Impact of TNF inhibitor therapy on joint replacement rates in rheumatoid arthritis: a matched cohort analysis of UK registry data

Authors: Samuel Hawley 1, M. Sanni Ali 1,2, Rene Cordtz 3,4, Lene Dreyer 5,6, Christopher J. Edwards 7, Nigel K. Arden 8,9, Cyrus Cooper 8,9, Andrew Judge 1,9,10, Kimme Hyrich 11,12, Daniel Prieto-Alhambra 1,13

Affiliations:
1. Pharmaco- and Device-Epidemiology Group, Centre for Statistics in Medicine, NDORMS, University of Oxford, UK
2. Faculty of Epidemiology and Population Health, London School of Hygiene and Tropical Medicine, London, UK
3. Centre for Rheumatology and Spine Diseases, Gentofte, Rigshospitalet, DK
4. The Parker Institute, Copenhagen, DK
5. Department of Rheumatology and Clinical Medicine, Aalborg University Hospital, Aalborg, DK
6. Aalborg University, Aalborg DK
7. NIHR Clinical Research Facility, University Hospital Southampton, UK
8. Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, UK
9. MRC Lifecourse Epidemiology Unit, University of Southampton, UK
10. Translational Health Sciences, University of Bristol, UK
11. NIHR Manchester Biomedical Research Centre, Manchester University NHS Foundation Trust, Manchester, UK
12. Arthritis Research UK Centre for Epidemiology, Division of Musculoskeletal & Dermatological Sciences, University of Manchester, Manchester, UK
13. GREMPAL Research Group, Idiap Jordi Gol and CIBERFes, Unviersitat Autonoma de Barcelona and Insituto de Salud Carlos III, Barcelona, Spain

Corresponding author: D. Prieto-Alhambra, Botnar Research Centre, Windmill Road, OX3 7LD, Oxford, UK
Abstract:

Objective: Previous ecological data suggest a decline in need for joint replacements in RA patients following the introduction of tumour necrosis factor inhibitor (TNFi) therapy, although patient-level data are lacking. Our primary aim was to estimate the association between TNFi use and subsequent incidence of total hip replacement (THR) and total knee replacement (TKR).

Methods: A propensity score matched cohort was analysed using the British Society for Rheumatology Biologics Registry (2001 – 2016) for Rheumatoid Arthritis (BSRBR-RA) data. Propensity score estimates were used to match TNFi users to similar conventional synthetic DMARD (csDMARD) users (with replacement) using a 1:1 ratio. Weighted multivariable Cox regression was used to estimate the impact of TNFi on study outcomes. Effect modification by baseline age and disease severity were investigated. Joint replacement at other sites was also analysed. An instrumental variable sensitivity analysis was also performed.

Results: The matched analysis contained a total of 19,116 patient records. Overall, there was no significant association between TNFi use versus csDMARD on rates of THR (HRs = 0.86 [95% CI: 0.60-1.22]) although there was significant effect modification by age (p<0.001). TNFi was associated with a reduction in THR among those >60 years old (HR= 0.60 [CI: 0.41 - 0.87] but not in younger patients. No significant associations were found for TKR or other joint replacement.

Conclusions:
Overall, no association was found between the use of TNFi and subsequent incidence of joint replacement. However, TNFi was associated with a 40% relative reduction in THR rates among older patients.

Keywords: epidemiology, rheumatoid arthritis, biologics, TNFi, joint replacement, total hip replacement, total knee replacement, comparative effectiveness

Key messages:

- Overall, this analysis showed TNFi use was not associated with subsequent rates of joint replacement
- Among elderly patients, TNFi use was associated with a 40% reduction in subsequent THR rates
- Given prior ecological data, future studies are needed to confirm and/or further elucidate this relationship

Background:

Rheumatoid arthritis (RA) is a chronic autoimmune disease driven by pathological inflammatory processes in patients’ joints, subsequent hallmarks of which include structural damage to cartilage and bone (1-3). Joint damage is a central feature of RA and has been estimated to account for approximately 25% of disability in established disease (4). The permanent and often progressive nature of joint damage, in conjunction with associated pain, loss of function and failure to adequately respond to therapeutic options are strong indications for eventual joint replacement surgery (5, 6). Outcomes for hip and knee replacement in RA are generally considered good (7), although it has been observed that such patients are at increased risk of various adverse events compared to patients undergoing these procedures for osteoarthritis, including dislocation, infection, myocardial infarction, and revision (8, 9).
Furthermore, there are significant healthcare costs which in the UK are approximately £6,000 – £7,000 per operation (10). The prevention of irreversible joint damage through early and aggressive management using pharmacotherapy has been well demonstrated and is therefore recommended in numerous national guidelines (11-13). First-line therapy options include various conventional synthetic disease modifying anti-rheumatic drugs (csDMARDs).

