeful selection process. b/tsDMARDs: biologic/targeted synthetic DMARDs; C-index: concordance index; CRP: C-reactive protein; csDMARD: conventional synthetic DMARD; CVD: cardiovascular disease; DAPSA28: Disease Activity Index for Psoriatic Arthritis using 28 joints; DM: diabetes mellitus; DMARD: disease-modifying antirheumatic drug; GDP: gross domestic product; HAQ: Health Assessment Questionnaire; HR: hazard ratio; LDA: low disease activity; OR: odds ratio; PGA: physician global assessment; SEC: secukinumab; SJC28: swollen joint count of 28 joints; TJC28: tender joint count of 28 joints.

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Table 3. Sex-stratified multivariable analyses of baseline predictors at 6-months for DAPSA28 LDA and DAPSA28 moderate response, and drug discontinuation within 12 months based on a multiple imputed population cohort from the EuroSpA collaboration.

Predictors	DAPSA28 LDA at 6 Months		DAPSA28 Moderate Response at 6 Months		Drug Discontinuation Within 12 Months	
	Male, Multivariable Analysis[a], OR (95% CI)	Female, Multivariable Analysis[a], OR (95% CI)	Male, Multivariable Analysis[a], OR (95% CI)	Female, Multivariable Analysis[a], OR (95% CI)	Male, Multivariable Analysis[a], HR (95% CI)	Female, Multivariable Analysis[a], HR (95% CI)
Age at SEC start						
Years since diagnosis						
BMI, kg/m^2, per unit						
Current smoking vs never/previous						
Concomitant csDMARDs vs none						
No. of previous b/tsDMARDs (0/1/≥ 2)	0.83 (0.74-0.92)		0.82 (0.70-0.95)		1.13 (1.04-1.23)	
CVD vs never			[b]			
DM type 1 or 2 vs never			[b]			
Psoriasis vs never					0.65 (0.42-1.02)	0.72 (0.52-1.00)
CRP > 10 vs ≤ 10 mg/L	1.61 (1.09-2.36)		2.14 (1.41-3.27)	1.91 (1.20-3.03)	[b]	
Patient pain score, 0-10	0.84 (0.76-0.93)	0.85 (0.76-0.95)		[b]	[b]	[b]
Patient fatigue score, 0-10	[b]	[b]	[b]	0.97 (0.86-1.09)	[b]	1.10 (1.01-1.19)
PGA, 0-10						
HAQ, 0-3	0.65 (0.48-0.88)	0.66 (0.49-0.89)	0.60 (0.41-0.88)	0.60 (0.38-0.93)		
SJC28			1.11 (1.06-1.17)	1.09 (1.03-1.15)		
TJC28	0.90 (0.87-0.94)	0.92 (0.90-0.95)		1.06 (1.03-1.10)	[b]	[b]
C-index	0.75 (0.71-0.78)	0.73 (0.70-0.76)	0.72 (0.67-0.76)	0.72 (0.67-0.76)	0.63 (0.59-0.66)	0.62 (0.59-0.65)

[a] Multivariable analyses a priori adjusted for GDP per capita and year of SEC initiation (2015-2021). [b] Variables estimated to be statistical confounders during the purposeful selection process. b/tsDMARD: biologic/targeted synthetic DMARD; C-index: concordance index; CRP: C-reactive protein; csDMARD: conventional synthetic DMARD; CVD: cardiovascular disease; DAPSA28: Disease Activity Index for Psoriatic Arthritis using 28 joints; DM: diabetes mellitus; DMARD: disease-modifying antirheumatic drug; GDP: gross domestic product; HAQ: Health Assessment Questionnaire; HR: hazard ratio; LDA: low disease activity; OR: odds ratio; PGA: physician global assessment; SEC: secukinumab; SJC28: swollen joint count of 28 joints; TJC28: tender joint count of 28 joints.

12 months, higher number of previous b/tsDMARDs was a male-specific predictor of the outcome, whereas absence of PsO remained a significant predictor among female individuals and a nonsignificant predictor among male individuals. Statistical confounders were CRP > 10 mg/L, patient pain score, patient fatigue score, and TJC28 in the analysis of male patients, and patient pain score and TJC28 in the analysis of female patients.

