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ORIGINAL ARTICLE - EXERCISE AND RMD

Decreased physical activity and cardiorespiratory fitness in adults with ankylosing spondylitis: a cross-sectional controlled study

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Abstract The health benefits of physical activity (PA) in the general population are numerous; however, few studies have measured PA among adults with ankylosing spondylitis (AS). The aims of this study were to: (1) objectively measure the PA levels and cardiorespiratory fitness of adults with AS and compare these to population controls, and (2) examine the relationships between PA, cardiorespiratory function and condition-specific outcomes. This cross-sectional study included participants (>18 years) meeting the modified New York criteria for AS, and matched population controls. Exclusion criteria were the presence of comorbidities limiting PA, or recent changes in medication usage. Participants completed clinical questionnaires assessing disease activity, physical function and quality of life. Tri-axial accelerometers recorded habitual PA over 1 week. Cardiorespiratory fitness was assessed by submaximal treadmill test with breath-by-breath gas analysis and heart rate monitoring. Thirty-nine adults with AS and 39 controls were recruited. The AS group spent significantly less time performing vigorous-intensity PA than controls [mean difference (95 % CI) 1.8 min/day (1.2–2.7)] and performed significantly fewer bouts of health-enhancing PA [1.7 min/day (1.1–2.5)]. The AS group had significantly lower predicted VO_{2MAX} than controls [6.0 mL kg^{-1} min^{-1} (1.8–10.1)]. PA was associated with aerobic capacity. Sedentary time was associated with disease activity and physical function. Adults with AS participate in less health-enhancing PA than population controls. Fewer than half meet PA recommendations, despite exercise being a key component of AS management. Explorations of PA behaviour and strategies to increase PA participation are needed.

Keywords Physical activity · Exercise · Spondyloarthritis · Spondylitis, ankylosing · Motor activity

Introduction

Ankylosing spondylitis (AS) is a chronic inflammatory rheumatic condition that primarily affects the axial skeleton and is the major subtype of spondyloarthritis (SpA). Clinically, AS is characterised by inflammatory back pain and stiffness, with decreased spinal mobility and limitations in physical function [1]. Accompanying extra-articular features may include uveitis, osteoporosis, bowel disease, and cardiac, pulmonary, skin (psoriasis) and kidney involvement [2]. Ischaemic heart disease and cardiovascular risk factors have been found to be elevated in this population [3]. Respiratory abnormalities in AS are typically of a restrictive pattern [4], and a reduction in aerobic capacity compared to the general population has been observed [5–8]. AS is associated with decreased physical fitness, reduced work productivity and lower health-related quality of life [7, 9–11].

A combination of pharmacological and non-pharmacological treatment modalities is recommended by the Assessment of SpondyloArthritis international Society

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(ASAS) and the European League Against Rheumatism (EULAR) for optimal management of adults with AS [12]. The advent of anti-TNF therapy has transformed the pharmacological management of AS. Education, therapeutic exercise and physiotherapy are key components of the non-pharmacological management. Exercise programmes have shown beneficial effects on disease activity, physical function, spinal mobility and condition-related symptoms [13, 14].

The term physical activity (PA) includes any bodily movement produced by skeletal muscles that results in energy expenditure [15]; in addition to exercising, this may be achieved during free-living work, transport, and leisure-time and domestic activities. The health-related benefits of PA are numerous and well documented. In the general population, PA has been found to reduce the risk of cardiovascular disease, obesity, colon and breast cancers, type 2 diabetes and osteoporosis. It also improves musculoskeletal health and reduces symptoms of depression [16].

The PA profile of adults with SpA is less clear, and the condition-related benefits associated with PA (not limited to exercise) have not been explored. A recent systematic review identified two studies which objectively measured PA in adults with AS and compared results to population controls [17–19]. Results from these studies are equivocal; PA levels among adults with AS may be lower than, or equivalent to, the general population. Self-report questionnaires have also been used to measure PA among adults with AS [17]. Results from these studies are also conflicting, and the reliability and validity of these questionnaires have been questioned [20]. Furthermore, sedentary behaviour in adults with AS remains relatively unknown. The associations between PA, cardiorespiratory fitness and disease activity, physical function and AS-related quality of life have not been explored.

