DISABILITY, FATIGUE, PAIN AND THEIR ASSOCIATES IN EARLY DIFFUSE CUTANEOUS SYSTEMIC SCLEROSIS: THE EUROPEAN SCLERODERMA OBSERVATIONAL STUDY (ESOS)

Sébastien Peytrignet, Centre for Musculoskeletal Research, The University of Manchester, Manchester Academic Health Science Centre, Manchester, M 13 9PT, UK.

Christopher P Denton, Centre for Rheumatology and Connective tissue Diseases, UCL Division of Medicine, Royal Free Campus, London, UK.

Mark Lunt, Centre for Musculoskeletal Research, The University of Manchester, Manchester Academic Health Science Centre, Manchester, M13 9PT, UK.

Roger Hesselstrand, Department of Rheumatology, Lund University, Lund, Sweden.

Luc Mouthon, Service de Médecine Interne, Hôpital Cochin, Centre de Référence pour les Vascularites Nécrosantes et la Sclérodermie Systémique, Université Paris Descartes, Assistance Publique-Hôpitaux de Paris (AP-HP), Paris, France.

Alan Silman, Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences,University of Oxford, Oxford,  OX3  7LD.

Xiaoyan Pan, Centre for Musculoskeletal Research, The University of Manchester, Manchester Academic Health Science Centre, Manchester, M13 9PT, UK.

Edith Brown, Member of Steering Committee, contact via Professor Herrick, The University of Manchester, Manchester M13, 9PT.

László Czirják, Department of Rheumatology and Immunology, Medical Center, University of Pécs, Hungary.

Jörg HW Distler, Department of Internal Medicine 3, University of Erlangen-Nuremberg, Erlangen, Germany.

Oliver Distler, Department of Rheumatology, University of Zurich, Zurich, Switzerland.

Kim Fligelstone, Royal Free London NHS Foundation Trust, London, UK.

William J Gregory, Rehabilitation Services, Salford Royal NHS Foundation Trust, Salford, M6 8HD, UK.

Rachel Ochiel, Royal Free London NHS Foundation Trust, London, UK.

Madelon Vonk, Department of the Rheumatic Diseases, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands.

Codrina Ancuţa, “Grigore T. Popa” University of Medicine and Pharmacy; Rheumatology 2 Department, Clinical Rehabilitation Hospital, Iași, Romania.

Voon H Ong, Centre for Rheumatology and Connective Tissue Diseases, UCL Division of Medicine, Royal Free Campus, London, UK.

Dominique Farge, Unité Clinique de Médecine Interne, Maladies Auto-immunes et Pathologie Vasculaire, UF 04, Hôpital Saint-Louis, AP-HP Assistance Publique des Hôpitaux de Paris, INSERM UMRS 1160, Paris Denis Diderot University, France.

Marie Hudson, Jewish General Hospital, Lady Davis Institute and McGill University, Montreal, H3E 1T2, Canada.

Marco Matucci-Cerinic, Dept Experimental and Clinical Medicine, Div Rheumatology AOUC, University of  Florence, Florence, Italy.

Alexandra Balbir-Gurman, B. Shine Rheumatology Unit, Rambam Heath Care Campus; Rappaport Faculty of Medicine, Technion, Haifa, Israel.

Øyvind Midtvedt,  Rheumatology Unit Oslo University Hospital Rikshospitalet, Norway.

Alison C Jordan, Queen Elizabeth Hospital Birmingham, UHB Foundation Trust, Heritage Building, Birmingham B15 2TH, UK.

Wendy Stevens, St Vincent’s Hospital, Melbourne, Australia.

Pia Moinzadeh, Department for Dermatology, University of Cologne Kerpenerstr. 62

50937 Köln, Germany.

Frances C Hall, Cambridge University NHS Hospital Foundation Trust, Cambridge, UK.

Christian Agard, Department of Internal Medicine, Hôtel-Dieu Hospital, University of Nantes, Nantes, France.

Marina E Anderson, University of Liverpool, Aintree University Hospital, Liverpool L9 7AL, UK.

Elisabeth Diot, Service de Médecine Interne, Hôpital Bretonneau Tours 37009 Cedex, France.

Rajan Madhok, Centre for Rheumatic Diseases, Royal Infirmary, 84 Castle Street, Glasgow, G4 0SF,UK.

Mohammed Akil, Sheffield Teaching Hospitals, Sheffield S10 2JF, UK.

Maya H Buch, Leeds Institute of Rheumatic and Musculoskeletal Medicine, University of Leeds and NIHR Leeds Musculoskeletal Biomedical Research Unit, Leeds Teaching Hospitals NHS Trust, UK.

Lorinda Chung, Stanford University, Stanford, CA, USA.

Nemanja Damjanov, University of Belgrade School of Medicine, Institute of Rheumatology, Belgrade, Serbia.

Harsha Gunawardena, Clinical and Academic Rheumatology, North Bristol NHS Trust, Bristol, BS10 5NB, UK.

Peter Lanyon, Nottingham University Hospitals NHS Trust, and Nottingham NHS Treatment Centre, Nottingham, UK.

Yasmeen Ahmad, Peter Maddison Rheumatology Centre, Llandudno, LL30 1LB, UK.

Kuntal Chakravarty, Queens Hospital, Romford, UK.

Søren Jacobsen, University of Copenhagen, Copenhagen Lupus and Vasculitis Clinic, Center for Rheumatology and Spine Diseases, Rigshospitalet, DK-2100 Copenhagen, Denmark.

Alexander J MacGregor, Norwich Medical School, University of East Anglia, UK NR4 7UQ, UK.

Neil McHugh, Royal National Hospital for Rheumatic Diseases, Upper Borough Walls, Bath, BA11RL, UK.

Ulf Müller-Ladner, Department of Rheumatology and Clinical Immunology, Justus-Liebig University Giessen, Kerckhoff Klinik, Bad Nauheim, Germany.

Gabriela Riemekasten, Department of Rheumatology, University of Lübeck, Lübeck, Germany.

Michael Becker, Dept of Rheumatology and Clinical Immunology, University Hospital Charité Berlin, Germany.

Janet Roddy, Department of Rheumatology, Royal Perth Hospital, Perth, Australia.

Patricia E Carreira, Servicio de Reumatologia. Hospital Universitario 12 de Octubre, Madrid, Spain.

Anne Laure Fauchais, Internal Medicine Unit, Limoges University Hospital, France.

Eric Hachulla, Centre National de Référence Maladies Systémiques et Auto-immunes Rares, Département de Médecine Interne et Immunologie Clinique, Université de Lille, Inserm, U995, FHU Immune-Mediated Inflammatory Diseases and Targeted Therapies, F-59000 Lille, France.

Jennifer Hamilton, Gateshead Hospitals Foundation Trust, Sheriff Hill, Gateshead, NE9 6 SX.

