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Performance of 3 Composite Measures for Disease Activity in Peripheral Spondyloarthritis

Esther Beckers[1], Marin Been[1], Casper Webers[1], Annelies Boonen[1], Peter M. ten Klooster[2], Harald E. Vonkeman[3], and Astrid van Tubergen[1]

ABSTRACT. ***Objective***. To investigate concurrent validity and discrimination of the Disease Activity Index for Psoriatic Arthritis (DAPSA) score, Psoriatic Arthritis Disease Activity Score (PASDAS), and Ankylosing Spondylitis Disease Activity Score (ASDAS) in peripheral spondyloarthritis (pSpA) in clinical practice.

Methods. Data from a Dutch registry for SpA (SpA-Net) were used. Predefined hypotheses on concurrent validity of the composite measures with 15 other outcome measures of disease activity, physical function, and health-related quality of life were tested. Concurrent validity was considered acceptable if ≥ 75% of the hypotheses were confirmed. Discrimination was assessed by stratifying patients in DAPSA, PASDAS, and ASDAS predefined disease activity states and studying mean differences in health outcomes by 1-way ANOVA. Further, the concordance in disease activity states was determined. All analyses were repeated in subgroups with and without psoriasis (PsO).

Results. DAPSA, PASDAS, and ASDAS scores were available for 191, 139, and 279 patients with pSpA, respectively. The concurrent validity and discrimination of all composite measures were acceptable, as the strength of correlations were as hypothesized in ≥ 75% of the studied correlations. With increasing disease activity states, scores in nearly all outcome measures worsened significantly. The DAPSA, PASDAS, and ASDAS classified 22%, 56%, and 48% of the patients, respectively, in the 2 highest disease activity states. Stratified analyses for concomitant PsO revealed no relevant subgroup differences.

Conclusion. The performance of DAPSA, PASDAS, and ASDAS in pSpA was acceptable, and independent of concomitant PsO. Due to discrepancy in classification, the validity of existing thresholds for disease activity states warrants further study in pSpA.

Key Indexing Terms: disease activity score, outcome assessment, psoriatic arthritis, spondyloarthropathy

Peripheral spondyloarthritis (pSpA) is characterized by the presence of arthritis, enthesitis, and/or dactylitis. Concomitant extramusculoskeletal manifestations such as uveitis, psoriasis (PsO), and inflammatory bowel disease may occur.[1] The treatment of pSpA usually consists of a combination of education, exercise therapy, and pharmacotherapy.[2,3,4] Response to treatment can be evaluated with the Peripheral SpondyloArthritis Response Criteria (pSpARC40).[5] Such response criteria have been developed to assess how many and which patients have responded adequately to treatment in randomized controlled trials, to facilitate comparison across different trials, and to assess factors that predict treatment response.[6] In clinical practice, response criteria may not be useful for monitoring disease activity as there is no baseline visit against which to compare.[7] Further, their dichotomous scores only show whether the criteria are met, but they do not give any information on the degree of disease activity nor are they able to identify disease activity states.

Currently, a tool specifically developed and validated to quantify and monitor disease activity in a comprehensive way in clinical practice is lacking for pSpA. Assessment of disease activity in pSpA is commonly physician-oriented, and single or multiple components of the disease activity construct are considered, such as the number of tender and swollen joints or the presence of enthesitis or dactylitis, but these are not explicitly integrated into a composite score to support management decisions.

For psoriatic arthritis (PsA), a subpopulation of pSpA, the Disease Activity Index for Psoriatic Arthritis (DAPSA) score has been recommended as an instrument to measure disease activity in a treat-to-target strategy,[8] whereas the Group for

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[1]E. Beckers, MSc, M. Been, MD, C. Webers, MD, PhD, A. Boonen, MD, PhD, Professor, A. van Tubergen, MD, PhD, Professor, Department of Internal Medicine, Division of Rheumatology, Maastricht University Medical Center, and Care and Public Health Research Institute (CAPHRI), Maastricht University, Maastricht; [2]P.M. ten Klooster, PhD, Department of Psychology, Health & Technology, University of Twente, Enschede; [3]H.E. Vonkeman, MD, PhD, Department of Psychology, Health & Technology, University of Twente, Enschede, and Department of Rheumatology, Medisch Spectrum Twente, Enschede, the Netherlands.

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Address correspondence to Ms. E. Beckers, Department of Internal Medicine, Division of Rheumatology, Maastricht University Medical Center, P Debyelaan 25, 6229 HX, Maastricht, the Netherlands.
Email: esther.beckers@mumc.nl.

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Research and Assessment of Psoriasis and Psoriatic Arthritis (GRAPPA) recently voted to use the PsA Disease Activity Score (PASDAS) as the preferred measure for disease activity in clinical trials.[9] Both the DAPSA and PASDAS are joint-based composite scores. The PASDAS also assesses extraarticular involvement components and physical health-related quality of life (HRQOL; Figure 1).[8,10,11] The performance of the DAPSA and PASDAS have been studied in patients with PsA in clinical practice, but not yet in the total pSpA population, including those without PsO.[10,12]

Alternative composite measures for disease activity in PsA are the Minimal Disease Activity (MDA) index, the modified MDA (mMDA), the Composite Psoriatic Disease Activity Index, and the GRAPPA Composite Exercise index.[11,13,14,15,16] However, these instruments may be less useful, as the presence of PsO is included in their calculation (except for the mMDA), which is not applicable to patients without PsO.

For patients with axial (ax-) SpA, the Ankylosing Spondylitis Disease Activity Score (ASDAS) has been developed to assess disease activity (Figure 1).[17] The ASDAS might also be useful for pSpA, as it also contains a question related to peripheral joint pain and swelling and 1 general question each on morning stiffness and global disease activity. To date, the performance of the ASDAS in pSpA has been studied only in clinical trial settings and specific patient populations. It has been shown that the ASDAS had a high sensitivity to change and a high ability to discriminate both between active and placebo treatment and between high and low disease activity (LDA).[18,19] Further, the ASDAS improvement criteria were able to detect a clinically important or major improvement in patients with active treatment compared to placebo treatment.[18,20] Although promising in trials, the performance of the ASDAS in pSpA in daily practice is unknown.