Over recent decades the emergence of biologic therapies such as tumour necrosis factor inhibitors (TNFi) has revolutionised the management of RA as these drugs are widely recognized to improve numerous outcomes of the disease, including joint damage (14, 15). Despite this, to our knowledge there are no RCT studies addressing the issue of whether biologic therapies prevent/delay ultimate joint failure, as indicated by the need for a joint replacement. Recent ecological data from the UK and Denmark have indicated a reduction in the incidence of knee replacement among RA patients following the introduction of TNFi in 2002/2003 (16, 17), however concurrent to this has been an increasing emphasis on early and more aggressive usage of csDMARDs. Patient-level data on this topic is required to disentangle these issues, yet such data remain scarce.

Our current aim was to estimate the comparative effectiveness of TNFi vs. csDMARDs on subsequent rates of total hip replacement (THR) and total knee replacement (TKR) among a large cohort of RA patients.

**Materials and Methods:**

*Data sources and exposures*
We obtained data from the British Society for Rheumatology Biologics Register for RA (BSRBR-RA). This register contains prospectively collected observational data on over 20,000 RA patients recruited from 2001 onwards, primarily in order to evaluate the real-world safety of TNFi. The initial UK NICE guidance on use of TNFi stipulated clinicians initiating such therapy must register the patient into the BSRBR-RA, and recruitment continued originally until the target of at least 4,000 patients per TNFi cohort (etanercept, infliximab or adalimumab) was reached (last “original” patient recruited 2008) but reopened recruitment to these three originator drugs from 2010 onwards. NICE guidance restricts National Health Service prescribing of TNFi to patients with a sustained 28-joint disease activity score (DAS28) >5.1 who have failed to adequately respond to two csDMARDs, with each treatment lasting ≥6 months. The BSRBR-RA contains an additional comparator cohort of non-biologic treated RA patients on csDMARDs, entry into which was dependent on having active disease (guide DAS28 >4.2). Recruitment to this cohort closed in 2008.

Participants in all study cohorts are followed up indefinitely using physician questionnaires sent from BSRBR-RA to the patients’ rheumatology clinic. These were sent every six months for a patients’ first three years of follow-up, and annually thereafter. In addition to collecting data on changes to therapy and disease details, physicians were asked what serious/adverse events had occurred since last follow-up date. In addition, patients were asked to complete a health diary every six months for the first three years in the study in which they detailed any hospital admissions. These free text responses were coded by BSRBR-RA staff using the MedDRA hierarchy (Medical Dictionary for Regulatory Activities (18)). Mortality data for participants were obtained from the Health and Social Care Information Centre (HSCIC) (now merged into NHS digital) via alerts generated from Office for National Statistics records. The BSRBR steering committee provided approval for the project, granting data
access in 2016. All patients provided written informed consent, no further approvals were necessary.

Outcomes
The primary outcomes of interest were first occurrence of THR or TKR, analysed separately. Patients were followed up from date of registration into BSRBR-RA until the earliest date of either outcome event, follow-up form date indicating change in TNFi exposure status (stopping among TNFi users or starting biologics among csDMARD users), last follow-up form or death. Other joint replacement (OJR) (a composite outcome consisting of elbow, shoulder, hand or other small joint replacement) was a secondary outcome.

Study population
Our study sample (Supplementary File 1) consisted of all biologic-naïve RA patients, either in the control cohort or those initiating a TNFi (etanercept, infliximab or adalimumab) no more than 6 months prior to registration within BSRBR-RA. Patients with a THR or TKR recorded prior to registration were excluded, as were patients with less than 6 months of follow-up (i.e. those who did not return at least one follow-up questionnaire). In analyses of OJR, further exclusion was made of patients who had undergone an OJR prior to baseline.