Murat İnanç, Istanbul University, Istanbul Medical Faculty, Department of Internal Medicine, Division of Rheumatology, Istanbul, Turkey.

John S McLaren, Fife Rheumatic Diseases Unit, Whyteman’s Brae Hospital, Kirkcaldy, Scotland, KY1 2ND, UK.

Jacob M van Laar, Department of Rheumatology and Clinical Immunology, UMC Utrecht, Heidelberglaan 100, Utrecht, the Netherlands.

Sanjay Pathare, James Cook University Hospital, Middlesbrough, UK.

Susanna Proudman, Rheumatology Unit, Royal Adelaide Hospital, and Discipline of Medicine, University of Adelaide, Adelaide, South Australia, 5000.

Anna Rudin, Dept of Rheumatology and Inflammation Research, The Sahlgrenska Academy at Gothenburg University, Box 480, 405 30 Gothenburg, Sweden.

Joanne Sahhar, Monash Centre for Inflammatory Diseases, , Monash Health and Department Medicine, Monash University, Clayton,  Melbourne, Australia, 3168.

Brigitte Coppere, Department of Internal Medicine, Hôpital Edouard Herriot, Lyon, France.

Christine Serratrice, Department of Internal Medicine, Foundation Hospital Saint Joseph, 26 Boulevard de Louvain, 13008 Marseille, France.

Tom Sheeran, Cannock Chase Hospital, Cannock, WS11 5XY, UK.

Douglas J Veale, St Vincent's University Hospital, Dublin, Ireland.

Claire Grange, Centre Hospitalier Lyon Sud, Department of Internal Medicine 69310, Pierre Benite, France.

Georges-Selim Trad, Internal Medecine, Ambroise Paré Hospital, AP-HP 92100 Boulogne Billancourt, France.

Ariane L Herrick, Centre for Musculoskeletal Research, The University of Manchester, Salford Royal NHS Foundation Trust, Manchester Academic Health Science Centre, Manchester, M13 9PT, UK and NIHR Manchester Musculoskeletal Biomedical Research Unit, Central Manchester NHS Foundation Trust, Manchester Academic Health Science Centre, UK.

Corresponding author: Ariane Herrick, The University of Manchester, Salford Royal NHS Foundation Trust, Manchester Academic Health Science Centre, Manchester UK. Telephone: 0161 275 5993. Email: [ariane.herrick@manchester.ac.uk](mailto:ariane.herrick@manchester.ac.uk)

SHORT TITLE: Associates of disability in early diffuse SSc

ABSTRACT

Objectives.Our aim was to describe the burden of early diffuse cutaneous systemic sclerosis (dcSSc) in terms of disability, fatigue and pain in the ESOS (European Scleroderma Observational Study) cohort, and to explore associated clinical features.

Methods. Patients completed questionnaires at study entry, 12 and 24 months, including the Health Assessment Questionnaire-disability index (HAQ-DI), the Cochin Hand Function Scale (CHFS), the Functional Assessment of Chronic Illness Therapy (FACIT)-fatigue and the Short Form 36 (SF36). Associates examined included the modified Rodnan skin score (mRSS), current digital ulcers and internal organ involvement. Correlations between 12-month changes were also examined.

Results.The326 patients (median disease duration 11.9 months) recruited displayed high levels of disability (mean HAQ-DI 1.1, SD 0.83), with 'grip'; and 'activity' being most affected. Of the 18 activities assessed in the CHFS, those involving fine finger movements were most affected. High HAQ-DI and CHFS scores were both associated with high mRSS (ρ=0.34, p<0.0001 and ρ=0.35, p<0.0001 respectively). HAQ-DI was higher in patients with digital ulcers(p=0.004), pulmonary fibrosis(p=0.005), cardiac(p=0.005) and muscle involvement(p=0.002). As anticipated, HAQ-DI, CHFS, FACIT, and SF36 scores were all highly correlated, in particular the HAQ-DI with the CHFS (ρ=0.84, p<0.0001). Worsening HAQ-DI over 12 months was strongly associated with increasing mRSS (ρ=0.40, p<0.0001), decreasing hand function (ρ=0.57, p<0.0001) and increasing fatigue (ρ=-0.53, p<0.0001).

Conclusions. ESOS highlights the burden of disability in early dcSSc, with high levels of disability and fatigue, associating with the degree of skin thickening (mRSS). Impaired hand function is a major contributor to overall disability.

KEY WORDS. Early diffuse cutaneous systemic sclerosis, disability, hand function, fatigue, pain

INTRODUCTION

Patients with the diffuse cutaneous subtype of systemic sclerosis (SSc) have a high mortality due to early internal organ involvement of their disease. It is therefore understandable that in patients with this subtype of SSc, clinicians have tended to focus on early recognition and treatment of lung, heart and kidney involvement. Perhaps less well recognised is the substantial burden of disability, fatigue and pain of early diffuse cutaneous SSc (dcSSc), caused in large part by progressive skin tightening and musculoskeletal manifestations: levels of disability have been found to be higher in patients with high than with low skin scores [1,2], and in those with joint pain, tendon friction rubs, and contractures [1]. Thus, early dcSSc can have a major impact on quality of life.

A Canadian study published in 2011 specifically addressed the impact of SSc in terms of ability to carry out everyday activities [3], and highlighted the importance of fatigue, pain, and limitation of hand function. However, only 59 of the 464 patients studied definitely had the diffuse cutaneous subtype of SSc (and of unspecified duration). Functional impact, fatigue and pain specifically relating to early diffuse disease have been little studied. The European Scleroderma Observational Study (ESOS) [4] was a prospective observational study of treatment outcome in 326 patients with early dcSSc: data collected included a number of self-administered questionnaires relating to functional ability and quality of life. ESOS therefore afforded a unique opportunity to perform a detailed evaluation of disease impact in a large multinational cohort with very early disease (median disease duration from onset of skin thickening 11.9 months). Our aim was to describe, in the ESOS cohort, the burden of early dcSSc in terms of disability, fatigue and pain, and to explore disease features that associate with this burden both at the baseline visit and over the subsequent 24 months. Although some summary data have been previously reported in the ESOS paper describing treatment efficacy [4], here we focus (and expand on) the different measures of disability, fatigue and pain.

METHODS

ESOS study design

This is described fully elsewhere [4]. In summary, patients with early dcSSc were recruited into a prospective, observational cohort study (ClinicalTrials.gov Identifier: NCT02339441), the overall aim of which was to compare the effectiveness of four different treatment protocols (methotrexate, mycophenolate mofetil, cyclophosphamide or ‘no immunosuppressant’), selected on the basis of clinician and patient preference. A secondary objective of ESOS was to benchmark the severity of disability in patients with early dcSSc, examine the associates of disability and describe its patterns of change over the two year study period. The main inclusion criteria for ESOS were early dcSSc (skin involvement extending to proximal to elbow or knee and/or involving the trunk [5] and within three years of the onset of skin thickening), and age more than 18 years. Patients attended three-monthly for 12 to 24 months. The primary outcome measure of ESOS was modified Rodnan skin score (mRSS) [6] and secondary outcome measures included questionnaire-based measures of disability and fatigue as described below. The Ethics Committee of each participating centre approved the study, and each patient gave written informed consent.