Therefore, the primary aim of the present study was to investigate the concurrent validity of the DAPSA, PASDAS, and ASDAS as well as their discrimination across thresholds of disease activity in pSpA in clinical practice. A secondary aim was to study the performance of these disease activity measures in subgroups of patients with pSpA with and without PsO. In addition, data on the performance of the ASDAS in axSpA are provided as a benchmark for interpreting the findings of the ASDAS in pSpA.

METHODS

Study population. Cross-sectional data from an ongoing, disease-specific prospective registry for SpA in daily practice in the Netherlands (SpA-Net) were used. SpA-Net started in April 2016 and is registered in the Netherlands Trial Registry (NTR 6740).[21] For the current study, data collected in 2 medical centers participating in SpA-Net (Maastricht University Medical Center and Medisch Spectrum Twente) were used. All care providers were trained to use SpA-Net in clinical practice and a standard operating procedure was provided for optimal record keeping. Patients with clinically diagnosed SpA were included if ≥ 1 DAPSA, ≥ 1 PASDAS, or ≥ 1 ASDAS scores could be calculated. Patients were categorized into axSpA or pSpA according to current or past SpA features (Figure 2). For subanalyses, the group of patients with pSpA was further stratified for the presence or absence of PsO.

DAPSA [10]	PASDAS [11]	ASDAS [17]
CRP [0-∞] (mg/dL) Patient global [0-10] Overall pain [0-10] Tender joint count of 68 joints [0-68] Swollen joint count of 66 joints [0-66]	CRP [0-∞] (mg/dL) Patient global [0-100] Physician global assessment [0-100] Tender joint count of 68 joints [0-68] Swollen joint count of 66 joints [0-66] Leeds Enthesitis Count (LEI score) [0-6] Dactylitis count [0-20] SF36 Physical component score (SF36 PCS)	CRP [0-∞] (mg/L) or ESR (mm/h) Patient global [0-10] Pain and swelling in peripheral joints [0-10] Back pain [0-10]* Duration morning stiffness [0 -10]
Formula = Tender joint count of 68 joints + Swollen joint count of 66 joints + CRP (mg/dL) + Overall pain + Patient global	*Formula PASDAS=* *((0.18 √physician global VAS)* *+ (0.159* √patient global VAS)* *- (0.253*√ SF-36 PCS)* *+ (0.101 * ln (swollen joint count+1))* *+ 0.048 *ln(tender joint count +1))* *+ 0.23 ln(Leeds Enthesitis Count + 1))* *+ 0.377 ln(dactylitis count + 1))* *+ 0.102 ln(CRP (mg/L) + 1)) + 2) * 1.5*	*Formula ASDAS-CRP = 0.12 x Back Pain + 0.06 x Duration of Morning Stiffness + 0.11 x Patient Global + 0.07 x Peripheral Pain/Swelling + 0.58 x Ln(CRP (mg/L)+1)* *Formula ASDAS-ESR = 0.08 x Back Pain + 0.07 x Duration of Morning Stiffness + 0.11 x Patient Global + 0.09 x Peripheral Pain/Swelling + 0.29 x √(ESR)*
Thresholds for the DAPSA disease activity score are: remission ≤4, low disease activity ≥5 to ≤14, moderate disease activity ≥15 to ≤28 and high disease activity ≥29	Thresholds for the PASDAS disease activity score are: remission ≤ 1.9, low disease activity >1.9 and <3.2, moderate disease activity ≥3.2 and<5.4 and high disease activity ≥ 5.4	Thresholds for the ASDAS disease activity score are: inactive disease <1.3, low disease activity ≥1.3 to <2.1, high disease activity ≥2.1 to ≤3.5 and very high disease activity >3.5

*This question "How do you rate your back pain due to your AS?" was slightly adapted to "How do you rate your back pain due to your rheumatic condition?" in the present study

DAPSA = Disease Activity Psoriatic Arthritis Score, PASDAS = Psoriatic Arthritis Disease Activity Score, ASDAS = Ankylosing Spondylitis Disease Activity Score, CRP = C-reactive protein, ESR = Erythrocyte Sedimentation Rate

Figure 1. Components, formulas, and cut-offs of the DAPSA, PASDAS, and ASDAS. AS: ankylosing spondylitis; LEI: Leeds Enthesitis Index; PCS: physical component summary scale; SF-36: 36-item Short Form Health Survey; VAS: visual analog scale.