Statistical analysis
Owing to confounding by indication, i.e. TNFi users vs. csDMARD users likely having a different baseline risk of THR/TKR, we decided a-priori to match TNFi users to csDMARD users based on their propensity for receiving treatment. Propensity scores (PS), i.e. the probability of receiving treatment conditional on observed baseline characteristics (including those predictive of outcome) were estimated for all patients using logistic regression. The list
of potential confounders included in the propensity score equation (and described in Table 1) consisted of: age, gender, ethnicity, index of multiple deprivation (socio-economic status), body mass index (BMI), smoking status, year of registration (quintiles), time since RA diagnosis, DAS28, health assessment questionnaire (HAQ) score, quality of life (SF36 domains), 1987 ACR criteria, systemic involvement, co-morbidities and co-medications. A full description of these variables are included in Supplementary File 2. We matched each TNFi patient to the csDMARD patient with the most similar PS within a caliper distance of 0.2 standard deviations of the logit of the PS (19). Patients falling outside this common support region remained unmatched and were excluded from further analysis. We used matching with replacement (20) owing to fewer available csDMARD patients than TNFi users in the register. Missing data were imputed using chained equations and 10 imputed datasets were created. Statistical analyses were carried out in Stata 15.1 and R.

Baseline characteristics of the TNFi user and csDMARD cohorts were summarised and differences assessed by way of standardised mean differences (SMD) (22, 23), with smaller values indicative of greater similarity between cohorts. This assessment was carried out for the cohort prior to matching and in the 10th imputed dataset. Incidence rates of each outcome event with 95% confidence intervals (CI) were calculated among matched TNFi users and csDMARD users. Weighted Cox regression was used to compare THR, TKR and OJR rates, taking into account the number of times each individual csDMARD user was included by the matching with replacement, and adjusting the standard error of the estimates accordingly. We censored all patients at 12 years due to the small and unstable size of the csDMARD cohort after this time. Baseline characteristics that were not sufficiently similar post-matching, defined as SMD >0.1 (21), were entered into a final multivariable Cox model for further
adjustment (21). Final models were run for all 10 datasets created in the multiple imputation process and hazard ratios (HRs) were pooled using Rubin’s rules.

Age and disease severity were a-priori specified as potential effect modifiers of the association between TNFi use and subsequent need for joint replacement. We tested for these by including interaction terms for approximately median age (≤/≥ 60 years old) and DAS28 (≤/>5.1 NICE cut-off) in the weighted Cox model and used the likelihood ratio test to assess model fit. In the event of a significant interaction (p<0.1), matching and survival models were re-run stratified by the significant effect modifier.

**Sensitivity analyses**

We addressed the potential of unobserved confounding through the use of an instrumental variable (IV) approach, using physician preference as the instrument, as has been done previously (24, 25). Details of this sensitivity analysis are described in Supplementary File 3. We also repeated the main PS analysis after excluding TNFi users recruited into the registry after the csDMARD cohort had closed, in order to maximise comparability between groups.

**Results:**

Of 13,126 eligible RA patients identified in BSRBR-RA, 97% (9,558) of the TNFi users and 51% (1,644) of the csDMARD users were retained following PS matching (Supplementary File 1). Given the 1:1 matching with replacement, a total of 19,116 patient records were used in subsequent analyses, with each csDMARD user being used a median of 3 (IQR: 1-6) times.
Baseline characteristics of TNFi users were markedly different in the unmatched study sample compared to the csDMARD cohort (Supplementary File 2), especially in aspects of disease severity. Specifically, the TNFi cohort had on average higher DAS28, HAQ score, proportion fulfilling the 1987 ACR RA criteria, lower health-related quality of life (as per SF36), longer disease duration and a higher prevalence of prior non-major joint replacement. Conversely, baseline characteristics between exposure cohorts were much more similar post-matching (Table 1). The only persisting differences (SMD>0.1) between the matched cohorts were calendar period of registration, low deprivation and the proportion of patients fulfilling ACR criteria.