Patients

Patient recruitment took place between July 2010 and September 2014. Demographic and clinical characteristics including age, gender, smoking habit, ethnicity, antibody status (anti-topoisomerase-1 [anti-Scl-70], anti-RNA polymerase III, anticentromere) and presence of visceral organ involvement were recorded for all patients. 326 patients from 50 centres (in 19 countries) were recruited: 65 started on methotrexate, 118 on mycophenolate mofetil, 87 on cyclophosphamide and 56 no immunosuppressant [4].

Outcome measures relating to functional ability, fatigue and pain

At the baseline, 12 month and 24 month visits, patients were asked to complete a set of patient questionnaires to assess functional ability, fatigue and pain. The patient questionnaires were the Scleroderma Specific Health Assessment Questionnaire (sHAQ, including the HAQ-DI disability index), the Cochin Hand Function Scale (CHFS), the Functional Assessment of Chronic Illness Therapy (FACIT) fatigue score and the Short Form 36 Health Survey (SF36), with brief descriptions and justification for inclusion as follows.

*Scleroderma Health Assessment Questionnaire (sHAQ).* Global disability in patients with SSc is usually measured by the HAQ, a self-report questionnaire consisting of 20 items divided into eight categories (dressing and grooming, arising, eating, walking, hygiene, reach, grip and activities), which are averaged into the final HAQ-DI score [7]. Items are rated from 0 (no difficulty) to 3 (unable to do). The sHAQ questionnaire [8] includes the generic HAQ-DI index, and six additional disability measures, graded on a visual analogue scale (VAS) from 0 (least disability) to 100 (most disability). Using these VAS scales, patients self-assess the extent to which (in addition to pain), gastrointestinal symptoms, breathing problems, Raynaud’s phenomenon and digital ulcers interfere with their daily activities, with an additional scale for perceived overall disease severity from SSc. The HAQ-DI is a validated outcome measure for use in clinical studies in patients with SSc as per OMERACT criteria [9]. The HAQ-DI and sHAQ have both been widely applied in studies of SSc [10].

*Cochin (Duruöz) Hand Function Scale (CHFS)* [11]. The CHFS index corresponds to the sum of 18 questions relating to the difficulty of daily manual activities at the time of assessment. Each individual question is ranked on a Likert scale from 0 (without difficulty) to 5 (impossible to do). The total score is obtained by adding the scores of all items (range 0-90). The reliability and validity of the CHFS have been demonstrated in patients with SSc [12,13]. Because of translational issues, patients from certain centres did not complete the CHFS.

*FACIT fatigue scale*. The FACIT (Functional Assessment of Chronic Illness Therapy) fatigue index is derived from a 13-item questionnaire, measuring the extent of a patient’s fatigue over the past week [14]. The final FACIT fatigue score is graded from 0 (higher fatigue) to 52 (lower fatigue).

*SF36.* The Medical Outcome Study (MOS) 36-item SF36 questionnaire is a generic measure of health-related quality of life (HRQOL) in relation to the previous 4 weeks. This self-administered questionnaire covers 8 areas: physical function, physical role, bodily pain, general health, vitality, social function, emotional role, and mental health. For each area, the score ranges from 0 (poorer health status) to 100 (better health status). Scores can also be summarized in 2 global scores: the physical (PCS) and mental (MCS) component summaries [15].

Statistical analysis

In analysing baseline and follow-up data, the immunosuppressant treatment assignment was not accounted for, given that the goal of this paper was not to establish a causal effect between any of these treatments and the progression of disability.

*Baseline associations of disability*. In order to assess baseline associations between patient characteristics and levels of disability, the distribution of each disability indicator was compared between levels of categorical variables (e.g. gender or presence of organ involvement) using the Kruskal-Wallis test. For continuous variables, Spearman correlations (ρ) were used to examine associations with the disability indicators. Each pair of continuous variables uses the subset of observations available to compute each ρ.

*Changes in disability*. Patterns of change were examined by computing the shares of improvers and regressors (of any magnitude) for each indicator during the first 12 month.

*Associates of changes in disability*. Then, Spearman correlations (ρ) were used to examine associations between the 12-month evolution of each disability indicator with the evolution in corresponding continuous variables. For instance, we evaluated the association between the increase in skin fibrosis (mRSS) and the change in disability. The numbers of observations for each pair of variables differ due to data availability and loss to follow-up. Simple linear regression was used to translate these correlations into marginal effects due to changes.

RESULTS

Baseline values (Table 1 and Figures 1 and 2)

*Baseline distribution of HAQ-DI.* The mean and median HAQ-DI scores were 1.1 (standard deviation 0.83) and 1.0 (interquartile range 0.4-1.8) respectively (Figure 1). Fifty (16.3%) patients reported a HAQ-DI lower than 0.15, including 36 null scores, indicating no or very low disability for these patients. On the other hand, 10 (3.3%) patients reported a score of 2.75 or higher, indicating severe disability.

By subdividing the HAQ-DI index into its eight components, grip and activity contributed the most, with 49.0% and 39.0% of patients being 'unable' or reporting much difficulty in the corresponding questions (Figure 2). Rising and walking were the areas which contributed the least to disability (78.0% and 75.8% were capable without any or only some difficulty).

*Baseline distribution of CHFS*. Out of 230 patients with a CHFS score at baseline, the mean and median CHFS were 18.7 (SD 20.7) and 11 (IQR 3.0-29.0) respectively (Figure 1), while 28 (12.2%) patients reported no impairment in hand function according to the CHFS.

Out of 18 activities assessed by the hand function questionnaire, picking up coins, peeling fruit and buttoning a shirt (i.e. activities involving fine finger movements) had the highest mean difficulty (Figure 2). On the other hand, squeezing a new tube of toothpaste, pricking things with a fork and holding a bowl (activities requiring less dexterity) had the lowest mean difficulty.

*Baseline distribution of FACIT fatigue*. The mean and median scores were 30.2 (SD 13.0) and 31.0 (IQR 20.0-41.0) respectively (Figure 1). Among the questionnaire items, 110 patients (35.8%) reported feeling ‘quite a bit’ or ‘very much’ fatigued. By the same approach, 120 (38.7%) patients reported frustration from being too tired to do the things they want to do and 23 (7.4%) reported being too tired to eat (Figure 2).