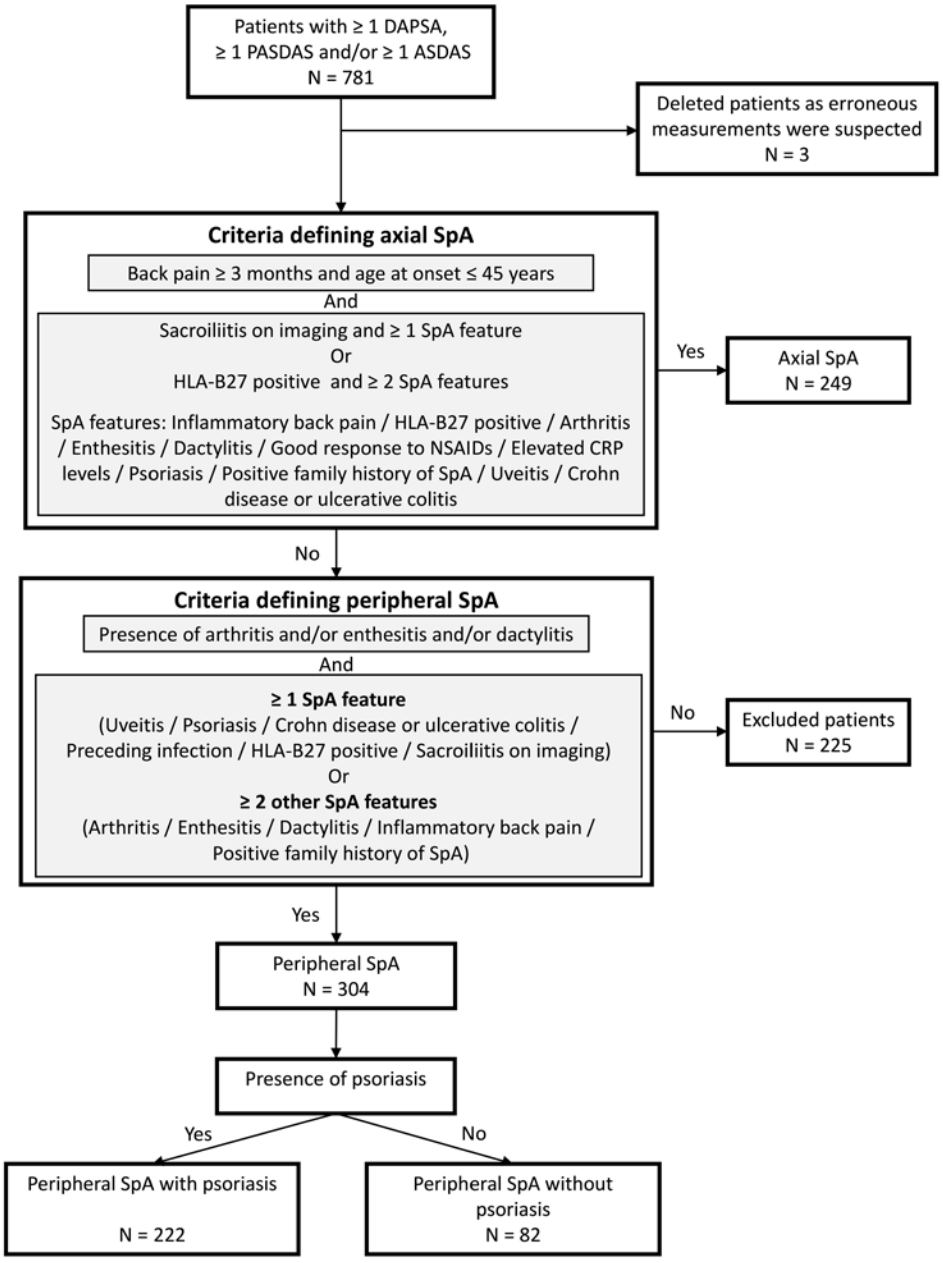

Figure 2. Flowchart of patients included in this study. ASDAS: Ankylosing Spondylitis Disease Activity Score; CRP: C-reactive protein; DAPSA: Disease Activity Index for Psoriatic Arthritis; NSAID: nonsteroidal antiinflammatory drug; PASDAS: Psoriatic Arthritis Disease Activity Score; SpA: spondyloarthritis.

Methods of data collection. Clinical characteristics, outcome measures, results of clinical examinations, and laboratory investigations were collected in SpA-Net at every outpatient visit. Clinical examination was performed for the number of tender and swollen joints (tender joint count in 68 joints [TJC68] and swollen joint count in 66 joints [SJC66], respectively), presence of enthesitis (any location), and presence of dactylitis (any location), depending on the patient's presenting symptoms without structured examination. Outcome measures in this registry consisted of validated measures of disease activity, physical function, overall SpA-specific health impact, generic HRQOL, and health utility.

In SpA-Net, the ASDAS question related to back pain ("How do you rate your back pain due to your ankylosing spondylitis?") was slightly adapted to, "How do you rate your back pain due to your rheumatic condition?" to make this also applicable to patients with other forms of SpA.

The patient global assessment on a visual analog scale (VAS; 0–10) was defined as "How active was your disease on average in the last week?" and the physician global assessment (PGA) on a VAS (0–10) was defined as "How active is the patient's disease on average?" Enthesitis and dactylitis were measured with the Leeds Enthesitis Index and dactylitis count, respectively.[22]

Physical function was measured with the Health Assessment Questionnaire for Spondyloarthropathies (HAQ-S).[23] Overall SpA-specific health impact was measured with the Assessment of SpondyloArthritis international Society Health Index (ASAS HI).[24] HRQOL was measured by the 36-item Short Form Health Survey (SF-36), which has a physical component summary and a mental component summary (MCS), and health utility was measured by the EuroQol with 5D (EQ-5D).[25,26]

Ethics considerations. The ethics committee of the Maastricht University Medical Center/Maastricht University determined that the Medical Research

Involving Human Subjects Act did not apply as data were collected in routine care and official approval was not required for this study. Patients provided written informed consent for the data to be used for research purposes.

Statistical analyses. All data were checked for outliers using scatterplots and data were cleaned if erroneous measurements were suspected. Clinical and demographic characteristics were summarized using descriptive statistics.

Concurrent validity was assessed by Spearman correlations (r_s) of the DAPSA, PASDAS, or ASDAS with all outcome measures, as not all assumptions for Pearson correlations checked with scatterplots were met in some of the outcome measures. The expected degree of correlation was hypothesized a priori (Supplementary Table 1, available with the online version of this article). The strength of correlation was based on predefined criteria: $r_s \leq 0.29$ for very low correlation, $0.30 \leq r_s \leq 0.49$ for low correlation, $0.50 \leq r_s \leq 0.69$ for moderate correlation, $0.70 \leq r_s \leq 0.89$ for high correlation, and $r_s \geq 0.90$ for very high correlation.[27] The frequency in which the hypotheses were confirmed between the DAPSA (11 hypotheses), PASDAS (8 hypotheses), or ASDAS (13 hypotheses) with other outcome measures that were not components of the composite scores was calculated (Figure 1). Concurrent validity was considered acceptable if ≥ 75% of the observed correlations were as hypothesized.[28] This threshold for hypothesis testing has been accepted by international experts in a Delphi study.[29] Observed correlations were considered comparable if they had the same level of strength. Discrimination across thresholds of disease activity in pSpA was assessed by stratifying patients according to established DAPSA, PASDAS, and ASDAS disease activity states and subsequently comparing the means of several external health outcomes across these states by 1-way ANOVA analyses.[30,31] We hypothesized that worsening in disease activity states would also be reflected in worsening of other health outcomes. In addition, we determined the concordance in DAPSA, PASDAS, and ASDAS disease activity classification of patients.