The aims of this study were to (1) objectively measure the PA levels, the cardiorespiratory fitness and the pulmonary function of adults with AS and compare these to the general population, and (2) examine the relationships between PA, cardiorespiratory function and condition-specific outcomes.

Materials and methods

Study design and recruitment

This cross-sectional, controlled study was conducted between May 2013 and March 2014. Approval for this study was granted by the local research ethics committee. A convenience sample of adults with AS was recruited from a dedicated AS clinic in the Rheumatology Department of St. James's Hospital, Dublin. An information leaflet and an invitation to participate in the study were extended to consecutive attendees of the clinic who potentially met the recruitment criteria. Concurrently, control group participants were recruited by posters in the locality. Written informed consent was obtained for each subject prior to participation, in compliance with the Declaration of Helsinki.

Eligibility criteria

Adults between 18 and 64 years of age diagnosed by a rheumatologist as meeting the modified New York criteria for AS were eligible for inclusion in the study [21]. Participants were excluded if they had a concomitant cardiac, respiratory or neurological condition, a comorbidity restricting their PA, an acute lower limb injury, uncontrolled epilepsy, a cognitive impairment, were pregnant, were unable to ambulate without a mobility aid or had changed medication within 6 weeks of testing. Non-English speakers were also excluded. Frequency matching of controls for gender and age was used to increase the similarity in distribution of confounding variables between groups; age bands were 18–19, 20–24 and 5-year age ranges up to 64 years.

Assessment

Participants enrolled in the study attended an exercise laboratory on one occasion to complete sociodemographic and clinical questionnaires, and to undergo physical examination. All equipment was calibrated as per manufacturer recommendations prior to each session. Participants were asked to refrain from smoking, eating or drinking (including alcohol and caffeine), or engaging in strenuous exercise prior to testing. All measures were taken by the same physiotherapist.

Sociodemographic and condition-related variables

Participants' age, gender, employment status, education level achieved, smoking history and number of exercise sessions performed per week were ascertained. Subjects with AS were additionally asked about symptom duration, time since diagnosis and current medication usage. In the absence of a gold standard to measure disease activity, C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) are commonly used. A venous blood sample was taken from the AS group and analysed for these acute phase reactants [22].

Additionally, a number of self-administered questionnaires endorsed by the ASAS were used to measure aspects of the condition [23]. These comprised a number of questions rated on a numeric rating scale (NRS) from 0 (best response, e.g. "no pain") to 10 (worst response, e.g. "most severe pain"). An NRS was used to quantify nocturnal and

total back pain. The Bath Ankylosing Spondylitis Global Score (BAS-G) measured global well-being over the previous week and previous 6 months [24].

Disease activity was measured subjectively on the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI). The index consists of six questions relating to fatigue, back pain, pain and/or swelling of peripheral joints, localised tenderness, and morning stiffness in the previous week, with each question scored on an NRS. A total score out of ten is then calculated [25, 26]. In addition, the Ankylosing Spondylitis Disease Activity Score ($ASDAS_{CRP}$) was calculated [27, 28]. The ASDAS is a composite index developed by the ASAS, incorporating CRP and subjectively reported back pain, morning stiffness duration, patient-rated global disease activity, and peripheral joint pain and swelling.

Physical function was measured on the Bath Ankylosing Spondylitis Functional Index (BASFI), a widely used index consisting of ten questions assessing activities of daily living and functional ability over the previous week [29]. Each question is scored by NRS, and the mean of the individual scores yields a total score out of ten [29, 30].

The Ankylosing Spondylitis Quality of Life Questionnaire (ASQoL) consists of 18 yes/no items designed to measure the impact of AS on health-related quality of life [31]. While not part of the ASAS core set of questionnaires, reliability and construct validity have previously been established [25].

Physical activity measurement

The RT3 (Stayhealthy Inc., Monrovia, California) is a triaxial accelerometer that measures accelerations in three orthogonal planes. Output expressed in "counts", was converted to minutes spent at different activity intensities using previously established cut-points [32]. Time spent in ≥10 min bouts of moderate- and/or vigorous-intensity PA (PA_{BOUTS}) was also calculated; this is the minimum recommended duration PA should be sustained for in order to derive health benefits [16].