*Other measures*. The mean and median scores for the SF36 physical component (PCS) were 36.9 (SD 9.7) and 37.4 (IQR 29.9-45.0) respectively, and were 38.5 (SD 7.1) and 38.3 (IQR 34.3-44.0) for the mental component (MCS). For the sHAQ pain scale, the mean and median scores were 32.9/100 (SD 26.9) and 29.0/100 (IQR 8.7-52.7).

Baseline associations (Table 1 and Figures 3 and 4)

*HAQ-DI (0-3, [3 most disabled])* (Figure 3). Table 1 indicates that many clinical and laboratory features of dcSSc were associated with increased disability: current or previous steroid use (p=0.002), current digital ulcers (p=0.004, with a difference in medians of 0.6 units between those with and without ulcers), pulmonary fibrosis (p=0.005, and with reduced FVC [p=0.001] and DLCO [p=0.001]), cardiac involvement (p = 0.005) and muscle involvement (p=0.002). Disability was not correlated with the duration of skin thickening, although there was a correlation with total skin thickening (ρ=0.34, p<0.0001) as well as with skin thickening as measured in the fingers and dorsum of hand (ρ=0.23, p<0.0001). Lower levels of haemoglobin and higher levels of platelets, erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) associated with higher HAQ-DI scores (p<0.0005 for all four). As expected, the HAQ-DI score was strongly associated with the other disability indexes and in particular the CHFS (ρ=0.84, p<0.0001) (Figure 3).

*CHFS hand function (0-90, [90 most disabled])* (Figure 4). The following were associated with reduced hand function: current or previous corticosteroid use (p=0.009), current digital ulcers (p=0.025 and 8.5 difference in median CHFS scores) and pulmonary fibrosis (p=0.019, and with reduced FVC [p=0.016] and DLCO [p=0.008]). Skin thickening was also correlated with impaired hand function (ρ=0.35, p<0.0001) although its duration was not (p=0.901). Among other disability indicators, pain and the severity of Raynaud’s phenomenon (from the sHAQ questionnaire) were both strongly associated with impaired hand function (ρ=0.59 for pain and ρ=0.43 for Raynaud’s, p<0.0001 for both).

*FACIT fatigue (0-52, [0 most disabled])* (Table 1). Associates with increased fatigue were current or previous use of corticosteroids (p=0.004) and several indicators of organ involvement: pulmonary fibrosis (p<0.0005, and with reduced FVC [p<0.0001] and DLCO [p<0.0005]) and pulmonary hypertension (p=0.006), and renal and cardiac involvement (p=0.013 and p=0.001 respectively). Skin thickening was also associated with more fatigue (ρ=-0.20, p=0.0005). Lower levels of haemoglobin (p<0.0001) and higher levels of CRP (p<0.001) and ESR (p<0.0005) were associated with more fatigue.

*SF36 physical (PCS) and mental components (MCS) (0-100, [0 most disabled]).* As described in Table 1, associations of lower SF 36 PCS scores (representing increased physical disability) included current or previous use of corticosteroids (p=0.004), pulmonary fibrosis (p=0.004, and with reduced FVC [p<0.0005] and DLCO [p<0.0001]), cardiac (p=0.007) and muscle involvement (p=0.009), and increased skin thickening (p<0.0001). The mental component (SF36 MCS) was not significantly associated with organ involvement measures and was not significantly correlated with the extent of skin thickening. The strongest associations of the MCS score was with fatigue (ρ=0.29, p<0.0001).

*sHAQ Pain VAS scale (0-100, [100 most disabled]).* Patients with pulmonary fibrosis (p=0.033) and cardiac involvement (p=0.088) reported more pain compared to those without (Table 1). Older patients tended to report slightly lower levels of pain (ρ=-0.11, p=0.055). Skin thickening was associated with more pain (ρ=0.17, p=0.002), as were higher levels of ESR and CRP (p=0.015 and p=0.002 respectively). Pain correlated strongly with other disability measures, including HAQ-DI, hand function and fatigue (p<0.0001 for all three).

Changes in disability

*Trajectories of disability*. The 12-month changes in all indicators followed an approximately normal distribution centred around zero and underline the heterogeneity in the evolution of disability (Supplementary Figure S1). For the HAQ-DI, changes ranged from -1.95 to 1.67 in the first 12 months. There was a tendency, for each measure of disability, for half of the cohort to improve while the other became more disabled.

Supplementary Figure S2 plots the baseline values of the HAQ-DI, CHFS, FACIT fatigue, SF 36 (physical and mental components) and sHAQ Pain VAS against their change in the 12 months. In general, those with more disability at baseline tended to improve while those with the least disability tended to become worse (suggesting regression to the mean). Supplementary Figure S3 describes the evolution of these indicators from baseline to 24 months, further underlining the variability in individual trajectories.

*Associates of changing disability.* The data on 12 month changes are shown in Supplementary Table S1 with changes in several of the measures of disability correlating with each other.

Worsening disability according to HAQ-DI was strongly associated with increasing overall skin thickening (ρ=0.40, p<0.0001), decreasing hand function (ρ=0.57, p<0.0001) and increasing fatigue (ρ=-0.53, p<0.0001). In addition, worsening hand function was also associated with increasing fatigue (ρ=-0.50, p<0.0001). In a regression setting, a 5 unit increase in the skin score resulted in a 0.15 unit increase in the HAQ-DI (0-3) and a 1.58 increase in the CHFS index (0-90) (Figure 5).

DISCUSSION

ESOS has benchmarked the high burden of disability, fatigue and pain in patients with early dcSSc. Although several recent studies (as discussed below) have reported the functional disability, fatigue and pain associated with SSc, ESOS is the first to make such a detailed analysis specifically in patients with the early dcSSc subtype, and has provided new insights into the associates of disability and fatigue in this patient population. Disability, fatigue and pain were all associated with mRSS (the greater the degree of skin thickening, the greater the disability, fatigue, and pain), with hand function, and with internal organ involvement. In addition, HAQ-DI and hand function were reduced in patients with current digital ulcers, reinforcing previous reports of the functional impact of SSc-related digital ulcers [16-20].

Patients with the *early diffuse* cutaneous subtype of SSc have a particular set of problems, with rapidly progressive skin thickening (often with early contractures) and internal organ involvement. We have shown that this skin thickening is likely to be a key driver of disability, in large part through its effect on hand function: not only were HAQ-DI and CHFS associated with mRSS (reflecting the extent of skin thickening) at baseline, but changes in HAQ-DI over 12 months correlated with changes in mRSS (including specifically with changes in skin score relating to the hands). This suggests the changes are not generated simply by regression to the mean, and makes clinical sense: stiff, painful, hands (due to skin thickening) impact significantly on an individual’s ability to perform activities of everyday living, and this is further exacerbated if there is concomitant finger ulceration.