Subgroup analyses were performed on data from patients who had all 3 disease activity measures available at the same point in time. Further, all analyses were repeated after stratification for the presence of PsO. We hypothesized that the performance of the disease activity measures would be comparable in patients with or without PsO.

To allow benchmarking for the ASDAS performance, the results of the ASDAS in patients with pSpA were compared to the results of the ASDAS in patients with axSpA, who were also included in SpA-Net (Figure 2). We hypothesized that the performance would be comparable in all subgroup analyses. Statistical analyses were performed using SPSS Statistics 24 (IBM Corp.).

RESULTS

Study population. In 781 patients, at least 1 DAPSA, PASDAS, or ASDAS score could be calculated (Figure 2). Three patients had to be excluded because of inconsistencies in the data. Of the remaining 778 patients, 249 patients had axSpA, 304 patients had pSpA, and 225 patients could not be classified due to insufficient or missing variables. Of the patients with pSpA, 222 (73%) had concomitant PsO. In 124 of the 304 (41%) patients with pSpA, all 3 disease activity measures were simultaneously available.

On average, disease activity in patients with pSpA was low according to the DAPSA, moderate according to the PASDAS, and high according to the ASDAS (Table 1). Patients had low TJC68 and SJC66 scores and experienced moderate difficulties in daily functioning based on the HAQ-S. Clinical characteristics and health outcomes were comparable between patients with and without PsO, except for sex distribution and csDMARDs use (Supplementary Table 1, available with the online version of this article). Patients with pSpA differed clinically from patients with axSpA, but health outcomes were comparable (Table 1; Supplementary Table 2).

Concurrent validity by correlation with external measures. In the total population of patients with pSpA, the strength of correlation between the DAPSA and other outcome measures was as hypothesized for 10 out of 11 (91%) measures, between the PASDAS and other outcome measures as hypothesized for 6 out of 8 (75%) measures, and between the ASDAS and other outcome measures as hypothesized for 11 out of 13 (85%) measures (Table 2; Supplementary Table 3, available with the online version of this article). The correlations were lower than expected between the PASDAS with SF-36 MCS, between the ASDAS with VAS pain, and between the ASDAS with PGA (Table 2; Supplementary Table 3). Nearly all hypotheses were confirmed between the disease activity measures and measures of physical function, overall SpA-specific health impact, HRQOL, and health utility.

Discrimination across thresholds of disease activity and concordance in classification. In the total population of patients with pSpA, we found with worsening DAPSA, PASDAS, or ASDAS disease activity states, there was significant worsening for all other scores for measures of disease activity, physical function, overall SpA-specific health impact, HRQOL, and health utility (all $P < 0.01$, Table 3), except for enthesitis and dactylitis (all measures), C-reactive protein (CRP) in worsening PASDAS disease activity states ($F = 2.4$, $P = 0.07$), and SJC66 in worsening ASDAS disease activity states ($F = 2.2$, $P = 0.09$).

Overall, substantially fewer patients were categorized as having high disease activity (HDA) by the DAPSA (n = 1 [0.8%]) and PASDAS (n = 5 [4.0%]) compared to having HDA or very high disease activity by the ASDAS (n = 60 [48.4%]; Table 4). When moderate disease activity was included in the definition of HDA by the DAPSA, the difference compared to the ASDAS remained substantial (n = 27 [21.8%] vs n = 60 [48.4%]), whereas including moderate disease activity in the definition of HDA in the PASDAS resulted in more patients classified as having HDA compared with the ASDAS (n = 70 [56.4%] vs n = 60 [48.4%]).

Subgroup analyses. Subgroup analyses in patients with simultaneously available DAPSA, PASDAS, and ASDAS measures showed that nearly all results for concurrent validity and discrimination across thresholds of disease activity were comparable to the total pSpA sample in which at least 1 disease activity measure was available (Supplementary Tables 4–5, available with the online version of this article). The strength of correlations between the DAPSA, PASDAS, or ASDAS with other outcome measures in patients with all 3 disease activity measures available were as hypothesized for 9 out of 11 (81.8%), 5 out of 8 (62.5%), and 8 out of 13 (61.5%) outcome measures, respectively. The hypotheses for concurrent validity of the PASDAS with DAPSA and ASAS HI, and ASDAS with HAQ-S and ASAS HI were not met as the correlations were in fact higher than expected.

In patients with and without PsO, the strength of correlation between either the DAPSA, PASDAS, or ASDAS with other health and clinical outcome measures was almost always comparable (Table 2).

Discrimination across existing thresholds of disease activity did not differ substantially after stratification for the presence or

Table 1. Clinical and demographic characteristics of patients with pSpA.