Participants wore the small lightweight device on their right hip during waking hours over a 7-day period. Wear time was deemed valid when worn for ≥10 h on a minimum of 4 days (including at least one weekend day) [33]. The device was removed only for showering and swimming. Non-wear time was documented in a daily log.

Anthropometric measures

Barefoot standing height (Leicester portable height measure, Invicta Plastics Ltd, Leicester, United Kingdom) and mass (MC-180 MA, Tanita Corp, Tokyo, Japan) were measured, from which body mass index (BMI) was calculated.

Cardiorespiratory fitness testing

Chest expansion was measured at the fourth intercostal level. Pulmonary function tests were conducted using a portable spirometer (MicroLab, CareFusion, USA). Testing was performed seated, with participants wearing a nose clip. Subjects inhaled rapidly and completely, inserted a mouthpiece ensuring their lips formed a seal and, with a pause of <1 s at total lung capacity, exhaled maximally until no more air could be expelled. The manoeuvre was repeated for ≥3 times. Testing concluded when the criteria for acceptable spirometry were met: (1) individual spirograms were free from artefacts (cough, early termination, leak, etc.), (2) exhalation was ≥6 s or a plateau of the volume time curve was observed, and (3) <150 mls variance between forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV1) was registered between individual manoeuvres. Coaching and encouragement was provided throughout [34]. Outcomes included FVC, FEV1 and peak expiratory flow (PEF).

Participants undertook a multistage, submaximal exercise test on a treadmill. Submaximal testing is a valid and reliable way of predicting cardiorespiratory fitness without participants reaching maximal exertion [35]. Resting heart rate (HR) and blood pressure (BP) were measured prior to a 5-min walking familiarisation period. The incremental test followed the modified Bruce protocol [36]. Breath-by-breath gas analysis and heart rate were recorded throughout (Quark; Cosmed, Rome, Italy). Participants completed two or more 3-min submaximal stages of continuous exercise that raised the HR to >100 bpm. Data averaging was performed after test completion using 30-s averages. The test was terminated when 85 % of age-predicted HR_{MAX} was attained, or if the participant requested to stop. The highest oxygen uptake recorded during the test (VO_{2PEAK}) was recorded. The American College of Sports Medicine's (ACSM) metabolic equation was used to estimate VO_{2MAX} [37]. The ratio of the difference between two submaximal VO_2 measures from the final two completed stages to corresponding change in HR was used to calculate slope (*b*) [Eq. 1]. Slope (*b*) was then used to predict VO_{2MAX} by extrapolating the VO_2/HR values from the final completed stage to the estimated maximal heart rate (220—age) [Eq. 2].

$$b = \left(VO_{2\ \text{last stage}} - VO_{2\ \text{penultimate stage}}\right) / \left(HR_{\text{last stage}} - HR_{\text{penultimate stage}}\right) \quad (1)$$

$$VO_{2MAX} = VO_{2\ \text{last stage}} + b\left(HR_{max} - HR_{\text{last stage}}\right) \quad (2)$$

Statistical methods

Statistical analyses were performed with SPSS for Windows version 21 (IBM, Armonk, NY, USA). Descriptive