**Total Hip Replacement**

A total of 589 THRs were reported during follow-up (median = 4.94 years [IQR:1.52 to 10.04] for TNFi and 5.97 years [IQR: 2.05 to 9.55] for csDMARD) of the propensity-matched cohorts. Incidence rates (per 1,000 PYs) were 5.22 [95% CI: 4.66 to 5.88] and 6.30 (95% CI: 4.24 to 9.76) among TNFi users and csDMARD users, respectively (Supplementary File 4). Comparing TNFi to csDMARDs yielded a pooled HR = 0.91 [95% CI: 0.64 to 1.31; p=0.62], which when adjusted for any remaining post-matching imbalance in baseline covariates was 0.86 [95% CI: 0.60 to 1.22; p=0.39] (Figure 1).

**Total Knee Replacement**

Among the matched sample, a total of 864 TKRs were reported during followup (median = 4.85 years [IQR:1.50 to 10.01] for TNFi and 5.98 years [IQR: 2.03 to 9.55] for csDMARD) of the propensity-matched cohorts. Incidence rates (per 1,000 PYs) were 8.89 [95% CI: 8.13 to 9.72] and 8.09 [95% CI: 5.32 to 12.89] among TNFi users and csDMARD users, respectively (Supplementary File 4). This yielded a pooled HR = 1.18 [95% CI: 0.90 to 1.56;
which when adjusted for any remaining post-matching imbalance in baseline covariates was 1.11 [95% CI: 0.84 to 1.47; \( p=0.46 \)] (Figure 1).

**Other Joint Replacement**

Among the matched sample, a total of 336 OJRs occurred during follow-up (median = 4.93 years [IQR:1.52 to 10.02] for TNFi and 5.98 years [IQR: 2.05 to 9.12] for csDMARD) among the propensity-matched cohorts. Incidence rates (per 1,000 PYs) were 4.34 [95% CI: 3.76 to 5.02] and 3.87 [95% CI: 1.97 to 8.73] among TNFi and csDMARD users, respectively (Supplementary File 4). There was no significant difference in OJR rates between the exposure cohorts (Figure 1).

**Interactions**

Age was found to be a significant \( (p<0.001) \) effect modifier for both THR and TKR outcomes, although disease severity was not \( (p>0.1) \). In subsequent stratified analyses (Supplementary File 5), TNFi was associated with an estimated 40% reduction in incidence of THR among older patients \( (HR = 0.60 [95\% \, CI: \, 0.41 \, \text{to} \, 0.87; \, p=0.008]) \) (Figure 2). Differences in THR or TKR incidence rates between TNFi and csDMARD cohorts among younger patients were non-significant (Figure 2, Supplementary File 5).

**Sensitivity analyses**

Results were unchanged when PS matching and subsequent survival analysis was repeated following exclusion of \( (n=1,213) \) patients recruited into the TNFi cohort after the csDMARD cohort had closed. Comparative effectiveness estimates were HR=0.81 (95% CI: 0.55 to 1.18) for THR and 1.11 (95% CI: 0.83 to 1.50) for TKR. Results of the sensitivity IV analysis (Supplementary Files 6 & 7) confirmed main findings, with a borderline reduction in risk of
THR (absolute risk reduction of -1.88 per 100 patients [95% CI: -3.86 to 0.10; \(p=0.063\)]) but no association between biologics use and TKR risk (-0.57 per 100 patients [95% CI: -2.69 to 1.54; \(p=0.60\)]).

Discussion:

Main findings

We’ve here sought to address the scarcity of patient-level data comparing use of TNFi versus csDMARDs on rates of joint replacement in RA. Using a large UK-based RA biologics register, overall we found no difference in subsequent rates of joint replacement between PS matched TNFi and csDMARD users. When stratified by age, TNFi was associated with a significant 40% reduction \((p=0.008)\) in THR incidence among patients \(\geq 60\) years old (Figure 2), although non-significant increases were observed in TKR for the same age group and in THR for those <60 years old.

Findings in context

Our overall incidence rates of THR and TKR (results not shown) of 4.95/1,000 PYs and 7.84/1,000 PYs, respectively, align well with previous estimates of joint replacement among RA patients within the UK (16) and elsewhere (17, 26, 27).

