The Journal of Rheumatology 2022;49:577–84
doi:10.3899/jrheum.211062
First Release April 15 2022

The Journal of Rheumatology

Central Obesity in Axial Spondyloarthritis: The Missing Link to Understanding Worse Outcomes in Women?

Sinead Maguire[1], Fiona Wilson[2], Phil Gallagher[3], and Finbar O'Shea[1]

ABSTRACT. ***Objective.*** To determine (1) the prevalence of central obesity in axial spondyloarthritis (axSpA) and its effect on disease-related outcomes and (2) how this differs between sexes.

Methods. Data were extracted from the Ankylosing Spondylitis Registry of Ireland. Patients with physical measurements for the calculation of anthropometric measures were included. BMI and waist-to-hip ratio (WHR) were used to compare classifications of obesity. Comparison analyses based on sex and central obesity were carried out. Multivariate analysis examined the effects of these factors on the following patient-reported outcomes: the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), the Bath Ankylosing Spondylitis Functional Index (BASFI), the Ankylosing Spondylitis Quality of Life (ASQoL) questionnaire, and the Health Assessment Questionnaire (HAQ).

Results. In total, 753 patients were included in the analysis. Of these patients, 29.6% (n = 223) were classified as obese based on their BMI, and 41.3% (n = 311) were classified as centrally obese according to the WHR. The prevalence of central obesity was significantly higher among women with axSpA compared to men (71.6% vs 29.9%, $P < 0.01$). Central obesity had a clear effect on patient outcomes, regardless of sex. Presence of central obesity was associated with significantly worse BASFI scores ($P < 0.01$), HAQ scores ($P < 0.01$), and ASQoL questionnaire scores ($P = 0.01$), with a nonsignificant trend toward worse BASDAI scores ($P = 0.07$).

Conclusion. There was a high prevalence of central obesity as assessed by the WHR in axSpA, most notably among women with axSpA. This modifiable comorbidity was significantly associated with worse quality of life, greater impairment of functional ability, and a trend toward worse disease activity. Regular use of the WHR to screen for central obesity as part of an axSpA assessment would provide an opportunity for prompt identification and intervention for at-risk patients.

Key Indexing Terms: abdominal obesity, ankylosing spondylitis, arthritis, obesity, spondyloarthropathies, women's health

Worldwide prevalence of obesity has been steadily increasing[1,2] despite numerous public health campaigns to increase public awareness. Obesity is known to be associated with an increased risk of all-cause mortality[3] and is the second most common preventable cause of death in the United States.[4] As the prevalence of this health issue surges, so too do the frequencies of associated complications, such as type 2 diabetes and cardiovascular disease, which have a significant effect on patients' overall quality of life (QOL) and place significant demands on the healthcare system.[5]

The Ankylosing Spondylitis Registry of Ireland is supported by unrestricted funding from AbbVie, Pfizer, and UCB.

[1]S. Maguire, MB, BAO, BCh, MRCPI, F. O'Shea, MB, BAO, BCh, MRCPI, Department of Rheumatology, St James' Hospital, and School of Medicine, Trinity College Dublin; [2]F. Wilson, BSc, MSc (Sports Medicine), PhD, Discipline of Physiotherapy, Trinity College Dublin; [3]P. Gallagher, RGN, Department of Rheumatology, St. Vincent's Hospital, Dublin, Ireland.

SM is the recipient of the Gilead inflammation fellowship and has received grants for educational events from AbbVie, Pfizer, Lilly, UCB, and Janssen. The remaining authors declare no conflicts of interest relevant to this article.

Address correspondence to Dr. S. Maguire, Department of Rheumatology, St James' Hospital, Dublin 8, Ireland. Email: sineadmaguire@rcsi.ie.

Accepted on February 4, 2022.

This rising prevalence is especially concerning in axial spondyloarthritis (axSpA), an inflammatory arthritis predominantly involving the axial spine.[6] Obesity in axSpA has previously been associated with higher levels of disease activity[7,8] and decreased response to treatment.[9] The presence of obesity has even been linked to new syndesmophyte formation and enthesitis.[10] This is related to adipose tissue secretion of proinflammatory cytokines, called adipocytokines, which in high concentrations can promote a persistent systemic inflammatory state.[11] Serum levels of adipocytokines are directly related to body fat content, with elevated levels contributing to the development of metabolic disorders, including insulin resistance and accelerated atherosclerosis.[12] Despite the established negative effect of obesity in axSpA, it remains a frequently encountered comorbidity with a reported prevalence of 14% to 27%.[13,14]

The presence of obesity is commonly determined by calculation of BMI. However, additional anthropometric scores have been developed to move beyond weight excess and focus on determining the prevalence of abdominal or central obesity. The waist-to-hip ratio (WHR) is a validated measure that is used to screen for central obesity in the general population.[15] Central deposition of adipose tissue is associated with increased risk of cardiovascular disease, type 2 diabetes, and premature

death.[16,17,18,19] Typically, central obesity is more often found among males because of deposition of visceral fat, whereas females are more prone to gluteal-femoral subcutaneous fat deposition.[20] During menopause, there is a shift toward more central fat deposition, which increases further in the postmenopausal period.[21,22]

The aim of this study was to capture the prevalence of central obesity in a large cohort of patients with axSpA and assess how this affects disease-related outcomes. This analysis also examined how this differs between men and women with axSpA.