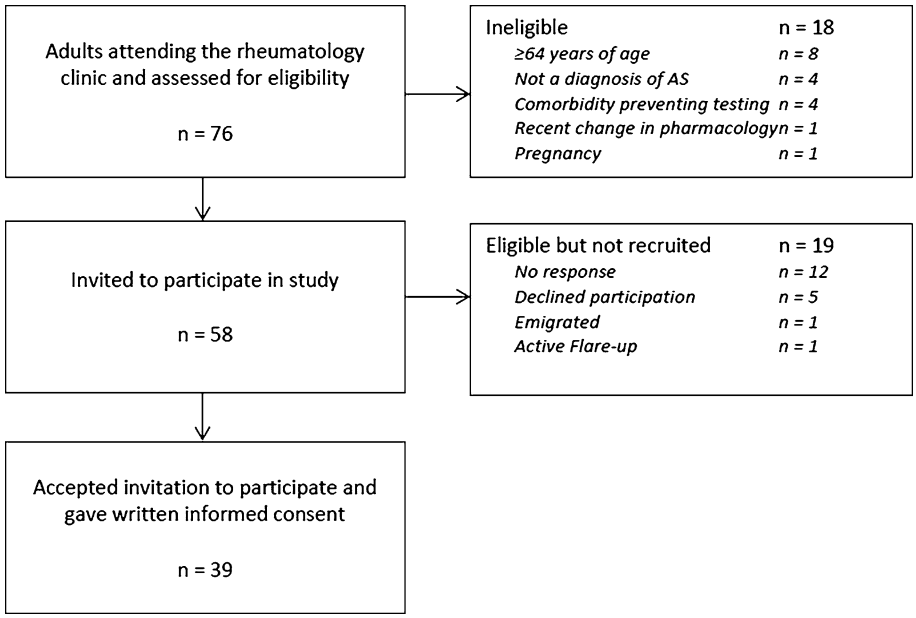

Fig. 1 Participant recruitment strategy

statistics of participant characteristics were reported as frequency and percentage for categorical variables, and continuous data were reported as mean and standard deviation (SD) or median and interquartile range (IRQ), as appropriate. Skewed anthropometric, accelerometry and cardiorespiratory variables were transformed (square root or $\log_{10}$) for analytic purposes. For all analyses, $p < .05$ (two-tailed) was taken as statistically significant. Group differences were examined by Chi-squared tests for categorical variables and by independent-samples *t*-tests for normally distributed variables. Univariate analyses of covariance were performed to explore the between-group differences in PA behaviour and cardiorespiratory fitness, adjusted for education and employment status.

Regression analyses were used to explore the associations between disease activity, physical function, quality of life, cardiorespiratory capacity and physical activity. Simple linear regressions were conducted with PA_{BOUTS} and time spent sedentary (PA_{SED}) as dependent variables, and VO_{2MAX}, BASDAI, BASFI and ASQoL as separate independent variables. The proportion of variance accounted for by each relationship is reported as R^2, expressed as a percentage. Level of probability was calculated from *F* values.

Results

Participant recruitment

Of the 76 adults attending the rheumatology clinic over the recruitment period, 58 (76.3 %) were potentially eligible for inclusion in the study. Eighteen (23.7 %) adults were ineligible due to being older than 64 years ($n = 8$, 44.4 %), not meeting the diagnostic criteria for AS ($n = 4$, 22.2 %), having a comorbidity preventing safe physical testing ($n = 4$, 22.2 %), recently changing pharmacological management ($n = 1$, 5.6 %) or being pregnant ($n = 1$, 5.6 %). Thirty-nine AS patients, 32 males and 7 females (67.2 % of those eligible), accepted the invitation to be included in the study. Of those eligible but not recruited, five declined to participate (26.3 %), one emigrated (5.3 %), one had a flare-up (5.3 %), and twelve gave no response when contacted (63.2 %). Non-participants (14 men, 5 women) had a mean (SD) age of 39.9 years (10.6) and were not significantly different to those entering the study across age and gender variables ($p > .05$ for both). Thirty-nine age- and gender-matched population controls were recruited. Participant recruitment is shown in Fig. 1.

Participant characteristics

Participant characteristics are summarised in Table 1. Fifteen participants in the AS group (38.5 %) did not provide a blood sample for ESR and CRP; $ASDAS_{CRP}$ could not be calculated in these cases. One participant in the AS group did not fully complete the BASDAI or BASFI questionnaires. There were no statistically significant differences between groups with regard to age, gender, smoking status or self-reported weekly exercise. A significantly higher proportion of the control group were employed and had completed education to third level or higher. Participants in the AS group were significantly shorter than controls, while body mass was not significantly different; consequently, BMI was significantly increased in the AS group. The AS group also showed significant restrictions in chest expansion compared to controls.