Model performance. Evaluation of the performance of both the overall (Table 2) and sex-stratified (Table 3) multivariable regression models showed acceptable discrimination for DAPSA LDA and DAPSA moderate response at 6 months (C-index between 0.72 and 0.75). For drug discontinuation within 12 months, the discrimination was poor in both overall and sex-stratified analyses (C-index between 0.62 and 0.63)

DISCUSSION

In this real-world study, we explored baseline predictors of drug effectiveness in 2790 European routine care patients with PsA initiating SEC treatment. We found that male sex, elevated CRP, lower number of previous b/tsDMARDs, and lower HAQ score were predictors of achieving DAPSA28 LDA and DAPSA28 moderate response at 6 months. Further, nonsmoking status, lower TJC28, and lower patient pain score were predictive of DAPSA28 LDA, whereas higher SJC28 and higher TJC28 were predictive of DAPSA28 moderate response. Predictors of SEC discontinuation within 12 months were absence of PsO, higher patient fatigue score, and higher TJC28. When stratified by sex, certain variables remained predictors independently of sex, whereas others did not.

Few previous studies have investigated predictors of treatment response in patients with PsA treated with SEC. These studies have mainly been observational, single-country studies of smaller populations with varying definitions of study populations, biological treatments, or outcome measures.[17-20] Although HAQ, SJC28, and TJC28 have been found to be predictors in studies of TNFi effectiveness,[11,12,14] we found no reports on these measures in earlier studies on SEC effectiveness.

In line with our findings, an observational study by Perrotta et al, including 70 patients with PsA treated with either SEC or an IL-12/23i, found that male sex and higher CRP were predictors of MDA at 6 months.[17] Another observational study by Molica Colella et al, including 65 patients with PsA and 29 patients with radiographic axSpA treated with SEC, found that male sex was the only independent predictor of remission at 12

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months, whereas age, disease duration, concomitant methotrexate use, higher baseline disease activity, PsA diagnosis, and previous TNFi treatment had no significant predictive value.[20] These results are in line with the present study findings, except that we found lower numbers of previous b/tsDMARDs predict both DAPSA28 LDA and DAPSA28 moderate response.

Male sex seems to be a consistent predictor of positive treatment response in SEC-treated patients with PsA.[17,18,20] Although a posthoc analysis of the Managing Axial Manifestations in Psoriatic Arthritis with Secukinumab (MAXIMISE) trial by Baraliakos et al did not find male sex to predict treatment response in patients with PsA and axial involvement,[19] a meta-analysis of randomized trials by Eder et al showed that, compared to their female counterparts, male patients with PsA who were treated with IL-17i were significantly more likely to experience the efficacy outcomes American College of Rheumatology (ACR) 20, ACR50, and MDA.[35] Results from the metaanalysis further suggested that the male-to-female difference in treatment response rates were lower with higher drug doses.[35]

The growing evidence of divergent treatment effects, along with the known differences in disease manifestations and disease course between the sexes,[2] could suggest the presence of underlying sex-specific biologic differences in the disease mechanisms. These potentially inherent sex-dependent differences in PsA underscore the relevance of exploring predictors of treatment response separately for male and female individuals. Notably, this requires a large sample size, as in the present study. Accordingly, this is the first study to our knowledge to investigate predictors of SEC effectiveness in separate cohorts of male and female individuals with PsA. Although we found that predictors of SEC effectiveness were mostly consistent between the sexes, an interesting result was that fewer previous b/tsDMARDs was a predictor of all 3 outcomes in male individuals, but not a predictor of any of the assessed outcomes in female individuals. Since the study by Molica Colella et al[20] included mainly women, our finding of a link between male sex and the predictive role of previous b/tsDMARDs might offer a potential explanation for the contradictory finding that previous TNFi treatment was not predictive of treatment response to SEC in their analysis.