Emerging observational data indicate that the number and/or incidence of RA related joint surgery has been in decline across numerous developed countries (16, 17, 27-37), although this has primarily been seen for smaller joints (35, 37-39). Many of these studies have inferred a possible role of biologics in this decline. Indeed, a reduction in need for joint replacement associated with TNFi use would be an expected finding given previous evidence
of TNFi use reducing joint damage as measured radiographically (15). A previous meta-
analysis of 70 RCT studies reported that annual radiographic progression was 0.6% less in
patients treated with biologics compared to those on a single DMARD (40). Similarly,
another meta-analysis has demonstrated that patients on initial combination therapy
(methotrexate plus a biologic agent) are 30% more likely to experience non-progression at 1-
year than those on methotrexate alone (41). In this context, a 40% reduction in THR rates
associated with TNFi use among a more elderly subgroup of patients as found in the present
study is quite plausible, and a lack of translation of positive findings on joint erosion from
prior RCTs into a “real world” reduction in rates of joint replacement within our main study
sample is initially surprising.

However, a more detailed examination of prior RCT findings indicate that an expectation of
widespread reduction in joint replacement associated with TNFi use is potentially
unwarranted. There is a large degree of variation in the nature of comparator groups used in
prior studies (42, 43), and this could be an important factor in considering the lack of effect as
described in our main findings. For instance, whilst RCT studies have shown reduced
radiographic progression among biologic users versus csDMARD monotherapy, an almost
equal reduction has been achieved among combination csDMARD users relative to
csDMARD monotherapy (40). Similarly, whilst TNFi has been shown to confer early benefits
over combination csDMARD therapy, these benefits have been reported to disappear during
the second year of follow-up (44), possibly due to time-to-efficacy and time to achieve
maximal dose of csDMARDs. The use of etanercept (vs. oral triple therapy) resulted in only
small radiographic benefits in another trial (45), with another showing triple therapy to be
non-inferior to biologics in terms of change in DAS28 at 48 weeks (46). Given these previous
data, it could be that the reduced THR rates in older patients may reflect a general
improvement in management of RA over the past 20 years and earlier and more aggressive use of csDMARDs rather than solely the effect of TNFi. Intriguingly, a registry-based study on the topic (47) recently found increased rates of major joint replacement associated with use of biologic therapy, although the authors concluded residual confounding was an issue given the small number of confounding factors for which the analysis was adjusted.

We found a reduction in THR incidence among an older patient subgroup, but no significant impact on TKR incidence, which is interesting as one might expect any effect to be expressed approximately equally at hip and knee. It could be that the relatively long disease duration at our baseline meant there was greater potential for prevention of joint destruction at the hip over knee, although details of differential natural history of RA disease at these two joints are not well established. It’s also very difficult to disentangle the impact of TNFi on improved function and overall quality of life and how this may have mediated effects on longer-term progression of joint damage, potentially differentially at the knee and hip. Another factor could be the role of trauma related THRs among the older subgroup and whether there may be some pathway to reduced THR rates via TNFi associated improvement in bone quality. It should be emphasised however that the positive impact on THR incidence was only observed in a subgroup of patients that have not been well studied in this regard previously and that prior studies at the population-level have identified different patterns in this regard, some finding reduced rates of TKR (16, 17) and others THR (27, 34) following introduction of TNFi.