METHODS

Patient population. Data for the analysis were extracted from the Ankylosing Spondylitis Registry of Ireland (ASRI), a rich source of epidemiological data on axSpA in Ireland. This large national registry recruited patients from 12 rheumatology centers, representing all major geographic regions of the country. Since being launched in 2013, 892 patients have been enrolled in the ASRI, with recruitment ongoing in multiple centers. This analysis included all participants with anthropometric data recorded who were enrolled in the ASRI since the time of its inception.

All participants were required to meet several inclusion criteria in order to be considered for enrollment: diagnosed with axSpA by a rheumatologist; met the Assessment of SpondyloArthritis international Society (ASAS) criteria for axSpA at the time of enrollment, which allowed for data collection on both radiographic axSpA (r-axSpA) and nonradiographic axSpA (nr-axSpA); aged > 18 years; had full capacity; and fluent in English. All eligibility criteria were required at the time of enrollment in order to be included in the ASRI.

Written informed consent was obtained from each patient prior to enrollment. The consent process included discussion of the purpose of data collection, data protection, and publication of studies using data from the ASRI. Patients were informed of their right to withdraw their data at any time and encouraged to discuss questions with investigators prior to signing the consent declaration. Ethical approval was received from local hospital ethics boards at each site that contributed patients to the ASRI. For the main center, St James's Hospital, the study was approved by the St James's Hospital/Tallaght University Hospital Joint Research Ethics Committee (approval no. 2019-07[27]; Supplementary Table 1, available with the online version of this article).

Outcome definitions and assessment. Each participant attended a single clinical visit conducted by a trained investigator, allowing all data to be collected at a single timepoint. Medical records were reviewed for radiology results, patterns of disease, and medication usage. Data were collected on participant demographics; disease duration; delay to diagnosis; patterns of disease, including both articular and extraarticular manifestations; and presence of comorbidities.

Participants completed self-administered questionnaires to provide information on patient outcomes; responses were recorded on a numerical scale, with higher scores indicating greater severity. Specific outcomes that were investigated include those measured by the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), the Bath Ankylosing Spondylitis Functional Index (BASFI), Ankylosing Spondylitis Disease Activity Score (ASDAS), the Health Assessment Questionnaire (HAQ), and the Ankylosing Spondylitis Quality of Life (ASQoL) questionnaire. A focused clinical examination measured spinal mobility to allow for calculation of the Bath Ankylosing Spondylitis Metrology Index (BASMI). Physical measurements were also recorded: waist circumference measured halfway between the lowest rib and the iliac crest, and hip circumference measured at the widest part of the hips and buttocks region.[23] All outcome measures in this analysis were validated for use in axSpA.

Participants were analyzed on the basis of sex and the presence of obesity. Obesity was defined by BMI, calculated as weight in kilograms divided by height in meters squared; a participant with a result > 30 was categorized as obese, as per the Centers for Disease Control and Prevention definition.[24] Central obesity was assessed by the WHR and defined according to the World Health Organization guidelines[25] (Table 1).

Statistical analysis: IBM SPSS Statistics for Windows (version 26; IBM Corp) was used for statistical analysis and data processing. Comparison analyses determined variation in the prevalence of obesity and variation between sexes. Categorical variables were recorded as frequencies with percentages, with a chi-square test for independence or a Fisher exact test for statistical significance. Means and SDs were calculated for numerical variables within each group, with an independent *t* test or Mann-Whitney *U* test to assess the significance of differences between groups. A Shapiro-Wilk test was carried out on all included variables to determine normality of the distribution. To assess the relationship between the WHR and BMI, a Spearman rank-order correlation was run because variables were not normally distributed. Scatterplots were constructed to visualize the presence of a monotonic relationship for each analysis.

A 2-way multivariate ANOVA assessed the effects of sex (ie, male vs female) and central obesity, as measured by the WHR, on patient-reported outcomes (PROs; ie, BASDAI, BASFI, ASQoL, and HAQ). An α level of < 0.05 was deemed significant. A binary logistic regression model examined the effects of age, sex (ie, male vs female), axSpA classification (ie, radiographic vs nonradiographic), BASDAI score, BASFI score, and BASMI score on the likelihood of central obesity. A Bonferroni correction was applied to determine *P* values for levels of statistical significance of linearity. All necessary assumptions for each statistical test were met.

RESULTS

At data extraction, physical measurements were available for 753 participants enrolled in the ASRI; of these participants, 88.4% (n = 666) were White, 27.6% (n = 208) were female, and 71.4% (n = 538) were male (Table 2). The mean age of the participants was 45.6 (SD 12.6, range 18–85) years; the mean disease duration was 18.8 years (SD 12.3). Out of all the participants, 75.2% (n = 566) were classified as having r-axSpA, whereas 24.8% (n = 187) were classified as having nr-axSpA. Mean scores for the self-administered questionnaires were as follows: BASDAI, mean 4.11 (95% CI 3.91–4.26); BASFI, mean 3.68 (95% CI 3.46–3.84); BASMI, mean 4.0 (95% CI 3.37–4.45); HAQ, mean 0.527 (95% CI 0.49–0.57); ASQoL, mean 6.72 (95% CI 6.31–7.12); and ASDAS, mean 2.4 (95% CI 1.99–2.65). In terms of anthropometric measurements, the mean BMI was 28.2 (SD 6.3) and the mean WHR was 0.941 (SD 0.104).