The role of comorbidities and BMI in the prediction of b/tsDMARD effectiveness is often investigated and debated. In relation to SEC, the study by Perrotta et al found that absence of comorbidities, such as hypertension, type 2 DM, metabolic syndrome, and CVD, was predictive of attaining MDA.[17] However, the present study findings suggest that neither CVD nor DM play a predictive role for SEC effectiveness; rather they seem to play a confounding role for the outcome of DAPSA28 moderate response at 6 months, particularly among male individuals. Moreover, our overall and sex-stratified results could not confirm BMI to be predictive of any of the outcomes, which is in line with findings from previous studies on SEC effectiveness.[17,19,20] However, since patients with PsA have a higher burden of comorbidities including CVD, obesity, and DM than the background population,[36] additional studies are needed to clarify the potential role of comorbidities and obesity in relation to SEC treatment response.

We found that patient pain and fatigue scores were selected in the modeling as either predictors or confounders in nearly all multivariable models. We consider these divergent roles to reflect collinearity between the variables,[25] as well as an overlap between the predictive value of patient pain and patient fatigue score. Moreover, the applied method for variable selection, purposeful selection,[27] is a thorough method using several iterations to identify the most accurate set of predictors while taking statistical confounders into account. This approach may cause slight changes to the estimates and significance levels as the model develops and expands, and therefore nonsignificant predictors might be selected in the final multivariable models.[27]

This study has several limitations, the first being the use of DAPSA28 instead of DAPSA based on 66/68 joint counts. Although the DAPSA based on 66/68 joint counts is recommended for the assessment of treatment effects among patients with PsA,[4,37] the DAPSA28 has been reported to perform well in registry studies, where DAPSA is not available.[15,23] Moreover, a study conducted in a population similar to the current study cohort, including patients with PsA from 9 European countries, found that predictors of TNFi effectiveness on DAPSA and DAPSA28 overlapped extensively.[15]

In addition, the 30-day time window for the baseline visit following SEC initiation may have introduced a risk of underestimating the treatment response. However, < 2% of the patients had visits later than 2 weeks after treatment initiation (data not shown). Also, patients were included in the study if they had a diagnosis of PsA even without registrations of clinical PsO at any registered visits. Another limitation is the amount of missing data in the initial study cohort. We addressed this by multiple imputation and data were assumed to be missing at random, although the application of multiple imputation on data with large amounts of missingness poses a risk of introducing bias to the analyses.[38] Although sensitivity analyses on complete cases would have strengthened the results, such analyses were not feasible owing to the low number of complete cases.

In conclusion, male sex, elevated CRP, lower number of previous b/tsDMARDs, and lower HAQ scores were predictors of 6-month DAPSA28 LDA and DAPSA28 moderate response in European patients with PsA treated with SEC. In separate cohorts of male and female individuals, lower number of previous b/tsDMARDs and increased CRP were male-specific predictors of treatment effectiveness. Awareness of these findings may contribute to better personalized treatment decisions for patients with PsA.

CONTRIBUTIONS

JH: conceptualization, methodology, validation, formal analysis, investigation, resources, writing (original draft), writing (review and editing), visualization, project administration; SG: conceptualization, methodology, software, validation, formal analysis, investigation, resources, writing (review and editing), visualization, supervision, project administration; ZFA: investigation, resources, writing (review and editing); B. Glintborg: conceptualization, methodology, validation, investigation, resources, writing (review and editing), visualization, supervision, project administration, funding acquisition; IC: investigation, resources, writing (review and editing); MSK: investigation, resources, data curation, writing (review and editing); AGL: investigation, resources, writing (review and editing); B. Michelsen: investigation, resources, writing (review

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ETHICS AND PATIENT CONSENT

The study was approved by the respective national Data Protection Agencies and Research Ethical Committees according to legal regulatory requirements in the participating countries and was performed in accordance with the Declaration of Helsinki (Supplementary Table S3, available with the online version of this article). The present study followed the Strengthening the Reporting of Observational Studies in Epidemiology guidelines (STROBE).[39]

DATA AVAILABILITY

The data in this article were collected in the individual registries and made available for secondary use through the EuroSpA Research Collaboration Network (https://eurospa.eu/#registries). Relevant patient level data may be made available on reasonable request to the corresponding author but will require approval from all contributing registries.

SUPPLEMENTARY DATA

Supplementary material accompanies the online version of this article.

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