	DAPSA, n = 191		PASDAS, n =139		ASDAS, n = 279	
	Patients With an Available Assessment, n	Value	Patients With an Available Assessment, n	Value	Patients With an Available Assessment, n	Value
Age, yrs	191	56.1 (11.2)	139	57.2 (10.3)	279	55.7 (12.3)
Female, n (%)	191	103 (53.9)	139	76 (54.7)	279	145 (52.0)
Symptom duration, yrs	140	13.4 (9.1)	112	13.2 (8.7)	213	12.6 (9.4)
Current NSAID use, n (%)	–	91 (47.6)	–	70 (50.4)	–	132 (47.3)
Current cDMARD use, n (%)	–	117 (61.3)	–	70 (50.4)	–	158 (56.6)
Current bDMARD use, n (%)	–	97 (50.8)	–	77 (55.4)	–	137 (49.1)
Current GC use, n (%)	–	10 (5.2)	–	10 (7.2)	–	14 (5.0)
Disease activity						
DAPSA (0–∞)	191	9.9 (6.9)	129	9.5 (6.7)	159	9.6 (6.7)
PASDAS (0–10)	115	3.3 (1.4)	139	3.3 (1.4)	123	3.3 (1.4)
ASDAS (0–∞)	160	2.2 (1.0)	130	2.1 (1.0)	279	2.2 (1.0)
BASDAI (0–10)	161	4.2 (2.4)	132	4.1 (2.4)	279	4.1 (2.3)
PtGA (0–10)	191	4.0 (2.7)	139	3.9 (2.7)	279	4.0 (2.6)
VAS pain (0–10)	191	3.9 (2.6)	129	3.7 (2.5)	230	3.9 (2.6)
PGA (0–10)	144	1.7 (1.5)	139	2.0 (1.5)	184	1.8 (1.6)
CRP, mg/L (0–∞)	191	4.4 (6.0)	139	4.0 (5.4)	279	4.6 (9.1)
PsO BSA (0–100%)	142	1.4 (5.5)	127	1.4 (5.7)	166	1.3 (5.1)
TJC68	191	1.2 (2.4)	139	1.1 (2.5)	197	1.1 (2.3)
SJC66	191	0.4 (0.9)	139	0.4 (0.9)	197	0.4 (1.1)
LEI score (0–6)	161	0.1 (0.4)	139	0.0 (0.2)	201	0.1 (0.3)
Dactylitis count (0–20)	161	0.1 (0.3)	139	0.0 (0.3)	201	0.0 (0.2)
Physical function and health impact						
HAQ-S (0–3)	128	0.8 (0.7)	106	0.8 (0.7)	194	0.8 (0.6)
ASAS HI (0–17)	147	5.3 (3.6)	127	5.2 (3.6)	219	5.3 (3.5)
HRQOL						
EQ-5D (0–1)	130	0.77 (0.18)	106	0.78 (0.20)	194	0.78 (0.19)
SF-36 MCS (0–100)	155	49.5 (10.9)	139	49.3 (10.9)	228	49.5 (10.8)
SF-36 PCS (0–100)	155	39.8 (10.4)	139	40.6 (10.7)	228	40.0 (9.9)

Values are presented as mean (SD) unless stated otherwise. ASAS HI: Assessment of SpondyloArthritis international Society Health Index; ASDAS: Ankylosing Spondylitis Disease Activity Score; BASDAI: Bath Ankylosing Spondylitis Disease Activity Index; bDMARD: biologic disease-modifying antirheumatic drug; BSA: body surface area; CRP: C-reactive protein; cDMARD: conventional disease-modifying antirheumatic drug; DAPSA: Disease Activity Index for Psoriatic Arthritis; EQ-5D: EuroQol 5 Dimensions; GC: glucocorticoid; HAQ-S: Health Assessment Questionnaire for the Spondyloarthropathies; HRQOL: health-related quality of life; LEI: Leeds Enthesitis Index; MCS: mental component summary score; NA: not applicable; NSAID: nonsteroidal anti-inflammatory drugs; PASDAS: Psoriatic Arthritis Disease Activity Score; PCS: physical component summary score; PGA: physician global assessment; pSpA: peripheral spondyloarthritis; PtGA: patient global assessment; PsO: psoriasis; SF-36: 36-item Short Form Health Survey; SJC66: swollen joint count in 66 joints; TJC68: tender joint count in 68 joints; VAS: visual analog scale.

absence of PsO (Supplementary Tables 6–8, available with the online version of this article).

Benchmark analyses. As a benchmark, the performance of the ASDAS in the total population of pSpA was compared with the performance of the ASDAS in patients with axSpA. The correlations between the ASDAS and other outcome measures were as hypothesized in axSpA for 10 out of 12 (83%) measures and in pSpA for 11 out of 13 (85%) measures (Table 2; Supplementary Table 9, available with the online version of this article).

The results for discrimination across thresholds of disease activity were comparable for the ASDAS in both pSpA and axSpA populations, except that significant differences in TJC68 were found across ASDAS states in patients with pSpA, but not in patients with axSpA (Table 3; Supplementary Table 10, available with the online version of this article).

DISCUSSION

Our study showed acceptable concurrent validity and discrimination across thresholds of disease activity for the DAPSA, PASDAS, and ASDAS in clinical practice patients with pSpA, with, on average, a low degree of peripheral joint involvement. The strength of correlation between the disease activity measures with a variety of other outcome measures was correct in more than 75%. In addition, increasing DAPSA, PASDAS, or ASDAS disease activity states were associated with worsening in patient- and physician-reported outcome measures for disease activity, impairment in physical function, overall SpA-specific health impact, generic HRQOL, and health utility. Remarkably, classifying patients in the disease activity states showed discordance in the HDA states.

The results of the subgroup analyses in patients with simultaneously available disease activity measures were comparable to the results of the total pSpA population. Subgroup analyses in patients with and without PsO showed some differences in the performance of the disease activity measures. However, these results should be interpreted with

Table 2. Spearman correlations of DAPSA, PASDAS, and ASDAS with outcomes measures in pSpA.