In total, 29.6% (n = 223) of the patients were considered obese based on BMI results, whereas 41.2% (n = 310) were considered centrally obese according to the WHR. Comparison

Table 1. WHR definitions for classification of central obesity as per the WHO[25].

	Males	Females
Normal	< 0.9	< 0.8
Overweight	0.9–0.99	0.8–0.84
Obese	≥ 1.0	≥ 0.85

Data are WHR values. WHO: World Health Organization; WHR: waist-to-hip ratio.

Table 2. Characteristics of participants, including comparison by sex and presence of central obesity as measured by the WHR.

	Total	Women	Men	*P*	No Central Obesity	Central Obesity	*P*
Participants, n	753	208	538	–	442	311	–
Age, yrs	45.6 (12.6)	43.6 (12.0)	46.1 (12.7)	**0.03**	43.7 (12.3)	48.6 (12.6)	**< 0.01**
Age of onset, yrs	26.8 (10.9)	25.9 (9.8)	27.1 (11.2)	0.22	25.7 (9.9)	28.7 (12.1)	**< 0.01**
Disease duration, yrs	18.8 (12.3)	17.8 (12.1)	19.0 (12.3)	0.25	18.1 (11.6)	19.9 (13.2)	0.06
Delay to diagnosis, yrs	7.8 (8.5)	7.34 (7.9)	8.0 (8.7)	0.35	7.7 (8.0)	7.9 (9.0)	0.73
HLA-B27+[a]	88.6 (530/598)	89.3 (150/168)	89.8 (380/423)	0.80	87.6 (324/370)	90.4 (206/228)	**< 0.01**
White	88.4 (666)	72.6 (151)	95.7 (515)	**< 0.01**	92.8 (410)	82.3 (256)	**< 0.01**
r-axSpA	75.2 (566)	69.7 (145)	78.3 (421)	**0.02**	73.5 (325)	77.5 (241)	0.21
nr-axSpA	24.8 (187)	30.3 (63)	21.7 (117)	**0.03**	26.5 (117)	22.5 (70)	0.34
NSAIDs	51.7 (389)	53.8 (112)	50.2 (270)	0.47	20.1 (89)	21.2 (66)	0.72
csDMARDs	18.7 (141)	20.7 (43)	18.0 (97)	0.42	20.8 (92)	23.2 (72)	0.24
bDMARDs	68.0 (512)	65.9 (137)	68.8 (370)	0.70	67.4 (298)	68.8 (214)	0.85

Continuous variables are expressed as mean (SD) and categorical variables are expressed as % (n) unless otherwise indicated. [a] Values in parentheses are n/N. Values in bold are statistically significant. bDMARD: biologic disease-modifying antirheumatic drug; csDMARD: conventional synthetic disease-modifying antirheumatic drug; nr-axSpA: nonradiographic axial spondyloarthritis; NSAID: nonsteroidal antiinflammatory drug; r-axSpA: radiographic axial spondyloarthritis; WHR: waist-to-hip ratio.

analysis based on sex revealed no significant variation in mean BMI (27.9 vs 28.3, $P = 0.44$) or prevalence of obesity based on BMI (29.8% vs 29.9%, $P = 0.21$) between women and men (Table 3). Normal weight was the most common classification for women, based on BMI, whereas overweight was the most common classification for men.

WHR analysis revealed higher mean WHRs among men compared to women (0.956 vs 0.897, $P < 0.01$). However, the prevalence of central obesity was significantly higher among women than men (71.6% vs 29.9%, $P < 0.01$; Figure 1). Obesity was the most common classification among women, affecting 71.6% (149/208) of them, whereas overweight was the most common classification among men, affecting 46.1% (248/538) of them. Further, only 12.0% (25/208) of women were classified as normal weight according to the WHR (Table 3).

Analysis of average PROs revealed significantly worse ASQoL scores (7.66 vs 6.05, $P < 0.01$), BASFI scores (4.23 vs 3.30, $P < 0.01$), HAQ scores (0.63 vs 0.45, $P < 0.01$), and BASDAI scores (4.37 vs 3.92, $P = 0.01$) among participants with central obesity compared to those without. As there was a higher proportion of women in the central obesity cohort, further analyses were carried out to determine if sex was a contributing factor in the differences observed.

A multivariate analysis was carried out to determine the effects of sex and central obesity on PROs, including the BASDAI, BASFI, ASQoL, and HAQ. A significant interaction effect was not detected between sex and central obesity ($F = 0.5$,

Table 3. Assessment of anthropometric measures by sex.

	Women	Men	*P*
Participants, n	208	538	–
Weight, kg	75.1 (18.0)	84.9 (15.4)	**< 0.01**
BMI	27.9 (6.7)	28.3 (6.2)	0.44
Weight classified by BMI			–
Underweight	2.9 (6)	0.9 (5)	0.21
Normal weight	35.6 (74)	28.1 (151)	–
Overweight	31.7 (66)	38.7 (207)	–
Obese[a]	29.8 (62)	29.9 (161)	–
Waist circumference, cm	91.3 (16.8)	97.6 (17.2)	**< 0.01**
Hip circumference, cm	101.8 (14.6)	102.1 (15.5)	0.78
WHR	0.897 (0.1)	0.956 (0.09)	**< 0.01**
Weight classified by WHR			–
Normal weight	12.0 (25)	24.0 (129)	**< 0.01**
Overweight	16.3 (34)	46.1 (248)	–
Obese	71.6 (149)	29.9 (161)	–
Height, cm	164.3 (8.5)	172.6 (17.4)	**< 0.01**

Continuous variables are expressed as mean (SD) and categorical variables are expressed as % (n). [a] Compared to the overall prevalence of obesity in Ireland of 27%. Values in bold are statistically significant. WHR: waist-to-hip ratio.