Table 1 Participant characteristics

Variable	AS $n = 39$	Controls $n = 39$	p value[a]	MD (95 % CI)[a]
Age (years)	40.0 (9.0)	38.9 (9.0)	.599	
Male (%)	32 (82.1)	32 (82.1)	1.000	
Height (cm)	167.7 (9.6)	176.4 (7.3)	<.001	−8.7 (−12.6 to −4.9)
Mass (kg)	78.1 (13.3)	74.3 (9.9)	.162	
Body mass index (kg/m^2)[b]	28.6 (6.8)	23.6 (3.4)	<.001	1.2 (1.1 to 1.2)
Chest expansion (cm)	3.8 (1.9)	6.2 (1.3)	<.001	−2.4 (−3.1 to −1.7)
Employed (%)	24 (61.5)	36 (92.3)	.001	
Completed ≥ tertiary education (%)	17 (43.6)	28 (71.8)	.012	
Smoker (%)	7 (17.9)	5 (12.8)	.530	
Exercise sessions per week (%)			.310	
0	4 (10.3)	2 (5.1)		
1–2	4 (10.3)	10 (25.6)		
3–4	15 (38.5)	14 (35.9)		
≥5	16 (41.0)	13 (33.3)		
ESR (mm/h)[b]	5.0 (13.8)	N/A		
CRP (mg/L)[b]	2.4 (5.7)	N/A		
Symptom duration (years)	16.6 (10.0)	N/A		
Time since diagnosis (years)[b]	6.0 (10.0)	N/A		
Pharmacology (%)		N/A		
Anti-TNFα	18 (46.2)			
NSAIDs	8 (20.5)			
Analgesia	3 (7.7)			
None	10 (25.6)			
Back pain—total	3.5 (2.3)	N/A		
Back pain—nocturnal[b]	3.0 (4.0)	N/A		
BAS-G	3.8 (2.1)	N/A		
BASDAI	3.6 (2.2)	N/A		
$ASDAS_{CRP}$	2.2 (1.0)	N/A		
BASFI[b]	2.9 (3.8)	N/A		
ASQoL[b]	5.3 (5.0)	N/A		

$ASDAS_{CRP}$ Ankylosing Spondylitis Disease Activity Score (C-reactive protein version), *ASQoL* Ankylosing Spondylitis Quality of Life Questionnaire, *BASDAI* Bath Ankylosing Spondylitis Disease Activity Index, *BASFI* Bath Ankylosing Spondylitis Functional Index, *BAS-G* Bath Ankylosing Spondylitis Global Score, *CRP* C-reactive protein, *ESR* erythrocyte sedimentation rate, *MD* mean difference, *N/A* not assessed, *NSAIDs* non-steroidal anti-inflammatory drugs, *TNFα* tumour necrosis factor alpha

[a] Independent-samples t-test or χ^2 test as appropriate

Mean (standard deviation) or number of participants (%), unless otherwise stated; [b] median (interquartile range)

Physical activity

Three participants in the AS group had invalid RT3 data (no weekend wear time, insufficient wear time and faulty device). One control participant emigrated before wearing the accelerometer. The median (IQR) days worn per week and daily wear time were 6 (1) days and 872.7 (79.0) min in the AS group, and 7 (1) days and 876.4 (77.0) min in the control group. Table 2 summarises free-living PA measured by accelerometry. The AS group spent significantly less time performing vigorous-intensity physical activity (PA_{VIG}) and performed significantly fewer PA_{BOUTS} than the control group; these results remained significant after adjusting for employment and educational status. The association between the group allocation and whether or not weekly PA recommendations were met approached statistical significance [$\chi^2(1) = 3.462$, $p = .063$].

Cardiorespiratory fitness

The results of the incremental treadmill and spirometer tests are summarised in Table 3. At rest, the control group