Outcome Measure	DAPSA						PASDAS						ASDAS					
	Total pSpA Population, n = 191		pSpA Without PsO, n = 49		pSpA With PsO, n = 142		Total pSpA Population, n = 139		pSpA Without PsO, n = 42		pSpA With PsO, n = 97		Total pSpA Population, n = 279		pSpA Without PsO, n = 82		pSpA With PsO, n = 197	
	r_s	Hypothesis	r_s	Hypothesis	r_s	Hypothesis	r_s	Hypothesis	r_s	Hypothesis	r_s	Hypothesis	r_s	Hypothesis	r_s	Hypothesis	r_s	Hypothesis
Disease activity																		
DAPSA	NA		NA		NA		0.91*	- H	0.85*	+	0.90*	- H	0.80*	+	0.79*	+	0.89*	+
PASDAS	0.92*	- H	0.85*	+	0.91*	- H	NA		NA		NA		0.84*	+	0.80*	+	0.83*	+
ASDAS	0.81*	+	0.77*	+	0.80*	+	0.85*	+	0.81*	+	0.84*	+	NA		NA		NA	
BASDAI[a]	0.76*	+	0.73*	+	0.76*	+	0.78*	+	0.67*	- L	0.80*	+	0.85*		0.83*		0.84*	
PtGA[a,b,c]	0.89*		0.87*		0.89*		0.92*		0.88*		0.91*		0.82*		0.79*		0.79*	
VAS pain[b]	0.89*		0.86*		0.90*		0.74*	+	0.71*	+	0.74*	+	0.69*	- L	0.63*	- L	0.69*	- L
PGA[c]	0.61*	+	0.61*	+	0.60*	+	0.81*		0.76*		0.80*		0.49*	- L	0.46*	- L	0.48*	- L
CRP[a,b,c]	0.19*		0.33*		0.13		0.15		0.25		0.12		0.48*		0.56*		0.44*	
PsO BSA	−0.04		NA		0.01	- L	−0.08		NA		0.00	- L	0.01		NA		0.14	- L
TJC68[b,c]	0.67*		0.75*		0.67*		0.52*		0.48*		0.58*		0.39*	+	0.35*	+	0.44*	+
SJC66[b,c]	0.46*		0.34		0.51*		0.43*		0.27		0.50*		0.19*	+	-0.00	+	0.28*	+
LEI[c]	0.12	+	0.18	+	0.07	+	0.10		0.17		0.05		0.11	+	0.15	+	0.09	+
Dactylitis count[c]	0.22	+	ND		0.26*	+	0.19*		ND		0.23*		0.08	+	ND		0.12	+
Physical function and health impact																		
HAQ-S	0.59*	+	0.62*	+	0.56*	+	0.68*	+	0.73*	- H	0.65*	+	0.63*	+	0.65*	+	0.60*	+
ASAS HI	0.67*	+	0.57*	+	0.67*	+	0.68*	+	0.60*	+	0.68*	+	0.63*	+	0.64*	+	0.57*	+
HRQOL																		
EQ-5D	−0.69*	+	−0.65*	+	−0.69*	+	−0.50*	+	−0.40*	+	−0.53*	+	−0.62*	+	−0.64*	+	−0.60*	+
SF-36 MCS	−0.30*	+	−0.31*	+	−0.28*	- L	−0.15	- L	−0.25	- L	−0.13	- L	−0.33*	+	−0.53*	+	−0.24*	- L
SF-36 PCS[c]	−0.65*	+	−0.67*	+	−0.64*	+	−0.76*		−0.82*		−0.72*		−0.67*	+	−0.69*	+	−0.64*	+

Correlations: "+" indicates strength of correlation as hypothesized. "-" indicates strength of correlation was not as hypothesized. "L" indicates that the strength of correlation is lower than hypothesized; "H" indicates that strength of correlation is higher than hypothesized; "ND" indicates that correlation could not be calculated as SD was zero. Individual components of the DAPSA, PASDAS, and ASDAS were not included in the calculation of the frequency of confirmed hypotheses for concurrent validity. [a] ASDAS components. [b] DAPSA components. [c] PASDAS components. * Correlation is statistically significant at the 0.05 level (2-tailed). ASAS HI: Assessment of SpondyloArthritis international Society Health Index; ASDAS: Ankylosing Spondylitis Disease Activity Score; axSpA: axial spondyloarthritis; BASDAI: Bath Ankylosing Spondylitis Disease Activity Index; BSA: body surface area; CRP: C-reactive protein; DAPSA: Disease Activity Index for Psoriatic Arthritis; EQ-5D: EuroQol-5 Dimensions; HAQ-S: Health Assessment Questionnaire for the Spondyloarthropathies; HRQOL: health-related quality of life; LEI: Leeds Enthesitis Index; MCS: mental component summary score; NA: not applicable; NSAID: nonsteroidal antiinflammatory drug; PASDAS: Psoriatic Arthritis Disease Activity Score; PCS: physical component summary score; PGA: physician global assessment; PtGA: patient global assessment; PsO: psoriasis; pSpA: peripheral spondyloarthritis; SF-36: 36-item Short Form Health Survey; SJC66: swollen joint count in 66 joints; TJC68: tender joint count in 68 joints; VAS: visual analog scale.

Table 3. Outcome measures stratified for DAPSA, PASDAS, or ASDAS disease activity states in peripheral spondyloarthritis.