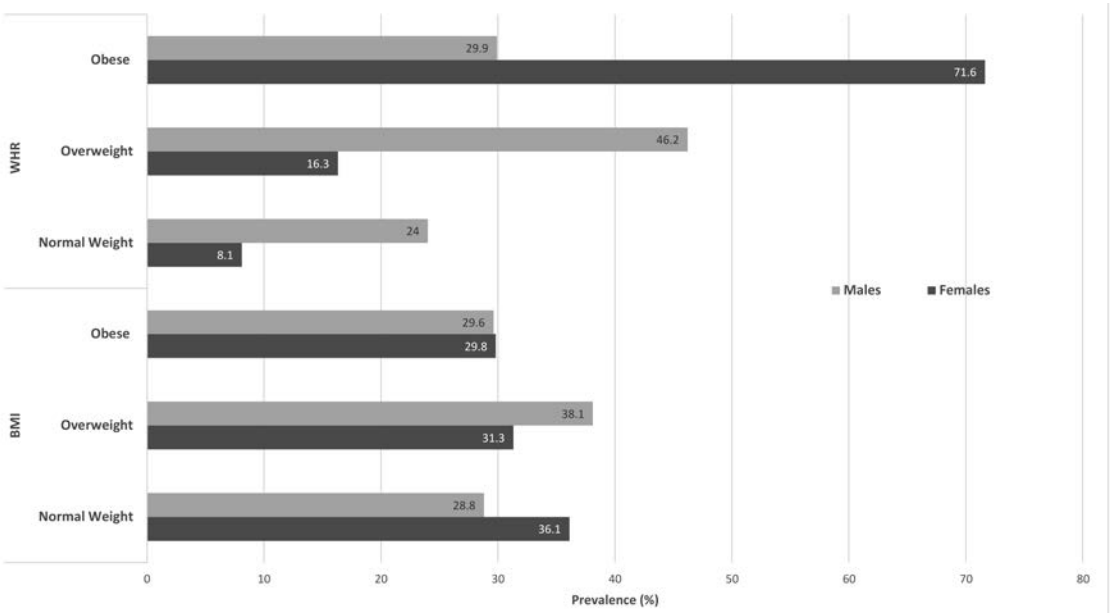

Figure 1. Weight classification as determined using the waist-to-hip ratio (WHR) and BMI by sex.

Wilks $\lambda = 0.997$, $P = 0.74$). However, there was a significant main effect of both sex ($F = 3.99$, $P < 0.01$) and central obesity ($F = 5.68$, $P < 0.01$) on PROs when assessed individually.

A follow-up univariate 2-way ANOVA found a significant main effect of central obesity on several PROs. Specifically, effects were found on ASQoL scores ($F = 7.87$, $P = 0.01$), BASFI scores ($F = 19.45$, $P < 0.01$), and HAQ scores ($F = 12.25$, $P < 0.01$), with a nonsignificant trend detected for BASDAI scores ($F = 3.63$, $P = 0.07$). Follow-up analysis of PROs between centrally obese and normal-weight participants revealed the following average differences: ASQoL, 2.00 (95% CI 3.31–0.70, $P < 0.01$); BASFI, 1.40 (95% CI 2.02–0.80, $P < 0.01$); HAQ, 0.24 (95% CI 0.36–0.12, $P < 0.01$); and BASDAI, 0.65 (95% CI 1.21–0.08, $P = 0.02$). For ASQoL, HAQ, and BASFI, these differences remained significant, though lesser in magnitude, even when comparing those classified as overweight compared to centrally obese participants.

There was a statistically significant positive correlation between BMI and the WHR among patients with axSpA ($r_s = 0.456$, $P < 0.01$). When assessed within each sex, the strength of this correlation was found to be stronger among men with axSpA ($r_s = 0.538$, $P < 0.01$) but weaker among women with axSpA ($r_s = 0.349$, $P < 0.01$), although both remained statistically significant.

A binomial regression analysis was performed to identify factors associated with central obesity as determined by the WHR. The logistic regression model was statistically significant ($\chi^2_7 = 96.23$, $P < 0.01$), with an area under the receiver-operating characteristic curve of 0.742 (95% CI 0.699–0.785), indicating an acceptable level of discrimination (Figure 2).

Of the 7 predictor variables assessed (ie, age, female sex, r-axSpA, BASMI, BASDAI, BASFI, and ASQoL), only 2 were statistically significant: age and sex (Table 4). This indicated that both increasing age (odds ratio [OR] 1.03, 95% CI 1.01–1.05) and female sex (OR 6.76, 95% CI 4.12–11.1) were associated with an increased likelihood of a patient with axSpA having central obesity.