Limitations

The potential for residual confounding by indication is a key limitation of the current study. Given that prior to matching there was a much higher disease severity among the TNFi group
(supplementary file 2), we cannot rule out that the overall lack of reduction in joint replacement rates among TNFi users may be due in part to a greater prevalence of unmeasured aspects of disease severity and unresponsiveness to therapy in this group, thereby maintaining a baseline ‘disadvantage’ even after PS matching. On-the-other-hand, estimates of impact of TNFi exposure may be subject to a general healthy user bias in that a clinician perceives sufficient patient ability to tolerate and benefit from more intensive therapy regimens, which may have here contributed to the reduced rate of THR in the older TNFi cohort. The use of an IV approach as a sensitivity analysis sought to address the issue of unmeasured confounding, in which the treatment effect was estimated using clinician preference for biologics as an IV, assuming this to be a strong predictor of exposure but unrelated/weakly-related to confounders of the TNFi - joint replacement relationship. However, the findings of this IV approach should be interpreted with caution given the instrument was here associated with several measured confounders (Supplementary File 3) which may undermine its validity as a means to obtain unbiased estimates in the presence of unmeasured confounding. The PS analytical approach taken, in which comparable csDMARD matches were found for each TNFi user - while much improving the internal validity - does mean our findings are not average treatment effects generalizable to the entire RA population but an estimate of the “average treatment effect on the treated” (ATT) (48). This is evident given that the csDMARD users included in the matched sample had more established and severe disease (thereby making them comparable to the TNFi sample) than the unmatched csDMARD sample (Supplementary File 2). The study findings should also be interpreted in the context of a relatively long median disease duration at baseline (Table 1), which means they are not necessarily generalisable to the context of early RA. Finally, we relied on a combination of physician-reported and self-reported incidence of THR, TKR and OJR for our study outcomes as per BSRBR-RA follow-up questionnaires. This may have introduced bias
if events were under-reported, although this would likely act non-differentially in regard to TNFi status and minimally during the early years of follow-up, during which time study participants were sent questionnaires every six months. These various limitations to the present analysis may partly explain differences in the results obtained here compared to previous ecological data on wide-spread reductions in joint replacement rates in RA during the biologic era. While a reduction in THR amongst older TNFi users offers some support for biologics playing a role in reducing need for joint replacement, it must also be noted that the lack of an overall protective effect is suggestive that other factors apart from TNFi are likely to be involved in the aforementioned downward population trends in joint replacement rates in RA.

**Strengths**

Our study’s key strengths are that BSRBR-RA is one of the largest RA registers in the world, which made it possible for us to adjust for many potential confounders and stratify analyses where there was significant effect modification. We were also able to accurately censor follow-up given the linkage to HSCIC mortality data. The use of PS matching is a strong method for dealing with bias (49) arising from likely confounding by TNFi indication, and we were able to reach good balance between the two exposure groups in terms of baseline characteristics across most variables.

**Conclusion**

In this large prospective study, we found no overall association between TNFi versus csDMARD therapy and subsequent incidence of joint replacement among RA patients, although a 40% relative reduction in THR rates was found among older patients. Future
studies are needed to confirm and/or further elucidate the relationship between TNFi use and joint replacement

Figure Legends:

Figure 1: Estimated impact of TNFi on subsequent joint replacement rates among matched TNFi and csDMARD patients

Figure 2: Estimated impact of TNFi on subsequent joint replacement rates among matched TNFi and csDMARD patients: stratified by age

Author Contributions:

Study Concept: all authors; Data Acquisition: all authors; Data Analysis: SH, SA, DPA;
Drafting Manuscript: SH; Revising and approving final manuscript: all authors

Acknowledgements:

DPA is funded by a National Institute for Health Research (NIHR) Clinician Scientist Award (project number CS-2013-13-012). AJ is supported by the NIHR Biomedical Research Centre at the University Hospitals Bristol NHS Foundation Trust and the University of Bristol. The views and opinions expressed in the manuscript are those of the authors and do not necessarily reflect those of the NIHR, NHS or the Department of Health. The data that support the findings of this study are available from the British Society for Rheumatology Biologics Registry but restrictions apply to the availability of these
data, which were used under license for the current study, and so are not publicly available.

**Competing Interests:**

S.H., R.C., C.C., S.A. and K.H have nothing to disclose. L.D. reports personal fees from UCB Pharma. and from MSD. C.J.E. has been a speaker for, received honoraria or research support from Abbvie, BMS, Celgene, Pfizer, Biogen, Mundipharma, UCB Pharma., Roche, MSD. N.K.A. reports grants from Bioberica and personal fees from Bioventus, from Regeneration, and from Smith&Nephew. A.J. has received consultancy fees from Freshfields Bruckhaus Deringer, and is a member of the Data Safety and Monitoring Board (which involved receipt of fees) from Anthera Pharmaceuticals outside the submitted work. DPA’s group have received unrestricted research grants from Servier Laboratoires, Amgen, and UCB Pharma.