	DAPSA, n = 191						PASDAS, n = 139						ASDAS, n = 279					
	DAPSA Cut -offs				1-way ANOVA		PASDAS Cut -offs				1-way ANOVA		ASDAS Cut-offs				1-way ANOVA	
Outcome Measure	≤ 4,	5 to ≤ 14,	15 to ≤ 28,	≥ 29,	*F*	*P*	≤ 1.9,	1.9 to < 3.2,	3.2 to < 5.4,	≥ 5.4,	*F*	*P*	< 1.3,	1.3 to < 2.1,	2.1 to ≤ 3.5,	> 3.5,	*F*	*P*
	n = 49	n = 99	n = 41	n = 2		n = 23	n = 4	n = 69	n = 7			n = 59	n = 83	n = 105	n = 32			
	(25.7%)	(51.8%)	(21.5%)	(1.0%)		(16.5%)	0 (8.8%)	(49.6%)	(5.0%)			(21.1%)	(29.7%)	(37.6%)	(11.5%)			
Disease activity																		
DAPSA (0–∞)	2.1 (1.4)	9.5 (2.9)	18.9 (3.0)	34.7 (7.8)	346.6	< 0.01	1.7 (1.9)	5.5 (2.9)	13.3 (5.2)	22.1 (3.6)	69.7	< 0.01	3.2 (2.9)	7.2 (4.8)	12.9 (5.9)	17.1 (3.8)	50.2	< 0.01
PASDAS (0–∞)	1.7 (0.9)	3.4 (0.7)	5.0 (0.6)	–	132.6	< 0.01	1.0 (0.5)	2.7 (0.4)	4.1 (0.6)	5.9 (0.4)	307.7	< 0.01	1.8 (0.9)	3.1 (1.0)	4.2 (0.7)	4.9 (0.6)	64.2	< 0.01
ASDAS (0–∞)	1.1 (0.5)	2.2 (0.7)	3.2 (0.8)	3.2 (–)	62.5	< 0.01	0.9 (0.3)	1.5 (0.6)	2.7 (0.7)	3.4 (0.8)	64.7	< 0.01	0.9 (0.3)	1.7 (0.2)	2.7 (0.4)	3.9 (0.4)	717.4	< 0.01
BASDAI (0–10)	1.8 (1.6)	4.6 (1.8)	6.2 (1.9)	7.6 (–)	45.5	< 0.01	1.0 (0.8)	2.9 (1.7)	5.4 (1.7)	7.0 (1.7)	54.1	< 0.01	1.5 (0.9)	3.2 (1.4)	5.3 (1.6)	7.0 (1.4)	151.8	< 0.01
PtGA (0–10)	1.0 (0.9)	4.1 (1.8)	7.2 (1.6)	7.5 (0.7)	117.0	< 0.01	0.4 (0.7)	2.2 (1.1)	5.6 (1.8)	8.3 (1.1)	116.2	< 0.01	1.1 (1.1)	3.2 (1.8)	5.2 (2.0)	7.4 (1.4)	119.0	< 0.01
VAS pain (0–10)	0.7 (0.7)	4.2 (1.9)	6.7 (1.4)	6.3 (1.0)	119.6	< 0.01	0.9 (1.9)	2.6 (2.2)	4.9 (1.8)	7.4 (0.8)	33.6	< 0.01	1.6 (2.2)	2.9 (2.0)	5.3 (2.0)	6.3 (1.4)	56.2	< 0.01
PGA (0–10)	0.8 (0.9)	1.6 (1.0)	3.2 (1.6)	8.0 (–)	34.7	< 0.01	0.3 (0.6)	1.4 (0.8)	2.4 (1.0)	5.6 (1.6)	70.2	< 0.01	1.0 (1.1)	1.5 (1.2)	2.3 (1.7)	3.3 (1.8)	14.5	< 0.01
CRP, mg/L (0–∞)	2.3 (2.1)	4.0 (4.2)	7.5 (9.8)	13.5 (16.3)	8.3	< 0.01	3.2 (2.9)	2.4 (3.0)	5.1 (6.8)	5.6 (5.8)	2.4	0.07	1.6 (1.1)	2.5 (2.5)	4.7 (5.6)	15.2 (21.9)	21.9	< 0.01
TJC68 (0–68)	0.0 (0.3)	0.6 (1.1)	3.2 (2.4)	15.5 (9.2)	94.5	< 0.01	0.0 (0.2)	0.3 (0.6)	1.7 (3.2)	3.1 (1.7)	6.5	< 0.01	0.2 (0.5)	0.8 (1.3)	1.5 (3.1)	1.9 (2.0)	5.1	< 0.01
SJC66 (0–66)	0.0 (0.3)	0.3 (0.6)	1.1 (1.3)	4.0 (1.4)	28.0	< 0.01	0.0 (0.2)	0.2 (0.4)	0.4 (1.0)	1.9 (1.9)	9.2	< 0.01	0.1 (0.4)	0.4 (0.8)	0.6 (1.4)	0.6 (1.2)	2.2	0.09
LEI (0–6)	0.0 (0.0)	0.1 (0.3)	0.2 (0.7)	0.0 (–)	1.3	0.29	0.1 (0.2)	0.1 (0.2)	0.0 (0.2)	0.1 (0.4)	0.9	0.44	0.0 (0.0)	0.1 (0.3)	0.1 (0.4)	0.1 (0.3)	1.6	0.18
Dactylitis count (0–20)	0.0 (0.0)	0.0 (0.1)	0.2 (0.6)	0.0 (–)	2.4	0.07	0.0 (0.0)	0.0 (0.0)	0.0 (0.4)	0.1 (0.4)	0.7	0.54	0.0 (0.3)	0.0 (0.1)	0.0 (0.3)	0.1 (0.3)	0.5	0.71
Physical function and health impact																		
HAQ-S (0–3)	0.2 (0.3)	1.0 (0.6)	1.2 (0.7)	1.0 (–)	19.3	< 0.01	0.1 (0.2)	0.5 (0.4)	1.2 (0.6)	2.0 (0.4)	27.7	< 0.01	0.2 (0.3)	0.6 (0.6)	1.1 (0.6)	1.3 (0.6)	30.1	< 0.01
ASAS HI (0–17)	1.8 (1.7)	6.0 (3.1)	7.5 (3.3)	11.0 (–)	29.2	< 0.01	1.5 (1.9)	3.3 (2.2)	7.1 (3.2)	8.2 (3.3)	28.1	< 0.01	2.2 (1.7)	4.3 (2.7)	6.9 (3.4)	8.3 (3.2)	38.2	< 0.01
HRQOL																		
EQ-5D (0–1)	0.94 (0.06)	0.76 (0.12)	0.64 (0.23)	0.41 (–)	25.7	< 0.01	0.92 (0.13)	0.85 (0.11)	0.70 (0.23)	0.87 (0.11)	8.0	< 0.01	0.93 (0.08)	0.81 (0.14)	0.71 (0.18)	0.63 (0.24)	22.9	< 0.01
SF-36 MCS (0–100)	55.4 (7.1)	47.6 (10.9)	47.8 (11.4)	22.1 (–)	8.2	< 0.01	54.3 (10.1)	49.4 (9.2)	47.4 (11.4)	50.8 (13.8)	2.4	0.07	54.5 (7.4)	51.9 (9.9)	46.1 (11.1)	44.9 (12.4)	10.0	< 0.01
SF-36 PCS (0–100)	49.7 (6.9)	38.5 (8.9)	32.1 (8.2)	35.9 (–)	31.2	< 0.01	51.3 (7.5)	46.8 (7.6)	35.2 (7.3)	24.5 (9.2)	47.0	< 0.01	49.1 (7.0)	42.9 (8.9)	35.4 (8.1)	30.8 (5.0)	47.9	< 0.01

Values are presented as mean (SD) unless stated otherwise. ASAS HI: Assessment of SpondyloArthritis international Society Health Index; ASDAS: Ankylosing Spondylitis Disease Activity Score; BASDAI: Bath Ankylosing Spondylitis Disease Activity Index; CRP: C-reactive protein; cDMARD: conventional disease-modifying antirheumatic drug; DAPSA: Disease Activity Index for Psoriatic Arthritis; EQ-5D: European Quality of Life 5 Dimensions; HAQ-S: Health Assessment Questionnaire for the Spondyloarthropathies; LEI: Leeds Enthesitis Index; MCS: Mental Component summary; NSAID: nonsteroidal antiinflammatory drugs; PASDAS: Psoriatic Arthritis Disease Activity Score; PCS: Physical Component summary; PGA: physician global assessment; PtGA: patient global assessment; SF-36: 36-item Short Form Health Survey; SJC66: swollen joint count in 66 joints; TJC68: tender joint count in 68 joints; VAS: visual analog scale.