DISCUSSION

This study detailed the high prevalence and detrimental effects of central obesity in axSpA using data from a large, well-characterized national axSpA registry. Obesity, as classified by BMI, has previously been shown to be one of the most prevalent comorbidities in axSpA, with numerous negative implications regarding disease activity and disease progression. Although central obesity has known negative health consequences in the general population, there is scant literature on central obesity in the context of axSpA. This analysis is novel, not only in capturing the prevalence of central obesity in axSpA but also in demonstrating the significant negative effects of this modifiable risk factor on patient outcomes, including disease activity, functional ability, and QOL.

Prevalence of obesity, as classified by BMI, was similar among both sexes (29.8% vs 29.9%, $P = 0.21$). Obesity is one of the most prevalent comorbidities in axSpA, with a recent metaanalysis reporting a pooled prevalence of 14%.[13] This is notably lower than the prevalence reported in the ASRI, which likely reflects the rising prevalence of obesity in the general population in Ireland.[26,27] Although it is difficult to determine the true national prevalence of obesity, most recent data report an Irish obesity prevalence of 27%[28] compared to 25.2% in the European Union.[29] Obesity prevalence in Ireland is currently similar among men and women, although evidence suggests this will soon change.[27] Longitudinal data indicate that the European population with the steepest rise in obesity is Irish women.[27] Alarmingly, young women, aged 18–35 years, are driving this rapid increase. This emphasizes the need for early recognition and lifestyle modification from an early age.

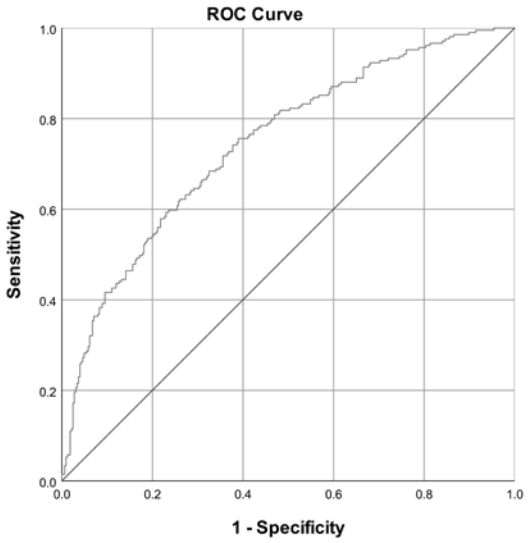

Figure 2. Receiver-operating characteristic (ROC) curve for factors associated with central obesity.

Table 4. Determining the likelihood of central obesity as measured by the WHR.

	OR	95% CI	*P*
Age	1.03	1.01–1.05	**0.01**
Female sex	6.76	4.12–11.1	**< 0.01**
r-axSpA	0.75	0.46–1.21	0.24
BASMI	1.06	0.93–1.21	0.36
BASDAI	0.92	0.82–1.04	0.18
BASFI	1.08	0.94–1.24	0.30
ASQoL	1.04	0.98–1.10	0.24

Values in bold are statistically significant. ASQoL: Ankylosing Spondylitis Quality of Life; BASDAI: Bath Ankylosing Spondylitis Disease Activity Index; BASFI: Bath Ankylosing Spondylitis Functional Index; BASMI: Bath Ankylosing Spondylitis Metrology Index; OR: odds ratio; r-axSpA: radiographic axial spondyloarthritis; WHR: waist-to-hip ratio.

The most surprising finding from this current analysis was the significantly higher prevalence of central obesity among women with axSpA compared to men (71.6% vs 29.9%, $P < 0.01$). Previously, central obesity in the general population was perceived as more common among males.[20] However, an epidemiological study examining trends in central obesity in the US noted that prevalence was increasing steadily at an annual rate of 0.56% among males and 0.75% among females and that, by 2030, it would affect up to 55.6% of males and 80% of females.[30] This finding is cause for alarm, as central obesity is known to be associated with insulin resistance,[31] renal impairment,[32] and higher risk of mortality, even among women with a normal BMI.[16] For women of childbearing age, central obesity is associated with an increased risk of gestational diabetes, preeclampsia, and the need for cesarean sections.[33,34] Unfortunately, there is scant literature examining this issue specifically in axSpA. Research in obesity has demonstrated that excess adipose tissue creates a persistent low-grade inflammatory state driven by proinflammatory adipocytokines.[35] This is especially concerning in patients with inflammatory arthritis, such as axSpA, as persistent inflammation could drive worsening of disease activity. As the concentration of adipocytokines is directly related to body fat mass, reduction of excess adipose tissue has the potential to correct this systemic inflammatory reaction. Given the disproportionate percentage of females with central obesity and the trend for females with axSpA to average worse PROs compared to males, this is a key modifiable lifestyle factor to target in this population. Thus, central obesity in women, especially those with axSpA, is a critical issue that requires greater public awareness and recognition.