Table 2 Daily physical activity

Physical activity variable[a]	AS $n = 36$	Controls $n = 38$	p value[b]	MD (95 % CI)[b]	p value[c]	Adjusted MD (95 % CI)[c]
Sedentary activity	450.9 (118.1)	495.9 (73.9)	.056	−45.0 (−91.1 to 1.1)	.079	−46.7 (−95.0 to 1.5)
% Sedentary time (/day)	51.7 (12.9)	56.0 (7.9)	.095	−4.3 (−9.3 to 0.8)	.062	−5.0 (−10.2 to 0.3)
Light activity	358.0 (107.6)	323.1 (75.4)	.113	34.9 (−8.5 to 78.3)	.080	40.9 (−5.0 to 87.0)
Moderate activity	50.8 (26.4)	52.1 (19.3)	.805	−1.3 (−12.0 to 9.4)	.794	−1.5 (−13.2 to 10.1)
Vigorous activity[d]	6.6 (9.0)	14.0 (17.0)	.008	−1.8 (−2.7 to −1.2)	.018	−1.8 (−2.8 to 1.1)
Moderate/vigorous activity	59.1 (29.6)	68.2 (25.6)	.165	−9.0 (−21.8 to 3.8)	.436	−9.0 (−23.0 to 5.1)
PA^{d}_{BOUTS}	18.6 (16.0)	27.1 (29.0)	.014	−1.7 (−2.5 to −1.1)	.021	−1.7 (−2.7 to 1.1)
Average counts (/day)	278.1 (94.6)	301.1 (87.2)	.280	−23.0 (−65.1 to 19.1)	.414	−18.9 (−64.7 to 26.9)
Meeting PA guidelines, *n* (%)	14 (38.9)	23 (60.5)	.063			

MD Mean difference, PA_{BOUTS} physical activity performed at moderate and/or vigorous intensity lasting a minimum of 10 min

[a] Minutes per day, expressed as mean (SD) unless otherwise stated

[b] Unadjusted independent-samples *t*-test or χ^2 test as appropriate

[c] Analysis of covariance adjusted for employment status and education level achieved

[d] Median (interquartile range)

had significantly lower resting HR and diastolic BP, but no significant difference was observed in resting systolic BP. At test conclusion, the AS group had significantly lower VO_{2PEAK}, HR and METs than the control group. Fewer participants with AS achieved 85 % of HR_{MAX} during the test, although there was no difference in the test stage reached. Predicted VO_{2MAX} was significantly lower in the AS group than in the controls. FVC, FEV1 and PEF were significantly lower in the AS group than in the control group.

Relationships between physical activity, cardiorespiratory capacity and condition-related outcomes

PA_{BOUTS} were positively associated with VO_{2MAX} ($R^2 = 27.5$ %, $\beta = .524$, $p = .001$) (Table 4). Health-enhancing PA_{BOUTS} were not statistically associated with clinical questionnaires ($p > .05$). Time spent sedentary was significantly associated with BASFI and BASDAI accounting for 17.8 and 21.8 % (R^2) of the total variance ($\beta = -.422$, $p = .011$ and $\beta = -.466$, $p = .005$, respectively) (Table 5). PA_{SED} was not significantly associated with ASQoL or VO_{2MAX}. Associations between PA and disease activity were similar irrespective of whether the latter was measured by BASDAI or $ASDAS_{CRP}$ (Supplementary Table 1).

Discussion

The first aim of this study was to objectively measure PA and cardiorespiratory fitness in adults with AS, and to contrast results with population controls. It was found that participants with AS spent approximately 30 % less time performing health-enhancing PA_{BOUTS} and engaged in significantly less PA_{VIG} than controls. Fewer than half of adults with AS achieved the recommended amount of weekly PA, although this was not statistically different to controls ($p = .063$). Aerobic capacity was significantly lower in the AS group compared to population controls. A third of participants in the AS group displayed a restrictive respiratory pattern, with a significantly lower FVC, FEV1 and PEF than controls. Predicted VO_{2MAX} was 13.5 % lower in the AS group than in controls.

The second aim of this study was to explore the relationship between PA, cardiorespiratory function and condition-specific outcomes. Health-enhancing PA_{BOUTS} were not significantly associated with disease activity, physical function or quality of life ($p > .05$); this suggests that factors other than disease process influence participation in PA_{BOUTS} and that disease activity, outside of a flare-up, does not limit PA. It also suggests that PA and exercise do not adversely affect the disease process.

Clinical implications

The number of participants with AS meeting weekly PA recommendation is low (38.9 %) relative to the control group and the general population [38]. This low adherence rate to PA guidelines is of concern considering the multiple health benefits derived from PA observed in other groups [16]. Furthermore, the guidelines are minimum recommendations, but as the benefits of PA are dose dependent, exceeding the recommendations may enhance the benefits accrued.