**References:**


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Table 1: baseline characteristics of propensity score matched cohorts*: stratified by use of TNFi vs. Conventional Synthetic DMARDs

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>CS-DMARD (N=9,558) (1,644 unique patients)</th>
<th>TNFi (N=9,558)</th>
<th>SMD</th>
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</thead>
<tbody>
<tr>
<td>Age: Mean (S.D.)</td>
<td>55.2 (12.1)</td>
<td>55.2 (12.3)</td>
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</tr>
<tr>
<td>Gender: % Female</td>
<td>7,289 76.3</td>
<td>7,259 75.9</td>
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<tr>
<td>ethnicity: % White/Caucasian</td>
<td>9,114 95.4</td>
<td>9,118 95.4</td>
<td>0.00</td>
</tr>
<tr>
<td>Index Multiple Deprivation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quintile 1</td>
<td>1282 13.4</td>
<td>1322 13.8</td>
<td>0.01</td>
</tr>
<tr>
<td>Quintile 2</td>
<td>1420 14.9</td>
<td>1485 15.5</td>
<td>0.02</td>
</tr>
<tr>
<td>Quintile 3</td>
<td>1413 14.8</td>
<td>1640 17.2</td>
<td>0.07</td>
</tr>
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<td>Quintile 4</td>
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<td>1710 17.9</td>
<td>0.05</td>
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<td>Quintile 5</td>
<td>1284 13.4</td>
<td>1650 17.3</td>
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<tr>
<td>Unknown</td>
<td>2615 27.4</td>
<td>1751 18.3</td>
<td>-0.22</td>
</tr>
<tr>
<td>BMI</td>
<td>26.8 (5.9)</td>
<td>27.1 (6.3)</td>
<td>0.06</td>
</tr>
<tr>
<td>Smoking?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Current</td>
<td>2448 25.6</td>
<td>2259 23.6</td>
<td>-0.05</td>
</tr>
<tr>
<td>% Ex</td>
<td>3272 34.2</td>
<td>3577 37.4</td>
<td>0.07</td>
</tr>
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<td>Calendar period of registration</td>
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<td></td>
<td></td>
</tr>
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<td>Oct 01 - Oct 03</td>
<td>1481 15.5</td>
<td>2262 23.7</td>
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<td>May 07 - May 16</td>
<td>2553 26.7</td>
<td>1995 20.9</td>
<td>-0.14</td>
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<tr>
<td>Years since diagnosis: Median (IQR)</td>
<td>10.8 (10.7)</td>
<td>11.0 (8.8)</td>
<td>0.02</td>
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<td>DAS 28: Mean (S.D.)</td>
<td>6.47 (1.09)</td>
<td>6.43 (0.98)</td>
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</tr>
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<td>Overall HAQ score</td>
<td>1.91 (0.63)</td>
<td>1.91 (0.62)</td>
<td>-0.01</td>
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<tr>
<td>ACR: Ever rheumatoid positive: %</td>
<td>5,532 57.9</td>
<td>6,055 63.4</td>
<td>0.11</td>
</tr>
<tr>
<td>ACR: Deformity of ≥3 joint areas?: %</td>
<td>7,425 77.7</td>
<td>8,118 84.9</td>
<td>0.19</td>
</tr>
<tr>
<td>ACR: Erosions on hands/feet: %</td>
<td>4,651 48.7</td>
<td>5,282 55.3</td>
<td>0.13</td>
</tr>
<tr>
<td>ACR: Ever had nodules %</td>
<td>4,034 42.2</td>
<td>3,988 41.7</td>
<td>-0.01</td>
</tr>
<tr>
<td>ACR: Symmetry %</td>
<td>7,468 78.1</td>
<td>7,883 82.5</td>
<td>0.11</td>
</tr>
<tr>
<td>ACR: Deformity of hand joint %</td>
<td>6,771 70.8</td>
<td>7,602 79.5</td>
<td>0.20</td>
</tr>
<tr>
<td>ACR: Morning stiffness &gt;1 hour: %</td>
<td>8,901 93.1</td>
<td>8,966 93.8</td>
<td>0.03</td>
</tr>
<tr>
<td>Non-major prior joint replacement^</td>
<td>1742 18.2</td>
<td>1989 20.8</td>
<td>0.07</td>
</tr>
</tbody>
</table>
Results shown are for the 10th imputed dataset. Matching was performed using replacement of the cs-DMARD users. 9,558 biologic users were each matched to one of the 3,229 cs-DMARD users (with replacement). Number of csDMARD patients represented in final matched sample was 1,644

^ Composite variable consisting of: shoulder, elbow, neck or other small joint replacement (e.g. hand)
SMD: standardised mean difference (smaller values indicative of better balance)