Identification of central obesity is the first step in improving recognition in axSpA. This analysis highlighted disparities in obesity detection using 2 anthropometric tools (ie, BMI and WHR) among women with axSpA. For men with axSpA, the prevalence of obesity was similar regardless of the tool used (BMI, 29.6% vs WHR, 29.9%). However, for women, there was a stark change in prevalence of obesity when comparing BMI (29.8%) and the WHR (71.6%). This difference in classification between sexes was quantified in a correlation analysis, which found the relationship between BMI and the WHR to be stronger among men than women with axSpA. This suggests that although BMI is a quick tool to screen for obesity, it underestimates obesity in women. This difference in the strength of association between sexes may reflect the fact that BMI was a tool developed and validated for use in males.[36] Since its development in the 1830s by a Belgian statistician to describe the average man, BMI has become one of the most commonly used tools to quantify physical size and general health.[37] However, studies in postmenopausal women indicate that BMI is not a reliable indicator of obesity status among women.[38] In addition, universal BMI cut-offs for obesity have been found to perform poorly among women of differing ethnic backgrounds.[39] This clearly demonstrates that it is time to reconsider the use of BMI to screen for obesity in females, especially those with axSpA.

The prevalence of central obesity was similar among those with r-axSpA and nr-axSpA (42.6% vs 37.4%, $P = 0.21$). However, the prevalence of HLA-B27 was higher in patients with central obesity compared to those with no central obesity (90.4% vs 87.6%, $P < 0.01$; Table 2). There is limited knowledge of central obesity in axSpA; however, an ankylosing spondylitis study did note that central obesity was associated with radiographic progression over time.[40] The ASAS COMOrbidities in SPondyloArthritis (COMOSPA) study also demonstrated that mean waist circumference was significantly lower in patients with axSpA who were positive for HLA-B27 compared to those who were negative for HLA-B27.[41] Additional longitudinal data are required to investigate the relationship between radiographic disease, presence of HLA-B27, and central obesity in axSpA.

Assessment of baseline demographics of patients with central obesity and those without revealed that those with central obesity were older (mean 48.6 vs 43.7 years, $P < 0.01$) and had a later age of onset (mean 28.7 vs 25.7 years, $P < 0.01$; Table 2). Risk of central obesity in the general population is recognized to increase with age,[42] with men and postmenopausal women

having up to twice as much visceral adipose tissue (VAT) compared to premenopausal females.[43] In women, these changes are mediated by increased androgen secretion and a decline in estrogen concentration associated with reduction in ovarian function during menopause.[21] While women from the general population report an increase in myalgia and arthralgia during the onset of menopause,[44] there are limited and conflicting data on the effects of changes in estrogen concentration on disease activity among women with axSpA.[45]

To examine this further, a model was constructed to determine the factors that are associated with the presence of central obesity in axSpA. Despite the numerous predictors assessed, only age and female sex were found to be significantly associated with central obesity in axSpA. The association was especially strong among women with axSpA, who averaged 6.76 times higher odds of central obesity compared to men with axSpA, highlighting the dramatically higher prevalence of central obesity among women with axSpA.

Women with axSpA have previously demonstrated worse PROs compared to men, despite a lower prevalence of radiographic disease and better spinal mobility.[45] This disconnect between radiographic burden and outcome scores has perplexed axSpA researchers for some time. Obesity in axSpA is known to contribute to worse patient outcomes regardless of sex.[7,46] Given the unexpectedly high prevalence of central obesity detected among women in this study, a follow-up analysis examined the interaction between female sex and central obesity to determine if there was a synergistic effect on PROs. Although the interaction did not reach statistical significance, the effects of both female sex and central obesity remained significant when considered individually. Central obesity was found to be significantly associated with all PROs, with the exception of the BASDAI outcome, which demonstrated a nonsignificant trend toward worse scores in central obesity ($P = 0.07$). Differences in BASDAI scores between the 2 cohorts were more subtle than for the other PROs, which is likely the reason that the association between central obesity and this outcome did not reach significance. However, if tested on a larger scale, it is suspected that the effect of central obesity on BASDAI scores would be significant. This suggests that central obesity could play a key role in explaining the sex differences observed in PROs in axSpA. Further studies are needed to corroborate these findings in other axSpA cohorts; development of longitudinal data is also needed to determine if there is a causal relationship between central obesity and worse PROs.

The health risks associated with central obesity are attributable to the presence of VAT, which can be directly measured by various imaging modalities, including dual-energy x-ray absorptiometry (DXA) and magnetic resonance imaging.[47] Studies using DXA suggest that persistent disease activity in axSpA is associated with increased free fat mass in women,[48] with higher body fat content associated with a worse response to anti–tumor necrosis factor-α therapies.[49] In clinical practice, it is not practical or economical to repeatedly image patients to screen for central obesity. During an axSpA consultation, physical measurements are routinely recorded for calculation of the BASMI. In this setting, calculation of the WHR would be a simple yet effective modality to effectively assess a patient's body habitus. Improving recognition of central obesity is important, as this is a potentially modifiable state. Prompt identification creates a window of opportunity for multidisciplinary intervention, including education on lifestyle modification, dietary management with dieticians, and exercise therapy with physiotherapists. Obesity research has proven that early intervention and comprehensive structured programs are the most effective strategies for weight reduction and long-term maintenance.[50] Thus, incorporation of the WHR is essential for improving identification of central obesity in axSpA.

Our study has some limitations. Due to the cross-sectional nature of the ASRI, relationships between variables could only be assessed for association and not causation. Plans are in place to collect longitudinal data within the ASRI, which would allow for further analysis of these relationships. Not all patients within the ASRI had physical measurements recorded; as such, they were excluded from the analysis where such measurements were not available.