Table 3 Results of cardiorespiratory fitness testing

Variable[a]	AS $n = 39$	Controls $n = 39$	p value[c]	MD (95 % CI)[c]
Resting variables				
Heart rate (bpm)	66.0 (12.1)	61.2 (8.8)	.046	4.9 (0.1 to 9.6)
Systolic BP (mmHg)	130.1 (13.0)	125.4 (12.5)	.107	
Diastolic BP (mmHg)	80.5 (9.2)	75.2 (9.9)	.016	5.3 (1.0 to 9.7)
At end of treadmill test				
Stage reached (%)				
2	1 (2.6)	0		
3	6 (15.4)	2 (5.1)		
4	15 (38.5)	14 (35.9)		
5	16 (41.0)	23 (59.0)		
6	1 (2.6)	0		
Test duration (s)[b]	828.0 (193.0)	904.0 (163.0)	.029	4.5 (0.1 to 16.1)
VO_{2PEAK} (mL kg^{-1} min^{-1})[b]	26.5 (12.5)	34.9 (10.1)	<.001	−1.3 (−1.4 to −1.1)
HR (bpm)	147.4 (13.0)	153.6 (7.9)	.012	−6.3 (−11.1 to −1.4)
Energy expenditure (METs)[b]	7.6 (3.6)	10.0 (2.9)	<.001	−1.3 (−1.4 to −1.1)
Predicted VO_{2MAX} (mL kg^{-1} min^{-1})	37.8 (9.8)	43.7 (8.6)	.006	−6.0 (−10.1 to −1.8)
Reason for ending test [*n* (%)]				
85 % HR_{MAX} reached	25 (64.1)	36 (92.3)		
SOBOE	6 (15.4)	3 (7.7)		
Unwilling to run	8 (20.5)	0		
Spirometry results				
FVC (L)[b]	3.5 (1.6)	4.9 (1.2)	<.001	−1.3 (−1.4 to −1.2)
FEV1 (L)[b]	2.9 (1.5)	3.9 (0.9)	<.001	−0.0 (−0.1 to −0.0)
PEF (L min^{-1})	479.9 (88.4)	566.7 (111.5)	<.001	−86.8 (−132.2 to −41.4)
FEV1/FVC (%)	81.9 (6.9)	79.5 (6.8)	.119	
Respiratory pattern [*n* (%)]				
Normal	25 (64.1)	36 (92.3)		
Obstructive	1 (2.6)	2 (5.1)		
Restrictive	13 (33.3)	1 (2.6)		

BP Blood pressure, *FEV1* forced expiratory volume in 1 s, *FVC* forced vital capacity, *HR* heart rate, *MD* mean difference, *METs* metabolic equivalents, *PEF* peak expiratory flow, *SOBOE* shortness of breath on exertion

[a] Mean (standard deviation) or number of participants (%), unless otherwise stated

[b] Median (interquartile range)

[c] Independent-samples *t*-test

Table 4 Associations between health-enhancing physical activity (PA_{BOUTS}), condition-specific outcomes (BASDAI, BASFI and ASQoL) and cardiorespiratory function (VO_{2MAX})

	BASDAI	BASFI	ASQoL	VO_{2MAX}
R^2 (%)	0.1	5.2	0.0	27.5
F	0.017	1.825	0.004	12.889
β	.022	−.229	−.011	.524
p value	.898	.186	.951	.001

ASQoL Ankylosing Spondylitis Quality of Life Questionnaire, *BASDAI* Bath Ankylosing Spondylitis Disease Activity Index, *BASFI* Bath Ankylosing Spondylitis Functional Index, PA_{BOUTS} physical activity performed at moderate and/or vigorous intensity lasting a minimum of 10 min

Despite public health promotion campaigns, awareness of PA guidelines is low among patients with rheumatic conditions [39]. Healthcare practitioners report a lack of skills and confidence in the areas of PA promotion and exercise advice, although they are favourably disposed towards them [40]; this represents an important opportunity for improving awareness of, and adherence to, PA recommendations.