The association between both disability and fatigue with internal organ involvement is also of interest. Here inter-relationships are likely to be more complex. In part, internal organ involvement will be an index of disease severity (associating with extent of skin thickening [4,21]), but some internal organ involvements for example pulmonary fibrosis and muscle involvement are in themselves fatiguing.

Steen and Medsger in 1997 [8] reported a mean HAQ-DI of 1.22 in 222 patients with early dcSSc (less than 3 years duration), and 0.72 in patients with (any duration of) limited cutaneous SSc. This value of 1.22 is comparable to that in the ESOS cohort (1.1), and indicates a high level of disability. Steen and Medsger also reported that amongst the 163 patients with contemporaneous HAQ-DI and skin score data, increasing and decreasing skin scores were associated (respectively) with an increase and decrease in HAQ-DI, with changes in skin score correlating with changes in HAQ-DI (as we have also found). Although it is unclear how many of these 163 patients had diffuse cutaneous disease, 55% of the whole cohort had dcSSc [8]. The HAQ-DI score of 1.1 also closely matches scores in a meta-analysis of clinical trials in dcSSc including 629 patients [22].

High HAQ-DI scores have (unsurprisingly) been associated with work disability in patients with SSc [23], just one reflection on how functional disability impacts on patients’ lives in many different ways.

Previous studies have reported that hand function is more compromised in patients with dcSSc than limited cutaneous SSc [12,13], but these were not studies conducted specifically in patients with early disease. In the ESOS cohort, the degree of hand impairment correlated with skin score, and activities involving fine finger movement were especially affected. Although Brower and Poole [12] did not report a significant correlation between CHFS and skin score, most patients in this study had established limited cutaneous disease (mean duration 11 years) and therefore it is possible that other factors often associated with disease duration, for example severity of digital vasculopathy and degree of contracture, could have been more influential than skin tightening in impairing hand function (as was found by Mouthon et al [16]). Our finding suggests that in early dcSSc, skin thickening in itself is a major contributor to hand disability, and that impaired hand function is a major contributor to overall disability, confirming the results obtained by Rannou et al [13] who identified that hand disability explained 75% of the variance of global disability in a cohort of patients with either limited cutaneous (lcSSc) or dcSSc. In that study [13], a significant difference was observed between patients with lcSSc and dSSc for mean CHFS score (11.07  ± 11.04 vs 23.48  ±  19.45 respectively (p = 0.01). In the ESOS cohort, the median CHFS was 11, which is lower than in other studies, a finding possibly explained by the early disease: Brower and Poole [12] reported a mean score of 21.1 in their cohort of 40 patients with a mean disease duration of 11 years [12], whereas Mouthon et al [16] reported a mean score of 20.15 in a cohort of 213 patients with a mean disease duration of 10.4 years.

Fatigue is now recognised as a very major symptom in most patients with SSc with a number of recent studies describing fatigue and its associates [3,25-28], previously reported associates of fatigue including pain and poor physical function [25], symptoms suggestive of internal organ involvement (breathing problems and gastrointestinal symptoms [26]) and ability to work [27]. Again, the contribution of ESOS has been to quantify fatigue and describe the associates of fatigue specifically in early dcSSc: these associates include extent of skin thickening and internal organ involvement.

Pain, as measured by VAS, was also associated with degree of skin thickening. We found that pain was also associated with all measures of disability, confirming results from a previous study of 89 patients (67 had dcSSc) in whom pain was correlated with both physical and mental components of the SF36 [29], and from a very recent study from the Canadian Scleroderma Research Group [30]. However, the majority of patients in the latter study had limited cutaneous disease [30]. The pain associated with the skin thickening of early dcSSc has in the past been insufficiently recognised.

In conclusion, the message of our analysis is straightforward - early dcSSc is disabling, fatiguing, and associated with severe compromise in hand function and with pain. As options for treating the life-threatening organ based complications improve, the non-lethal burden is likely to require increasing attention for therapy. Pending the development of effective treatments to prevent or reverse progression of this devastating disease, clinicians need to be aware of this huge burden of disability, and recognise each patient’s need for multidisciplinary input including physiotherapy [31], occupational therapy and pain management, to minimise the impact on the individual.