In conclusion, there is a high prevalence of central obesity in axSpA, as classified by the WHR, most notably among women with axSpA. This modifiable comorbidity was significantly associated with worse functional ability, poorer QOL, and a trend toward worse disease activity. Presence of central obesity was also strongly associated with increasing age and female sex. These results are highly concerning and would support the use of the WHR when screening for obesity in this population. Central obesity is a potentially modifiable state that, if identified, may be a key target for intervention among patients with axSpA. Further public health campaigns are needed to raise awareness and improve recognition of this issue in axSpA.

ONLINE SUPPLEMENT

Supplementary material accompanies the online version of this article.

REFERENCES

1. NCD Risk Factor Collaboration (NCD-RisC). Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. Lancet 2016;387:1377-96.
2. Hales CM, Fryar CD, Carroll MD, Freedman DS, Ogden CL. Trends in obesity and severe obesity prevalence in US youth and adults by sex and age, 2007-2008 to 2015-2016. JAMA 2018;319:1723-5.
3. Global BMI Mortality Collaboration; Di Angelantonio E, Bhupathiraju Sh N, et al. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. Lancet 2016;388:776-86.
4. Mokdad AH, Marks JS, Stroup DF, Gerberding JL. Actual causes of death in the United States, 2000. JAMA 2004;291:1238-45.
5. Kinlen D, Cody D, O'Shea D. Complications of obesity. QJM 2018;111:437-43.
6. Sieper J, Braun J, Dougados M, Baeten D. Axial spondyloarthritis. Nat Rev Dis Primers 2015;1:15013.
7. Liew JW, Huang IJ, Louden DN, Singh N, Gensler LS. Association of body mass index on disease activity in axial spondyloarthritis: systematic review and meta-analysis. RMD Open 2020;6:e001225.