Table 4. Disease activity states of patients with peripheral spondyloarthritis with DAPSA, PASDAS, and ASDAS scores simultaneously available (n = 124).

		PASDAS				ASDAS			
	n (%)	Remission, ≤ 1.9, 18 (14.5%)	Low, > 1.9 to < 3.2, 36 (29.0%)	Moderate, ≥ 3.2 to < 5.4, 65 (52.4%)	High, ≥ 5.4, 5 (4.0%)	Inactive, < 1.3, 30 (24.2%)	Low, ≥ 1.3 to < 2.1, 34 (27.4%)	High, ≥ 2.1 to ≤ 3.5, 46 (37.1%)	Very High, > 3.5, 14 (11.3%)
DAPSA									
Remission, ≤ 4	33 (26.6)	16	17	0	0	22	11	0	0
Low, ≥ 5 to ≤ 14	64 (51.6)	2	19	43	0	8	20	33	3
Moderate, ≥ 15 to ≤ 28	26 (21.0)	0	0	21	5	0	3	12	11
High, ≥ 29	1 (0.8)	0	0	1	0	0	0	1	0
ASDAS									
Inactive, < 1.3	30 (24.2)	15	15	0	0				
Low, ≥ 1.3 to < 2.1	34 (27.4)	3	17	13	1				
High, ≥ 2.1 to ≤ 3.5	46 (37.1)	0	4	40	2				
Very high, > 3.5	14 (11.3)	0	0	12	2				

ASDAS: Ankylosing Spondylitis Disease Activity Score; DAPSA: Disease Activity Index for Psoriatic Arthritis; PASDAS: Psoriatic Arthritis Disease Activity Score.

caution as they may have been caused by the small number of patients without PsO.

As no gold standard exists to assess disease activity in pSpA, the performance of the DAPSA, PASDAS, and ASDAS was studied in relation to multiple subjective and objective outcome measures capturing several disease aspects from both the physician and patient perspective. Overall, these analyses provided elaborated evidence on the performance of these disease activity measures in patients with pSpA with low peripheral joint involvement in the majority of the patients in clinical practice. The comparable performance of the ASDAS in patients with pSpA and axSpA strengthens the hypothesis that the ASDAS could also be a valid measure in patients with pSpA.

An important finding was the substantial discordance when classifying patients into the disease activity states. The DAPSA classified 22%, the PASDAS 56%, and the ASDAS 48% of the patients in the 2 highest disease activity states. These results might be explained by different individual components of each composite measure. Involvement of peripheral joints has substantially more weight in the cumulative calculation of the DAPSA, where the absolute number of affected joints is included, compared to the ASDAS, where only a general question on peripheral joint involvement is asked, and the PASDAS, where joint involvement has a relative weight. Alternatively, the discrepancy could also be an indication that the existing thresholds for disease activity states of the DAPSA and PASDAS used for patients with PsA and the ASDAS for axSpA might not be applicable to patients with pSpA, but this interpretation requires a note of caution, as the number of patients with a high number of swollen joints was limited in our study.[30,31] However, the discrepancy may have large implications for clinical practice. The number of patients with pSpA who did not achieve remission or LDA was much higher using the PASDAS and ASDAS compared to DAPSA, and consequentially more patients would qualify for treatment intensification based on the PASDAS and ASDAS compared to the DAPSA. This discrepancy in classification and the validity of existing thresholds for disease activity states therefore warrants further study in pSpA.

Practically, the ASDAS may have some advantages over the DAPSA and PASDAS. First, assessment of the ASDAS is much faster than the DAPSA and PASDAS, which require full joint examination. Second, the ASDAS can be used for remote monitoring of disease activity as its components, including measuring CRP levels, are assessor independent. Third, with the ASDAS, disease activity can be assessed in both axSpA and pSpA with the same measure, allowing comparison as well as aggregation of the 2 populations. The DAPSA might also have an advantage over the PASDAS and ASDAS, as calculating these measures is complex and requires an online tool.

Some concerns about the usefulness of the DAPSA as a measure of disease activity for patients with PsA have been expressed.[32] The DAPSA assesses peripheral joint disease, but does not take into account other aspects of disease activity, such as PsO, dactylitis, and enthesitis, which are important to patients. This limitation of the DAPSA also applies to the ASDAS.

Our study has several strengths. The performance of the disease activity measures in pSpA was evaluated in daily practice and the results therefore represent real life rather than research settings, increasing the generalizability of the findings. Further, data from all patients with pSpA and axSpA were collected in 1 patient register using the same standardized method.

This study also has several limitations. First, patients in this study were adequately treated and had on average low CRP levels, as well as low TJC68 and SJC66 scores, which limits the generalizability to other pSpA populations with more active disease. Second, the sample size of patients with pSpA without PsO was relatively low, which might have affected the results when comparing the performance of the disease activity measures between patients with or without PsO. Third, we have not tested the responsiveness of the DAPSA, PASDAS, and ASDAS in pSpA in our population, because we have only limited follow up data from our patients thus far as SpA-Net is an observational cohort of well-treated patients with only a limited number of treatment adaptations.

In conclusion, this study showed that the DAPSA, PASDAS, and ASDAS have acceptable concurrent validity and discrimination across thresholds of disease activity in pSpA, which was

independent of the presence of PsO. Based on results of clinical trial data and our results in daily practice, the DAPSA, PASDAS, and ASDAS could be useful for measuring disease activity in pSpA in clinical practice. However, the discrepancy in classification of individual patients in disease activity states currently limits their use for decision making in clinical practice and warrants further study in pSpA.

DATA AVAILABILITY

The data underlying this article will be shared on reasonable request to the corresponding author.

ONLINE SUPPLEMENT

Supplementary material accompanies the online version of this article.

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