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**Table 1. Baseline associates of HAQ-DI, CHFS, FACIT fatigue, SF36 PCS, SF36 MCS and sHAQ Pain VAS. Index medians (IQR) across levels of binary variables and correlations with continuous variables.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **HAQ-DI  (0-3), n=307** [3 most disabled] | | **CHFS  (0-90), n=230** [90 most disabled] | | **FACIT fatigue  (0-52), n=310** [0 most disabled] | | **SF36 Physical index (0-100), n=311** [0 most disabled] | | **SF36 Mental index**  **(0-100), n=311** [0 most disabled] | | **sHAQ Pain VAS   (0-100), n=309**  [100 most disabled] | |
| **Overall indicator median (IQR)** | 1.0  (0.4 - 1.8) | | 11.0  (3.0 - 29.0) | | 31.0  (20.0 - 41.0) | | 37.4  (29.9 - 45.0) | | 38.3  (34.3 - 44) | | 29.0  (8.7 - 52.7) | |
|  | | | | | | | | | | | | |
| **Binary variables** | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** |
| Female | 1.0  (0.4 - 1.9) | 0.8  (0.4 - 1.4) | 12.0  (3.0 - 29.0) | 9.0  (3.0 - 19.0) | 30.7  (19.0 -  41.0) | 32.5  (24.5 - 41.5) | 37.1  (29.3 - 44.7) | 37.7  (31.7 - 45.4) | 37.3  (33.2 - 44.0)  [\*] | 39.8  (35.9 - 44.4)  [\*] | 30.0  (9.3 - 53.3) | 27.7  (4.7 - 49) |
| Current or previous steroid use | 1.3  (0.5 - 2.0)  [\*\*\*] | 0.9  (0.4 - 1.5)  [\*\*\*] | 16.0  (5.0 - 34.0)  [\*\*\*] | 8.0  (2.0 - 22.0)  [\*\*\*] | 27.5  (17.2 - 38.5)  [\*\*\*] | 34.0  (24.0 - 42.0)  [\*\*\*] | 35.6  (28.2 - 41.8)  [\*\*\*] | 38.6  (32.0 - 45.8)  [\*\*\*] | 39.1  (34.4 - 44.4) | 37.8  (34.3 - 43.5) | 35.0  (10.7 - 59.0)  [\*\*] | 24.7  (6.0 - 46.7)  [\*\*] |
| Previous use of immuno-suppressants | 0.9  (0.5 – 2.0) | 1.0  (0.4 - 1.6) | 10.0  (3.0 - 22.0) | 11.0  (3.0 - 29.0) | 35.0  (24.0 - 38.0) | 31.0  (20.0 - 41.0) | 37.9  (29.2 - 43.0) | 37.3  (30.4 - 45.0) | 36.6  (34.3 - 42.5) | 38.5  (34.3 - 44.0) | 24.3  (5.7 - 48.0) | 29.2  (8.8 - 54.0) |
| Current digital ulcers | 1.5  (0.6 - 2.3)  [\*\*\*] | 0.9  (0.4 - 1.6)  [\*\*\*] | 18.5  (3.5 - 43.5)  [\*\*] | 10.0  (3.0 - 26.0)  [\*\*] | 27.0  (20.0 - 37.5)  [\*] | 32.3  (20.0 - 42.0)  [\*] | 36.0  (28.5 - 41.8) | 37.5  (30.8 - 45.1) | 37.6  (32.7 - 43.2) | 38.5  (34.4 - 44.2) | 37.0  (6.3 - 63.7) | 27.3  (9.0 - 50.3) |
| Pulmonary fibrosis | 1.5  (0.8 - 2.1)  [\*\*\*] | 0.9  (0.4 - 1.6)  [\*\*\*] | 23.5  (11.0 - 40.0)  [\*\*] | 10.0  (3.0 - 26.0)  [\*\*] | 21.5  (14.0 - 30.5)  [\*\*\*] | 33.0  (22.0 - 42.0)  [\*\*\*] | 31.8  (24.9 - 38.9)  [\*\*\*] | 37.8  (31.0 - 45.1)  [\*\*\*] | 37.9  (33.9 - 42.3) | 38.3  (34.3 - 44.1) | 44.0  (21.0 - 67.3)  [\*\*] | 26.7  (6.7 - 50.7)  [\*\*] |
| Pulmonary hypertension | 1.4  (0.7 - 2.2)  [\*] | 0.9  (0.4 - 1.6)  [\*] | 13.0  (1.0 - 21.0) | 11.0  (3.0 - 29.0) | 22.5  (15.5 - 31.0)  [\*\*\*] | 32.5  (21.0 - 42.0)  [\*\*\*] | 31.4  (24.2 - 42.4)  [\*] | 37.5  (30.7 - 45.0)  [\*] | 38.8  (33.6 - 43.9) | 38.2  (34.3 – 44.0) | 30.0  (4.5 - 69.0) | 29.0  (8.8 - 51.0) |
| Renal involvement | 1.2  (0.6 - 2.1) | 1.0  (0.4 - 1.6) | 18.0  (4.0 - 33.0) | 11.0  (3.0 - 26.0) | 23.5  (17.0 - 34.0)  [\*\*] | 32.0  (21.0 - 42.0)  [\*\*] | 35.9  (24.5 - 45.7) | 37.4  (30.7 - 44.7) | 35.7  (32.0 - 40.6) | 38.5  (34.4 - 44.1) | 30.0  (5.0 - 59.0) | 29.0  (9.0 - 52.0) |
| Cardiac involvement | 1.3  (0.9 - 2.3)  [\*\*\*] | 0.9  (0.4 - 1.7)  [\*\*\*] | 11.0  (5.0 - 39.0) | 11.0  (3.0 - 27.0) | 23.5  (12.0 - 34)  [\*\*\*] | 32.0  (21.0 - 42.0)  [\*\*\*] | 32.0  (24.1 - 40.2)  [\*\*\*] | 37.6  (30.8 - 45.1)  [\*\*\*] | 36.1  (32.7 - 41.9)  [\*] | 38.5  (34.4 - 44.2)  [\*] | 45.2  (16.3 - 59.3)  [\*] | 27.7  (7.3 - 51.7)  [\*] |
| Muscle involvement | 1.9  (1.0 - 2.3)  [\*\*\*] | 0.9  (0.4 - 1.6)  [\*\*\*] | 16.0  (5.0 - 55.0) | 10.0  (3.0 - 26.0) | 25.5  (16.0 - 38)  [\*] | 32.0  (21.0 - 42.0)  [\*] | 31.5  (25.5 - 39.2)  [\*\*\*] | 37.6  (30.8 - 45.1)  [\*\*\*] | 38.6  (32.4 - 45.0) | 38.3  (34.4 - 43.9) | 40.7  (5.7 - 64.7) | 28.3  (8.7 - 51.0) |
| Anti-topoisomerase (anti-ScL70) | 0.9  (0.4 - 1.7) | 1.0  (0.5 - 1.8) | 11.0  (3.0 - 26.0) | 10.0  (3.0 - 29.0) | 30.3  (19.0 - 41.0) | 32.0  (22.0 - 42.0) | 37.4  (29.7 - 44.5) | 37.4  (31.0 - 45.1) | 38.5  (34.3 - 43.7) | 38.1  (34.4 - 44.0) | 31.0  (10.7 - 58.7)  [\*] | 25.3  (3.7 - 49.0)  [\*] |
| Anti-RNA polymerase III | 1.0  (0.6 - 1.6) | 0.9  (0.4 - 1.7) | 10.5  (6.0 - 29.0) | 11.0  (2.0 - 26.0) | 29.6  (18.0 - 41.0) | 30.9  (20.5 - 41.5) | 35.6  (29.6 - 42.7) | 37.6  (30.6 - 45.0) | 38.9  (33.5 - 45.6) | 37.9  (33.6 - 43.7) | 27.5  (10.5 - 51.2) | 30.2  (8.7 - 54.7) |
| Anticentromere | 0.6  (0 - 1.5)  [\*] | 1.0  (0.4 - 1.8)  [\*] | 8.5  (0 - 26.0) | 11.0  (3.0 - 27.0) | 34.5  (22.0 - 44.0) | 31.0  (20.0 - 41.0) | 38.5  (33.0 - 46.0) | 37.3  (29.9 - 44.7) | 37.6  (31.9 - 45.3) | 38.2  (34.4 - 44.0) | 36.0  (15.3 - 47.0) | 27.3  (7.0 - 53.7) |
|  |  | |  | |  | |  | |  | |  | |
| **Continuous variables** | **Spearman's ρ** | | **Spearman's ρ** | | **Spearman's ρ** | | **Spearman's ρ** | | **Spearman's ρ** | | **Spearman's ρ** | |
| Age | -0.05 | | -0.04 | | 0.04 | | 0.08 | | 0.10  [\*] | | -0.11  [\*] | |
| Months since onset of skin thickening | 0.01 | | -0.01 | | -0.01 | | 0.01 | | 0.01 | | 0.02 | |
| mRSS (0-51) | 0.34  [\*\*\*] | | 0.35  [\*\*\*] | | -0.20  [\*\*\*] | | -0.27  [\*\*\*] | | 0.03 | | 0.17  [\*\*\*] | |
| mRSS in fingers and hand dorsa (0-12) | 0.23  [\*\*\*] | | 0.32  [\*\*\*] | | -0.13  [\*\*] | | -0.2  [\*\*\*] | | 0.02 | | 0.13  [\*\*] | |
| Haemoglobin (g/l) | -0.29  [\*\*\*] | | -0.18  [\*\*\*] | | 0.24  [\*\*\*] | | 0.26  [\*\*\*] | | 0.03 | | -0.14  [\*\*] | |
| White blood count (WBC) (x109/l) | 0.08 | | 0.06 | | -0.08 | | -0.14  [\*\*] | | 0.04 | | 0.01 | |
| Platelets (x109/l) | 0.21  [\*\*\*] | | 0.20  [\*\*\*] | | -0.08 | | -0.21  [\*\*\*] | | 0 | | 0.10  [\*] | |
| ESR (mm/hr) | 0.23  [\*\*\*] | | 0.22  [\*\*\*] | | -0.23  [\*\*\*] | | -0.27  [\*\*\*] | | 0.07 | | 0.16  [\*\*] | |
| CRP (mg/l) | 0.34  [\*\*\*] | | 0.27  [\*\*\*] | | -0.22  [\*\*\*] | | -0.34  [\*\*\*] | | 0.03 | | 0.21  [\*\*\*] | |
| Plasma creatinine (μmol/l) | -0.09 | | -0.09 | | 0.01 | | 0.03 | | -0.01 | | -0.03 | |
| eGFR (ml/min) | 0.01 | | 0.04 | | 0.02 | | -0.02 | | -0.04 | | 0.06 | |
| FVC  (% predicted) | -0.2  [\*\*\*] | | -0.16  [\*\*] | | 0.24  [\*\*\*] | | 0.22  [\*\*\*] | | -0.06 | | -0.09 | |
| DLCO  (% predicted) | -0.21  [\*\*\*] | | -0.19  [\*\*\*] | | 0.22  [\*\*\*] | | 0.25  [\*\*\*] | | -0.01 | | -0.06 | |
| HAQ-DI Disability index (0-3) | 1 | | 0.84  [\*\*\*] | | -0.67  [\*\*\*] | | -0.72  [\*\*\*] | | -0.18  [\*\*\*] | | 0.57  [\*\*\*] | |
| CHFS (0-90) | 0.84  [\*\*\*] | | 1 | | -0.63  [\*\*\*] | | -0.61  [\*\*\*] | | -0.19  [\*\*\*] | | 0.59  [\*\*\*] | |
| FACIT fatigue  score (0-52) | -0.67  [\*\*\*] | | -0.63  [\*\*\*] | | 1 | | 0.67  [\*\*\*] | | 0.29  [\*\*\*] | | -0.52  [\*\*\*] | |
| SF36 physical component  (0-100) | -0.72  [\*\*\*] | | -0.61  [\*\*\*] | | 0.67  [\*\*\*] | | 1 | | -0.02 | | -0.61  [\*\*\*] | |
| SF36 mental component  (0-100) | -0.18  [\*\*\*] | | -0.19  [\*\*\*] | | 0.29  [\*\*\*] | | -0.02 | | 1 | | -0.12  [\*\*] | |
| sHAQ Overall  (0-100) | 0.59  [\*\*\*] | | 0.55  [\*\*\*] | | -0.59  [\*\*\*] | | -0.58  [\*\*\*] | | -0.17  [\*\*\*] | | 0.62  [\*\*\*] | |
| sHAQ Pain  (0-100) | 0.57  [\*\*\*] | | 0.59  [\*\*\*] | | -0.52  [\*\*\*] | | -0.61  [\*\*\*] | | -0.12  [\*\*] | | 1 | |
| sHAQ Raynaud's phenomenon (0-100) | 0.37  [\*\*\*] | | 0.43  [\*\*\*] | | -0.41  [\*\*\*] | | -0.36  [\*\*\*] | | -0.16  [\*\*\*] | | 0.54  [\*\*\*] | |
| sHAQ Finger ulcers (0-100) | 0.26  [\*\*\*] | | 0.29  [\*\*\*] | | -0.23  [\*\*\*] | | -0.30  [\*\*\*] | | -0.04 | | 0.39  [\*\*\*] | |
| sHAQ Intestinal problems  (0-100) | 0.36  [\*\*\*] | | 0.37  [\*\*\*] | | -0.45  [\*\*\*] | | -0.40  [\*\*\*] | | -0.18  [\*\*\*] | | 0.49  [\*\*\*] | |
| sHAQ Breathing problems  (0-100) | 0.36  [\*\*\*] | | 0.33  [\*\*\*] | | -0.43  [\*\*\*] | | -0.45  [\*\*\*] | | -0.06 | | 0.43  [\*\*\*] | |