8. Bindesbøll C, Garrido-Cumbrera M, Bakland G, Dagfinrud H. Obesity increases disease activity of Norwegian patients with axial spondyloarthritis: results from the European Map of Axial Spondyloarthritis Survey. Curr Rheumatol Rep 2020;22:43.
9. Zurita Prada PA, Urrego Laurín CL, Guillén Astete CA, Kanaffo Caltelblanco S, Navarro-Compán V. Influence of smoking and obesity on treatment response in patients with axial spondyloarthritis: a systematic literature review. Clin Rheumatol 2021;40:1673-86.
10. Bakirci S, Dabague J, Eder L, McGonagle D, Aydin SZ. The role of obesity on inflammation and damage in spondyloarthritis: a systematic literature review on body mass index and imaging. Clin Exp Rheumatol 2020;38:144-8.
11. Unamuno X, Gómez-Ambrosi J, Rodríguez A, Becerril S, Frühbeck G, Catalán V. Adipokine dysregulation and adipose tissue inflammation in human obesity. Eur J Clin Invest 2018;48:e12997.
12. Zorena K, Jachimowicz-Duda O, Ślęzak D, Robakowska M, Mrugacz M. Adipokines and obesity. Potential link to metabolic disorders and chronic complications. Int J Mol Sci 2020;21:3570.
13. Zhao SS, Robertson S, Reich T, Harrison NL, Moots RJ, Goodson NJ. Prevalence and impact of comorbidities in axial spondyloarthritis: systematic review and meta-analysis. Rheumatology 2020;59:iv47-57.
14. Fitzgerald G, Gallagher P, O'Shea FD. Multimorbidity in axial spondyloarthropathy and its association with disease outcomes: results from the Ankylosing Spondylitis Registry of Ireland cohort. J Rheumatol 2020;47:218-26.
15. Huxley R, Mendis S, Zheleznyakov E, Reddy S, Chan J. Body mass index, waist circumference and waist:hip ratio as predictors of cardiovascular risk--a review of the literature. Eur J Clin Nutr 2010;64:16-22.
16. Sun Y, Liu B, Snetselaar LG, et al. Association of normal-weight central obesity with all-cause and cause-specific mortality among postmenopausal women. JAMA Netw Open 2019;2:e197337.
17. Anderson CAM, Mongraw-Chaffin M. Central obesity in older adults: what should be the priority? J Am Heart Assoc 2018;7:e010119.
18. Wan J, Zhou P, Wang D, et al. Impact of normal weight central obesity on clinical outcomes in male patients with premature acute coronary syndrome. Angiology 2019;70:960-8.
19. Vazquez G, Duval S, Jacobs DR, Jr., Silventoinen K. Comparison of body mass index, waist circumference, and waist/hip ratio in predicting incident diabetes: a meta-analysis. Epidemiol Rev 2007;29:115-28.
20. Palmer BF, Clegg DJ. The sexual dimorphism of obesity. Mol Cell Endocrinol 2015;402:113-9.
21. Dmitruk A, Czeczelewski J, Czeczelewska E, Golach J, Parnicka U. Body composition and fatty tissue distribution in women with various menstrual status. Rocz Panstw Zakl Hig 2018;69:95-101.
22. Ambikairajah A, Walsh E, Tabatabaei-Jafari H, Cherbuin N. Fat mass changes during menopause: a metaanalysis. Am J Obstet Gynecol 2019;221:393-409.e50.
23. World Health Organization. Waist circumference and waist to hip ratio: report of a WHO expert consultation. Geneva, Switzerland: WHO; 2008.
24. Centers for Disease Control and Prevention. Defining adult overweight & obesity. [Internet. Accessed June 15, 2021.] Available from: https://www.cdc.gov/obesity/adult/defining.html
25. Nishida C, Ko GT, Kumanyika S. Body fat distribution and noncommunicable diseases in populations: overview of the 2008 WHO Expert Consultation on Waist Circumference and Waist-Hip Ratio. Eur J Clin Nutr 2010;64:2-5.
26. McCarthy SN, Gibney MJ, Flynn A, Irish Universities Nutrition Alliance. Overweight, obesity and physical activity levels in Irish adults: evidence from the North/South Ireland food consumption survey. Proc Nutr Soc 2002;61:3-7.
27. Boylan EA, McNulty BA, Walton J, Flynn A, Nugent AP, Gibney MJ. The prevalence and trends in overweight and obesity in Irish adults between 1990 and 2011. Public Health Nutr 2014; 17:2389-97.
28. Altobelli E, Angeletti PM, Profeta VF, Petrocelli R. Lifestyle risk factors for type 2 diabetes mellitus and national diabetes care systems in European countries. Nutrients 2020;12:2806.
29. Krzysztoszek J, Laudańska-Krzemińska I, Bronikowski M. Assessment of epidemiological obesity among adults in EU countries. Ann Agric Environ Med 2019;26:341-9.
30. Wang Y, Beydoun MA, Min J, Xue H, Kaminsky LA, Cheskin LJ. Has the prevalence of overweight, obesity and central obesity levelled off in the United States? Trends, patterns, disparities, and future projections for the obesity epidemic. Int J Epidemiol 2020;49:810-23.
31. Liu MM, Liu QJ, Wen J, et al. Waist-to-hip ratio is the most relevant obesity index at each phase of insulin secretion among obese patients. J Diabetes Complications 2018;32:670-6.
32. Tsao YC, Chen JY, Yeh WC, Li WC. Gender- and age-specific associations between visceral obesity and renal function impairment. Obes Facts 2019;12:67-77.
33. Yao D, Chang Q, Wu QJ, et al. Relationship between maternal central obesity and the risk of gestational diabetes mellitus: a systematic review and meta-analysis of cohort studies. J Diabetes Res 2020;2020:6303820.
34. Lim J, Han K, Kim SY, et al. Effects of central obesity on maternal complications in Korean women of reproductive age. Obes Res Clin Pract 2019;13:156-63.
35. Chimenti MS, Perricone C, D'Antonio A, et al. Genetics, epigenetics, and gender impact in axial-spondyloarthritis susceptibility: an update on genetic polymorphisms and their sex related associations. Front Genet 2021;12:671976.
36. Blackburn H, Jacobs D Jr. Commentary: origins and evolution of body mass index (BMI): continuing saga. Int J Epidemiol 2014;43:665-9.
37. Gutin I. In BMI we trust: reframing the body mass index as a measure of health. Soc Theory Health 2018; 16:256-71.
38. Banack HR, Wactawski-Wende J, Hovey KM, Stokes A. Is BMI a valid measure of obesity in postmenopausal women? Menopause 2018;25:307-13.
39. Rush EC, Goedecke JH, Jennings C, et al. BMI, fat and muscle differences in urban women of five ethnicities from two countries. Int J Obes 2007;31:1232-9.
40. Chen CH, Chen HA, Liu CH, Liao HT, Chou CT, Chen CH. Association of obesity with inflammation, disease severity and cardiovascular risk factors among patients with ankylosing spondylitis. Int J Rheum Dis 2020;23:1165-74.
41. Arévalo M, López-Medina C, Moreno Martinez-Losa M, et al. Role of HLA-B27 in the comorbidities observed in axial spondyloarthritis: data from COMOSPA. Joint Bone Spine 2020;87:445-8.
42. Tchernof A, Després JP. Pathophysiology of human visceral obesity: an update. Physiol Rev 2013;93:359-404.
43. Kotani K, Tokunaga K, Fujioka S, et al. Sexual dimorphism of age-related changes in whole-body fat distribution in the obese. Int J Obes Relat Metab Disord 1994;18:207-2.
44. Watt FE. Musculoskeletal pain and menopause. Post Reprod Health 2018;24:34-43.
45. Rusman T, van Vollenhoven RF, van der Horst-Bruinsma IE. Gender differences in axial spondyloarthritis: women are not so lucky. Curr Rheumatol Rep 2018;20:35.

46. Maas F, Arends S, van der Veer E, et al. Obesity is common in axial spondyloarthritis and is associated with poor clinical outcome. J Rheumatol 2016;43:383-7.
47. de Koning L, Merchant AT, Pogue J, Anand SS. Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. Eur Heart J 2007;28:850-6.
48. Ibáñez Vodnizza S, Visman IM, van Denderen C, et al. Muscle wasting in male TNF-α blocker naïve ankylosing spondylitis patients: a comparison of gender differences in body composition. Rheumatology 2017;56:1566-72.
49. Ibáñez Vodnizza SE, Nurmohamed MT, Visman IM, et al. Fat mass lowers the response to tumor necrosis factor-α blockers in patients with ankylosing spondylitis. J Rheumatol 2017;44:1355-61.
50. Ramage S, Farmer A, Eccles KA, McCargar L. Healthy strategies for successful weight loss and weight maintenance: a systematic review. Appl Physiol Nutr Metab 2014;39:1-20.