Exercise programmes, even when good compliance is reported, do not appear to sustain PA behaviour change beyond the intervention period. Niedermann et al. [41] observed that on completion of a 12-week aerobic exercise intervention, habitual PA levels measured by accelerometer returned to pre-intervention levels. The

Table 5 Associations between sedentary time (PA_{SED}), condition-specific outcomes (BASDAI, BASFI and ASQoL) and cardiorespiratory function (VO_{2MAX})

	BASDAI	BASFI	ASQoL	VO_{2MAX}
R^2 (%)	21.8	17.8	8.4	6.7
F	9.178	7.163	3.129	2.436
β	−.466	−.422	−.290	−.259
p value	.005	.011	.086	.128

ASQoL Ankylosing Spondylitis Quality of Life Questionnaire, *BASDAI* Bath Ankylosing Spondylitis Disease Activity Index, *BASFI* Bath Ankylosing Spondylitis Functional Index

inclusion of motivational strategies (based on social cognitive theory, motivational interviewing, self-determination theory or cognitive behavioural theory) can increase adherence to exercise, improve self-efficacy, reduce levels of activity limitation and have a positive effect on long-term PA behaviour [42]. To our knowledge, these approaches have not been trialled in cohorts with rheumatic conditions.

Prolonged sedentary time, independent of PA, is positively associated with deleterious health outcomes [43]. This study found higher time spent sedentary to be associated with lower disease activity and decreased functional limitations. A possible explanation may be that patients with lower disease activity may better tolerate static, sedentary activities, whereas higher disease activity may prompt an increased light activity in a bid provide symptomatic relief through movement. Sedentary behaviour in AS is under-researched and poorly understood. Few studies have objectively measured sedentary behaviour and PA in an SpA cohort [18, 19]. Methodological limitations and heterogeneity of accelerometry outcome variables limit direct comparisons to these studies and prevent firm conclusions from being drawn [17].

Aerobic capacity is a powerful predictor of mortality among men with and without cardiovascular disease, with an increase of 3.5 mL min^{-1} kg^{-1} (1 MET) associated with a 11–12 % improvement in survival [44, 45]. The lower cardiorespiratory capacity observed in the AS group is in keeping with other studies that have compared AS cohorts to controls. The magnitude of the difference varies across studies from 7 to 24 %; this variance may be due to differing patient characteristics, test protocols and methods of VO_{2PEAK} estimation [5–8]. Small increases in absolute VO_{2PEAK} are associated with lower mortality from cardiovascular disease. Recent exercise programmes incorporating aerobic components (swimming, cycling, brisk walking and Nordic walking) have been effective in improving aerobic capacity of AS groups [41, 46, 47]; this study observed a strong association between cardiorespiratory capacity and PA_{BOUTS}.

The results of spirometry testing reported in this study are in keeping with the previous literature, in which restrictive patterns are reported to range from 18 to 52 % [4, 48]. Mechanical restrictions, primarily of the thoracic spine and costo-vertebral joints, contribute significantly to restrictions in respiratory function [4, 5]. Maintaining, or improving, spinal mobility and chest wall extensibility should be incorporated into treatment programmes aiming at addressing aerobic capacity. Many factors may influence cardiorespiratory performance including body composition, muscular fitness, individual characteristics, psychological factors, cardiovascular conditioning and habitual exercise [5, 35]; many of these are modifiable through targeted exercise programmes and offer healthcare practitioners alternate avenues for improving cardiorespiratory fitness.

Limitations

The cross-sectional design of this study prevents determination of causality between variables. The convenience sampling used may have resulted in selection bias; participants attending the rheumatology clinic may not be representative of all adults with AS. Studies investigating PA are likely to recruit participants who are interested in exercise; participants in the study may be more physically active than non-volunteers, although individuals in both groups reported similar weekly exercise frequencies. Although a valid measure of PA, limitations of accelerometers include an inability to discern increases in energy cost due to walking or running up an incline, static activities, upper-body movements, and carrying loads and consequently may have underestimated the energy expenditure during these tasks [33]. Finally, comparisons of spirometry results were made between participant current standing height and reference values; as a result, some cases of restrictive pulmonary impairment may have been underestimated.

Conclusions

Adults with AS participate in less health-enhancing PA than population controls. Fewer than half meet PA recommendations, despite exercise being a key component of AS management. Adults with AS also have significantly lower cardiorespiratory capacity than controls. Explorations of PA behaviour and strategies to increase PA participation are needed.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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