For binary variables, p-value from Kruskal-Wallis' test, comparing distribution of disability indicator between levels of each binary variable. For continuous variables, p-value for the correlation (ρ) significance.

[\*] p-value ≤ 0.10  
[\*\*] p-value ≤ 0.05  
[\*\*\*] p-value ≤ 0.01

Each pair of variables in the table above used the subset of patients available, according to data availability. The number of patients having data for each disability index was equal to or higher than 93.9% except for the pairs involving the following variables: anti-RNA polymerase III, ESR, CRP, plasma creatinine, eGFR and DLCO. For those variables, the coverage rates did not go below 71.8%.

CRP: C-reactive protein  
DLCO: Carbon monoxide diffusing capacity  
eGFR: Estimated glomerular filtration rate  
ESR: Erythrocyte sedimentation rate  
FVC: Forced vital capacity  
HAQ-DI: Health Assessment Questionnaire - Disability Index  
mRSS: modified Rodnan skin score (17 sites)  
sHAQ: Scleroderma Health Assessment Questionnaire

LEGENDS TO FIGURES

Figure 1. Baseline distribution of disability indicators.

Figure 2. Composition of disability indicators at baseline for HAQ-DI, CHFS, and FACIT fatigue.

*For each questionnaire item, the distribution of answers is displayed based on the number of respondents for each individual question.*

Figure 3. Associates of HAQ-DI.

*For the relation between HAQ-DI and binary variables (here current digital ulcers and pulmonary fibrosis), box plots (with median and interquartile ranges) summarize the distribution of the index within each level of the binary variable. In addition, a strip plot shown next to each box plot gives more detail on the dispersion of all individual points.  
  
For the relation between HAQ-DI and continuous variables (here mRSS, CHFS and sHAQ Pain VAS), a scatter plot is shown for each pair and superimposed with a linear regression line to describe the correlation direction.*

Figure 4. Associates of CHFS.

*Same as Figure 2, but for CHFS associates.*

Figure 5. Co-movements of skin fibrosis (mRSS), HAQ-DI and CHFS in first 12 months.

*These four scatter plots describe the 12 month changes in mRSS (overall and in fingers and hand dorsum) with respect to the change in HAQ-DI and CHFS. In each axis, the symbol ∆ denotes change. A regression line shows in each case the marginal effect of a one-unit increase in the skin score, equal to the regression coefficient (β), shown here alongside its significance p-value.*

LEGENDS TO SUPPLEMENTARY FIGURES

Supplementary Figure S1. 12-month changes in disability indicators.

Supplementary Figure S2. 12-month changes in the disability and fatigue indicators with respect to their baseline values.

Supplementary Figure S3. Values of HAQ-DI, CHFS and FACIT fatigue at baseline, 12 months and 24 months.

*For each disability indicator, a ‘lasagna’ plot is constructed by stacking individual lines on top of each other, each line representing the evolution of disability for a patient from baseline to 24 months. Each line changes colour during this period as disability evolves, according to the colour scale shown at the right of each plot.*

CONFLICT OF INTEREST STATEMENT

CPD has done consultancy for GSK, Actelion, Bayer, Inventiva and Merck-Serono, received research grant funding from GSK, Actelion, CSL Behring and Inventiva, received speaker’s fees from Bayer and given trial advice to Merck-Serono. JHWD has consultancy relationships and/or has received research funding from Actelion, BMS, Celgene, Bayer Pharma, Boehringer Ingelheim, JB Therapeutics, Sanofi-Aventis, Novartis, UCB, GSK, Array Biopharma, Active Biotech, Galapagos, Inventiva, Medac, Pfizer, Anamar and RuiYi and is stock owner of 4D Science GmbH. OD has received consultancy fees from 4D Science, Actelion, Active Biotech, Bayer, Biogenidec, BMS, Boehringer Ingelheim, EpiPharm, Ergonex, espeRare Foundation, Genentech/Roche, GSK, Inventiva, Lilly, Medac, Medimmune, Pharmacyclics, Pfizer, Serodapharm, and Sinoxa and received research grants from Actelion, Bayer, Boehringer Ingelheim, Ergonex, Pfizer and Sanofi, and has a patent mir-29 for the treatment of systemic sclerosis licenced. WG has received teaching fees from Pfizer. CA has served as a consultant for Abbvie, Pfizer, Roche, UCB, MSD, BMS, Novartis, and has received research funding and speaker fees from Abbvie, Pfizer, Roche, UCB, MSD, BMS, Novartis. FH has received research funding from Actelion. MEA has undertaken advisory board work and received honoraria from Actelion, and received speaker’s fees from Bristol-Myers Squibb. LC has done advisory board work for Gilead and Actelion and served on Data Safety Monitoring Boards for Cytori and Reata. ND has done consultancy for Abbvie, Pfizer, Roche and MSD, received speaker’s fees from Abbvie, Boehringer-Ingelheim, Pfizer, Richter Gedeon, Roche and MSD. HG has done consultancy work and received honoraria from Actelion. UM-L is funded in part by EUSTAR,EULAR and the European Community (Desscipher program). JMvL has received honoraria from Eli Lilly, Pfizer, Roche, MSD and BMS. SP has received research grants from Actelion Pharmaceuticals Australia, Bayer, CSL Biotherapies, GlaxoSmithKline Australia and Pfizer and speaker fees from Actelion. AR receives funding from AstraZeneca. ALH has done consultancy work for Actelion, served on a Data Safety Monitoring Board for Apricus, received research funding and speaker’s fees from Actelion, and speaker’s fees from GSK. XP, SP, ML, RH, LM, AS, EB, LC, KF, RO, MV, VHO, DF, MH, MM-C, AB-G, OM, ACJ, WS, PM, CA, ED, RM, MA, MHB, PL, YA, KC, SJ, AJM, NM, GR, MB, JR, PEC, AF, EH, JH, MI, JSM, SP, JS, BC, CS, TS, DJV, CG and, GT declare no competing interests.

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KEY MESSAGES

1. Early dcSSc is associated with a high burden of disability, fatigue and pain, which all associate with mRSS.

2. Impaired hand function is a major contributor to overall disability.

**Figure 1. Baseline distribution of disability indicators.  
  
 **

**Figure 2. Composition of disability indicators at baseline for HAQ-DI, CHFS, and FACIT fatigue.**

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**Figure 3. Associates of HAQ-DI.**

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**Figure 4. Associates of CHFS.**

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**Figure 5. Co-movements of skin fibrosis (mRSS), HAQ-DI and CHFS in first 12 months.**

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**Supplementary Table S1. Correlations between 12-month changes.**

*For each pair of variables, Spearman’s ρ, its significance p-value [between brackets] and sample size for computation (n) are shown.*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | mRSS | mRSS hand and fingers | HAQ-DI | CHFS | FACIT fatigue | SF 36 PCS | SF 36 MCS | sHAQ Pain VAS |
| mRSS | 1 |  |  |  |  |  |  |  |
| mRSS hand and fingers | 0.66  [<0.0001]  (226) | 1 |  |  |  |  | Spearman’s ρ  [p-value]  (n) |  |
| HAQ-DI | 0.40  [<0.0001]  (175) | 0.27  [<0.0005]  (173) | 1 |  |  |  |  |  |
| CHFS | 0.19  [0.035]  (126) | 0.24  [0.006]  (125) | 0.57  [<0.0001]  (131) | 1 |  |  |  |  |
| FACIT fatigue | -0.17  [0.023]  (171) | -0.14  [0.073]  (170) | -0.53  [<0.0001]  (176) | -0.50  [<0.0001]  (129) | 1 |  |  |  |
| SF 36 PCS | -0.27  [<0.0005]  (177) | -0.10  [0.196]  (175) | -0.48  [<0.0001]  (182) | -0.33  [<0.0005]  (132) | 0.38  [<0.0001]  (178) | 1 |  |  |
| SF 36 MCS | -0.01  [0.878]  (177) | 0  [0.953]  (175) | -0.13  [0.091]  (182) | -0.19  [0.026]  (132) | 0.30  [<0.0001]  (178) | -0.26  [<0.0005]  (184) | 1 |  |
| sHAQ Pain VAS | 0.13  [0.090]  (175) | 0.09  [0.258]  (173) | 0.32  [<0.0001]  (180) | 0.31  [<0.0005]  (132) | -0.39  [<0.0001]  (176) | -0.45  [<0.0001]  (182) | -0.09  [0.210]  (182) | 1 |

**Supplementary Figure S1. 12-month changes in disability indicators.**

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**Supplementary Figure S2.** 12-month changes in the disability and fatigue indicators with respect to their baseline values.

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**Supplementary Figure S3. Values of (A) HAQ-DI, (B) CHFS and (C) FACIT fatigue at baseline, 12 months and 24 months.**

*For each disability indicator, a ‘lasagna’ plot is constructed by stacking individual lines on top of each other, each line representing the evolution of disability for a patient from baseline to 24 months. Each line changes colour during this period as disability evolves, according to the colour scale shown at the right of each plot.*

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